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MALAYSIAN SOCIETY OF AGRICULTURAL AND FOOD ENGINEERS

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7th SOUTHEAST ASIAN AGRICULTURAL ENGINEERING STUDENT CHAPTER ANNUAL REGIONAL CONVENTION 2021

ARC2021

8TH JULY - 8TH AUGUST 2021

"ADVANCEMENT OF IR 4.0 FOR AGRICULTURE SUSTAINABILITY AND FOOD SECURITY"

Organized by

UNIVERSITI PUTRA MALAYSIA BINTULU SARAWAK CAMPUS

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FOREWORD FROM THE CAMPUS DIRECTOR

Welcome to Universiti Putra Malaysia Bintulu Sarawak Campus, and welcome to the 7th Agricultural Engineering Student Chapter Annual Regional Convention 2021 (ARC2021).

I would like to extend my warm congratulations for the closing of this Convention and best wishes to all attendants for a successful event.

This international convention serves as a good platform for undergraduates, postgraduates as well as young researchers in several countries namely from Malaysia, Indonesia, Thailand, Republic of the Philippines, Brunei and Nepal to share and explore related research work and innovations particularly in the field of Agricultural Engineering or Technology. The main focus of this convention is on five sub-themes of Agricultural Engineering, Food Engineering, Biotechnology, Green Technology and Agricultural Waste Management. The well-diversified sub-themes show that the theme of the convention "Advancement of IR 4.0 for Agriculture Sustainability and Food Security" is very much reflected. The sharing session by keynote speakers renowned in their respective fields, Prof. Dr. Abdul Rashid b. Mohamed Shariff, Prof. Sibudjing Kawi and Dr. Yudha Prambudia, is yet another hallmark of this Convention.

To summarise, we hope that we have managed to deliver a very successful Convention. It would be more effective if all of us engage – not just in presenting posters and video – but also by actively participating in the discussion and by taking advantage of the networking opportunities.

I would like to take this opportunity to congratulate the Organizing Committee of ARC2021, especially to the Department of Science and Technology, Faculty of Humanities, Management and Science, Universiti Putra Malaysia Bintulu Campus (UPMKB) together with the Malaysian Society of Agricultural and Food Engineer (MSAE) for their tremendous efforts in bringing this international event to new heights. The fruitful engagement and collaboration among the Universities, Research Institutes, Government and other Institutions during the entire Convention will undoubtedly build the network and promote networking in AE (Agricultural Engineering) both in Malaysia as well as in the international arena.

I sincerely hope you have a very successful Convention.

Thank you.

Assoc. Prof. Dr. Shahrul Razid Sarbini
Campus Director
Universiti Putra Malaysia Bintulu Sarawak Campus

FOREWORD FROM THE ARC2021 CHAIRMAN

Dear Authors and esteemed readers,

A warm welcome to the 7th Agricultural Engineering Student Chapter Annual Regional Convention 2021 (ARC2021). On behalf of the organizing committee of ARC2021, I am very grateful to everyone for their great enthusiasm and cooperation that has made this event a grand success.

This event is proudly organized by the Department of Science and Technology, Faculty of Humanities, Management and Science, Universiti Putra Malaysia Bintulu Campus (UPMKB) in collaboration with the Malaysian Society of Agricultural and Food Engineers (MSAE) from the 8th July 2021 to 10th August 2021. This year's program carries the theme of "Advancement of IR 4.0 for Agriculture Sustainability and Food Security" and it is being conducted virtually due to the current pandemic issue.

This convention had achieved its primary objective in expanding the network of institutions, industry and society at the national and international levels in the field of agricultural and food engineering or technology. Participants range from undergraduate and postgraduate students as well as academicians from several countries; namely Malaysia, Indonesia, Thailand, Republic of the Philippines, Brunei and Nepal with a total number of 171 registered teams. ARC2021's team was also truly overwhelmed with the total number of 213 competition outputs received which are from 149 posters, 33 research output videos and 31 model construction videos. The outcomes of this convention are significantly suit five sub-themes designated for ARC2021; Agricultural Engineering, Food Engineering, Bio-Technology, Green Technology and Agricultural Waste Management. These outputs had been evaluated by the local and international judges from diverse countries such as Malaysia, Indonesia, Republic of the Philippines, Thailand, Australia and Iraq.

In addition, we would like to extend my heartfelt congratulations to all the winners who deserved to receive a medal or medals from your participation. Furthermore, the sharing session by 3 keynote speakers prominent in their respective fields; Prof. Sr. Gs. Dr. Abdul Rashid b. Mohamed Shariff from Malaysia, Prof. Sibudjing Kawi from Singapore and Associate Prof. Dr. Yudha Prambudia from Indonesia, is also another great highlight of this convention. Hopefully, their sharing could help us in nurturing our interest in agriculture sustainability and food security in the ever-evolving IR. 4.0 era. We are also indebted to Proville Tech Sdn. Bhd and Business Event Sarawak (BES) for being the main sponsors of this event. As sponsorship is the key to ensuring the success of an event, you made our event a huge success.

We thank all authors and participants for their contributions.

Gs. Dr. Wan Nor Zanariah Zainol @ Abdullah
Chair
7th Agricultural Engineering Student Chapter Annual Regional Convention 2021

FOREWORD FROM THE CHIEF EDITOR

Greetings!

It is a great pleasure for me to welcome you to the e-Proceedings issue of the 7th Agricultural Engineering Annual Regional Convention 2021 (ARC2021). This issue mainly highlights the importance of industrial revolution 4.0 (IR 4.0) for agriculture sustainability and food security.

The convention was organized by Universiti Putra Malaysia Bintulu Campus (UPMKB) in collaboration with the Malaysian Society of Agricultural and Food Engineer (MSAE). ARC has been ongoing for years as a part of MSAE main event, an international convention to which students from international schools, universities, research institutes, as well as experienced and brilliant researchers and speakers are invited. This convention provides an excellent opportunity for youths and other scholars to communicate and collaborate on ideas, notably in the areas of agriculture sustainability and food security.

Sustainable agriculture is a style of farming that focuses on producing long-term crops and animals while causing the least amount of environmental damage possible. This style of agriculture attempts to strike a balance between the requirement for food production and the maintenance of the environment's ecological system. Meanwhile, food security plays a very important role in measuring the availability of food and those who can access to it. Hence the selected submissions for this issue will hopefully shed new light upon the complexities of this convention with the theme of "Advancement of IR 4.0 for Agriculture Sustainability and Food Security".

On behalf of the editorial board to which I eternally grateful, I congratulate all those who contributed to successfully completing this edition of the e-Proceedings of the 7th Agricultural Engineering Annual Regional Convention 2021 (ARC2021) and I look forward to future intellectual contributions.

Thank you for your interest in reading the papers published here.

Dr. Juniza Md Saad
Chief Editor

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A REVIEW ON HYPERSPECTRAL REMOTE SENSING FOR WEED DETECTION ANALYSIS IN AGRICULTURAL CROP

Nursyazyla Sulaiman[1], Syarifah Noor Irma Suryani Syd Ahmad[2], Zaid Ramli[2], Nik Norasma Che'Ya[1*], Muhammad Huzaifah Mohd Roslim[3]
[1]Department of Agricultural Technology, Faculty of Agriculture, Universiti Putra Malaysia, Serdang
[2]Department of Crop Science, Faculty of Agriculture, Universiti Putra Malaysia, Serdang
[3]Department of Crop Science, Faculty of Agricultural Science and Forestry, Universiti Putra Malaysia Bintulu Campus, Sarawak, Malaysia
*niknorasma@upm.edu.my

Abstract

The presence of weeds creates complications for crop plantation as they cause significant competition between crops and weeds in terms of nutrients, moisture and sunlight that lead to yield loss. The site-specific weed management can manage the weed by applying the herbicide to the weed zoning compared to the blanket application. However, detecting weeds is difficult due to the similarity of the colour and shape of the plants. Currently, particular weed management propositions such as mechanical, chemical, manual, and biological control strategies were initiated for weed control in the crop field and protected resources such as soil and groundwater. Nevertheless, these strategies came with certain constraints such as climatic circumstances, weed resistance, labor availability, and the ability to endure management expenses. Therefore, remote sensing technique has been established and utilised for weed detection in agriculture to produce weed maps that can be used in spot sprayer. This review summarises the potential of hyperspectral remote sensing implementation for weed detection in the agricultural crop using spectral classification analysis.

Keywords: Hyperspectral; Remote Sensing; Machine Learning; Weeds; Weed mapping

Introduction

In the agricultural ecosystem, weeds play a competitor with the actual crop for getting their source of light, nutrients, moisture intensity, and gaseous exchange, resulting in declining crop yield and product quality (Hassan et al., 2018). Many different types of weeds infest plantation areas, including grassy weeds, broadleaves and sedges. Weed infestation without good management practices can reduce crop production by 85% depending on cultivation methods, season, water scarcity, and management practices in the plantation area (Dilipkumar et al., 2020). The location and climate in a particular area can influence the type of weeds present in that area and become dominant within a certain period, especially in the dry season (Take-tsaba et al., 2018). Weed infestation becomes critical when that plant can be a host for insect pests and diseases and attack the crop (A'ihi, 2018; Peng et al., 2020). Therefore, early detection is crucial in identifying the types of weeds in cropping areas and making the precise decision to determine the method of weed control (Kamath et al., 2020). Several methods are available for weed control, such as manual weeding, conventional herbicides, mechanical and machines, and advanced artificial intelligence. Manual weeding is relevant to the small-scale area, but that practice is not suitable due to labor shortage for the agriculture industry (Chauhan, 2020). Chemical control using herbicides is a popular method among farmers because of the efficient impact and low cost compared with the other weed control methods (Jamil et al., 2018). However, the weeds become herbicide-resistant due to frequent herbicide usage in similar mechanisms in the agricultural area (Chauhan et al., 2017).

Integrated between artificial intelligence (AI) and unmanned aerial vehicles (UAV) or drones with various sensors such as hyperspectral, multispectral, RGB (red-green-blue), thermal and odour will help in site-specific weed management (SSWM) for early weed detection. Hyperspectral imaging can be used to classify weeds and crops. Hyperspectral data provide 1000 nm to 2500 nm wavelengths that can potentially differentiate weed species using discriminant analysis (Che'Ya et al., 2021), euclidean distance and wavelet coefficient (Okamoto et al., 2007). According to Basheer et al. (2019), the traditional remote sensing techniques are inadequate for plant species detection analysis due to low spatial resolution. However, in conjunction with the evolving transducer technology and sensor, remote sensing approaches were upgraded for weed detection and control, particularly with the emergence of hyperspectral sensing and imaging (Huang et al., 2016). Hence, this paper would like to review the implementation of hyperspectral remote sensing for weed detection analysis in the agricultural crop.

Application of Hyperspectral Remote Sensing (HRS) for Weed Detection in Agricultural Crop

Generally, hyperspectral imaging incorporates the modern imaging system and traditional spectroscopy technology (Qian, 2020). This remote sensing imagery provides information such as spatial resolution (size of the pixel) and spectral resolution (wavelength ranges) (Basheer et al., 2019). Over the last 15 years, many researchers have shown that employing spectral vegetation signatures to distinguish between crops and weeds species can achieve a per-pixel classification accuracy of over 80% (Alexander & James, 2016). Hyperspectral imaging is usually represented as hypercubes that contain two spatial and one spectral dimension, regarding the characteristics of each hyperspectral imagery. It is utterly different from grayscale or RGB imagery that includes only one or three channels (Wendel, 2018). Qian (2020) stated three different methods for obtaining the hyperspectral data. The methods depend on the type of spectrometers instrument that leads to obtaining the data, such as dispersive elements-based approach, spectral filters-based approach, and snapshots hyperspectral imaging. In order to collect the hyperspectral images with different spatial and temporal resolutions, the sensors used can be mounted on different platforms such as UAVs, aeroplanes, and close-range platforms (Lu et al., 2020).

Weed classification using the spectral reflectance

The application of remote sensing employed in agriculture research was established on the interaction between electromagnetic radiation and plant materials on the Earth's surface (Atzberger, 2013). The spectral resolution of hyperspectral data can be utilised to enhance vegetation classification by detecting the dissimilarity of structures and biochemicals in vegetation (Govender et al., 2008). Gray et al. (2009) stated that weed differentiation could be classified according to the dissimilarity characteristics of morphological and phenological among the selected weed and the surrounding crop field. Paap (2014) brief that plants spectral reflectance is identified based on the cellular and biochemical leaf's structure and canopy. Remote sensing method could detect the existence of non-crop plants between crop rows, such as the recognition of weeds within rows, whereas segregating weeds from crops and identifying weed species emerge from proximal sensing research, which has utilised both spectral reflectance and leaf shape analysis for identification (Shannon et al., 2020). Figure 1 represents the typical spectrum reflectance and transmitted wavelength of healthy leaf and stressed leaf. The contrast of the reflectance and transmittance spectra depend upon absorption, which is in the visible spectrum range 400-700 nm. The spectra were controlled by the absorption of various pigments and primarily chlorophylls. Near infra-red (NIR) reflectances are higher, close to 50%, and plateau, and it will decline because of the water absorption present in the leaf.

In precision weed management, it is important to discriminate the crop from the weeds. For instance, to distinguish between the broad-leaved weed species (dicots) and grasses (monocots) (Casa et al., 2019). Weed mapping is tricky due to the similar reflectance between weeds and crops (Che'Ya, 2016). However, a prevalent study on dispersing reflectance spectra of crop and weed leaves has found the potential of weed detection with reflectance measurement. The correlation among the plant pathology has been employed by remote sensing technique in contemplation to discover the discrete plant characteristics from their spectra reflectance (Vrindts et al., 2002). The application of hyperspectral remote sensing was comprehensively used in weed detection analysis. Previose studies show hyperspectral data has been used widely for weed classification such as maise classification (Gao et al., 2018), the discrimination on herbicide-resistance kochia with hyperspectral imaging (Nugent et al., 2018), early detection of spotted knapweed (*Centraurea maculosa*) and babysbreath (*Gypsophila paniculate*) (Lass et al., 2005), discrimination of grassweeds in winter cereal crops (Martin et al., 2011), identification of seedling cabbages and weeds (Wei et al., 2015), differentiate weedy rice and barnyard grass (Zhang et al., 2019), and the potential use of *Grapevine leafroll-associated virus* 3 (GLRaV-3) during asymptomatic and symptomatic stages of grapevine leafroll disease (GLD) in a red-berried wine grape (*Vitis vinifera*) cultivar (Gao et al., 2020). Casa et al. (2019) investigated hyperspectral imaging for weed discrimination in maise crops by using machine learning techniques (Figure 2).

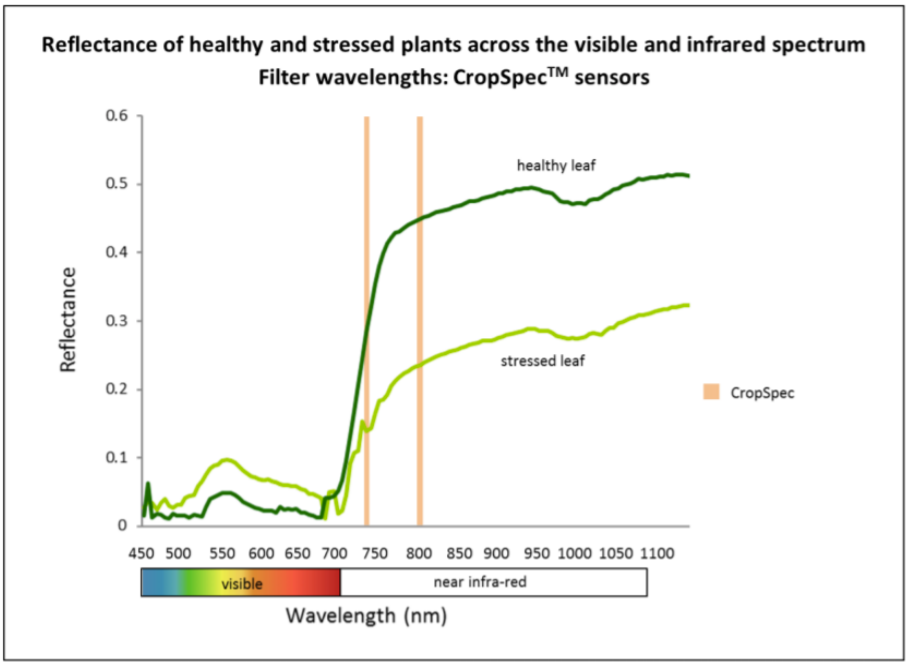

Figure 1. Spectral reflectance of healthy and stressed leaf in visible and NIR wavelength (Mcveagh et al. 2012).

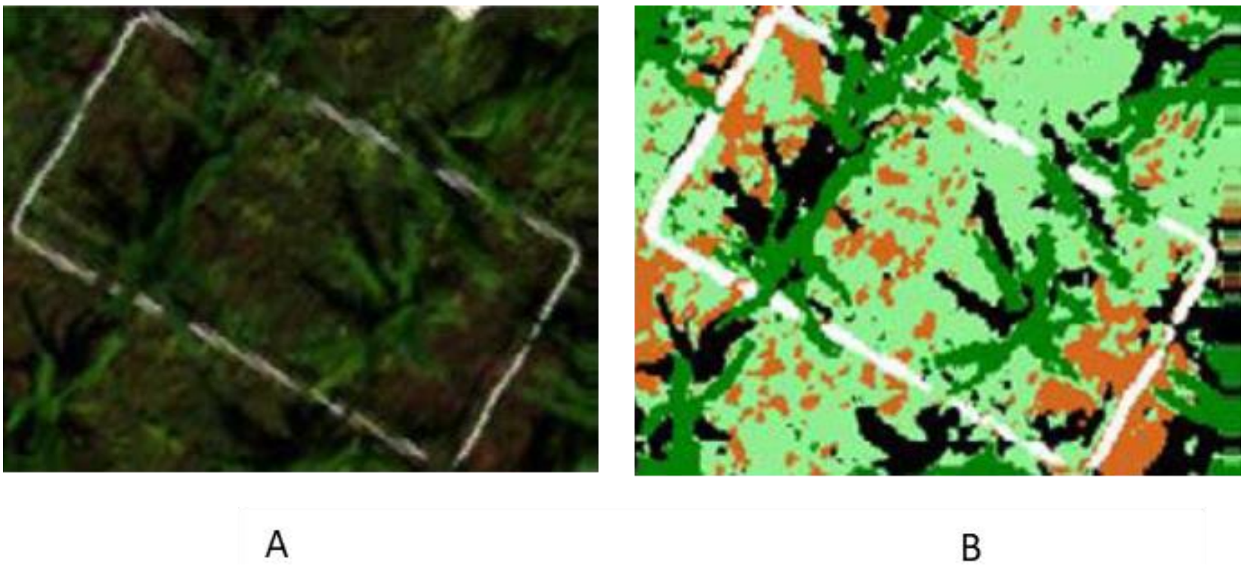

Figure 2: (A) Classification of UAV hyperspectral image sampling frame quadrat; (B) Using a supervised convolutional network. In the classified image (B) dark green color is maise crop, light green is weeds, brown is soil, black is shadow, and white is plastic (Casa et al., 2019)

Algorithm and classification techniques for weed mapping

For smart agriculture, an effective weed management procedure is critical. Implementing a reliable sensing technology to establish accurate discrimination of the weeds and crops at specific areas in the field is the most critical step for an automatic system to remove the targeted weeds in the crop rows (Su., 2020). Weed mapping is one of the most effective methods for managing crops. Within each crop type, weed populations vary spatially; hence, mapping weed infestations in annual crops has consequences not only for site-specific herbicide treatments but also for creating alternate management strategies and weed ecology analysis (Smith et al., 2003). It can be accomplished by using a variety of models and algorithms when performing data analysis and interpretation. Liakos et al. (2018) stated that Machine learning was created in conjunction with big data technologies and high-performance computers to open new avenues for unravelling, quantifying, and recognising data-intensive procedures in agricultural operating environments. Machine learning comprises several artificial neural networks, Bayesian models, deep learning, dimensionality reduction, decision trees, ensemble learning, instance-based models, support vector machines (SVM), Bayesian networks, convolutional neural networks (CNN), deep neural networks, ensemble neural networks, K-nearest-neighbour, least-square-support vector machine, multi-layer perceptron, multiple linear regression, principal component analysis (PCA) and partial least squares regression. According to Su (2020), machine learning methods combined with non-imaging spectroscopic or imaging technology enable practical and real-time plant discrimination and localisation (such as weeds). It allows for the exact application of the most appropriate herbicide dosage to site-specific zones rather than spraying entire fields uniformly, lowering herbicide costs while also protecting resources such as soil and groundwater. The study was done by Islam et al. (2020) presents that the development of a random forest-based algorithm to generate a weed map in chili plantations has resulted in an out-of-bag accuracy level of about 96%. A convolutional neural network (CNN) in deep learning performs well in object detection and autonomous feature engineering with uncontrolled illumination. The CNN models were used to train plant RGB pictures and successfully distinguish sugar beet plants from weeds, making them appropriate for field use (Milioto et al., 2018). The classification results of CNN show that the recognition rate of weeds from soybean crops reached 91.96% (Chavan & Nandedkhar, 2018). The study done by Santos et al. (2017) showed the application of ConvNets (with 98% accuracy level) to detect weeds in soybean crops images along with the discrimination between the broadleaved weeds and grass.

Conclusion

The use of hyperspectral remote sensing imaging (HRSI) allows for the accurate detection of weed patches in a plantation area, improving the long-term viability of weed management. Hyperspectral remote sensing imaging technology is site-specific weed management (SSWM) used to monitor weed detection systems. Early detection will make the precise decision to determine the weeds control methods at an early stage that will reduce the herbicide usage and reduce environmental impact. Furthermore, HRSI is used for data acquisition and can capture weeds images in more detail for spectral information and spatial ranges. The spectrum can indicate the chemical and physical characteristics of the plants. Thus, farmers can take action based on the crop condition and weed area to treat the spot area only. When paired with weed management planning, the knowledge gained from remote sensing image analysis will help effective weed control in the long run. Various machine learning algorithms could provide a precise weed classification to produce a weed map. In this review, it can be concluded that HRSI is a potential technique for weed mapping as it provides high spectral resolution accuracy. As we know, the weeds monitoring and control in the early growth to maturity stage needs intensive labor and high cost. Using a hyperspectral sensor instead of traditional ways to monitor weeds in the field can save time and money while being more precise in a large-scale area. A sprayer drone can be used to spray the spot area based on the weed map. It will reduce the labor and save the cost. These sensing technologies employed in smart agriculture have made significant progress by producing vast amounts of data from the fields. Given the recent surge in machine learning and sensor development, hyperspectral imaging is potentially one of the methods for weed and crop discrimination in real-time.

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References

A Basheer, M., B El Kafrawy, S., & A Mekawy, A. (2019). Identification of mangrove plant using hyperspectral remote sensing data along the Red Sea, Egypt. *Egyptian Journal of Aquatic Biology and Fisheries*, *23*(1), 27-36.

Alexander W., & James U. (2016). Self-Supervised Weed Detection in Vegetable Crops Using Ground Based Hyperspectral Imaging. *IEEE International Conference on Robotics and Automation (ICRA)* Stockholm, Sweden, May 16-21, 2016.

A'ihi, A. M. (2018). Impact and management of weed flora in cassava in West Coast Region of Peninsular Malaysia. *Photosynthetica*, *2*(1), 1–13. http://link.springer.com/10.1007/978-3-319-76887

Atzberger, C. (2013). Advances in remote sensing of agriculture: Context description, existing operational monitoring systems and major information needs. *Remote sensing*, 5(2), 949-981.

Bakhshipour, A., & Jafari, A. (2018). Evaluation of support vector machine and artificial neural networks in weed detection using shape features. *Computers and Electronics in Agriculture*, *145*, 153-160.

Casa, R., Pascucci, S., Pignatti, S., Palombo, A., Nanni, U., Harfouche, A., Laura, L., Di Rocco, M. & Fantozzi, P. (2019). UAV-based hyperspectral imaging for weed discrimination in maise. In *Precision agriculture'19* (pp. 24-35). Wageningen Academic Publishers.

Chauhan, B. S. (2020). Grand Challenges in Weed Management. *Frontiers in Agronomy*, 1–4. https://doi.org/10.3389/fagro.2019.00003

Chauhan, B. S., Matloob, A., Mahajan, G., Aslam, F., Florentine, S. K., & Jha, P. (2017). Emerging challenges and opportunities for education and research in weed science. Frontiers in Plant Science, 8(September), 1–13. https://doi.org/10.3389/fpls.2017.01537

Chavan, T. R., & Nandedkar, A. V. (2018). AgroAVNET for crops and weeds classification: A step forward in automatic farming. *Computers and Electronics in Agriculture*, *154*, 361-372.

Che'Ya, N.N, Dunwoody E, & Gupta M. (2021). Assessment of Weed Classification Using Hyperspectral Reflectance and Optimal Multispectral UAV Imagery. *Agronomy*. 2021; 11(7):1435. https://doi.org/10.3390/agronomy11071435.

Che'Ya, N.N. (2016). Site-Specific Weed Management Using Remote Sensing. Ph.D. Thesis, The University of Queensland, Gatton Campus, Queensland (QLD), Australia, 7 October 2016. Retrieved from https://doi.org/10.14264/uql.2016.821 (accessed on 20 July 2021)

Dilipkumar, M., Chuah, T. S., Goh, S. S., & Sahid, I. (2020). Weed management issues, challenges, and opportunities in Malaysia. *Crop Protection*, *134*, 104347. https://doi.org/10.1016/j.cropro.2017.08.027

Dos Santos Ferreira, A., Freitas, D. M., da Silva, G. G., Pistori, H., & Folhes, M. T. (2017). Weed detection in soybean crops using ConvNets. *Computers and Electronics in Agriculture*, *143*, 314-324.

Gao, J., Nuyttens, D., Lootens, P., He, Y., & Pieters, J. G. (2018). Recognising weeds in a maise crop using a random forest machine-learning algorithm and near-infrared snapshot mosaic hyperspectral imagery. *Biosystems Engineering*, *170*, 39-50.

Gao, Z., Khot, L. R., Naidu, R. A., & Zhang, Q. (2020). Early detection of grapevine leafroll disease in a red-berried wine grape cultivar using hyperspectral imaging. *Computers and Electronics in Agriculture*, *179*, 105807.

Govender, M., Chetty, K., Naiken, V., & Bulcock, H. (2008). A comparison of satellite hyperspectral and multispectral remote sensing imagery for improved classification and mapping of vegetation. *Water SA*, 34(2), 147-154.

Gray, C. J., Shaw, D. R., & Bruce, L. M. (2009). Utility of hyperspectral reflectance for differentiating soybean (Glycine max) and six weed species. *Weed Technology*, 23(1), 108-119.

Hassan, A. A. G., Ngah, I., & Applanaidu, S. D. (2018, November 14). *Agricultural Transformation In Malaysia: The Role Of Smallholders And Area Development.* Retrieved from https://www.researchgate.net/profile/Asan_Ali_Golam_Hassan/publication/341220143_AGRICULTURAL_TRANSFORMATION_IN_MALAYSIA_THE_ROLE_OF_SMALLHOLDERS_AND_AREA_DEVELOPMENT/links/5eb47f2e299bf1287f750fa3/AGRICULTURAL-TRANSFORMATION-IN-MALAYSIA-THE-ROLE-OF-SMALLHOLDERS-AND-AREA-DEVELOPMENT.pdf

Huang, Y., Lee, M. A., Thomson, S. J., & Reddy, K. N. (2016). Ground-based hyperspectral remote sensing for weed management in crop production. *International Journal of Agricultural and Biological Engineering*, 9(2), 98-109.

Islam, N., Rashid, M. M., Wibowo, S., Wasimi, S., Morshed, A., Xu, C., & Moore, S. (2020). Machine learning based approach for Weed Detection in Chilli field using RGB images. *In the International Conference on Natural Computation, Fuzzy Systems and Knowledge Discovery* (pp. 1097-1105). Springer, Cham.

Jamil, M. Z. A., Mutalib, S., rahman, S. A., & Aziz, Z. A. (2018). Classification of paddy weed leaf using neuro-fuzzy methods. *Malaysian Journal of Computing*, *3*(1), 54–66. http://gids.mohe.gov.my/index.php/mjoc/article/view/4883

Kamath, R., Balachandra, M., & Prabhu, S. (2020). Paddy Crop and Weed Discrimination: A Multiple Classifier System Approach. *International Journal of Agronomy*, *2020*. https://doi.org/10.1155/2020/6474536

Lass, L. W., Prather, T. S., Glenn, N. F., Weber, K. T., Mundt, J. T., & Pettingill, J. (2005). A review of remote sensing of invasive weeds and example of the early detection of spotted knapweed (Centaurea maculosa) and babysbreath (Gypsophila paniculata) with a hyperspectral sensor. *Weed Science*, 53(2), 242-251.

Liakos, K. G., Busato, P., Moshou, D., Pearson, S., & Bochtis, D. (2018). Machine learning in agriculture: A review. *Sensors*, *18*(8), 2674.

Lu, B., Dao, P. D., Liu, J., He, Y., & Shang, J. (2020). Recent advances of hyperspectral imaging technology and applications in agriculture. *Remote Sensing,* 12(16), 2659.

Martin, M. P., Barreto, L., Riaño, D., Fernández-Quintanilla, C., & Vaughan, P. (2011). Assessing the potential of hyperspectral remote sensing for the discrimination of grassweeds in winter cereal crops. *International Journal of Remote Sensing*, 32(1), 49-67.

Milioto, A., Lottes, P., & Stachniss, C. (2018). Real-time semantic segmentation of crop and weed for precision agriculture robots leveraging background knowledge in CNNs. In *2018 IEEE international conference on robotics and automation (ICRA)* (pp. 2229-2235). IEEE.

Mudereri, B. T., Dube, T., Niassy, S., Kimathi, E., Landmann, T., Khan, Z., & Abdel-Rahman, E. M. (2020). Is it possible to discern Striga weed (Striga hermonthica) infestation levels in maise agro-ecological systems using in-situ spectroscopy?. *International Journal of Applied Earth Observation and Geoinformation*, *85*, 102008.

Mcveagh, P., Yule, I., Grafton, M. (2012). Pasture yield mapping from your groundspread truck. *In Advanced Nutrient Management: Gains from the Past—Goals for the Future.* Occasional Report No. 25; Currie, L.D., Christensen, C.L., Eds.; Fertilizer and Lime Research Centre: Palmerston North, New Zealand, 1–5, 2012.

Nugent, P. W., Shaw, J. A., Jha, P., Scherrer, B., Donelick, A., & Kumar, V. (2018). Discrimination of herbicide-resistant kochia with hyperspectral imaging. *Journal of Applied Remote Sensing*, *12*(1), 016037.

Okamoto, H.; Murata, T.; Kataoka, T.; Hata, S.I. (2007) Plant classification for weed detection using hyperspectral imaging with wavelet analysis: Research paper. *Weed Biol. Manag, 7*(1), 31–37. https://doi.org/10.1111/j.1445-6664.2006.00234.x.

Paap, A. J. (2014). *Development of An Optical Sensor for Real-Time Weed Detection Using Laser Based Spectroscopy*. (Doctoral Dissertation, Edith Cowan University). Retrieved from https://ro.ecu.edu.au/cgi/viewcontent.cgi?article=2284&context=theses

Peng, X., Liu, L., Guo, X., Wang, P., Song, C., Su, S., Fang, G., & Chen, M. (2020). The survival and reproduction of rhopalosiphum padi (Hemiptera: Aphididae) on different plants: Exploring the possible host range for a serious wheat pest. *Journal of Economic Entomology*, *113*(1), 185–193. https://doi.org/10.1093/jee/toz263

Pflanz, M., Nordmeyer, H., & Schirrmann, M. (2018). Weed mapping with UAS imagery and a bag of visual words based image classifier. *Remote Sensing*, *10*(10), 1–17. https://doi.org/10.3390/rs10101530

Qian, S. E. (2020). *Hyperspectral Satellites and System Design.* Boca Raton, Florida: CRC Press.

Shannon, D. K., Clay, D. E., & Kitchen, N. R. (2020). *Precision Agriculture Basics (Vol. 176)*. United States of America: John Wiley & Sons.

Smith, A.M., & Blackshaw, R.E. (2003). Weed–Crop Discrimination Using Remote Sensing: A Detached Leaf Experiment. *Weed Technol*, *17*(4), 811–820. https://doi.org/10.1614/wt02-179.

Su, W. H. (2020). Advanced Machine Learning in Point Spectroscopy, RGB-and hyperspectral-imaging for automatic discriminations of crops and weeds: A review. *Smart Cities*, *3*(3), 767-792.

Take-tsaba, A. I., Juraimi, A. S. Bin, Yusop, M. R. Bin, Othman, R. B., & Singh, A. (2018). Weed competitiveness of some aerobic rice genotypes. *International Journal of Agriculture and Biology*, *20*(3), 583–593. https://doi.org/10.17957/IJAB/15.0526

Vrindts, E., De Baerdemaeker, J., & Ramon, H. (2002). Weed detection using canopy reflection. *Precision agriculture,* 3(1), 63-80.

Wei, D., Huang, Y., Chunjiang, Z., & Xiu, W. (2015). Identification of seedling cabbages and weeds using hyperspectral imaging. *International Journal of Agricultural and Biological Engineering*, 8(5), 65-72.

Wendel, A. (2018). *Hyperspectral Imaging from Ground Based Mobile Platforms and Applications in Precision Agriculture* (Doctoral Dissertation, The University of Sydney). Retrieved from https://ses.library.usyd.edu.au/handle/2123/19745

Zhang, Y., Gao, J., Cen, H., Lu, Y., Yu, X., He, Y., & Pieters, J. G. (2019). Automated spectral feature extraction from hyperspectral images to differentiate weedy rice and barnyard grass from a rice crop. *Computers and Electronics in Agriculture,* 159, 42-49.

CROP GROWTH MONITORING USING GEOTAGGED TECHNIQUE DERIVED FROM AERIAL IMAGERY AND VEGETATION INDICES ALGORITHM: A REVIEW

Nur Adibah Mohidem, Muhamad Irfan Ab Rahman, Nik Norasma Che'Ya*, Wan Fazilah Fazlil Ilahi, Mohd Amir Sabrin Zamri
Department of Agriculture Technology, Faculty of Agriculture, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia.
*niknorasma@upm.edu.my

Abstract

In conventional practices, farmers usually rely on paper-based records to store the field data, which is time-consuming and challenging to update the data for crop management. Furthermore, data sharing is limited because of the reliance on human labour, resulting in missing and inaccurate data. Using geographical information system (GIS) and unmanned aerial vehicle (UAV) approaches, farmers can locate and detect problems in their farms in the near real-time and take corrective measures once these areas have been evaluated. Furthermore, image processing techniques can be applied, such as vegetation indices (VIs) derived from the aerial imagery that is to be used for geotagged individual trees for crop plantation health monitoring. Therefore, we provide an overview of the geotagging technique and utilisation of VIs algorithm for crop management, focusing on the practical use of the most advanced UAV application. This review then concludes with a brief outlook into a potential future field of research regarding crop monitoring using a geotagged technique derived from UAV imagery in agriculture applications.

Keywords: Aerial imagery; Crop; Geotagging; Vegetation indices

Introduction

As people come up with insights on the utilisation of innovation, new technologies are established. Innovation laid the foundation for solutions to problems in several industries, particularly farming. Despite years of agricultural studies, pests and disease (PnD) and weeds impede agricultural productivity, affecting crop production and consumption. Specifically, they may reduce crop yield and its quality directly or indirectly by affecting crop health. The plant pathology discipline focuses on diseases caused by pathogens, infectious organisms, and other environmental conditions or physiological factors. Therefore, the main concern as a plant pathologist is monitoring plant conditions such as diseases and pest outbreaks. However, traditional practices using paper-based records to collect the field data is inconvenient since it is time-consuming, and loss of data caused by human error could lead to poor crop health management (Bharti et al., 2021).

Adopting GIS technology across all industries can be a powerful tool in collecting, storing, and managing data, thus providing effective and successful decision-making processes. Geographic tagging techniques, for example, provide a significant benefit of analysing data in point shape, particularly in agricultural industries. For instance, plant pathologists commonly adopt the functionality of Google Earth that allows a user to geocode latitude and longitude to map the location of infected crop diseases. However, the spatial resolution is low and might lead to inaccuracy. Furthermore, dealing with large amounts of data with the Global Positioning System (GPS) as the only identifier on the map can be difficult and time-consuming when getting precise data (Buladaco et al., 2020). Thus, there is a need to apply a geotagging tool as an Information Technology (IT) solution to efficiently provide an approach that can suit the particular needs of crop monitoring.

UAVs or drones have grown in popularity due to minimal user intervention and affordability. As a result, they have become more commonly used platforms for gathering aerial images (Hamylton et al., 2020). Compared to satellite imagery, the ability of UAVs to produce high-resolution imageries, low-cost, and precise positioning makes them the most potent platform (Norasma et al., 2019). Furthermore, the geotagged technique can be derived from high-resolution UAV images to produce an accurate map by validating Ground Control Points (GCPs) (Muhammad and Tahar, 2021). The VIs generated from the UAV imagery can help the farmers emphasise the area with the unhealthy conditions of the crop. Therefore, this study provides an overview of the geotagging application synchronises with a camera mounted on a UAV to provide georeferenced images and employs a VIs algorithm for rapid and automated damage detection and crop monitoring.

Geographic Information System in Agriculture

Crop plantation covers a large area and therefore needs a proper management system for monitoring plant health. This process is possible with GIS that is made up of hardware and software to capture, store, and analyse digital information such as graphs and maps (Talosig et al., 2019). GIS can develop a spatial database by storing and displaying geographically referenced data to geotag the crop. GIS development can be utilised using Aeronautical Reconnaissance Coverage Geographic Information System (ArcGIS) (Esri, Redlands, California, USA) and Quantum Geographical Information System (QGIS) (GNU Public License). They contain various functionality ranging from simple to advanced spatial analyses. Direct access to geographic information is performed by first making a geographic database connection in ArcGIS Desktop and then importing the connection file into the ArcGIS server. On the other hand, QGIS is an open-source GIS under Open Source Geospatial Foundation (OSGeo) (Heim et al., 2019). Both ArcGIS and QGIS contain the tools for processing the data and support many rasters, vector, and database formats.

Unmanned Aerial Vehicle in Agriculture

UAVs or drones have seen widespread use in precision agriculture in recent years. This technology can detect sub-field differences in crop health with greater accuracy (Zhang et al., 2021). It can assist farmers in monitoring plant and livestock conditions via ground-level spot controls (Revanasiddappae et al., 2020). UAVs can be used to assess crop growth, irrigation systems, fertiliser application, and disease detection. UAV sensors with high spectral, spatial, and temporal resolutions can detect disease in its early stages (Mateen and Zhu, 2019), thus increasing crop yield and productivity. The infrared sensors in UAVs are allowing farmers to improve agricultural conditions, which reduce the use of insecticides or fertilisers on the crop. These high-resolution images obtained from UAV aerial images could also eliminate the cloud problems (Tang et al., 2021) and produce high accuracy in plant detection (Che'Ya et al., 2021).

Geotagging Approach in Crop Monitoring

Geotagging is a fast-emerging trend in digital photography and community photo sharing. Geotagging means adding geospatial data to various forms of media such as photos or videos, including altitude, latitude, longitude, altitude, distance, and scale. In precision agriculture, a geotagging framework was used to estimate the location and coordinates from aerial images to tag the trees (Salem et al., 2021). The tagging can create unique characteristics and track and count the number of trees from the images. Each tree was captured using UAV imagery and can be map using the geotagged technique. The trees are marked using the number series to identify the unique pinpoint of each tree (Identity document, ID). The coordinate of each tree is obtained by geocoded when the photo is collected using smartphones or GPS instruments. Farmers can geotagged the trees by tagging the images with coordinates, and time can be included (Sottini et al., 2019). Since the smartphone has a built-in camera, the location and geotagged photos are automatically collected (Atunggal et al., 2017).

Farmers can conduct tree counting and profiling from aerial images. The detection technique includes edge enhancement, spectral and blob analysis, and segmentation (Ammara and Koubaa, 2020). This technique can measure the width and height for every trunk and identify the tree for tapping (Talosig et al., 2019). Accordingly, farmers can develop geotagged techniques using a monocular Micro Aerial Vehicle (MAV) for each tree by assigning the trees using their coordinates. Then, farmers can conduct image processing which geotagging all information such as imagery and camera parameters (Birdal et al., 2017). Each image can be visualized with geographical locations using GIS software (Figure 1). Alternatively, Google Street

Views, Google Earth, and Google Map are considered a user-friendly database of accurate geotagged imagery to provide spatial information.

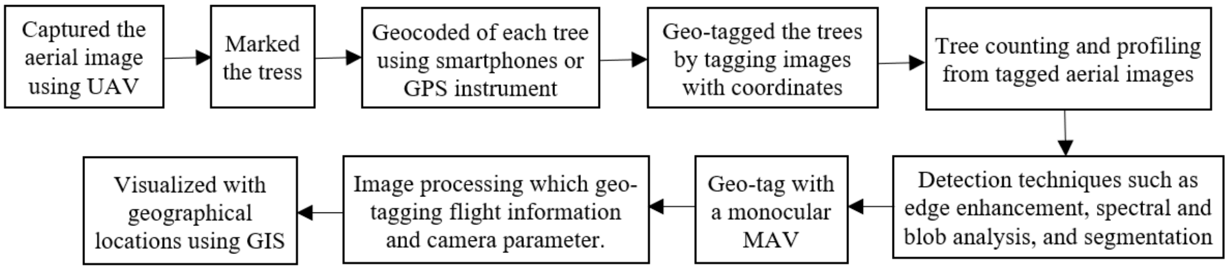

Figure 1: Geotagging framework in crop monitoring

Previous studies show geotagging technique in Kluang Valley Durian plantations was successful using QGIS software (Rahman, 2021). The coordinates were spatially joined with an attributes table that consists of ground data such as the height of trees, canopy width, girth's diameter, node distance, pH measure content, EC reading, and leaf sizes. This technique could help the farmers to monitor the durian plantation effectively. In this study, Rahman (2021) used RGB imagery and geotagged the tress using GIS software. The spatial points (durian trees) were linked with the attribute table in the ground. Figure 2 shows the durian trees that are linked with the ground data.

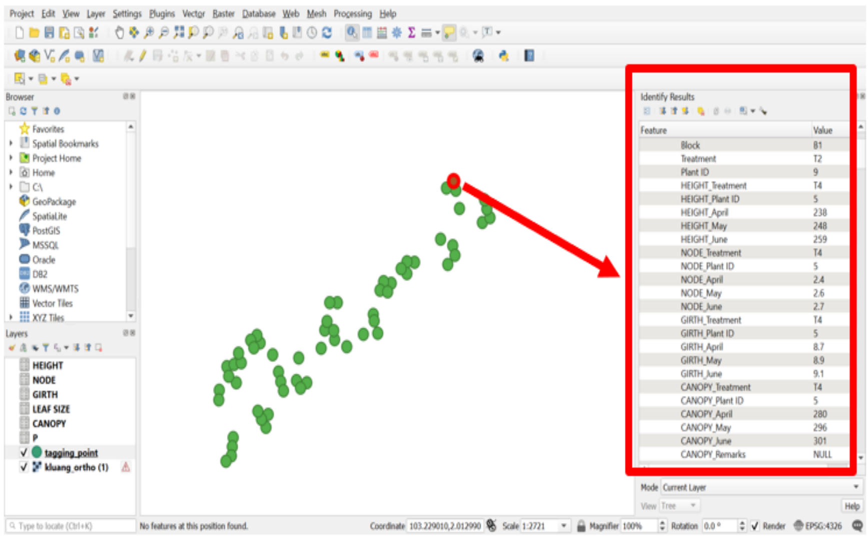

Figure 2: Geotagged the spatial data with the attribute table in QGIS (Rahman, 2021)

Previous studies also applied the geotagging approach for mapping trees on different crop types (Table 1). Additionally, the ground view was used in the previous studies of cross-view image matching (Sattler et al., 2016; Vo et al., 2017). Nevertheless, ground-view images are commonly limited to small spatial and temporal scales. Conversely, satellite-view images have a higher advantage with broad spatio-temporal coverage with their geotags. Previous studies have focused on cross-view image matching between the ground and satellite views to fully utilize the geotags of images by locating the images from different views. Tian et al. (2017) created image pairs between aerial and ground-view images using public image data sources. In this case, Google Maps provided the satellite-view images with geotags and this feature aids in the cross-view image matching of the UAV and satellite views.

Table 1. Application of geotagging techniques in crop monitoring

Reference	Study area	Study period	Platform	Application
Rahman (2020)	Durian plantation, Malaysia	January to December 2020	RGB UAV	Geotagged durian trees using RGB imagery and ground data.
Sawant et al. (2019)	Thanjavur, Tamil Nadu, India	August to November 2018	Google Earth Engine	Geotagged plot boundaries for the *Kharif* rice crop and coconut plantations.
Sottini et al. (2019)	Cecina river, Liborno, Italy	January 2005 to December 2017	Flickr Application Programming Interface	Geotagged on geomorphology and natural environment of the plantation.
Mohite et al. (2020)	Wardha, Maharashtra, India	June to November 2019	Rural Participatory Sensing	Geotagged plot boundaries and growth stage of soybean, cotton, red gram, orange, chilly, okra, mango crops
Yang et al. (2015)	San Angelo, Texas, United States	October 2014	GPS	Geotagged image for cotton root.
Navaja et al. (2019)	Brgy. Cantipay, Carmen, Cebu	January 2018 to May 2019	Manual such as human labour	Geotagged image for mango tress

Aerial Imagery Processing in Agriculture

Spectral Reflectance Technique for Vegetation

The spectral reflectance technique is used to estimate the functional components and nutritional status of various vegetation types, whereby differences in findings were found depending on the types of plant species, growth methods, and environmental conditions (Neto et al., 2018). The plant parts that affect its reflectance are the amount of chlorophyll content in the leaf, leaf water content, and the intercellular space in the leaf cell. The chemical characteristics of leaf pigments, water, and dry-matter content create distinct absorption features (Jiménez and Díaz-Delgado, 2015). Spectral reflectance has been measured at multiple spatial scales, such as a crop's leaf, stand, and canopy (Ryu et al., 2018). The reflectance spectroscopy technique was first used in the early twentieth century (Norris et al., 1974), showing that wavelengths in the infrared area were suitable to assess forage quality rapidly. Recently, Ngo et al. (2019) analysed reflectance spectra to evaluate the nutritional and functional components of diverse green plants and medicinal plants. In general, leaf reflectance spectra were low in the visible region from 400 to 700 nm, due to light absorption by photosynthetic pigments such as chlorophyll and carotenoids (Yu et al., 2018).

In higher plants, leaf pigments such as chlorophyll, carotenoids, and anthocyanins may be easily recognised in 400 to 800 nm reflectance. Precisely, total chlorophyll content was measured in beech leaves at 540 to 560 nm (green region) or 700 to 730 nm (red region) and 760 nm (red-edge) (Gitelson et al., 2006), lettuce at 540 to 560 nm and 700 to 705 nm which depending on detection point, and spinach at 510 to 540 nm (Xue and Yang et al., 2009). The ratio vegetation index (RVI), a well-known simple ratio (SR), was created by using the reflectance of the red and near-infrared (NIR) spectra (Birth and McVey 1968), which is designated as NIR/red. The NIR light is reflected in healthy leaves of 40-60%. However, the process is more located at the canopy level because of a range of effects such as additive reflectance, incidence angle, leaf orientation, shadow and soil background reflectance. The vegetative spectral reflectance curve is presented in Figure 3.

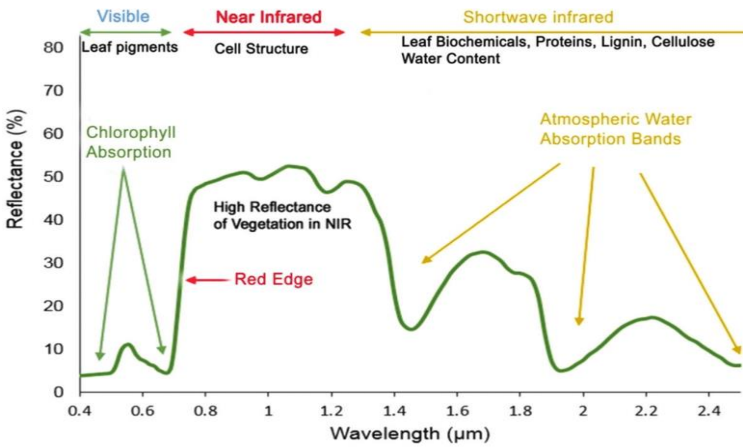

Figure 3: Vegetative spectral reflectance curve (Roman & Ursu, 2016)

Vegetation Indices Algorithm in Crop Monitoring

In traditional methods, the farmer usually manages the crop plantation based on experience and visual observation. However, it is difficult to detect the whole area of the crop plantation because of the limited visual observation on the ground. Therefore, aerial imagery can extract VIs that help the farmer monitor the crop stress conditions and variability (Radoglou-Grammatikis et al., 2020). VIs are mathematical estimations of canopy reflectance at specified visible and near-infrared wavelengths (Frels et al., 2018). The indices allow users to determine stressed and diseased crops and predict nitrogen (N) status by multiple bands imagery. Farmers with this knowledge can maximise the use of limited resources such as fertiliser, water, or manure by focusing on different parts of the field and conducting on-the-spot treatments. Various VIs have also been developed by taking into account the spectral reflectance features of plants. Accordingly, aerial imagery and VIs data from the image processing technique were exported, and trees and characteristics of the ground data were geotagged using GIS software. Then, this spatial data were processed and displayed in the form of a map. Hence, to improve crop plantation management, the farmer can use the combination of the GIS and aerial imagery approaches.

The successful application of UAV-based remote sensing depends on changes in sensitivity to VIs and growth stages (Olson et al., 2019). The processing of several vegetative indices has been related to physiological plant factors such as plant pigments, vigour, aerial biomass, yield estimation, plant physiology, and stress. Xue and Su (2017) assessed the developments and applications of 100 VIs in remote sensing. They found that some VIs use a range of reflectance values in a narrow band of the electromagnetic spectrum. Therefore, it will give more accurate measurements for grain yield and reliable information for yield prediction.

Nevertheless, they require more technologically such as multispectral or hyperspectral sensors. VIs are derived using red-green-blue (RGB) images estimated from commercial cameras as a low-cost option. Other investigations have demonstrated the ability to estimate grain output, quantify nutrient shortages, and assess the impact of illnesses (Buchaillot et al., 2019).

Zhou et al. (2018) found that combining agronomic factors with VIs could improve crop biomass and shoot nitrogen concentration in monitoring the accuracy. For example, Wan et al. (2018) discovered that combining VIs and image classification from RGB and multispectral photos could estimate the number of flowers in oilseed rape. Combining the multi-temporal normalised difference vegetation index, the normalised difference yellowness index, canopy height, and canopy coverage have resulted in high prediction accuracy of rice yield. Therefore, combining agronomy factors and VIs may be an important technique for estimating leaf nitrogen concentration, particularly during the summer maise grain filling stage, when summer maise tassels influence spectral reflectance. UAV-based monitoring has shown significant potential for the future infrastructure of monitoring plant health. Various VIs have been applied for crop monitoring (Table 2).

Table 2. Vegetation indices related to crop monitoring

Vegetation Index	Formula	Purpose	Reference
Visible-Band Difference Vegetation Index (VDVI)	$\frac{(2*G-R-B)}{(2*G+R+B)}$	To distinguish vegetation from non-vegetation objects without using the NIR domain, whereby in the case of visible light remote sensing images.	Xue & Su, (2017)
Visible atmospherically resistant index (VARI)	$\frac{(G-R)}{(G+R-B)}$	To emphasize vegetation in the visible portion of the spectrum, and mitigating illumination differences and atmospheric effects.	Eng et al., (2018)
Normalized Green-Red Difference Index (NGRDI)	$\frac{G-R}{G+R}$	To eliminate the influence of different irradiance on the spectral characteristics of the vegetation and to estimate the biomass of crops.	Bassine et al., (2019)
Red-Green Ratio Index (RGRI)	$\frac{R}{G}$	To estimate and distinguish divergent patterns of pigment activity such as anthocyanin and directly related to leaf structure, light regimes, and functional type.	Mallmann et al., (2020)
Modified Green Red Vegetation Index (MGRVI)	$\frac{(G^2-R^2)}{(G^2-R^2)}$	To capture reflectance differences due to chlorophyll a-absorption (420, 490, and 660 nm) and chlorophyll b-absorption (435 and 643 nm)	Bendig et al., (2015)
Excess Green Index (EXG)	$2*G-R-B$	To highlight the green vegetation cover and create a clear contrast between plant material and soil by producing a grayscale image.	Cermakova et al., (2019)
Color Index Of Vegetation (CIVE)	$0.441*r-0.881*G+0.385B+18.787$	To separate the green plant portion from the soil background and CIVE layer was used as input in the multi-threshold segmentation algorithm.	Zhang et al., (2018)
Vegetativen (VEG)	$\frac{G}{(R)^{a^*}*B^{(1-a)}}$	To identify plant pixels and separate the green component in images of crops using an index that is invariant over the range of natural daylight.	Zhang et al., (2018)

Conclusion

The application of the GIS technology in mapping the farm and assigning a unique crop tree identification number enables farmers to monitor the growth of the trees. This information is crucial for farmers or scientists to make timely decisions to improve crop management practices in their farm areas. The geotagging and VIs technique can be derived from RGB, multispectral, hyperspectral and thermal imagery for crop monitoring. However, the ground data is important for the accuracy assessment. In addition, geotagging will link spatial and attribute data in GIS software. Thus, farmers can monitor their crops by using the unique ID from the geotagged application and image analysis using VI.

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References

Ammar, A., Koubaa, A., & Benjdira, B. (2021). Deep-Learning-based Automated Palm Tree Counting and Geolocation in Large Farms from Aerial Geotagged Images. *Agronomy*, 11(8), 1458.

Atunggal, D., Ausi, N.H., Ma'ruf, B., dan Rokhmana, C. A. (2017, Oktober 11-13). Application of Low Cost RTK GPS Module for Precise Geotagging using Smartphone. *9th Multi GNSS Asia*, Jakarta, 89-92.

Bassine, F. Z., Errami, A., & Khaldoun, M. (2019). Vegetation Recognition Based on UAV Image Color Index. In *2019* IEEE International Conference on Environment and Electrical Engineering. *IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe)*, 1-4.

Bendig, J., Yu, K., Aasen, H., Bolten, A., Bennertz, S., Broscheit, J., Gnyp, M. L., & Bareth, G. (2015). Combining UAV-Based Plant Height from Crop Surface Models, Visible, and Near Infrared Vegetation Indices for Biomass Monitoring in Barley. *International Journal of Applied Earth Observation and Geoinformation*, 39, 79–87.

Birth, G. S. & McVey, G. R. (1968). Measuring the Color of Growing Turf with a Reflectance Spectrophotometer. *Agronomy Journal*, 60, 640–643.

Buchaillot, M., Gracia-Romero, A., Vergara-Diaz, O., Zaman-Allah, M. A., Tarekegne, A., Cairns, J. E., Prasana, M.P., Araus, J. L. & Kefauver, S. C. (2019). Evaluating Maise Genotype Performance under Low Nitrogen Conditions using RGB UAV Phenotyping Techniques. *Sensors*, 19(8), 1815.

Buladaco, M. V. M., & Ubay, F. L. (2020). GETMOSYS: A Plant Pathologists' Geotagging and Monitoring System for Infected Banana Plant. *International Journal of Scientific & Technology Research*, 9(4), 980-985.

Che'Ya, N. N., Dunwoody, E. & Gupta, M. (2021). Assessment of Weed Classification using Hyperspectral Reflectance and Optimal Multispectral UAV Imagery. *Agronomy*, 11(7):1435.

Cermakova, I., Komarkova, J., & Sedlak, P. (2019). Calculation of Visible Spectral Indices from UAV-Based Data: Small Water Bodies Monitoring. *In 2019 14th Iberian Conference on Information Systems and Technologies (CISTI)*, 1-5.

Eng, L. S., Ismail, R., Hashim, W., Mohamed, R. R., & Baharum, A. (2018). Vegetation Monitoring using UAV: A Preliminary Study. *International Journal of Engineering and Technology*, 7(4), 223–227.

Frels, K., Guttieri, M., Joyce, B., Leavitt, B., & Baenziger, P. S. (2018). Evaluating Canopy Spectral Reflectance Vegetation Indices to Estimate Nitrogen Use Traits in Hard Winter Wheat. *Field Crops Research*, 217, 82-92.

Gitelson, A. A., Keydan, G. P., & Merzlyak, M. N. (2006). Three-Band Model for Noninvasive Estimation of Chlorophyll, Carotenoids, and Anthocyanin Contents in Higher Plant Leaves. *Geophysical Research Letters*, 33(11).

Hamylton, S. M., Morris, R. H., Carvalho, R. C., Roder, N., Barlow, P., Mills, K., & Wang, L. (2020). Evaluating Techniques for Mapping Island Vegetation from Unmanned Aerial Vehicle Images: Pixel classification, Visual Interpretation and Machine Learning Approaches. *International Journal of Applied Earth Observation and Geoinformation*, 89, 102085.

Heim, R. H., Wright, I. J., Scarth, P., Carnegie, A. J., Taylor, D., & Oldeland, J. (2019). Multispectral, Aerial Disease Detection for Myrtle Rust (Austropuccinia psidii) on a Lemon Myrtle Plantation. *Drones*, 3(1), 25.

Mallmann, C. L., Zaninni, A. F., & Pereira Filho, W. (2020). Vegetation Index Based in Unmanned Aerial Vehicle to Improve the Management of Invasive Plants in Protected Areas, Southern Brazil. *In 2020 IEEE Latin American GRSS & ISPRS Remote Sensing Conference (LAGIRS)*, 66-69.

Mateen, A., & Zhu, Q. (2019). Weed Detection in Wheat Crop using UAV for Precision Agriculture. *Pakistan Journal of Agricultural Sciences*, 56(3).

Muhammad, M., & Tahar, K. N. (2021). Comprehensive Analysis of UAV Flight Parameters for High Resolution Topographic Mapping. *In IOP Conference Series: Earth and Environmental Science*, 767 (1), 012001.

Navaja, R. B., Campomanes, F. P., Patiño, C. L., & Flores, M. J. L. (2019). Analysing the Status of Mango Trees in Brgy. Cantipay, Carmen, Cebu Using Ndvi and Time Series Clustering. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, 42, 313-317.

Mohite, J., Sawant, S., Pandit, A., & Pappula, S. (2020). Integration of Sentinel 1 and 2 Observations for Mapping Early and Late Sowing of Soybean and Cotton Crop Using Deep Learning. *In IGARSS 2020-2020 IEEE International Geoscience and Remote Sensing Symposium*, 1941-1944.

Neto, A. S., Lopes, D. C., Toledo, J. V., Zolnier, S., & Silva, T. D. (2018). Classification of sugarcane varieties using visible/near infrared spectral reflectance of stalks and multivariate methods. *The Journal of Agricultural Science*, 156(4), 537-546.

Ngo, V. D., Jang, B. E., Park, S. U., Kim, S. J., Kim, Y. J., & Chung, S. O. (2019). Estimation of functional components of Chinese cabbage leaves grown in a plant factory using diffuse reflectance spectroscopy. *Journal of the Science of Food and Agricultur*e, 99(2), 711-718.

Olson, D., Chatterjee, A., Franzen, D. W., & Day, S. S. (2019). Relationship of drone-based vegetation indices with corn and sugarbeet yields. *Agronomy Journal*, 111(5), 2545-2557.

Rahman, M. I. (2021). *Durian Plantation Management using Aerial Imagery and GIS Application*. [Unpublished bachelor's thesis]. Universiti Putra Malaysia.

Revanasiddappa, B., Arvind, C., & Swamy, S. (2020). Real-time early detection of weed plants in pulse crop field using drone with IoT. *Technology*, 16(5), 1227-1242.

Roman, A., & Ursu, T. (2016). Multispectral satellite imagery and airborne laser scanning techniques for the detection of archaeological vegetation marks. *Landsc. Archaeol. North. Front. Rom. Emp. Porolissum*, 141-152.

Saleem, M. R., Park, J. W., Lee, J. H., Jung, H. J., & Sarwar, M. Z. (2021). Instant Bridge Visual Inspection using an Unmanned Aerial Vehicle by Image Capturing and Geo-Tagging System and Deep Convolutional Neural Network. *Structural Health Monitoring*, 20(4), 1760-1777.

Sattler, T., Havlena, M., Schindler, K. & Pollefeys, M. (2016). Large-Scale Location Recognition and the Geometric Burstiness Problem. *In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, 1582–1590.

Sawant, S., Mohite, J., Sakkan, M., & Pappula, S. (2019, July). Near real time crop loss estimation using remote sensing observations. *In 2019 8th International Conference on Agro-Geoinformatics (Agro-Geoinformatics)*, 1-5).

Sottini, V. A., Barbierato, E., Bernetti, I., Capecchi, I., Fabbrizzi, S., & Menghini, S. (2019). Rural Environment and Landscape Quality: An Evaluation Model Integrating Social Media Analysis and Geostatistics Techniques. *Aestimum*, 43-62.

Sottini, V. A., Barbierato, E., Bernetti, I., Capecchi, I., Fabbrizzi, S., & Menghini, S. (2019). The Use of Crowdsourced Geographic Information for Spatial Evaluation of Cultural Ecosystem Services in the Agricultural Landscape: the Case of Chianti Classico (Italy). *New Medit*, 18(2), 105-118.

Talosig, E. E., Adriatico, C., & Yap, F. R. P. (2019). Profiling and Geotagging of Rubber Tree Plantation through Geographic Information System. *Open Access Library Journal*, 6(7), 1-14.

Tang, F., Zhang, D., & Zhao, X. (2021). Efficiently Deep Learning for Monitoring *Ipomoea cairica (L.)* Sweets in the Wild. *Mathematical Biosciences and Engineering: MBE*, 18(2), 1121-1135.

Tian, Y., Chen, C., & Shah, M. (2017). Cross-View Image Matching for Geo-Localization in Urban Environments. *In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, 3608-3616.

Vo, N., Jacobs, N., & Hays, J. (2017). Revisiting im2gps in the deep learning era. *In Proceedings of the IEEE International Conference on Computer Vision*, 2621-2630.

Xue, L., & Yang, L. (2009). Deriving Leaf Chlorophyll Content of Green-Leafy Vegetables from Hyperspectral Reflectance. *ISPRS Journal of Photogrammetry and Remote Sensing*, 64(1), 97-106.

Xue, J., & Su, B. (2017). Significant Remote Sensing Vegetation Indices: A Review of Developments and Applications. *Journal of Sensors*, 2017.

Yang, C., & Hoffmann, W. C. (2015). Low-Cost Single-Camera Imaging System for Aerial Applicators. *Journal of Applied Remote Sensin*g, 9(1), 096064.

Yu, T. H., Hsieh, S. P., Su, C. M., Huang, F. J., Hung, C. C., & Yiin, L. M. (2018). Analysis of leafy vegetable nitrate using a modified spectrometric method. *International Journal of Analytical Chemistry*, 1–6.

Zhang, J., Cheng, T., Guo, W., Xu, X., Qiao, H., Xie, Y., & Ma, X. (2021). Leaf Area Index Estimation Model for UAV Image Hyperspectral Data Based on Wavelength Variable Selection and Machine Learning Methods. *Plant Methods*, 17(1), 1-14.

Zhang, D., Mansaray, L. R., Jin, H., Sun, H., Kuang, Z., & Huang, J. (2018). A Universal Estimation Model of Fractional Vegetation Cover for Different Crops Based on Time Series Digital Photographs. *Computers and Electronics in Agriculture*, 151, 93-103.

DEVELOPMENT OF THE AUTOMATED FERTIGATION SYSTEM USING MOBILE APPS

Nur Adibah Mohidem, Fakhrul Azran Nawi, Nik Norasma Che'Ya*, Wan Fazilah Fazlil Ilahi
Department of Agriculture Technology, Faculty of Agriculture, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia
*niknorasma@upm.edu.my

Abstract

The need to produce sufficient food for the Malaysian population is manifested via the National Key Economic Areas (NKEA) in the agriculture sector by the government. The NKEA focuses on the potential of growing subsectors, including a premium market for fruit and vegetables. The focus has shifted from labour to capital or technology-intensive. Therefore, automated fertigation equipped with the monitoring and control system towards a sustainable agricultural practice and higher production using the Internet of Things (IoT) such as mobile app is proposed. The system is expected to produce higher yield than the labour-based practice. The optimal amount of fertiliser and feeding time will be determined based on the data collected from the automated system. Prior to adoption of IoT, the ratio of elements required by plants involves commercial fertiliser or nutrients that are ready to use. Hence, it is crucial to develop a system that monitors all inputs of the growing environment, including pH adjusters and organic soil amendments. The proposed automated fertigation system is expected to assist farmers in optimising the amount of nutrient and water and as well as human resources needed in the farm operation.

Keywords: Automated fertigation control system; Fertilisers; Mobile apps; Plant

Introduction

Many technologies have been applied in agriculture to increase production and mitigate the environmental impact in edaphic waters due to excessive fertiliser. A fertigation system equipped with irrigation and fertiliser applications can improve water and fertiliser efficiency through crop zones, reduce nutrient leakage, and avoid the use of excessive underground water. In fact, the automated fertigation system can help farmers to make informed decisions in utilising optimal amount of water and nutrient, thus contribute to lower prevalence of crop disease. The main issue in a fertigation system is its control management, which is crucial to monitor the crop growth to prevent any system damage and failure. One of the solutions to improve the control aspect is the application of automated fertigation system. Abidin and Ibrahim (2015) used a web-based application to help users monitor the parameters such as water level, the flow of valves and pipes, and the entire operation of the automated fertigation system. Thus, an online platform is needed to provide information on the crop growth cycle from planting to harvesting. Feature extraction can be used to detect the condition of the plants in the greenhouse, and the model can be adopted as intelligent farming in the future (Aminulloh et al., 2019). Mobile apps are a new platform to share the details and update real-time data precisely. The farmers can visualise the data and retrieve the information regarding their fertigation system using their smartphone. The app also helps in terms of decision support system (DSS) to determine the optimal parameters for the fertigation application (Pérez-Castro, et al., 2017).

The use of mobile applications in agriculture is significant to deliver information about crops and the suitable crop management for high yield production to users. Roslin et al. (2021) developed mobile apps to monitor the crop in paddy fields for rice farming. Critical crop management includes sufficient fertilisers for specific types of crops, efficient water distribution, and irrigation scheduling. Efficient application of the correct type and amount of fertilisers to supply the nutrients is important to achieve better. Meanwhile, proper irrigation scheduling is essential for higher crop productivity, thus increasing the farmers income (Malo, 2020). In Malaysia and Thailand, most farmers use the conventional fertigation method by mixing water and nutrients manually or using a timer. Mechanical float is used to fill water into the mixing tank according to the required amount and the nutrient solution concentration is checked using a portable electrical conductivity (EC) sensor. However, farmers need to make and check manually the nutrient solution concentration regularly. This is labour-intensive and time-consuming. On the other hand, the irrigation system is scheduled using a timer for the crops to be water automatically. The water and nutrients provided may be excessive or insufficient, thus leads to lower production and causes diseases to the crops.

Recent advancements in information and communications technology (ICT) in agriculture enable low-maintenance and affordable automatic mixing, irrigation scheduling, as well as convenient monitoring and control systems for efficient crop management (Navulur et al., 2017). The automatic mixing feature is feasible using a controller such as an Arduino board and electrical conductivity (EC) sensor to maintain the specific nutrient solution concentration required by the plants (Ruan et al., 2015). The irrigation scheduling shall be operated based on the farm environment, weather, and soil condition using moisture and soil pH sensors to automate the irrigation system. The use of ICT enables a more flexible farm operation and more efficient irrigation system to deliver the nutrient solution to the crops (Yadav et al., 2021). Integration of this automation system into a mobile application can ease the monitoring and control of the farm operation. Nowadays, almost all people own a smartphone, and with this technology, the demand for mobile applications is higher. Therefore, a mobile application can help users provide information about the plant condition and control the farm operation. This is the potential aspect to help farmers increase the crop yield with lesser cost.

The proposed system is expected to leave significant impact to the practices in farming or agriculture by increasing productivity, minimising the production cost, and enhancing sustainable agriculture activities. Fertiliser formulation and automated mixing system that shall be developed enable farmers to identify the plants' specific requirements in terms of nutritional composition, as well as the timing and frequency of fertiliser and watering to control and optimise the consumption of resources. The Internet of Things (IoTs) and artificial intelligence (AI) systems enable real-time information to be gathered, processed, and aid farmers in decision-making. It reduces the amount of labour required for monitoring the farming activities and historical data management. The real-time information enables farmers to take prompt actions, while the historical data will assist farmers in the short-term and long-term strategic planning. In fact, the adoption of drip fertigation systems in China leaves a positive impact on the farmers' experiences and workers' skills (Yang et al., 2020). This study is expected to have a positive impact on farmers. However, the level of acceptance and readiness of farmers are yet to be determined. It is important to understand to what extent the farmers are ready, accept, and aware of the system. Therefore, the objectives of this study are (1) to develop the automated fertigation control system using IoT and mobile application and (2) to determine the level of knowledge, attitude, acceptance, and awareness of ICT in farming activities.

Methodology

Research site and design architecture

This study will be conducted in the EcoPark Green House, University Technology Malaysia (UTM), Skudai Johor, Malaysia, as illustrated in Figure 1. The crop that was used in this study is cherry tomato (*Solanum Lycopersicum* var. *Cerasiforme*).

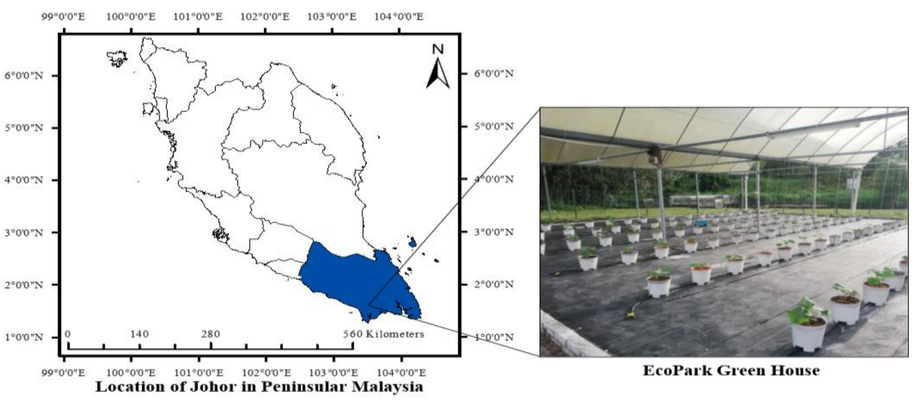

Figure 1. Location of the research site (EcoPark, UTM, Skudai, Johor)

The framework of this study is to develop the automated fertigation system equipped with monitoring and control features using bio-based fertiliser as the medium for efficient utilisation of fertiliser and water. The moisture sensor and automated fertigation system will be installed at the cultivation testbed. The architectural design for the development of automated fertigation system is illustrated in Figure 2.

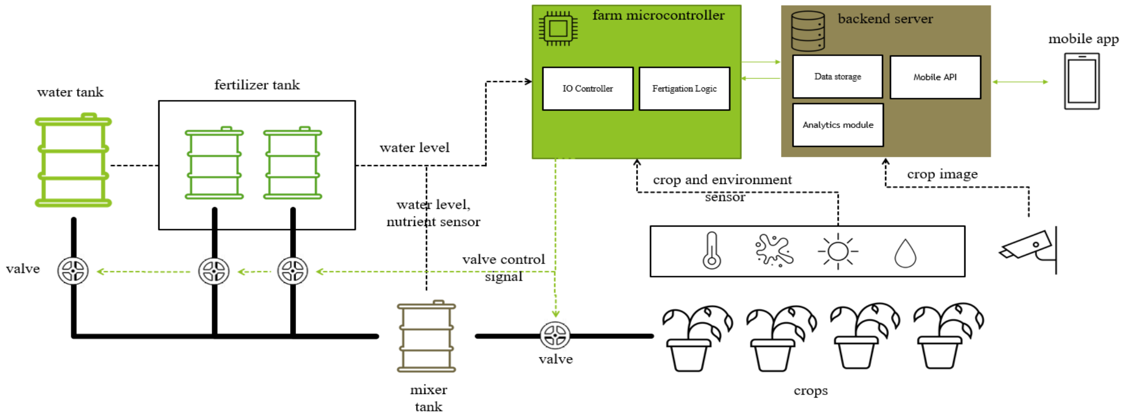

Figure 2. Architectural design for the development of automated fertigation system

Experimental design

Data collection on cultivation with and without the automated fertigation system will be identified to compare the growth and marketable yield of the crop. A randomised complete block design (RCBD) with subsamples will be organised in two blocks, with two treatments per block (treatment 1 (T1) to represent the conventional fertigation with time control and treatment 2 (T2) to represent the automated fertigation using mobile apps). There will be 30 samples of crop for each treatment, as shown in Figure 3. This means 120 unit of plants are required as samples for two blocks in this study. When it comes to the treatment, liquid tank and pipelines that are equipped with a control valve for the fertiliser mixing process will be prepared using a drip fertigation system. The electronic sensors installed at the cultivation area will monitor the moisture, temperature and pH of the soil.

Figure 3. Experimental design

Development of Automated Fertigation Control System (Objective 1)

The soil moisture sensor will be installed at the root zone of the crops to provide moisture readings real-time. This soil moisture data will be used as the input of the irrigation system at the prepared cultivation testbed. Using the soil sensor, the controller will switch on or switch off the water pump to irrigate the crops. Several sensors will be installed across the cultivation area to ensure the sensor readings of the soil moisture are reliable. The NodeMCU microcontroller unit (MCU) is equipped with WiFi connection to enable communication between the receiver and transmitter sensors in the wireless sensor network (WSN) configuration while the data is detected. The sensors will detect and record the crop's measurement, and all information will be sent to a central database. This enables the control unit to receive all the sensor readings. The central system will analyse the data and send the information to the mobile app. The mobile app shall consist of a graphical user interface (GUI). All parameters will be recorded and transferred to the cloud server. Thus, users can monitor their crop using the mobile app that has been developed.

The mobile app will enable users to monitor the water level in the fertiliser tank, electrical conductivity (EC), and soil moisture level. Furthermore, the app will immediately notify the users of any alarming situation. It provides a convenient platform for farmers to be more aware of the crop conditions using this modern fertigation system. A user satisfaction test will be conducted to verify the mobile app functions. The GUI features help users to use the mobile app and explore the functions in the mobile app accordingly. Using the feedback from the users, the functions in the mobile app can be tweaked to improve the automated fertigation system. The app can configure the different demands of the automated fertigation system and generate the database for irrigation, drainage, and fertiliser analysis.

Knowledge, attitude, acceptance, and awareness of ICT solution (Objective 2)

This study will also investigate the level of knowledge, attitude, acceptance, and awareness of ICT (monitoring and control features using mobile apps) in farming activities. This can be conducted through survey and interview sessions. This study will use a quantitative method via descriptive and inferential statistics. Data will be collected from the respondents using self-administered questionnaires. The responses to the questionnaire items will be rated according to the 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). The respondents will be notified that their participation is based on a voluntary basis.

Reliability and validation

Validation is mandatory due to several issues that may be detrimental to the crop or the equipment installed. The mobile app will analyse the inputs from the cultivation area and users will provide valuable information in the final mobile app development stage. The information includes pH problems due to fertiliser concentration in the automated fertigation system and user acceptance test to improve and verify the mobile app functions. This study shall involve two validity tests, which are face validity and content validity. The face and content validities are done when the questionnaire items are validated by the subject-matter experts in mobile app development. A reliability test is conducted to examine the consistency of the items used to measure the ICT attributes (monitoring and control features in the mobile app).

Data analysis

The parameters of crop growth shall include plant height, plant crown/diameter, leaf length, flower bud per plant, fruit per plant, length of fruit, diameter of fruit, and the fruit's weight. The measurement will be collected weekly upon transplanting. Meanwhile, the data gathered from the respondents involved in the survey will be transferred into the SPSS version 24 for Windows (Rel. 11.5.0. 2002; SPSS Chicago, IL, USA). This software is deemed to be the best statistical tool in addressing the objectives of this study. It is because SPSS can provide the complete solution for all analyses required in this study.

Expected results

The automated fertigation system serves as a solution for monitoring and control purposes using a mobile application that is to be developed. It is expected that there will be significant differences in terms of growth rate and yield of cherry tomatoes between conventional fertigation with time control and automated fertigation using the mobile app. Furthermore, the level of knowledge, attitude, acceptance, and ICT solutions such as automated mixing, monitoring and control features using the mobile app in the farming activities will be determined.

Acknowledgement

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References

Abidin, S. A. H. Z., & Ibrahim, S. N. (2015). Web-based monitoring of an automated fertigation system: An IoT application. *In 2015 IEEE 12th Malaysia International Conference on Communications (MICC)*, 1-5.

Aminulloh, L., Sesulihatien, W. T., & Pramadihanto, D. (2019, September). Feature Extraction of Tomato Growth Model using Greenhouse Monitoring System. *In 2019 International Electronics Symposium (IES)*, 370-375.

Malo, M. (2020). Irrigation Scheduling: A Smart Method of Water Management. *Biotica Research Today*, 2(5), 245-248.

Navulur, S., & Prasad, M. G. (2017). Agricultural management through wireless sensors and internet of things. *International Journal of Electrical and Computer Engineering*, 7(6), 3492.

Pérez-Castro, A., Sánchez-Molina, J. A., Castilla, M., Sánchez-Moreno, J., Moreno-Úbeda, J. C., & Magán, J. J. (2017). cFertigUAL: A fertigation management app for greenhouse vegetable crops. *Agricultural Water Management*, 183, 186-193.

Roslin, N. A., Che'Ya, N. N., Rosle, R., & Ismail, M. R. (2021). Smartphone Application Development for Rice Field Management Through Aerial Imagery and Normalised Difference Vegetation Index (NDVI) Analysis. *Pertanika Journal of Science & Technology*, 29(2).

Ruan, J., Liao, P., & Dong, C. (2015). The design and research on intelligent fertigation system. *In 2015 7th International Conference on Intelligent Human-Machine Systems and Cybernetics*, 2, 456-459.

Yadav, R. K., Jha, A., & Choudhary, A. (2021). IoT based prediction of water quality index for farm irrigation. *In 2021 International Conference on Artificial Intelligence and Smart Systems (ICAIS)*, 1443-1448.

Yang, Q., Zhu, Y., & Wang, J. (2020). Adoption of drip fertigation system and technical efficiency of cherry tomato farmers in Southern China. *Journal of Cleaner Production*, 275, 123980.

DEVELOPMENT OF OIL PALM PRECISION AGRICULTURE: SMART MANAGEMENT IN OIL PALM SEEDLING NURSERY

Azizul Hakim Lahuri*[a], Nor Hanifawati Inai*[b], Jamie Lazaroo, Nur Khairunnisa Mohd Kamaruzaman, Logeswary Muniandy
Department of Science and Technology, University Putra Malaysia Bintulu Campus, Nyabau Road, P.O Box 396, 97008 Bintulu, Sarawak, Malaysia.
*[a] azizulhakim@upm.edu.my and *[b] hanifawati@upm.edu.my

Abstract

Various technologies should be combined to resolve the problem faced by farmers. A strong demand for palm oil, cultivation of oil palms has expanded more in the past ten years than cultivation of any other crop. Palm Oil has become an important crop production to our country. Common challenges faced by the farmers are property safety, expenditure on unnecessary cost due to poor farm management in fertilization, pesticide application, diseases control and plantation landscape. Various advanced technologies could be deployed to resolve these problems and to enhance the smart management in oil palm seedling nursery. Precision agriculture in oil palm nursery could be an advantage in the management of the property and the data is also accessible accurately. This review includes the implementation of the technology, the results of applying the technologies and their challenges of implementation. The proposed integrated smart management oil palm seedling nursery could provide better digital farming through application of the technologies.

Keywords: Digital farming; Oil palm seedling nursery; Precision agriculture; Smart management

Introduction

The Malaysian oil palm industry continues to grow rapidly with the increase in oil palm areas, either planted or replanted. This industry, with the crop cultivated by estates and smallholders, also continues to be one of the major contributors to the national economy. In 2020, the oil palm planted area had reached 5.87 million hectares, a 0.6 percent decrease from the previous year (5.90 million hectares). This is primarily due to a 1.1 percent decrease in planted area in Peninsular Malaysia, or 13 280 ha. The imposition of movement control orders (MCO), which contributes to the decline in planted area, is primarily responsible for the restriction of oil palm expansion and the delay in oil palm replanting. Sarawak continues to be the most oil palm planted state, accounting for 1.58 million hectares or 27.0 percent of total Malaysian oil palm planted area, followed by Sabah and Pahang, with 1.54 million hectares and 0.78 million hectares, respectively (Ghulam Kadir,2021).

The activities in the oil palm seedling nursery can be categorized into the pre-nursery stage, the main nursery, site selection and preparation and preparation (Heriansyah, 2005) as shown in Table 1. Through these activities, there are several problems faced by the farmers. For instance, lack of water supply, poor or uneven coverage of irrigation system, uncontrollable pest management, unorganized farm management according to schedule, lack of employees, unmanaged proper data collection and insecurity of crop protection such as intruders, birds, snakes, and rats. Therefore, smart farming in oil palm seedling nurseries found to be relevant and could give tremendous advantages.

Smart farming is an emerging concept that refers to managing farms using technologies such as the Internet of Things (IoT), robotics, drones and Artificial Intelligence (AI). Employment of smart farming could increase the quantity and quality of products while optimizing the human labor required by production (FGV Prodata Systems Sdn. Bhd, 2013). In addition, IoT in smart farming technology is the concept of connected smart machines and sensors integrated on farms to make farming processes data-driven and data-enabled.

Table 1 Categorization of activities in Oil Palm Nursery (Heriansyah, 2005)

Activities categories	Activities in oil palm nursery
Pre – Nursery Stage	Polybag filling and placement
	Shading
	Planting germinated seeds into polybags
The Main Nursery	Polybag filling
	Spacing of bags
	Transplanting from pre-nursery into large polybags (main nursery)
Site Selection and preparation	Topography (Terrain)
	Water Supply
	Drainage
	Area
Preparation	Nursery Design
	Clearing
	Fencing
	The conventional Fence
	Electric Fence
	Lining

The data-driven farming processes could be generated by applying precision agriculture also known as precision agriculture or precision farming. It is practically accurate in farming and controlled when it comes to the growing of crops and raising livestock. This farm management approach applies Global Positioning System (GPS) guidance, control systems, sensors, robotics, drones, autonomous vehicles, variable rate technology, GPS-based soil sampling, automated hardware, telematics, and software. For instance, Sime Darby is a well-known oil palm plantation company in Malaysia that employs precision agriculture (Sime Darby Plantation, 2020). The Malaysia Palm Oil Board (MPOB) also applied precision agriculture in fertilizer management (Wahid, 2002).

Generally, oil palm seedling nurseries constitute huge land and raise difficulties in managing the property. This review aims to develop smart farming by adopting precision agriculture in oil palm seedling nurseries. The proposed design and planning of the smart management in oil palm plantation will be discussed further to provide an insight into utilizing the technology to get better results such as less wasted seed, fertilizer, fuel and time. If possible, it also helps to provide an accurate farming technique for planting and growing crops.

Development of smart farming

Based on the literature review, several technologies were recommended in developing smart farming. The technologies that could be adopted in the oil palm nursery management are tabulated in Table 2. A further insight understanding each of the technologies will be explained in detail.

Table 2. Recommendation of technologies in developing smart farming by adopting precision agriculture in oil palm nursery.

Technology	Techniques
Smart irrigation for plant monitoring using Internet of Thing (IoT)	Micro-sprinkler equipped with solar sync
Pest monitoring and fertilizer	Utilizing drone
Application of IoT: Digital farming	Drone for Surveillance (Remote Sensing)
	Accelerometer Sensor
	Geographic Information System (GIS)
	Smart Intrusion Detection
Smart management oil palm seedling nursery	Integrated system

Smart irrigation for plant monitoring equipped with solar power

A common irrigation problem faced by the oil palm seedling nursery is the poor irrigation system. Nevertheless, it could be solved by employing a micro-sprinkler equipped with solar sync (Figure 1) which allows irrigation to take place more efficiently, based on soil humidity, temperature, and pH values. Solar sync is a smart irrigation control system in the app that is capable of measuring evapotranspiration, sunlight and temperature which helps it adjust the amount of water according to the needs. It explains that the irrigation system will stop the water flow by detecting the weather and its temperature. For example, when the soil is in a moist condition which leads the soil temperature to decrease due to its soil moisture. Plants are not suitable to grow in wet soil because it causes stressed roots and drowns. In addition, the oxygen content is reduced and minimal oxygen is absorbed by the plant roots. Thus, it decreases the nutrient uptake of the plant's which leads to leaf yellowing and other symptoms.

The cost for employing this technology is approximately RM600 to 1,200 per acre (Ross, 2013). The technology was also provided by a China company known as Megawatt New Energy Technology Co. Ltd. which supplied the installation of the technology (Ecplaza, 2010). A sustainable and responsible conservation system is achieved upon utilizing a clean energy device that generates electricity from photovoltaic cells through solar technology. Furthermore, a real-time data monitoring process in a huge nursery including climate conditions is easily accessible. This will benefit places that have a shortage of water and an absence of an electrical grid (Babaa, 2020).

a) b)

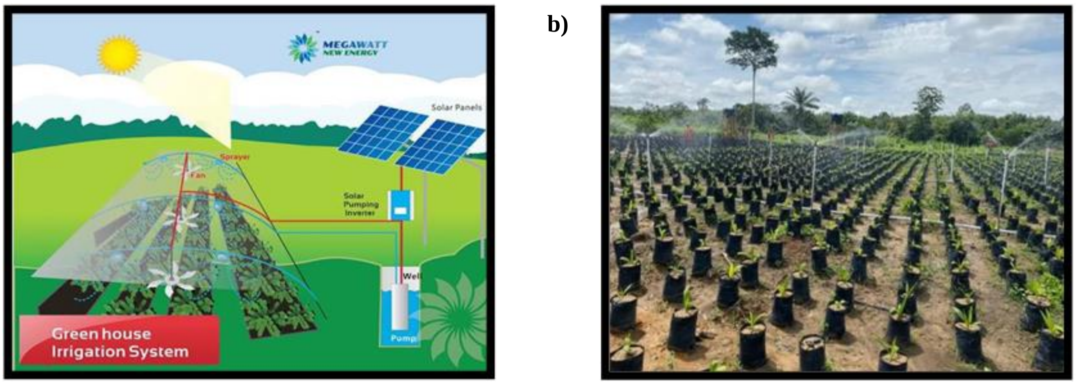

Figure 1. A schematic diagram of a) Smart irrigation system using the solar panel and b) Irrigation system using Micro-sprinkler. (Ecplaza.net)

However, the challenges in the deployment of this technology could be an obstacle due to high upfront cost, requires sunny weather to work better, limited to daytime usage only and the system will stop during low energy conversion rate (Panta, 2020). Besides, sun heat exposure affects tubes that could be broken for excessive heat production. Eventually, the sun degrades plastic sometimes and that affects soil and fertilizers too. The tubes also will be clogged and result in the water unable to pass through and roots get dehydrated (Al-Ali, 2019).

Drone for pest monitoring and fertilizer

A huge oil palm seedling nursery requires proper and systematic pest management and fertilizing. Relying on human capability is inevitable in identifying covered areas causing inefficiency in pest management and crop fertility control. Insufficient manpower to monitor the huge oil palm seedling nursery also delayed the work schedule. Therefore, utilizing the drone for pest monitoring and fertilizing could overcome these hurdles.

Utilizing drones in pest management could track and manage diseases by monitoring the state of plants that are in distress which eventually could easily control the diseases and reduces the damage. In addition, pesticide or fertilizer spraying by using a drone could save manpower and time. For instance, spraying of 1 hectare can be completed in 20 minutes which 100 times faster than trunk injections (Lim, 2018). Precision fertilization may result in significant in decreases fertilizer capital and the application cost (Devi, 2020). The cost for deploy this technology is acceptable which the drone can be purchased for approximately RM90 to 2,000, depending on the drone technology. It was observed that the cost for fertilizer and pesticide after drone technology employment is RM60 to 70/acre compared to before drone technology employment is RM100 to 150/acre. Thus, the application of drones in-field operation of oil palm nurseries and plantations is efficient for real plantation management and research purposes.

The deployment of drones in the field could improve monitoring and fast action could be taken upon detection on a certain area. Drones are a device that uses radio energy to detect an object. Drone detection radar sends out a signal and receives the reflection, measuring direction and distance (position). Most radars send their radio signal as a burst, then listen for the 'echo'. Optical sensors (cameras) are a type of digital sensor that are used in drones. The optical sensors use light to sense things. Data is then transferred into the device used to control the drone.

Nonetheless, the challenges still inevitable concerning national laws, are weather dependent and require well-trained personnel (Pathak, 2020). Besides, this technology is battery dependent, causing invasion of privacy, vulnerable to hackers and causing unemployment (Yaacoub, 2020).

Application of IoT: Digital farming

Integrating information and IoT in the agriculture industry could enhance the development of oil palm seedling nurseries. It was noteworthy to observe that the research on the evolution of smart farming in Malaysia began in the year 1999 with a study on precision farming (Gabriel Wee, 2020). The application of IoT in digital farming are drones equipped with remote sensing, accelerometer sensor and GIS.

Remote Sensing

The remote sensing can be equipped on the drone which consists of a camera for the surveillance system. The main purpose of this technology is to classify area, tree counting, age estimation, pest detection, disease detection, and yield estimation (Chong, 2017). It is not limited to that, but also could simply identify weed detection, dry crop at a certain area, monitor the health status and observe the oil palm growth. However, the sensor limitation through algorithm failure led to drones getting lost or colliding, as well as sensor failure under different environment conditions (Yaacoub, 2020).

Accelerometer sensor

The accelerometer sensor plays an important role in the maintenance of vital smart agriculture equipment. It allows monitoring palms remotely by contributing to the early detection such as red palm weevil infestation (Koubaa, 2020). The web/mobile applications can be used as a medium to observe the palm, thus, data also accessible using an accelerometer sensor by analyzing the signal process and statistical techniques. This technology requires expertise and well-trained personnel to operate the system and analyze the data.

Geographic information system (GIS)

Proper data management is essential for reporting accurate area classification. A huge oil palm seedling nursery certainly requires the aid of GIS to manage data collection (Nordiana, 2013). The implementation of GIS to oil palm plantations could provide mapping nutrient status (Rendana, 2016), production prediction, spatial management, and land evaluation (Nordiana, 2013). Accuracy in the plantation mapping could observe the discrepancies through records which proved to be a valuable tool in the management of the spatial data by displaying a clear structured manner of information. Application of this technology requires large storage of data, expensive data collection, complex data structures and the simulation is also difficult (Wieczorek, 2009).

Smart intrusion detection

The smart intrusion system was designed to protect farms and plantations from animals and intruders. A sound will be played upon detection so that wild animals will not enter the area. However, it could regularly alert on false detection due to the inability to differentiate passing objects (Shanono, 2020).

Integrated smart management oil palm seedling nursery

The proposed integrated-smart management oil palm seedling nursery by applying the technologies is shown in Figure 2 and cost comparison estimation is tabulated in Table 3. The smart management was observed to help to reduce the labor cost through IoT for watering, pest monitoring drones and fertilization using a drone. The cost for digitalized farming is higher than before the digitals and IoT applied. However, utilization of drones for surveillance helps the farmers to monitor the plant's growth and condition well and human mistake is avoidable while monitoring manually. This activity can be done fast, and it is precise. In addition, using sensors and detectors helps the farmers to be aware of their nursery's condition even at night. The data will be transferred quickly to the farmers and create an alert if there are wild animals or thieves get into the nursery.

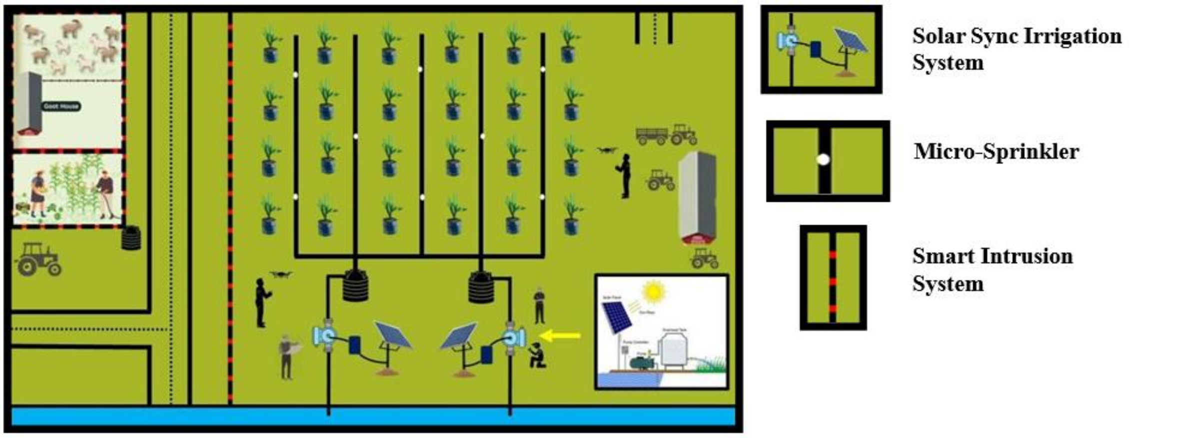

Figure 2. Integrated smart management oil palm seedling nursery.

Table 3. Cost Comparison smart management oil palm seedling nursery.

Technology	Category	Before smart management	After smart management
IoT for plant watering solar panels	Water supply	RM1,500 - RM2,000/acre	RM600 - RM1,200/acre
	Labor cost (manual)	RM100 - RM150/acre	RM30 - RM50/acre
Pumping System	Water supply	RM1,800 – RM2,500/acre	RM500 – RM1,000/acre
Maintenance	Solar Panels/ Water supply	RM1,500 - RM2,000/acre	RM600 - RM1,200/acre
Drone	for Pest monitoring and fertilization	Labor: RM100-150/acre	RM90-RM2,000
	Fertilizer and Pesticide	RM100-RM150/acre	RM60-RM70/acre
	Labor cost for pest monitoring and fertilizer (manual)	RM100-RM150/acre	RM60-RM70/acre
Applications of IoT: Digital farming	Drone for surveillance (Remote sensing)	Monitoring plant: RM100 - RM150/acre	RM300 - RM5,000
	Accelerometer sensor	Monitoring plant: RM100 - RM150/acre	RM370 - RM1,822
	GIS	Mapping, Data and Spatial management: RM100 - RM200/acre	RM150 - RM250
	Passive Infrared sensor (PIR)	Labor (Guards): RM100 - RM200/acre	RM100 - RM800
	Global system for Mobile communications (GSM) detector	Labor (Guards): RM100 - RM200/acre	RM300 - RM500

Conclusion

Numerous benefits for agricultural management can be obtained through the implementation of smart management. The deployment of mechanization and IoT in oil palm nurseries is a better choice rather than depending on the workforce. Numerous benefits such as time efficiency, appropriate water consumption and property safety. Considering mechanization and IoT in oil palm nurseries farmers also help the nation to bring the agriculture sector to the advanced level.

References

Ahmad, S. M., Arshad, F., Ismail, A., Ali Nordin, A. Z., Nambiappan, B. (2019). Cost of production in the Malaysia oil palm nursery sector. *Oil Plan Industry Economic Journal*, 19(2), 26-32.

Al-Ali, A. R., Al Nabulsi, A., Mukhopadhyay, S., Awal, M. S., Fernandes, Ailabouni, K. (2019). IoT- solar energy powered smart farm irrigation system. *Journal of Electronic Science and Technology*, 17(4), 100017.

Babaa, S. A. E., Ahmed, M., Ogunleye, B. S., Khan, S. A., Al-Jahdhami, A. A., Pillai, J. R. (2020). Smart irrigation system using Arduino with solar power. *International Journal of Engineering Research & Technology*, 9(5), IJERTV9IS050088.

Chong, K. L., Kanniah, K. D., Pohl, C., Tan, K. P. (2017). A review of remote sensing applications for oil palm studies, *Geo-spatial InformationScience*, 20(2), 184-200.

Devi, K. G., Sowmiya, N., Yasoda, K., Muthulakshmi, K., Kishore, B. (2020). Review on application of drones for crop health monitoring and spraying pesticides and fertilizer. *Journal of Critical Reviews*, 7(6), 667-672.

ECplaza. Agri solar irrigation system. https://megawatt.en.ecplaza.net/products/agri-solar-irrigation-system_3789875 [Retrieved July 13, 2021]

Gabriel Wee, W. E., Devanthran, H. (2020). The Development of Smart Farming Technologies And Its Application In Malaysia. *International Journal of Scientific & Technology Research*, 9(8), 562- 566.

Ghulam Kadir, A. P. (2021). Oil Palm Economic Performance in Malaysia and R&D Progress In 2020. *Journal Of Oil Palm Research*, 33, 181-214.

Heriansyah and Tan C. C. (2005). Nursery practices for production of superior oil palm planting materials. *Planter*, 81(948)N, 159-171.

Koubaa, A., Aldawood, A., Saeed, B., Hadid, A., Ahmed, M., Saad, A., Alkhouja, H., Ammar, A., Alkanhal, M. (2020). Smart palm: An IoT framework for red palm weevil early detection. *Agronomy*, 10(7), 987.

Lim, B., Innovation: Drones home in on plantations. https://www.nst.com.my/lifestyle/bots/2018/03/

349373/innovation-drones-home-plantations [Retrieved July 12, 2021]

Nordiana, A. A., Wahid, O., Esnan, A. G., Zaki, A., Tarmizi, A. M., Zulkifli, H., Norman, K. (2013). Land evaluation for oil palm cultivation using geospatial information technologies. *Oil Palm Bulletin*, 67, 17-29.

Panta, A. K., Adhikari, R., Adhikari, S., Poudel, S. (2020). Automatic irrigation system using solar energy. Arduino Projects. https://electronicsworkshops.com/2020/08/12/automatic-irrigation-system- using-solar-energy/ [Retrieved July 12th, 2021]

Pathak, H., Kumar, G. A. K., Mohapatra, S.D., Gaikwad, B. B. Rane, J. (2020). Use of drones in agriculture: Potentials, problems and policy needs, publication no. 300, *ICAR-National Institute of Abiotic Stress Management*.

Precision Agriculture. (2020, June 10). https://www.simedarbyplantation.com/innovation/precision-agriculture [Retrieved July 14th, 2021]

Rendana, M., Rahim, S. A., Idris, W. M. R., Lihan, T., Rahman, Z. A. (2016). Mapping nutrient status in oil palm plantation using geographic information system. *Asian Journal of Agricultural Research*, 10(3-4), 144-153.

Ross, S. D. Affordable solar irrigation system. https://borgenproject.org/affordable-solar-irrigation-system-fights-rural-poverty/ [Retrieved July 13, 2021]

Shanono, N. M., Abu, N. A., Yassin, W., Faizal, M. A. (2020). Intrusion Detection System Architecture: Issues and Challenges. *Technology Reports of Kansai University*, 62(7), 4121 [Retrieved July 11, 2021]

SMART FARMING – THE FUTURE OF AGRICULTURE BUSINESS IN MALAYSIA | FGV Prodata Systems Sdn Bhd, 2013 http://fgvprodata.com.my/?p=669 [Retrieved July 14th, 2021]

Wahid, O., Xaviar, A., Tarmizi, A.M., Ibrahim, S. (2002). Precision agriculture: fertilizer management map part 1: spatial and correlation analysis of yield and leaf nutrient. *MPOB Information Series*, 128.

What is Precision Agriculture and How is Technology Enabling it? (2017, April 24). https://agfundernews.com/what-is-precision-agriculture.html [Retrieved July 14th, 2021]

Wieczorek, W. F., Delmerico, A. M. (2009). Geographic information system. *Statistics and Computing*, 1(12), 167-186.

Yaacoub, J. P., Noura, H., Salman, O., Chehab, A. (2020). Security analysis of drones systems: Attacks, limitations, and recommendations. *Internet of Things*, *11*, 100218.

RICE CROP MONITORING USING NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI)

Rhushalshafira Rosle, Rowena Mat Halip, Nursyazyla Sulaiman, Nik Norasma Che'Ya*,
Wan Fazilah Fazlil Ilahi
Department of Agricultural Technology, Faculty of Agriculture, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia
*niknorasma@upm.edu.my

Abstract

Remote Sensing (RS) is a technique for data gathering or an event without coming into close contact with it or causing damage. Agriculture is one of the many applications of this technology. Unlike traditional agriculture, which was difficult to adopt and required considerable human resources, adopting this technology will enhance crop yields and strengthen the agriculture sector's management. RS was used to predict crop yield, identify crop types, evaluate yield loss and monitor crop growth. Therefore, this research aims to employ multispectral data from an Unmanned Aerial Vehicle (UAV) to monitor paddy growth. In order to achieve our goal, a popular vegetation index known as the Normalized Difference Vegetation Index (NDVI) derived by multispectral UAV was used to monitor the changes in the rice crop at 35 Day After Planting (DAP), 54 DAP, and 118 DAP which represent the vegetative stage, reproductive stage, and maturative stage as suggested by the International Rice Research Institute (IRRI). The image analysis results revealed that NDVI was able to monitor rice crop growth and discover the damage in the paddy plot at each growth stage. As a result, farmers can take immediate response to counteract the damage and fix the problematic areas.

Keywords: NDVI; Paddy; Remote sensing (RS); Unmanned Aerial Vehicle (UAV)

Introduction

In Malaysia, rice is a staple food for most of the population. Therefore, the government is making efforts to ensure that rice production can meet the population's needs in the future. However, Mutalib (2019) stated that rice production is still falling short, while the government aims at eight to 12 t/ha per year. Weather conditions, water supplies, insects and diseases are all factors that contribute to low rice yield. In addition, farm governance work on a broad scale was problematic for precision farming (PA). Therefore, in 2019, the government launched a program known as "*Halatuju Kementerian Pertanian dan Industri Asas Tani: Prioriti & Strategi 2019–2020*". Implementing precise agriculture through the introduction of new technologies and establishing a more systematic system of farm governance are both on the agenda. Its goal is to boost rice output across the country.

Precision farming (PA) provides farmers with a competitive advantage in operational costs, yield and quality optimization, and the ability to deliver more specific information for improved management (Srinivasan, 2006). Implementation of Remote Sensing (RS) into PA can strengthen the agriculture sector's management. The government's agenda recommends the employment of Unmanned Aerial Vehicles (UAVs). It is because its ability in delivering high quality and precise data can deliver accurate data for agricultural applications (Sabarina & Priya, 2015). UAVs equipped with cameras can provide a detailed picture of crop plots (Murugan et al., 2016). In this study, Remote Sensing (RS) technology was used to improve farm management. High-resolution Normalized Difference Vegetation Index (NDVI) readings can be obtained by utilizing UAVs and multispectral cameras. In agriculture, NDVI values are commonly used to estimate paddy yield and the efficacy of various treatments (Guan et al., 2019). Plant index readings are commonly used in agriculture to assess crop growth rates and determine either the crops are in excellent shape or not (Ghobadifar, 2015). The plant's leaf pigment will reflect Near-Infrared light (NIR) while absorbing visible wavelength. Therefore, the NDVI range value for each crop is different. The NDVI range that resulted from using a GIS system could identify various crops (Bhumika et al., 2019). Therefore, this study aims to monitor plant's growth by using NDVI at different growth stages, which comprise of (1) vegetative stage, (2) reproductive stage, and (3) maturative stage as suggested by the International Rice Research Institute (IRRI) by integrating the use of UAVs and multispectral imagery with vegetation index analysis to assess the efficacy of rice crop treatments.

Methodology

The research site was in Ladang Merdeka, Kampung Lundang Paku, Ketereh, Kelantan, Malaysia with a total area of 70,692.59 m^2. The paddy seed variety was PadiU Putra which is resistant to leaf blight disease. The experiment took place from January till May 2018. The flowchart of this research is shown in Figure 1.

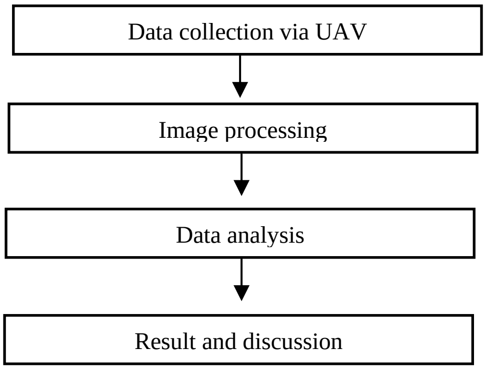

Figure 1: Research flow

The multirotor UAV, XR q350 pro mounted with multispectral sensor Parrot Sequoia (Parrot, France, Paris), was employed in this study as a multispectral sensor. Green (G), Red (R), Red Edge (RE) and Near Infrared (NIR) are the four wavelengths that this multispectral sensor can measure. Due to the availability of spectral bands, the Normalized Difference Vegetation Index (NDVI) was chosen to monitor rice growth using data flown on 6th March (35 Day After Planting (DAP)), 26th March (54 DAP), and 28th May (118 DAP).

This index is an excellent tool for assessing crop changes, condition and status (Rosle et al., 2019). The UAV flew at 10 a.m., with a flying height of 70 metres above ground, comparable to a ground spatial distance of 2.07 cm (GSD), and it took approximately 30 minutes to complete capturing the whole study area. Before data collection, a flying pattern (flight path) was created using Mission Planner software. Setting up the flight path can capture the entire area, and difficulties such as data loss and missed flights can be avoided.

Image processing and analysis

This study used multispectral and RGB digital camera images from UAVs to monitor rice crops. Structure from Motion (SfM) methods were implemented to mosaic and align the image using Agisoft Photoscan software. The digital numbers (DNs) from photos were transformed into reflectance values using an empirical regression equation. Later, in ArcGIS version 10.2, the NDVI of the research area was calculated using the equation:

$$NDVI = \frac{(NIR-RED)}{(NIR+RED)} \quad \text{Equation 1}$$

Result and Discussion

Series of RGB images captured can be used to view the whole plot area by crop stages. The NDVI map generated from the multispectral imagery can be used as an indicator for crop health. NDVI value range is between -1 to 1, where value -1 to 0 is indicated as non-vegetation, and value 0.1 to 1 is indicated as vegetation area (Rosle et al., 2019). The colour coding from the NDVI map in this study reflects the NDVI value that represents photosynthesis activity. The green colour shows the highest rate of photosynthesis activity by paddy's crop (> 0.66), the red colour shows the lowest rate of photosynthesis activity by paddy's crop (0.1-0.33), and the yellow colour shows the mid-range rate of photosynthesis activity by paddy's crop (0.33-0.66) as shown in Figure 2.

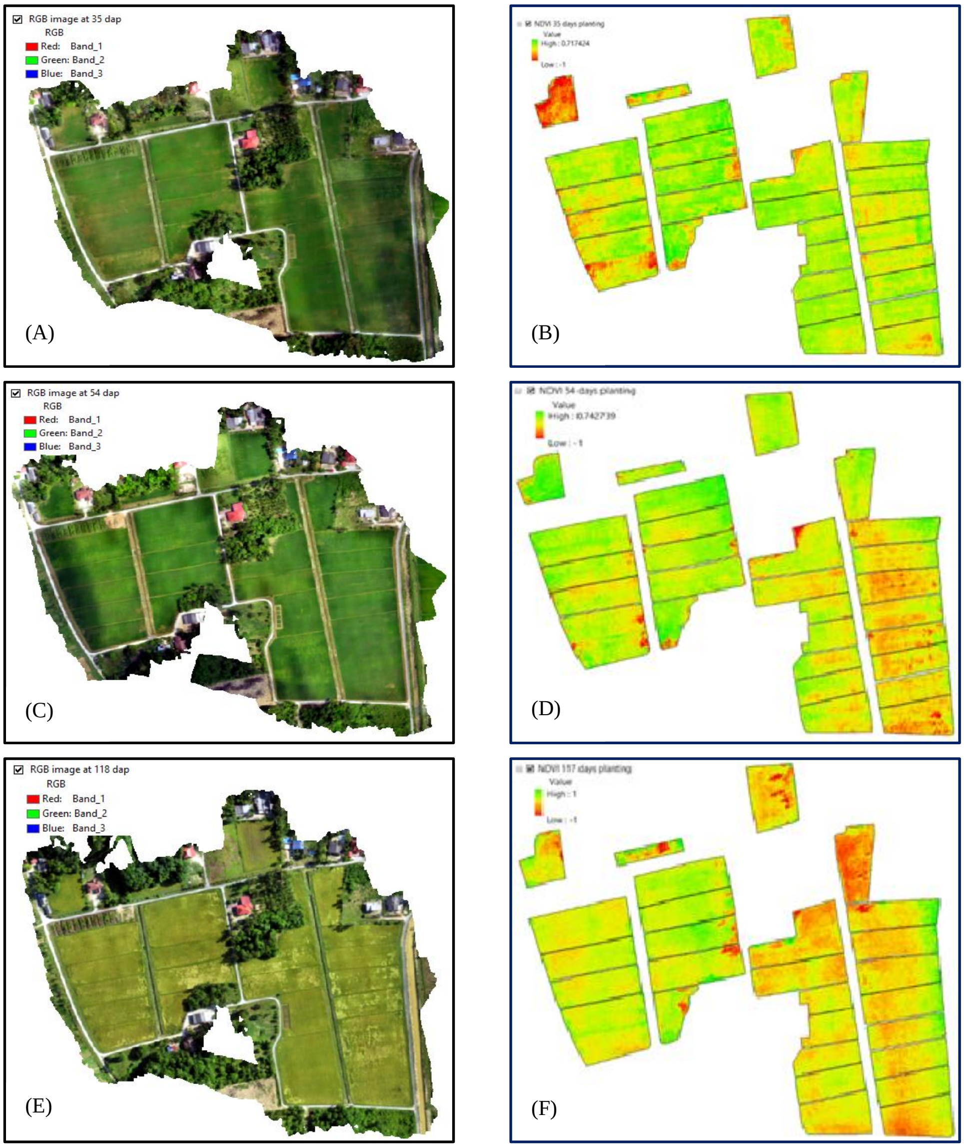

Figure 2: shows (A) RGB image at 35 DAP; (B) NDVI map at 35 DAP; (C) RGB image at 54 DAP; (D) NDVI map at 54 DAP; (E) RGB image at 118 DAP; and (F) NDVI map at 118 DAP

As a result, the green colour slowly changes to red, and its NDVI's value gradually decreases. This situation happened due to the active photosynthesis by a young and healthy rice crop during the vegetative stage, which gives good reflectance in the NIR reflectance and absorbs red reflectance (Din et al., 2017). However, the photosynthesis activity gradually decreases when entering the maturating stage, thus resulting in lower NDVI values.

The NDVI map was able to be used to monitor crop health by referring to the RGB image. For future research, combining this method with Geographic Information System (GIS) can help farmers reduce the unhealthy paddy crop at every growth stage. Farmers will acquire a complete image of their crop region using digitized geographic components, including crop layout and types of treatment needed to counteract the damage (Halip et al., 2020). Farmers can easily spot the affected area. Using this method, farmers can detect early warning signs for damaged crop areas and estimate their yield loss. They also can strategically plan and execute the in-field maintenance work, leading to better resources and cost-efficiency.

Conclusion

NDVI is an effective metric for measuring plant development. In addition, it can be an indicator to monitor rice crop growth. The results reveal that the RGB image can show the entire crop plot, while the NDVI map can show the crop condition in the field. Monitoring rice crop growth with NDVI is a viable technique to increase yield production by good monitoring and management in the field. Farmers can use NDVI maps to focus on non-uniform paddy planting regions for monitoring purposes. They can monitor their crops during the whole season, finding the damaged area and taking fast action to solve the problem.

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References

Bhumika, K., Vadher, B. M., & Agnihotri, P. G. (2019). Application of remote sensing and GIS in cropping pattern mapping: A case study of Olpad Taluka, Surat. *GRD Journal — Emerging Research and Innovations in Civil Engineering*. 4(9), 343–348.

Din M, Zheng W, Rashid M, Wang S and Shi Z. (2017) Evaluating hyperspectral vegetation indices for leaf area index estimation of Oryza sativa L. at diverse phenological stages. *Frontiers in Plant Science* 8 820

Faranak Ghobadifar. (2015). Pest attack determination in paddy areas using multispectral remote sensing images [Thesis]. Universiti Putra Malaysia.

Guan, S., Fukami, K., Matsunaka, H., Okami, M., Tanaka, R., Nakano, H., ... & Takahashi, K. (2019). Assessing correlation of high-resolution NDVI with fertilizer application level and yield of rice and wheat crops using small UAVs. *Remote Sensing*, *11*(2), 112.

Halip, R. M., Che'Ya, N. N., Fadzli, W. F. I., Roslee, R., Roslin, N. A., Ismail, M. R., ... & Omar, M. H. (2020). Pemantauan Tanaman Padi Menggunakan Sistem Maklumat Geografi dan Imej Multispektral. *Advances in Agricultural and Food Research Journal*, 1(1).

Kementerian Pertanian dan Industri Asas Tani. (2019). Halatuju Kementerian Pertanian & Industri Asas Tani: Prioriti & Strategi 2019-2020. Retrieved from https://www.moa.gov.my/documents/20182/139717/Hala+Tuju+2019-2020_LowVer.pdf/1ca7c2b3-f4fb-460a-8e04-1fdd051360cb.

Mutalib, Z. (2019, Ogos 6). MADA, KADA mula pelan tindakan dasar penyatuan tanah sawah. Berita Harian. https://www.bharian.com.my/berita/nasional/2019/08/593306/mada-kada-mula-pelan-tindakan-dasar-penyatuan-tanah-sawah.

Murugan, D., Garg, A., Ahmed, T., & Singh, D. (2016, December). Fusion of drone and satellite data for precision agriculture monitoring. In *2016 11th International Conference on Industrial and Information Systems (ICIIS)* (pp. 910-914). IEEE.

Parrot.com. (2019). Retrieved from https://www.parrot.com/global/parrot-professional/parrot-sequoia

Rosle, R., Che'Ya, N. N., Roslin, N. A., Halip, R. M., & Ismail, M. R. (2019, November). Monitoring early stage of rice crops growth using normalized difference vegetation index generated from UAV. In *IOP Conference Series: Earth and Environmental Science* (Vol. 355, No. 1, p. 012066). IOP Publishing.

Sabarina, K., & Priya, N. (2015). Lowering data dimensionality in big data for the benefit of precision agriculture. *Procedia Computer Science,* 48(2015); 548–554.

Srinivasan, A. (2006). *Handbook of Precision Agriculture: Principles and Applications*. CRC Press.

MAPPING OF BLACK PEPPER FARM USING LANDSAT 8 OLI AND SUPERVISED CLASSIFICATION

Siti Zul Lailee Kamsan*, Wan Nor Zanariah Zainol @ Abdullah
Department of Basic Sciences and Engineering, Universiti Putra Malaysia Bintulu Sarawak Campus, Bintulu, 97008, Malaysia
*zullaileekamsan@gmail.com

Abstract

In Malaysia, the cultivation of black pepper is commonly managed by smallholders with a limited understanding of the crop growth and its requirements. Besides, the Covid-19 pandemic that occurred in 2020 jeopardizes most of the large-scale and small-scale agricultural sectors. Hence, one potential solution to produce a better understanding of black pepper growth and farm monitoring is through mapping and monitoring the crop using geospatial technology with limited ground truth data. Therefore, this study aimed (i) to compare the outputs of two supervised classification methods of Landsat 8 OLI and (ii) to create a base map for black pepper farm in Kampong Bukit, Sungai Plan, Bintulu. Maximum likelihood (ML) and Support Vector Machine (SVM) were the methods used for the classification process. The results of supervised classification were evaluated using overall accuracy and kappa coefficient. SVM indicated higher accuracy with 84% on overall accuracy and 0.81 kappa coefficient. Whilst, ML classification shows 76% overall accuracy with 0.71 kappa coefficient. Through the results generated, further analysis can be done using classified images using SVM for crop monitoring hence the objective to enhance the understanding of black pepper growth and using Landsat 8 for small scale agriculture activities monitoring can be accomplished

Keywords: Black pepper; Landsat 8 OLI; Mapping; Maximum likelihood; Support vector machine

Introduction

In Malaysia, the production of black pepper majorly contributed by Sarawak at least 90% of Malaysia's black pepper total production (Rosli et al., 2013). The dominant cultivation of black pepper in Sarawak is often operated by the smallholder farmer (Shafinah et al., 2013), particularly with conventional management practices. Despite common issues in black pepper cultivation and management such as nutrient deficiency, pest disease, and inconsistency of crop production and price, the Covid-19 pandemic that occurred jeopardized these activities due to movement control order (MCO). Knowledge of black pepper conditions is important to enhance farmers' understanding of black pepper conditions and requirements. One potential solution to produce a better understanding of black pepper growth is through crop monitoring using remote sensing data.

The implementation of satellite-based remote sensing in monitoring agriculture activities has grown due to freely available satellite images such as Landsat 8 OLI (Charyulu et al., 2019; Rudiyanto et al., 2019). Mapping through remote sensing data is a notable geospatial technique for agricultural monitoring and enhancing crop production through monitoring the activities at spatial scales (Karthikeyan et al., 2020). However, studies on mapping of crop activities using remote sensing frequently cover large-scale crops instead of small-scale crops cultivation (Do Bendini et al., 2016; Dong et al., 2020; Ouzemou et al., 2018; Ramadhani et al., 2020). Understanding of crop growth monitoring can be obtained by combining remote sensing, geographic information system (GIS) based analysis and field surveying (Chiocchini et al., 2018). In addition, these methods provide cost-effective and site-specific assessments to monitor crop growth in real-time (Carolita et al., 2018). This study proposes the use of Landsat 8 OLI for mapping black pepper farms to enhance the knowledge on black pepper growth and its requirements. Hence, the objectives of this research are (i) to compare the outputs of ML and SVM classification on Landsat 8 OLI images for black pepper farm and (ii) to create a base map for black pepper farm in Kampong Bukit, Sungai Plan, Bintulu.

Methodology

Study area

The study area is located in Kampong Bukit, Sungai Plan pepper farm in Tanjung. Kidurong, Bintulu (Coordinate 3°16'9.18" N, 113°7'24.81" E) and the area is located in a remote area. The coordinates of the point of interests (POI) such as black pepper farm, housing area, roads, vegetation (other than black pepper crops) bare land area and water sources were collected using Garmin 64s Handheld GPS. This information has been used as training classes for image processing stages. Figure 1 shows the study sites area in Sungai Plan, Bintulu.

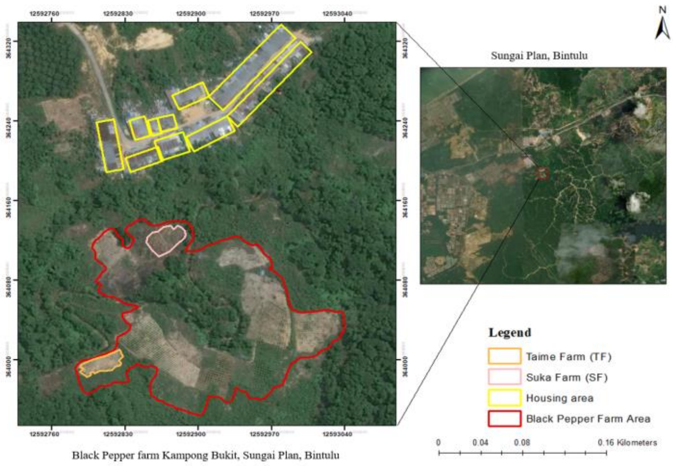


Figure 1. SEQ Figure * ARABIC 1 Study area in Kampong Bukit, Sungai Plan,

Satellite data

Landsat 8 OLI data is one of the satellite images that are freely available at https://earthexplorer.usgs.gov/. The product of Landsat 8 OLI was chosen from collection 1 Level 1 precision terrain (L1TP) and is fine enough for field-level crops, no geometric correction is needed and helps to downsize classification error caused by mixed pixel (Al-Bakri, 2015; Candra et al., 2019). Apart from that, images from the Level-1 collection contained two cloud covers by the CF Mask algorithm and NOAA world vector shoreline dataset that enhanced the quality of the satellite products. A series of images from scene 58/119 were collected and the images selected were filtered with cloud cover between 0% to 60%. Images from August 2019 and May, June, July 2020 were chosen based on clear images obtained in the study area. Information on satellite data used in this study are shown in Table 1 below.

Table 1. Selected Landsat 8 OLI images from 2020 data

Acquisition date	DOY	Path/ Row	Scene Cloud Cover	Land Cloud Cover	Classification
21082019	233	119/58	5.91	6.23	Clear
19052020	140	119/58	20.08	20.04	Clear
20062020	172	119/58	50.58	51.33	Cloudy
06072020	180	119/58	6.89	7.41	Clear

Image Pre – processing

Landsat 8 OLI images need the preprocess procedure to reduce noise and intensify the quality of the image (Shaharum et al., 2018). Through radiometric calibration and Quick Atmospheric Correction (QUAC), the conversion of a digital number from raw image satellite in the metadata turned into light reflectance was performed. Images were then reprojected from WGS 1984 to Timbalai 1984 RSO Borneo to suit the local region before subset into a focused area of interest (AOI). Next, low-resolution multispectral images of Landsat 8 OLI undergo image enhancement using high-resolution band 8 from the metadata resulting in cloud-free images. All the processes were processed using ENVI 5.3 software.

Image Processing

Maximum-likelihood (ML) and Support Vector Machine (SVM) using ENVI 5.3 software was done for classification analysis. The training classes use POIs collected during ground truth data collection. Each class was represented by a specific color with 50 samples for both areas as assigned in Figure 2. The parameter used in SVM was Kernel default's function since the accuracy of this parameter is higher than others. Composite images of 4,3,2 and 6,5,4 were applied to facilitate the analysis.

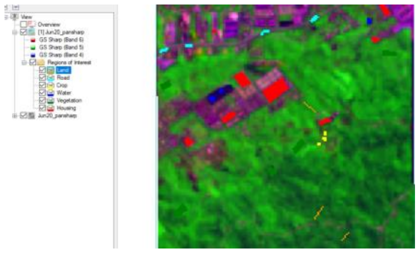


Figure 2. Training classes to be used in both classifiers for classification procedures

Accuracy Assessment

Accuracy assessment is an evaluation with the assistance of a remotely sensed dataset as it is convenient for the classification approach. Moreover, it is essential to assure the error exists (Abbas & Jaber, 2020). Overall accuracy is the most common assessment involving the confusion matrix. Besides, the evaluation also processes the results based on the number of representing a pixel on its category to correctly classified pixels. Then inter-reliability of the results was figured out using the Kappa coefficient. The evaluations were done using ArcGIS 10.4 and Google Earth Pro software.

The calculation for both accuracies is as follows:

Equation SEQ Equation * ARABIC 1 Overall accuracy Equation 1

Equation SEQ Equation * ARABIC 2 Kappa Coefficient Equation 2

where TS: Total samples, TCS: Total corrected samples

Results and Discussion

Supervised classification

The results from ML and SVM classification shows differences that determine their accuracy in this analysis (Figure 3). In ML classification, although six training classes were used, the image from August 2019 (a) was classified into five classes with a miss out of the exposed land area. Image from May (b), June (c) and July (d) of 2020, regardless of six training samples, the classification between housing area and road were still less detailed. Meanwhile, SVM classifiers (e, f, g, h) demonstrate better classifications by utilizing all six classes created. Segregation between housing and roads is higher in SVM rather than ML. It also presents some deforestation activities conducted nearby the black pepper farm area. Analysis is needed, since there was an erosion incident reported in November 2020 and the weather during that month was dominated by light, moderate and high rain. In terms of crop monitoring, the results from ML in Figure 4 (i-l), show the inconsistency of the black pepper that is represented by the crop class in yellow color. Hence, monitoring will be challenging. In Figure 4 (m-p) of SVM classification, the results can be further analyzed for crop growth monitoring since it shows comprehensive growth of black pepper from August 2019 to July 2020.

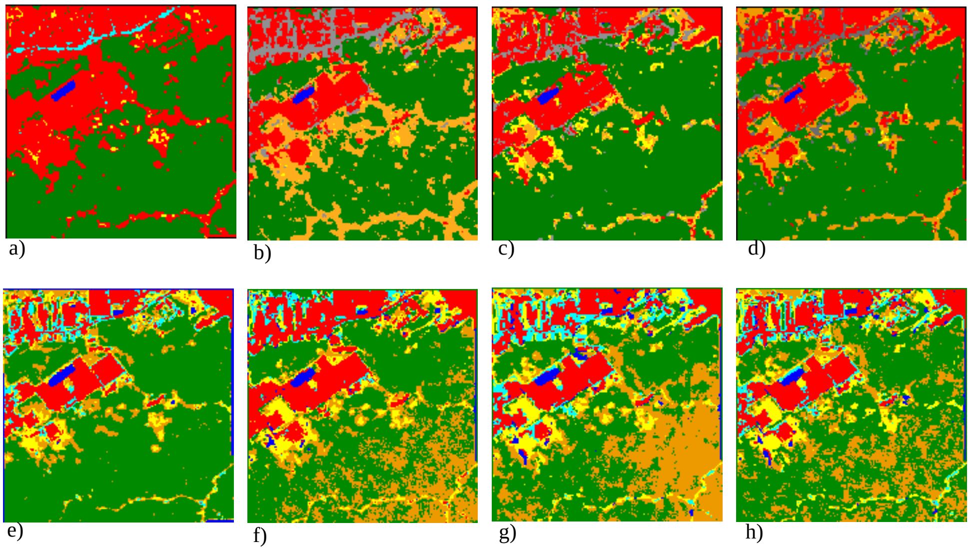


Figure 3. Output of pan-sharpen classified images. a-e are the results for ML classification while f-i is the SVM classification a) ML August 2019 b) ML May 2020 c) ML June 2020 d) July 2020 e) SVM August 19 f) SVM May 2020 g) SVM June 2020 h) SVM July 2020

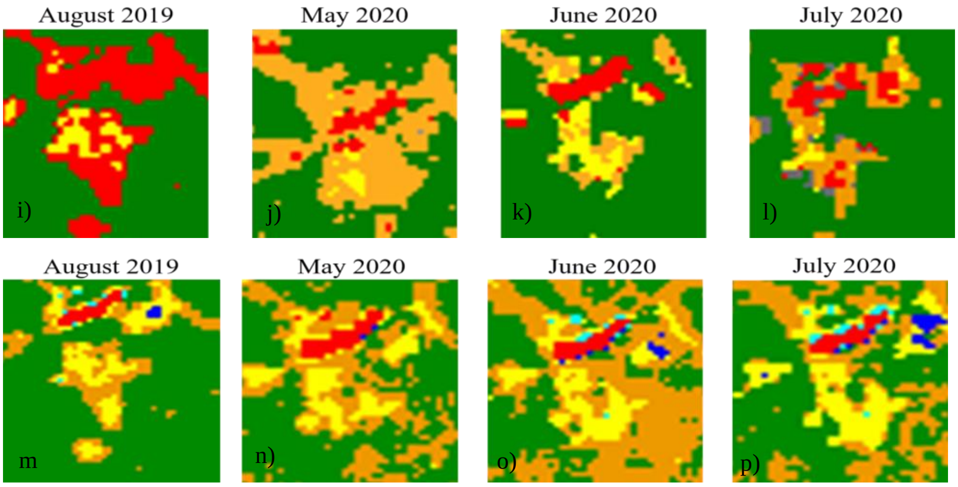


Figure 4 Crop observation at study area based on ML SVM classification. (i-l) ML classification. (m-p) SVM classification

Accuracy Assessment

Overall, the results of user's and producer's accuracy in Tables 2 and 3 indicated acceptable classification accuracy. The road was one of the classes with less than 70% user's accuracy in both classifiers which indicates that this class tends to be classified inaccurately. In this case, it was frequently misleading with housing areas or exposed land. Meanwhile, vegetation indicates higher accuracy by user's accuracy but low in producer's accuracy percentage due to its tendency to be falsely marked as other classes.

Concurrently, the overall accuracy and kappa coefficient show differences between both assessments but the differences are not significant. Following the user's producer's accuracy, SVM gives higher precision in classifying the images than ML classification. It could be through the ability of SVM to differentiate between housing areas and roads even though they were located nearby. Besides, SVM also provides better accuracy through the ability to detect water bodies/areas than ML classification hence it leads to sophisticated information.

Table 2. User's and Producer's accuracy for ML classification

Class	User accuracy (%)				Producer accuracy (%)			
	August19	May20	June20	July20	August19	May20	June20	July20
Housing	75	75	67	67	67	86	67	75
Vegetation	100	100	100	100	53	57	57	57
Water	75	100	75	100	100	100	100	83
Crop	50	63	88	88	100	100	100	100
Land	-	67	75	80	-	55	67	89
Road	50	56	56	40	67	100	100	67

Table 3. User's and Producer's accuracy for SVM classification

Class	User accuracy (%)				Producer accuracy (%)			
	August19	May20	June20	July20	August19	May20	June20	July20
Housing	78	88	75	100	64	88	100	100
Vegetation	100	89	100	100	62	62	67	47
Water	63	63	50	50	100	100	100	100
Crop	75	100	100	100	75	89	100	100
Land	78	56	89	44	64	50	67	100
Road	25	63	88	100	100	100	100	100

Table 4 Overall Accuracy and Kappa Coefficient of SVM and ML classification

Image	Support Vector Machine (SVM)		Maximum Likelihood (ML)	
	Overall Accuracy (%)	Kappa Coefficient	Overall Accuracy (%)	Kappa Coefficient
August 2019	70	0.64	70	0.62
May 2020	76	0.71	76	0.71
June 2020	84	0.81	76	0.71
July 2020	82	0.78	76	0.71

Conclusion

Mapping of black pepper farm in Kampong Bukit, Sungai Plan, Bintulu qualified using Landsat 8 OLI despite its remote location. The accuracy of Landsat 8 OLI classification analyzed using SVM and ML classification methods indicates SVM was capable of being utilized for sophisticated information on the map for small-scale agriculture cultivation in the future. Through the results generated from the image classification process, data can be future processed to monitor the growth and productivity of black pepper.

References

Abbas, Z., & Jaber, H. S. (2020). Accuracy assessment of supervised classification methods for extraction land use maps using remote sensing and GIS techniques. *IOP Conference Series: Materials Science and Engineering*, *745*(1). https://doi.org/10.1088/1757-899X/745/1/012166

Al-Bakri, J. T. (2015). *Crop mapping using remote sensing data of Landsat 8 : A Training Manual Resources Management and Capacity Building A training manual : Crop mapping using remote sensing data of Landsat 8*. *March*. https://doi.org/10.13140/2.1.5122.3842

Candra, D. S., Phinn, S., & Scarth, P. (2019). Automated cloud and cloud-shadow masking for Landsat 8 using multitemporal images in a variety of environments. *Remote Sensing*, *11*(17). https://doi.org/10.3390/rs11172060

Carolita, I., Sitorus, J., Manalu, J., & Wiratmoko, D. (2018). Growth Profile Analysis of Oil Palm By Using Spot 6 the Case of North Sumatra. *International Journal of Remote Sensing and Earth Sciences (IJReSES)*, *12*(1), 21. https://doi.org/10.30536/j.ijreses.2015.v12.a2669

Charyulu, K. R. C., Rao, G. S., Kumar, M. P., & Lokesh, M. (2019). Case Studies on the Utilization of Geospatial Technology for Sustainable Agriculture. *International Journal of Current Microbiology and Applied Sciences*, *8*(03), 112–120. https://doi.org/10.20546/ijcmas.2019.803.016

Chiocchini, F., Ciolfi, M., Sarti, M., & Morhart, C. (2018). Inventory of tree hedgerows in an Italian agroforestry landscape by remote sensing and gis based methods. *Agroforestry*.

Do Bendini, H. N., Sanches, I. D., Körting, T. S., Fonseca, L. M. G., Luiz, A. J. B., & Formaggio, A. R. (2016). Using Landsat 8 image time series for crop mapping in a region of Cerrado, Brazil. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, *41*(September), 845–850. https://doi.org/10.5194/isprsarchives-XLI-B8-845-2016

Dong, T., Liu, J., Qian, B., He, L., Liu, J., Wang, R., Jing, Q., Champagne, C., McNairn, H., Powers, J., Shi, Y., Chen, J. M., & Shang, J. (2020). Estimating crop biomass using leaf area index derived from Landsat 8 and Sentinel-2 data. *ISPRS Journal of Photogrammetry and Remote Sensing*, *168*(December 2019), 236–250. https://doi.org/10.1016/j.isprsjprs.2020.08.003

Karthikeyan, L., Chawla, I., & Mishra, A. K. (2020). A review of remote sensing applications in agriculture for food security: Crop growth and yield, irrigation, and crop losses. *Journal of Hydrology*, *586*(March), 124905. https://doi.org/10.1016/j.jhydrol.2020.124905

Ouzemou, J. E., El Harti, A., Lhissou, R., El Moujahid, A., Bouch, N., El Ouazzani, R., Bachaoui, E. M., & El Ghmari, A. (2018). Crop type mapping from pansharpened Landsat 8 NDVI data: A case of a highly fragmented and intensive agricultural system. *Remote Sensing Applications: Society and Environment*, *11*(November 2017), 94–103. https://doi.org/10.1016/j.rsase.2018.05.002

Ramadhani, F., Pullanagari, R., Kereszturi, G., & Procter, J. (2020). Mapping of rice growth phases and bare land using Landsat-8 OLI with machine learning. *International Journal of Remote Sensing*, *41*(21), 8428–8452. https://doi.org/10.1080/01431161.2020.1779378

Rosli, A., Radam, A., & Rahim, K. A. (2013). Technology Adoption in Pepper Farming: a Case Study in Sarawak, Malaysia. *The Internacional Journal of Social Sciences*, *1*, 19–22. https://www.tijoss.com/TIJOSS 11th Volume/anita2.pdf

Rudiyanto, Minasny, Shah, Soh, Arif, & Setiawan. (2019). Automated Near-Real-Time Mapping and Monitoring of Rice Extent, Cropping Patterns, and Growth Stages in Southeast Asia Using Sentinel-1 Time Series on a Google Earth Engine Platform. *Remote Sensing*, *11*(14), 1666. https://doi.org/10.3390/rs11141666

Shafinah, K., Sahari, N., Sulaiman, R., Alan, R., Abdul, F., & Zakry, A. (2013). Kebolehcapaian nasihat bagi pengurusan penyakit tanaman oleh pekebun kecil lada hitam , Sarawak : Tinjauan awal Critical extension services and the plight of Sarawak ' s black pepper farmers : A preliminary survey. *Malaysian Journal of Society and Space*, *9*(2), 17–26.

Shaharum, N. S. N., Shafri, H. Z. M., Gambo, J., & Abidin, F. A. Z. (2018). Mapping of Krau Wildlife Reserve (KWR) protected area using Landsat 8 and supervised classification algorithms. *Remote Sensing Applications: Society and Environment*, *10*(January), 24–35. https://doi.org/10.1016/j.rsase.2018.01.002

AUTOMATIC PLANT WATERING SYSTEM USING IOT AND ANDROID

Zainah Md. Zain *[1,2], Norhafizah Md. Zain[3,4], Nur Hiddayatul Ain Che Azman[1], Ling Kuok Fong[1], Ma Xian Xi [1]
[1]Faculty of Electrical and Electronics Engineering Technology, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia
[2]Centre of Automotive, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia
[3]Faculty of Agro-Based Industry, University Malaysia Kelantan, Jeli Campus, 17600 Jeli, Kelantan, Malaysia
[4]Institute of Food Security and Sustainable Agriculture, University Malaysia Kelantan, Jeli Campus, 17600 Jeli, Kelantan, Malaysia
*zainah@ump.edu.my

Abstract

This paper proposed a design for an automated plant watering system based-on android application using Maker Uno. Android application is used to control the plant watering system and monitor the reading from sensors while Wi-Fi technology as a communication protocol to connect system components. Four sensors such as soil moisture sensor, pH, temperature, and Light Dependent Resistor (LDR) used in this project. The moisture level (water content) of the plant is measured by the soil moisture sensor. If the moisture level of the soil is found to be below the desired level, the moisture sensor sends the signal to the microcontroller which triggers the pump to turn ON and supply the water to the plant. When the desired soil moisture level is reached, the system halts on its own and the pump is turned OFF. The watering system can be operated in dual-mode; automatic and manual. The whole information from sensors used in this system is sent to the Blynk application on android.

Keywords: Android; Automated plant watering; IoT

Introduction

The increase in the field of information technology and embedded systems in the era of digitalization leading to the study of control and automation system. Many researchers interested to the topic of microcontroller-based watering system integrated with internet of things (IoT) such as in (Ridwan etc., 2020), (Aradhana etc., 2020), (Ganesh etc., 2019), (Kritika etc., 2019) and (Yogeshwari etc., 2020). This is because the watering process that is often done by most plant farmers is still done manually by farmer workers. The use of manual system also has weaknesses; one of them is human error because the assessment of crop farmers is still subjective (Ridwan etc., 2020).

In accordance with the statement above, this research developed an automatic plant watering system based-on IoT by using a different type of microcontroller as the brain of the system. The developed system also can be controlled using android application for the control and monitoring purpose.

Proposed Architecture

The block diagram of the system is shown in Figure 1. The Maker Uno microcontroller acts as the brain of the system. Four sensors have been used in this project. Moisture sensor and pH sensor are attached to the soil of the plant to measure the moisture and pH of the soil, while LDR to measure the light intensity and temperature sensor to measure the environment temperature. To update the user regarding the condition of the system, ESP8266 was connected to Maker Uno. This device helps the Maker Uno board to connect to the internet and allows the integrating data from the Maker Uno board using the Blynk platform. The Blynk platform is a platform compatible for any Internet of Things (IoT) and can collect and store data from various sensors and microcontrollers.

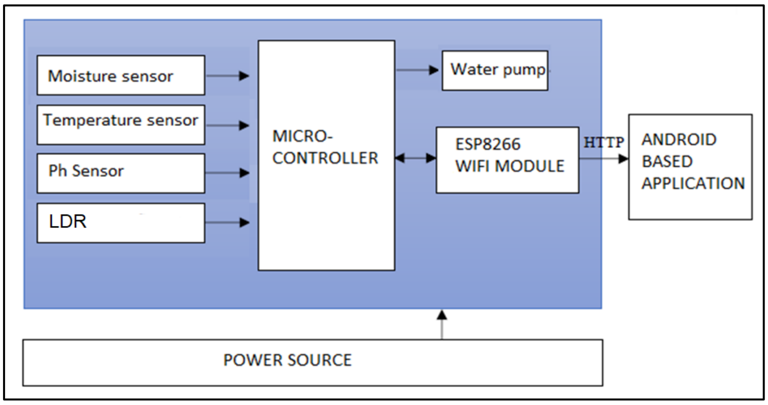


Figure 1. Block diagram of the system

This project is the integration of an offline automatic plant watering system and the online IoT system (dual mode). For the automatic plant watering, the pump will be activated when the reading of the moisture soil sensor is below the preset value. If the user plan to do manual watering, the user must press the on button on Maker Uno. The flowchart of the system that shows the dual mode operation is shown in Figure 2. Mini solar panel that charged the batteries was used to supply the power to the microcontroller.

ESP8266 Module

ESP8266 is a low cost WiFi module that is suitable for adding WiFi functionality to an existing microcontroller project via a UART serial connection. The module can even be reprogrammed to act as a standalone WiFi connected device. The special features of ESP8266 are 802.11 b/g/n protocol WiFi Direct (P2P), soft-AP Integrated TCP/IP protocol stack.

Maker Uno

Maker Uno is a microcontroller that has the same function with Arduino Uno and some additional functions which the Arduino Uno do not have. One of the benefits of using Maker Uno is that it has an LED at the output pin and that it is easy for us to know the status of the output pin. Besides that, maker uno also can supply higher current at 5 V and 3.3 V pin based on the USB source if compared to Arduino Uno.

DS18B20 Temperature Sensor

DS18B20 is a waterproof temperature sensor and it is compatible to use outdoors. DS18B20 has a wide working range which is from -55 °C to 125 °C / ((–67 °F to +257 °F) ± 0.5 °C). This character can make sure the project can work in any kind of environment in the world, which is desert or Arctic. Besides that, it has a precise temperature sense and can make sure the error of data collected is minimum. Each sensor has a unique 64-Bit Serial number etched into it and allows for a huge number of sensors to be used on one data bus.

pH Sensor

The pH sensor is working using the theory ion H^+ in the acid. If the pH is higher, the quantity of H^+ in the liquid is higher. Using this theory, the voltage at the data line can be used to determine the pH of the liquid and soil.

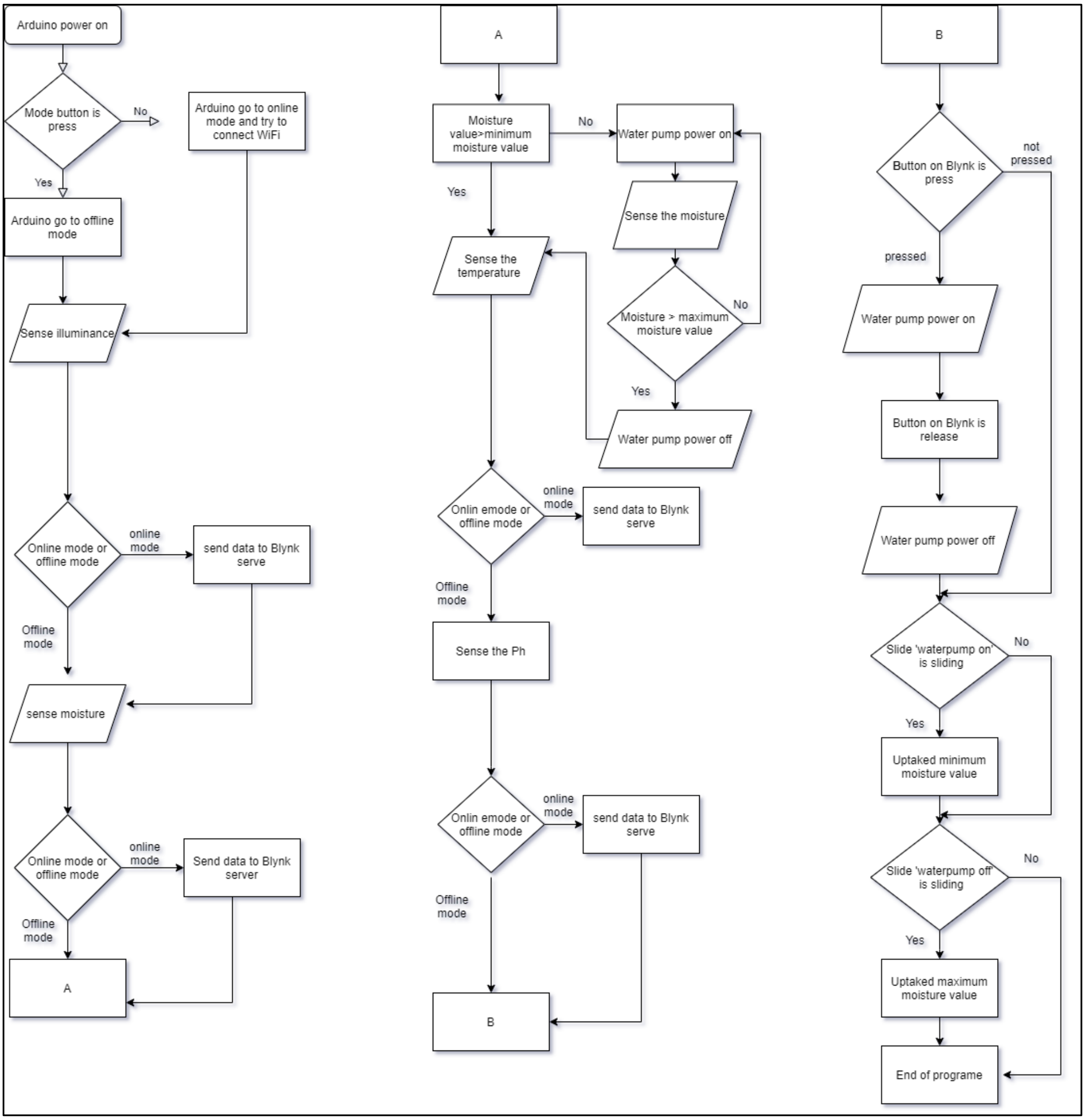


Figure 2. Flowchart of the system

LDR

LDR is a component that has a (variable) resistance that changes with the light intensity that falls upon it. This allows them to be used in light sensing circuits. In order to use the LDR to sense the light density, we must use the concept of voltage divider which is to add a known value resistor between LDR and group. Then, we connect a cable in the node between the LDR and resistor to get the voltage of the resistor. Last, we can know the voltage of the LDR sensor by formula 5 V – voltage resistor. We need to supply a 5 V power and ground to our DIY LDR sensor. The data line which connect between node of LDR and Resistor is connected to pin A3 of Maker Uno.

Moisture Sensor

This soil moisture sensor can be used to detect moisture. When the soil is dry, the sensor's output analog value will decrease, while moist soil will result in an increased analog value output. A key application for this sensor is for an automatic watering device. The sensor can sense whether your plant is thirsty or not, preventing overwatering or underwatering. In this proposed system, moisture sensor will sense the moisture level in the field and will send the updated information onto the Blynk cloud with the help of ESP8266 Wi-Fi module. Moisture sensor is connected to the Maker Uno board. It reads the water pump and sends it to the Maker Uno board. The soil moisture sensor uses capacitance to measure the water content of soil (by measuring the dielectric permittivity of the soil, which is a function of the water content). Simply insert this rugged sensor into the soil to be tested, and the volumetric water content of the soil is reported in percent.

Blynk Platform

Blynk is a mobile application for iOS and Android OS that can be used to control devices such as Arduino, Raspberry Pi, and ESP8266, as well as to display sensor data, store data, and visualise data via the internet (Bohara. etc. all., 2020). It's a digital dashboard where it can build a graphic interface for the user by simply drag and drop the widgets. There are three major stages in the Blynk platform; Blynk cloud, Blynk apps and Blynk database as shown in Figure 3.

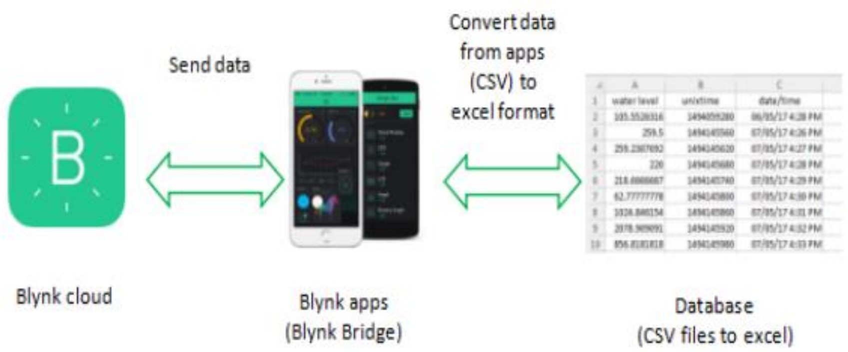


Figure 3. The flow of database via Blynk application

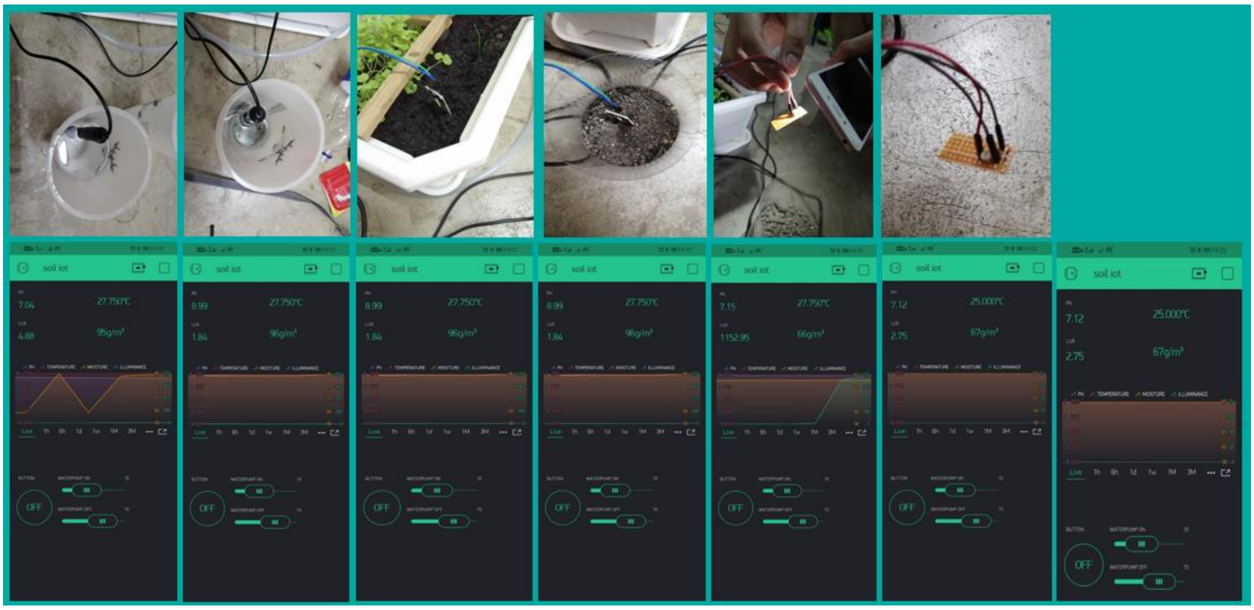
Results and Discussions

The Blynk mobile application was able to display the reading from various sensors as shown in Figure 4 (a). The sensors were tested in different environments in order to make sure the sensors give the correct reading and results of the testing were summarized in Table 1. Figure 4 (b) shows the complete experimental setup to test the developed system. As shown on the user interface (developed using Blynk app), the real-time data from sensors are displayed on the screen and also plotted in a graph. The user can download the stored data into excel format by clicking the Export to CSV button and the data will be emailed to the user's email.

Table 1. Preliminary sensors testing in different environment

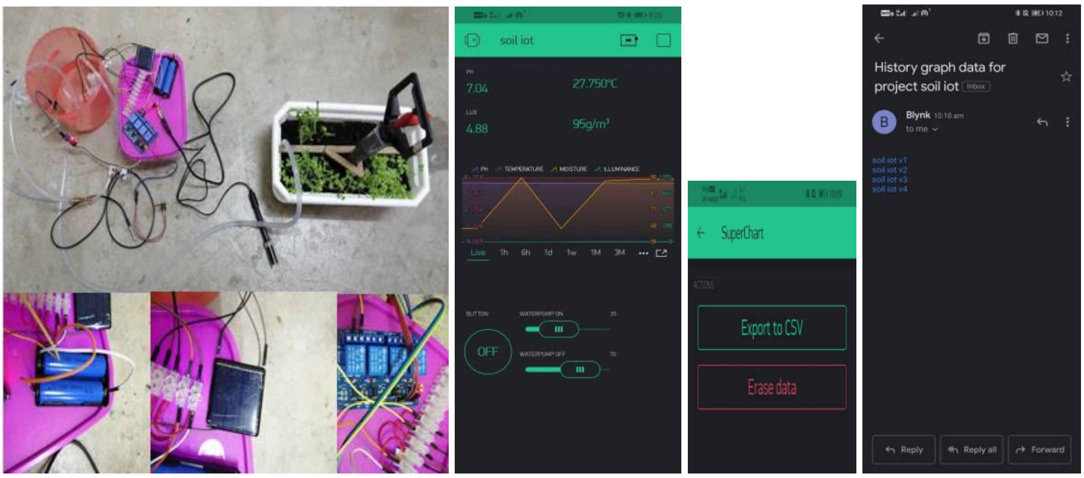
Sensor	Testing environment 1	Testing environment 2
pH	Tap water (7.04)	Alkaline water (8.99)
Moisture	Wet soil (96g/m^3)	Dry soil (66g/m^3)
LDR	Under HP lamp (lux: 1152.75)	Room light (in the lab) (lux: 2.75)
Temperature	Room temperature (in the lab) (25°C)	-

(i)



(a) Tap water (b) Alkaline water (c) Wet soil (d) Dry soil (e) HP lamp (f) Room light (g) Room temperature

(ii)



(a) (b) (c) (d)

Figure 4. (i) Testing all the sensors results and (ii) Experimental testing setup and the results display via Blynk Apps

Conclusion

This automatic watering system utilized inexpensive sensor technology with Maker Uno as a microcontroller with open ware Blynk platform which used the Wi-fi concept. Through the experiment conducted, it shows that this system can be used for automatic watering system, monitoring and storing the data from sensors via the Blynk application on the Android OS and resulting in an accurate and reliable system. By developing the automated plant watering system, it can maximize water productivity and reduce the labor cost.

Acknowledgement

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References

Aradhana A. Poojary, Megha S. Bhat, C. S. Aishwarya, B. M. Nandini Mahesh K. R. Shruthi, Soil (2020). Water and Air Quality Monitoring System using IoT, *International Research Journal of Engineering and Technology (ITJET), 7*(2), 416-418.

Bohara, B., Maharjan, S. and Shrestha, B.R., (2020). IoT based smart home using Blynk framework. arXiv preprint arXiv:2007.13714.

Ganesh Babu L., Mohan E. and Siva Kumar R. (2019). IoT Based Water and Soil Quality Monitoring System, *Int. Journal of Mechanical Engineering Technology (IJMET), 10*(2), 537-541.

Kritika S., Saylee P., Gaurav P., Shivam U. and Gayatri H. (2019). Proposed Automated Plant Watering System using IoT, *Engineering Research Network (EngRN) Mahatma Education Society's Transactions and Journals' Conference Proceedings* on CTFC 2019. Available in the SSRN eLibrary: http://ssrn.com/link/2019-CTFC.html

Ridwan S, Muhammad A. F. Billi R. K. Irmansyah, Irzaman (2020), Internet of Things: Automatic Plant Watering System Using Android, *Jurnal Teknik Pertanian Lampung, Vol.9*(4), 297-310.

Yogeshwari B., Rupesh B., Neha A., and Gaurav B. (2020), Plant Watering and Monitoring System Using IoT and Cloud Computing, *International Journal of Scientific Development and Research (IJSDR), 5*(4), 157-162.

PROTOTYPE MODEL OF OMNI-WHEELED TRACTOR TO REDUCE UNNECESSARY MOVEMENT

Evita Nugroho, RR. Yohana Wintan Pangesti, Eka Riskawati, Radi, Makbul Hajad*
Department of Agricultural and Biosystems Engineering, Faculty of Agricultural Technology, Universitas Gadjah Mada, Jln. Flora 1 Bulaksumur Yogyakarta Indonesia
*makbul.hajad@ugm.ac.id

Abstract

Implementation of agricultural mechanization such as the use of tractor is required to improve farming efficiency and increase the production capacity in term of strengthening global food security. The farmland in Indonesia is characterized as small farmland which imposes to higher time required for turning operation of tractor. The conventional design of tractor used non-holonomic maneuvering system which requires higher turning angle and increases the non-productive time during turning operation which is categorized as waste in farmland preparation using tractor. This paper proposed a prototype design model of an Omni-wheeled tractor to reduce unnecessary movement which enable tractor to make maneuver omni-directionally. This paper offered a concept of holonomic maneuvering system of tractor design to support the omni-directional motions on the farmland surfaces. The prototype design included the modification in operator space and three-point hitch design which allow operator to change direction of the motion and position of the implement to the desired direction. The comparison between the conventional tractor design and the proposed design prototype was highlighted for different size and shape of farmland. To generate the comparison, computer simulation using MATLAB software was constructed to calculate the both operating time and operational efficiency for both conventional tractor design with non-holonomic system and the proposed prototype design model. The results showed that the proposed protype design model with holonomic maneuver system allows tractors to move omnidirectionally; can reduce the time losses during turning time and increase the operational efficiency which is suitable to use in a limited size of farmland.

Keywords: Holonomic motion; Omni-directional wheels; System maneuver; Tractor design

Introduction

During covid-19, there was a disruption in the global food chain which caused an imbalance between supply and demand (FAO, 2020). This situation requires more effort to strengthen the global food security. The involvement of agricultural mechanization is required to increase the farmland productivity and farming efficiency. Agricultural mechanization refers to the use of machines such as tractor, transplanter, sprayer, and harvester for agricultural production activity (Akdemir, 2013). The use of tractor for farmland preparation in Indonesia tends to increase year by year especially for rice commodity. Tractor is a machine that provide power for performing agricultural tasks especially land preparation before planting stage. The application of tractor is very important to increase the cultivating efficiency in terms of farmland management. Tractors can be used to pull a variety of farm implements for examples: plowing, planting, cultivating, fertilizing, harvesting, and can be used for transporting materials. Problems related to the use of agricultural mechanization may vary due to region and land characteristics (Akdemir, 2013), however the main agricultural mechanization problem in Indonesia is the limited size of farmland which can reduce the operational efficiency of tractor.

The limited size of farmland induces a problem in using a tractor in Indonesia where the tractor requires larger turning angle and time which are categorized as non-productive time for tractor operation and it is desired to be eliminated. During tractor operation, tractor needs to move from one trajectory to the adjacent trajectory until it finishes the required area, thus, it must have high maneuverability to reduce the non-productive time on maneuvering. In general, the design of tractor use a non-holonomic system just like most other vehicles. This system causes the mobile system to require wider turning angles while operating on the farmland to make turns from one finished trajectory to the adjacent trajectory which can reduce the operational productivity of using tractors (Purbawaskito, 2017). A holonomic system on tractor wheels is expected to overcome this maneuvering problem due to the ability of the holonomic system to move omnidirectionally without changing orientation (Purbawaskito and Hsu, 2017). This holonomic system is also known as Omni-directional wheels of vehicle. omni-directional wheel will allow tractor to move flexibly with holonomic maneuvering system that can promise a shorter time for turning operation. A conventional tractor with non-holonomic systems involves 2 operated Degree of Freedom (DOF) in vehicle wheels. The conventional tractor uses conventional wheels system to move forward, backward, and rotating (Nagatani el al, 2017). While, the proposed prototype design with holonomic maneuvering system consisted of 3 DOF, which are moving forward, backward, shift sideway, and rotate in a fixed area (Yunardi el al, 2021).

In this paper, we proposed a solution for implementing a holonomic maneuvering system on a modified tractor design using Omni-directional wheels. A Holonomic-maneuvering system enable the movement of a mobile system in all directions without changing its orientation (Purbawaskito and Hsu, 2017). This system allows the wheels to move omnidirectionally to reduce the time required during turning operation. An innovation in tractor mechanical design is expected to overcome the mentioned problem of tractor maneuvering on agricultural land by applying Omni-directional movement (Purbawaskito, 2017). An innovative design was proposed to create the proposed prototype of future tractor that can move omnidirectionally on the surface of farmland. To assess the performance of the proposed prototype tractor model, the comparison of conventional tractor design and a modified tractor with the holonomic maneuvering system is provided. The time required and efficiency of tractors were studied and discussed with the above two different model in various shapes and sizes of farmland. To calculate the operational time of the tractor on the farm, computer simulation was done by using MATLAB software. Several studies on the design of holonomic systems using omni-directional wheels have been caried out. Concept and mechanical design modelling of an UGV prototype for omni-directional motion for agricultural land. Holonomic implementation of omni-directional mobile robot using DC motors (Yunardi el al, 2021).

Material and Method

Construction of Omni-wheeled Tractor prototype model

The tractor is designed using four-wheeled where each wheel is set to perform independently and then they are programmed to perform an omni-directional motion. This type of motion is proposed to reduce the non-productive movement that can increase the effectivity of the use of tractor especially on a limited size of farmland. To support the omni directional movement of the proposed tractor model, the modification on steering part and the three-point hitch position were designed to be adjustable base on the required movement direction that enable tractor to move omnidirectionally while still possibly cultivate the adjacent line. The steer connected with cylinder swing case that pairing tractor’s body and the base of tractor wheel to help changing the orientation of the wheels as well as the tractor body according to the required cultivating direction (fig. 1). This prototype model was designed using solidwork computer software.

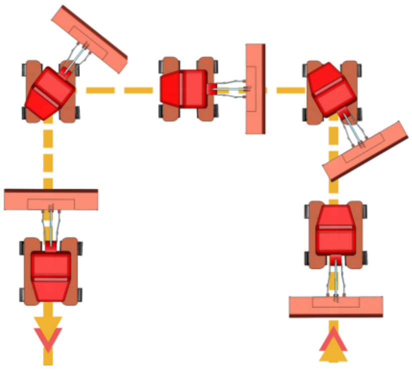


Figure 1. Omni-wheeled tractor trajectory

Performance Analyses

To assess the performance of the proposed tractor prototype model, the tractor operation simulation was conducted on different shape and size of the farmland. This simple simulation is done with the help of MATLAB application. In the MATLAB, a processed image is inserted where there are several dots with a certain distance. At that dots, the tractor's travel time is measured to move from one place to another at a speed of 10 km/hour. There are two shapes of land used in the computer simulation: square shape and rectangular shape of the farmland. After that, the possible gridline of both conventional tractor (non-holonomic system) and the proposed prototype model (holonomic-system) is generated on the land area in different size: 6X6, 9X9, 12X12, 15X15, and 18X18 for square shape and 3X1, 5X12, 7X14, 9X16, and 11X18 for rectangular shape. There are two parameters used to decide the performance of the prototype model: (1) operational time and (2) cultivating efficiency. The operational time is calculated using the equation bellow:

$$t = \frac{s}{v} \qquad \text{Equation 1}$$

Where, t is the operational time; s is the length of the possible operational gridline; v is the velocity of the tractor which is assigned to be constant. The time required for adjusting the steering and implement position for both conventional and proposed tractor prototype is neglected to simplify the comparison purpose. To calculate the length of the possible gridline and operational time, tractor operational simulation is created for the mentioned farmland shape and size. Then, the operational efficiency of the proposed tractor prototype model is calculated using equation 2.

$$efficiency\ (\%) = \frac{t_p - t_c}{t_c} \times 100\% \qquad \text{Equation 2}$$

Where, t_p is operational time required by the proposed tractor prototype model; and t_c is the operational time required by the conventional tractor design. The efficiency was calculated on different type and size of the farmland.

Result and Discussion

Omni-Directional Tractor Model

In this model, we use a four-wheeled type of tractor that is affordable, easy to repair, easy to develop, lightweight, and provides good steering but puts a lot of pressure on the soil (Roshanianfard et al, 2020). Since it is designed for semi-wet ground, the tractor ground pressure is minimized by increasing the wheel surfaces area. This design also equips with swing drive to move the implement freely as in Figure 2.

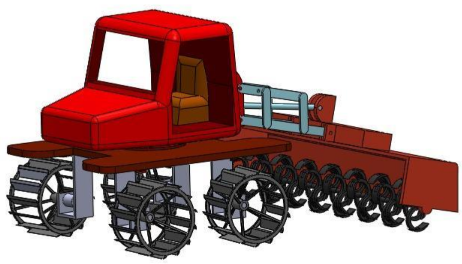


Figure 2. Prototype model of omni-directional wheel tractor design

In agricultural land cultivating activities, the tractor will need to move from one line to another until it finish all required area. In order to move from one line to another line, the tractor will require a turning operation (fig. 2). During this turning operation, the tractor actually not cultivate the land where the implement is moved up, thus it is considered as a non-productive time and desired to be eliminated. In the simulation designed by Kise et al. (2002), forward turning requires three circles on its trajectory. This shows that the turning space of the tractor operation on land required large angle and it takes up a lot of space. This area can be minimized by using an omni-directional wheel that can make maneuver perpendicularly.

Performance Analysis

Table 1 shows the result of tractor operational simulation and computation for both conventional tractor design and omni-directional wheeled tractor design for square type of land. While, simulation and computational result of tractor for both conventional tractor design and omni-directional wheeled tractor design for the rectangular shape of land as provided in Table 2. The simulation revealed that the proposed model can reduce the non-productive time during turning operation of the tractor (fig. 3) for both square and rectangular type of the land while increase the tractor operational efficiency (fig. 4). According to Figure 3(a), it revealed that less time is needed to cultivate a square-shaped land using an omni-directional wheeled tractor compared to common tractor design. This also can be seen on the rectangular shape of land Figure 3(b). However, according to Figure 3, the reduction in operational time on rectangular land is smaller than the operational time square land. This is because on rectangular land there were less turning operation and it was dominated by long straight lines trajectory.

Table 1. Tractor operational simulation result for square shape of land

Size of Farmland	Operational time		Efficiency (%)
	Conventional tractor	Omni-directional wheeled tractor	
6X6	67.2187	49.9350	0.2571
9X9	143.1693	92.7058	0.3525
12X12	222.4497	135.7383	0.3898
15X15	265.8017	162.2352	0.3896
18X18	314.1186	188.8571	0.3988

Table 2. Tractor operational simulation result for rectangular shape of land

Unit area simulation	Operational Time		Efficiency
	Common tractor	Omni-directional wheeled tractor	
3X10	59.2407	53.8538	0.0909
5X12	94.0373	75.3826	0.1984
7X14	128.9085	97.5255	0.2435
9X16	173.4225	120.0000	0.3080
11X18	210.6585	142.6788	0.3227

With the mentioned characteristics, when the tractor is used on different field shape, the tractor shows different efficiency. Figure 3 shows that the omni-directional wheeled tractor is more efficient on a square type of the land where more turn operations are required. Moreover, the results showed that more time reduction is obtained in larger size of the farmland. This model tractor is also suitable for the irregular field which requires more turn operations. In addition, the proposed model also can be utilized on various land shape because it was equipped with a swing drive that can rotate the implement position in horizontal direction by 360 degrees. So that the implement can be adjusted directionally not only behind the tractor but also in front of the tractor without switching the wheels direction. Even under certain conditions, this vehicle can be used to shift sideways. This statement supported by previous research which shown that the omni-directional wheel can be used for high maneuverable movement especially in crowded and narrow places (Kanjanawanishkul, 2015). Finally, the proposed protype model can be implemented to in different machine such as transplanter machine and combine harvester machine to increase the operational efficiency of the agricultural machines. The prototype model also can be operated manually or by using remote-controlled program so that this can be fit with the next era of agriculture 4.0 concept.

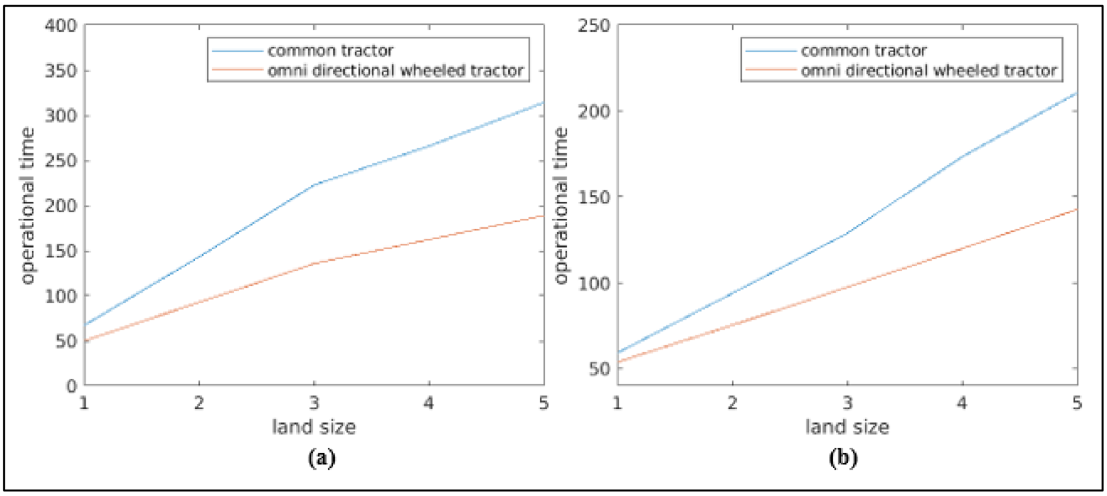


Figure 3. Time comparison (a) on the square land, (b) on the rectangular land.

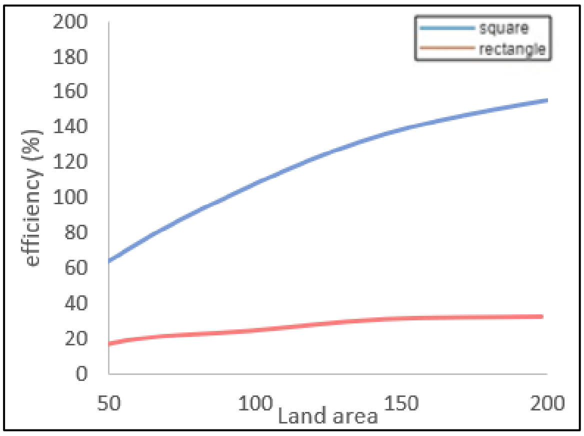


Figure 4. Efficiency comparison

Conclusion

Modified tractor with a holonomic maneuvering system allows tractor to move omni-directionally and significantly reduce time losses during turning time which is suitable to use in a limited size farming. This is because the time required for the omni-directional wheeled tractor to cultivate the land is less than the common tractor in both square and rectangular fields. This tractor also will be more useful when used on square land that requires many turns in cultivating the land.

Acknowledgements

We would like to express great appreciation to Mr. Widagdo Purbowaskito that giving us a lot of advices on designing the prototype model. This paper is supported by Department of Agricultural and Biosystems Engineering Faculty of Agricultural Technology, Universitas Gadjah Mada, Yogyakarta.

References

Akdemir, B. (2013). Agricultural Mechanization in Turkey. International Conference on Agricultural and Natural Resources Engineering, *IERI Procedia 5*(2013), 41-44.

FAO. (2020). Impacts of COVID-19 on food security and nutrition: developing effective policy responses to address the hunger and malnutrition pandemic. Rome, FAO. (also available at http://www.fao.org/3/cb1000en/cb1000en.pdf)

Kanjanawanishkul, K. (2015). Omnidirectional wheeled mobile robots: wheel types and practical applications. *International Journal of Advanced Mechatronic Systems, 6*(6), 289-302.

Kise, M., Noguchi, N., Ishii, K., & Terao, H. (2002). Enhancement of Turning Accuracy by Path Planning for Robot Tractor. Automation Technology for Off-Road Equipment. *Proceedings of the July*, 26-27.

Nagatani, K., Seiga, K., Yoshito, O., Satoshi, T., Takeshi, N., Tomoaki, Y., Eiji, K., and Yasushi, H. (2011). Redesign of Rescue Mobile Robot Quince. In *2011 IEEE International Symposium on Safety, Security, and Rescue Robotics*, 13-18.

Purbawaskito, W. (2017). Pemodelan Konsep dan Rancangan Mekanik Sebuah Purwarupa Unmanned Ground Vehicle untuk Pergerakan Omnidirectional. *Dinamika Rekayasa, 13*(2), 51-59.

Purbuwaskito, W and Hsu, C. H. (2017). Sistem Kendali PID untuk Pengendalian Kecepatan Motor Penggerak Unmanned Ground Vehicle untuk Aplikasi Industri Pertanian. *Jurnal Infotel, 9*(4), 376-381.

Rijalusalam, D. U and Iswanto. (2021). Implementation Kinematics Modeling and Odometry of Four Omni Wheel Mobile Robot on The Trajectory Planning and Motion Control Based Microcontroller. *Journal of Robotics and Control (JRC), 2*(5), 448-455.

Roshanianfard, A., Noguchi, N., Okamoto, H., and Ishii, K. (2020). A Review of Autonomous Agricultural Vehicles (The Experience of Hokkaido University). *Journal of Terramechanics, 91*, 155-183.

Yunardi, R. T., Arifianto, D., Bachtiar, F., and Prananingrum, J. I. (2021). Holonomic Implementation of Omnidirectional Mobile Robot using DCMotors. *Journal of Robotics and Control (JRC), 2*(2), 65-71.

DEVELOPMENT OF PORTABLE LOW-PRICED VISIBLE/ NEAR INFRARED REFLECTANCE SPECTROMETER TO DISTINGUISH COCOA BEANS FROM DIFFERENT REGIONS

Tiana Nur Annisa, Tio Farros Atalla, Rudiati Evi Masithoh*, Arifin Dwi Saputro
Department of Agricultural and Biosystem Engineering, Faculty of Agricultural Technology, Universitas Gadjah Mada. Jln. Flora No. 1 Bulaksumur, Yogyakarta 55281, Indonesia
*evi@ugm.ac.id

Abstract

The process of recognizing and distinguishing cocoa beans is often carried out using destructive methods so that in the process, it can damage the cocoa beans that are used as samples. Vis-NIR spectroscopy is a method that can be used to identify and distinguish cocoa beans without damaging the sample or is called a non-destructive method. In this study, the AS7265x chipset sensor is used, which is affordable and easy to use. The AS7265x chipset sensor used in this study can distinguish cocoa beans through spectral detection as well as Vis-NIR spectroscopy. Spectral data processing is carried out using the Principal Component Analysis (PCA) method, and through processing, the data can be recognized and analyzed the differences of each cocoa bean through the obtained spectral values (680, 705, 830, 900, 940 nm). In addition, the price of commercial spectra with low-cost spectra is much different with a price comparison of 39:1.

Keywords: Cocoa bean; Sensor AS7265x; Spectroscopy; Vis-NIR

Introduction

Cocoa beans are the raw material for making chocolate widely cultivated in various regions (origin). Cocoa beans from different origins also have different physiochemical that can affect the chocolate flavor. Spectroscopy is a method that can be used to distinguish cocoa beans from different origins non-destructively. Spectroscopy has several models, including Vis-NIR (Visible-Near-Infrared), FT-NIR (Fourier Transform-Near-Infrared), and Mid-Infrared spectroscopy. Among the available spectroscopic models, Vis-NIR has the advantages of high penetration energy and low sample heating. The application of this method does not need to damage the material, sample preparation is easier than other methods, does not require chemicals, and can detect fruit parameters quickly (Cen et al. 2007, Gomez et al. 2006, Liu et al., 2008). However, existing commercial Vis-NIR spectroscopic instruments are currently sold at relatively high costs. Previously, research on portable spectrometers for non-destructive testing was carried out to detect soluble solid content (SSC) in apples and succeeded in predicting SSC in apples effectively (Tran et al., 2020). Therefore, this observation aims to develop a portable low-cost spectrometer system using the AS7265x chipset sensor to quickly and non-destructively distinguish cocoa origins. The purpose of this study was to determine the performance of the AS7265x chipset sensor circuit in distinguishing chocolate origins quickly and without damage.

Material and Methods

The materials used in this experiment are Kulon Progo cocoa beans, Lampung cocoa beans, AS7265x chipset sensor, Arduino Uno. While the methods used are as follows:

Sample preparation

The samples used were Lampung cocoa beans and Kulon Progo cocoa beans. Cocoa bean samples were stored in an airtight and dry sealed container at room temperature to maintain the quality of the cocoa beans. All spectral measurements and non-destructive tests were carried out under room temperature conditions.

Spectra acquisition

The spectra were taken with a AS7265x chipset sensor. This chipset consists of 3 sensor chips, and each chip is integrated with a built-in aperture, optical filter, and photodiode array. The AS7265x chipset sensor has a combination of three types of sensors built-in which are visible light (VIS), ultraviolet (UV), and near-infrared (NIR) sensors. Reflectance spectra measurements were carried out using the AS7265x chipset sensor, as shown in Figure 1.

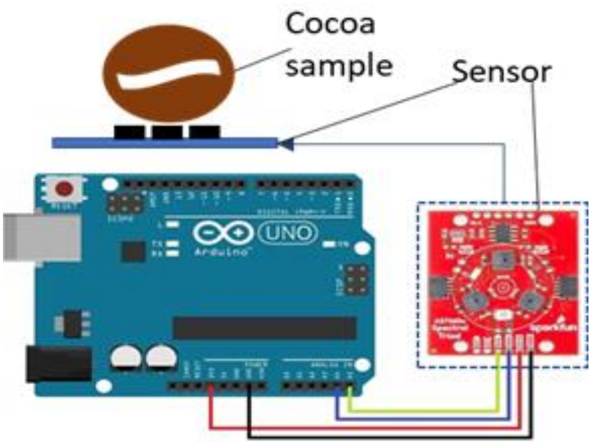


Figure 1. Sensor Arrangement and spectral acquisition set-up

The AS7265x chipset sensor can measure the reflectance of 18 spectra in the 410-940 nm wave range. with the 20 nm of the full unified wave at half maximum (FWHM). This sensor has built-in LEDs in the form of white LEDs (5700K), UV LEDs (405 nm), and IR LEDs (875 nm). Spectra data were collected in a black chamber to minimize external light intervention and repeated three times for each cocoa bean. The spectra taken are compared with the white and dark reference spectra. The white reference is obtained using a material that produces 100% reflectance, while the dark reference is obtained by turning off the light source. The obtained spectra were converted into absorbance using Equation 1. The absorbance spectra were then normalized before spectral analysis was performed.

$$A_\lambda = -log_{10}\left(\frac{S_\lambda - D_\lambda}{R_\lambda - D_\lambda}\right) \qquad \text{Equation 1}$$

Where,
S_λ = Intensity of sample at wavelength λ nm
D_λ = Intensity of dark at wavelength λ nm
R_λ = Intensity of white reference at wavelength λ nm

Chemometric analysis

In this test, a multivariate calibration model was created using Unscrambler X version 10.4 software (CAMO Software AS, Oslo, Norway). Principal Component Analysis (PCA) is used to reduce dimensions and find patterns in the spectral variables. PCA analysis diagram to get the desired results is carried out as shown in Figure 2. After PCA were done using absorbance spectra, the plot scores of PCA were analyzed. If the results of the plot scores shows a distinct classification of the sample from each region, then the results of the analysis can be used. Meanwhile, if the plot score shows that the sample were unclassified, the loading line were then investigated. The loading line can show the corelated wavelength that contributed to the PCA classification. From the loading line, the spectrum of wavelengths that do not affect the measurement could be decided and then eliminated. The PCA were then reanalyzed using the same method with the remaining spectrum.

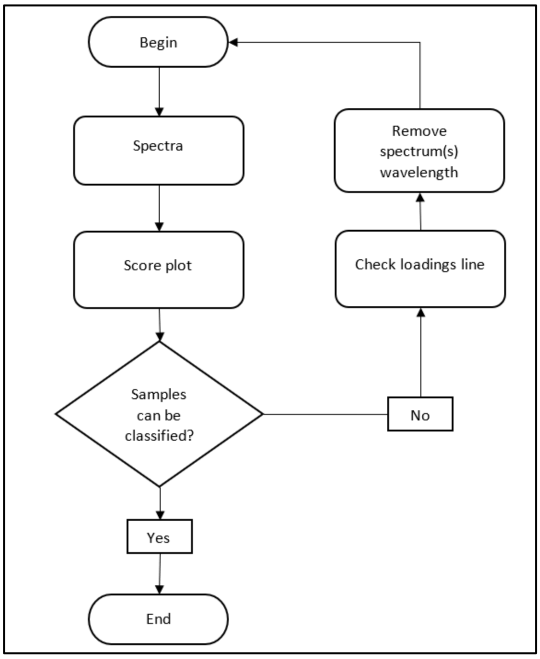


Figure 2. Chemometric analysis diagram

Results and Discussion

Research on non-destructive analysis for determining chocolate quality parameters was carried out using the AS7265x chipset sensor circuit using Arduino Uno as the microcontroller. Data analysis was carried out qualitatively using PCA and is shown in Figure 3.

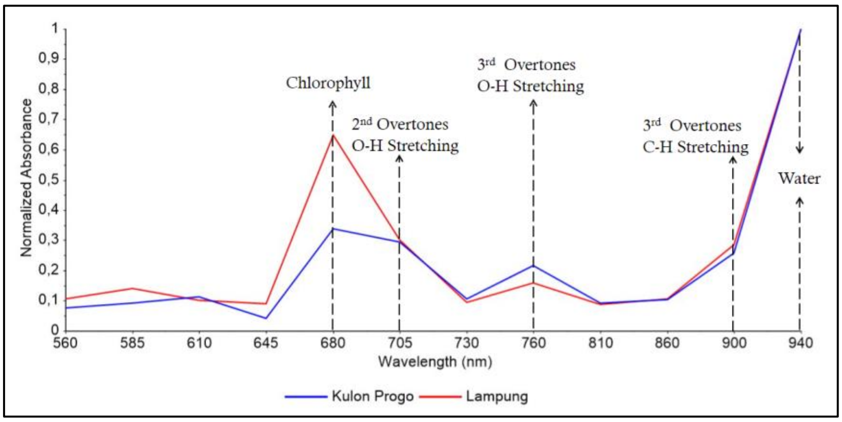
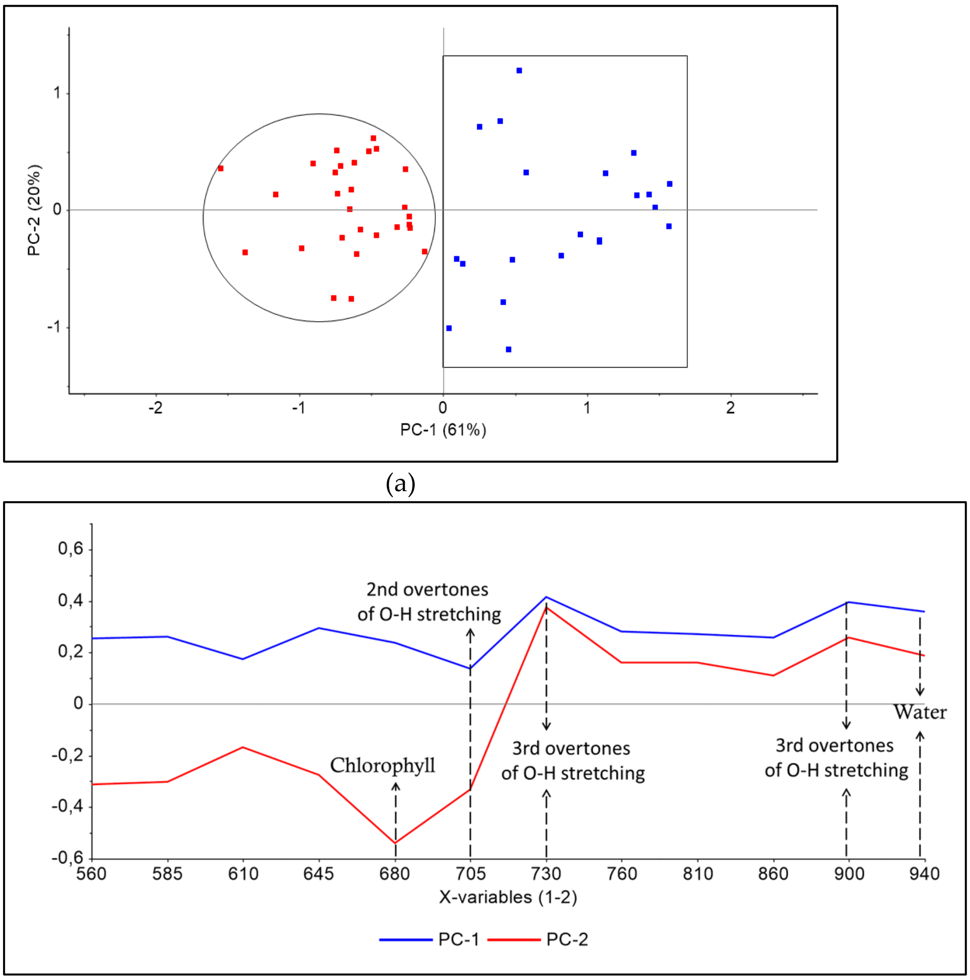


Figure 3. Spectra of Kulon Progo Chocolate and Lampung Chocolate

Based on Figure 3, it is seen that there are absorbance peaks at wavelengths of 680, 705, 760, 900, and 940 nm. The wavelength of 680 nm is correlated with chlorophyll (Chia et al., 2013, Guo et al., 2016), 705 is correlated with 2nd overtones of O-H stretching (Fernández-Novales et.al, 2019), 760 is associated with 3rd overtones of O-H stretching (Guo et al., 2016), 900 is associated with 3rd overtones of C-H stretching (Golic et al., 2003), and 940 nm is affected by 2nd overtones of O-H stretching or water (Fernández-Novales et al., 2019). Of all the wavelengths, the most obvious difference is seen at the 680 nm wavelength, correlated with chlorophyll.

PCA is used for qualitative analysis of the obtained spectra and to find patterns between the spectral variables. The best result of PCA analysis in this research was yielded using 12 wavelength spectra, with a range of 560-940 nm. Figure 4 (a) shows the results of the PCA analysis of cocoa beans. The total variance obtained from the scores plot is 81%, with PC-1 of 61% and PC-2 of 20%. The maximum plot score is 100%, so the plot score of 81% is considered able to be used to classify cocoa beans based on their origin. By using

PC-1, cocoa beans can be grouped based on their origin. Cocoa beans from Lampung had a negative PC-1 value, while cocoa beans from Kulon Progo had a positive PC-1 value.



(b)

Figure 4. (a) Scores plot principal component analysis of cocoa beans from Kulon Progo (blue) and Lampung (red) regions. and (b) Loadings plot principal component analysis of cocoa beans from Kulon Progo and Lampung regions.

Figure 4 (b) shows the loading plot of the cocoa bean PCA. The loading plot spectra were used to see the waves that influence the grouping of cocoa beans into two groups. Based on the figure, it is seen that on PC-1, the most influential wavelengths are valleys at 705 and peaks at 730 and 900. The two most influential wavelengths for PC-2 are the valleys at 680 and the peaks at 730 and 900. The wavelength of 680 nm correlates with chlorophyll, 705 correlates with 2nd overtones of OH stretching, 730 corresponds to maximum reflectance peak (Giovenzana et al., 2014), and 900 corresponds to 3rd overtones of CH stretching. Based on the results of the analysis that has been carried out, the sensor arrangement of the AS7265x chipset with Arduino Uno is proven to be able to distinguish the types of Kulon Progo cocoa beans and the type of Lampung cocoa beans. This sensor can be an option to perform non-destructive analysis of cocoa beans with the VIS-NIR spectroscopy method but with a lower cost and simple equipment with low production costs. Not only for cocoa beans samples, this sensor also can be used for other fruits like banana, apple, pear, and avocado. The price comparison between commercial spectroscopy and low-cost spectroscopy is shown in Table 1.

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Table 1. Comparison of Commercial Spectroscopy Prices with Low-Cost Spectroscopy

No	Description	Unit Price (USD)	No	Description	Unit Price (USD)
1	"OCEAN OPTICS" High Thermal Stability Spectrometer, Model FLAME-T-VIS-NIR, for VIS NIR Range (350-1000 nm)	5,170.00	1	Breadboard 400 point project	2.08
2	"OCEAN OPTICS" Tungsten Halogen Light Sources for the Vis-NIR, Model HL-2000-HP-FHSA, w/ Integrated Filter Holder, Attenuator & Shutter	2,690.00	2	ARDUINO UNO R3 ATMEGA 328P + USB Cable	5.86
3	"OCEAN OPTICS" Premium Grade Reflection Probe, Model QR400-7-VIS-NIR	1,450.00	3	AS7265x Triad Spectrometer Sensor	207.96
			4	Manufacturing	16.42
Total Price (USD)		9,310.00		Total Price (USD)	232.32

Conclusions

A spectrometer with an AS7265x sensor chipset can be used to measure the spectrum of cocoa beans. The spectrometer built combined with PCA can distinguish the spectra of cocoa beans from 2 different regions (Lampung and Kulon Progo). However, this study has proved that the portable spectrometer with low-priced sensors can be used for food analysis.

Acknowledgement

The authors would like to acknowledge Universitas Gadjah Mada (UGM) for providing the technical and financial assistance during this work.

References

Cen, H., He, Y. (2007). Theory and Application of Near Infrared Reflectance Spectroscopy in Determination of Food Quality. *Trends in Food Science & Technology* (18) pp. 72-83.

Giovenzana, Valentina., R. Beghi., C. Malegori., R. Civelli., and R. Guidetti. (2014). Wavelength Selection with a View to a Simplified Handheld Optical System to Estimate Grape Ripeness. *Am. J. Enol. Vitic* (65:1) pp. 117-123, doi: 10.5344/ajev.2013.13024

Gomez, A.H., He, Y., Pereira, A.G. (2006). Non-destructive measurement of acidity, soluble solids and firmness of Satsuma mandarin using Vis/NIR-spectroscopy techniques. *Journal of Food Engineering* (77) pp.313-319.

J. Fernández-Novales, T. Garde-Cerdán, J. Tardáguila, G. Gutiérrez-Gamboa, E. P. Pérez-Álvarez, and M. P. Diago. (2019). Assessment of amino acids and total soluble solids in intact grape berries using contactless Vis and NIR spectroscopy during ripening. *Talanta*. vol. 199, no. February, pp. 244–253, doi: 10.1016/j.talanta.2019.02.037.

K. S. Chia, H. Abdul Rahim, and R. Abdul Rahim. (2013). Evaluation of common preprocessing approaches for visible (VIS) and shortwave near infrared (SWNIR) spectroscopy in soluble solids content (SSC) assessment. *Biosyst. Eng*., vol. 115, no. 1, pp. 82–88 , doi: 10.1016/j.biosystemseng.2013.02.008.

Liu, Y., Chen, X., Ouyang, A. (2008). Nondestructive determination of pear internal quality indices by visible and near-infrared spectroscopy. *LWT-Food Science and Technology* (41) pp.1720-1725.

M. Golic, K. Walsh, and P. Lawson. (2003). Short-wavelength near-infrared spectra of sucrose, glucose, and fructose with respect to sugar concentration and temperature. *Appl. Spectrosc* , vol. 57, no. 2, pp. 139–145, 2003, doi: 10.1366/000370203321535033.

Tran, Nhut-Thanh and Masayuki Fukuzawa. (2020). A Portable Spectrometric System for Quantutative Prediction of the Soluble Solids Content of Apples with a Pre-calibrated Multispectral Sensor Chipset. *Sensors* (20) pp. 1-11

Z. Guo, W. Huang, Y. Peng, Q. Chen, Q. Ouyang, and J. Zhao. (2016). Color compensation and comparison of shortwave near infrared and long wave near infrared spectroscopy for determination of soluble solids content of 'Fuji' apple. *Postharvest Bio. Technol*., vol. 115, pp. 81–90, 2016, doi: 10.1016/j.postharvbio.2015.12.027

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THREE-DIMENSIONAL (3D) RECONSTRUCTION OF PLANT USING CLOSE RANGE PHOTOGRAMMETRY FOR LEAF TYPE VARIATIONS

Diaz Habib Dananta, Andri Prima Nugroho*, Wilda Monicha Mukti, Diah Nur Rahmi, Lilik Sutiarso
Smart Agriculture Research Group, Department of Agricultural and Biosystem Engineering, Faculty of Agricultural Technology, Universitas Gadjah Mada. Jln. Flora No.1 Bulaksumur, Yogyakarta 55281, Indonesia
*andrew@ugm.ac.id

Abstract

The increase in the population increased energy and food needs. This situation can lead to national food shortages. To reduce the resulting impact, efforts are needed to reduce energy and water consumption. Therefore, it is necessary to apply precision agriculture. The application of precision agriculture is one of them is to take measurements in the growth of crops. In the past, conventional measurement of plants with direct measurements could pose a risk of crop damage. Therefore, a non-destructive plant monitoring and measurement system is required. The purpose of this study is to develop a plant growth system based on 3D models through non-destructive measurements using Close Range Photogrammetry (CRP) to estimate the volume of vegetation models and determine the suitability of leaf shapes against the CRP method by volume. 3-dimensional plants are essential for monitoring systems, visual 3 dimensions obtained are used to measure the direct state of plants without damaging plants. This paper used a close-range photogrammetry method of shooting using a DSLR camera with 3DFzephyr software for 3-dimensional reconstruction of plants. Stages in 3-dimensional reconstruction are dense reconstruction and meshes. Furthermore, the data obtained from meshes is calculated to represent the estimated volume. The RMSE value sequentially of Chinese cabbage, lettuce, and the pagoda is 27.65 cm3, 14.12 cm3, and 2.22 cm3. MAPE was 2.15%, 18.61%, and 12.04% respectively. The 3-dimensional visual obtained has presented the original plant. The CRP method for measuring plant volume is best suited for Chinese cabbage due to the slight overlap of leaves when shooting.

Keywords: 3D reconstruction; Close-range photogrammetry; Non-destructive measurement; Plant monitoring

Introduction

Population growth in Indonesia is increasingly happening. In 2020 the population of Indonesia is 270.2 million people, an increase of 32.056 million people when compared to the results of the 2010 population census (Bps.go.id., 2020). This increase in population certainly causes various impacts in life, one of which is the increase in energy and food needs. Efforts to meet the number of energy and food needs often have an impact on the environment. The application of an agricultural system that can meet the number of food and energy needs but has a minimal impact is needed.

Precision farming or precision agriculture is a specific agricultural system that aims to optimize inputs, improve efficiency, and sustainability focusing on the right management practices at the right time and in the right place (Gebbers, R., 2010). Precision agriculture is a method that utilizes information technology (IT), as well as a remote control that is useful to improve all functions and services in the agricultural sector (Khanal, S., Fulton, J., & Shearer, S., 2017).

Plant factory forms a good environment for growing plants by implementing a monitoring system. The monitoring system ensures the availability of plant needs such as water, nutrients, and light in their growth and development. An example of a monitoring system that has been studied is a three-dimensional reconstruction of plant growth and development. The advantage of the monitoring system is that it is able to measure plant volume in a non-contact-destructive manner, which only uses image imagery (Arief, M.A.A., et al., 2021). But the study is still limited to measurements of dummy plants or fake plants, so it is considered less able to represent native plants.

Measurement of plant growth and development can be done by applying precision agriculture. Measurements are done non-destructively by not touching and damaging plants. One of the fundamental implementations in terms of precision agriculture is that accurate measurement of plants are needed to observe the rate of growth. Plant growth is one important thing to be able to evaluate the environmental field and also improve agricultural production systems (Rosell, J.R., et al., 2009). Direct measurements in the field using conventional measuring instruments have become a way to be able to measure plants (Wijanarko, A., et al., 2019). However, with the development of precision agriculture a plant monitoring system began to be implemented that aimed to observe the conditions and the growth of the plant (Ni, Z., Burks, T. F., & Lee, W. S., 2016). The precision data of plant growth can be used to improve agricultural systems and evaluate the environment.

This study was conducted to find out the application of close-range photogrammetry in the three-dimensional reconstruction of plant leaf type variations. Three-dimensional reconstruction is not only used to measure the height, weight, and volume of plants but also to visualize plant objects in a virtually 3-dimensional form (Aguilar, M.A., et al., 2010). This sample-based on the volume of the various leaves which is estimated from real-world measurements using close-range photogrammetry, 3D modeling tools, and digital photographs analysis respectively (Cross, J.V., et al., 2003). Previously many research results mentioned that measurements like this can be done using laser scanners and ultrasonic sensors to obtain more accurate results (Aguilar, M.A., et al., 2010). However, measurement using lasers and ultrasonic sensors is overpriced and more difficult in operation. The price for a unit of laser scanner sold in several online marketplaces ranges from tens to hundreds of millions of rupiah depending on the features and quality. This study used the Close-Range Photogrammetry (CRP) method of shooting using a DSLR camera with 3DFzephyr software that is considered cheaper and easy to process for the alternative use of lasers.

The purpose of this study was to develop a plant growth system based on 3D models through non-destructive measurements using Close Range Photogrammetry (CRP) to estimate the volume of vegetation models and determine the suitability of leaf shapes against the CRP method by volume. The scope of this study is the modeling and measurement of the volume of the three-dimensional form of the original plant using the Close-Range Photogrammetry method.

Material and Method

This research was conducted in January to June 2021 at the Smart Agriculture Research Group, Agro-Informatics Sub-Laboratory, Laboratory of Energy and Agricultural Machinery, Department of Agricultural and Biosystems Engineering, Faculty of Agricultural Technology, Universitas Gadjah Mada, Yogyakarta.

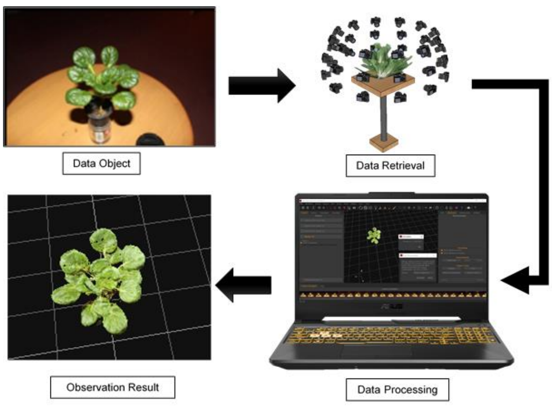

Figure 1. Schematic design of the scanner and 3D reconstruction system

The schematic design in this study showed in Figure 1. Based on the figure, monitoring system research on native plants is done by shooting with the CRP method. This research was conducted with a low-cost concept then only used tools in the form of canon 700D cameras and laptops Asus TUF with AMD Ryzen™ 7 4800H. Photo data capture is done using a Canon 700D camera. The photo capture method is done manually with orbital techniques. The shooting was done three times rotation, the first rotation of the image appears sideways in other words the camera is as close as the crop, then the image appears top with an angle of approximately 45 degrees from the y-axis and an angle of 270 degrees from the y-axis is done circularly. The images obtained are then processed using the 3DF Zephyr for three-dimensional reconstruction.

The analysis in this study used three different types of commodities, namely Chinese cabbage, lettuce, and Tat Choy. The selection of these three types of commodities is based on the characteristic differences of each type of vegetable. One of the characteristics that are used as the reason for the selection of commodities is the difference in the shape of plants, especially on the leaves.

After obtaining volumetric measurement data through the 3DFZephyr application, volumetric measurements with manual or conventional measurements are required using the CRP method. Once both data are obtained, it is necessary to validate the volume estimation by comparing the results of conventional manual data with the 3DFZephyr application to show the relationship between the two calculation methods. To know the accuracy of the data, test errors, and design of model performance needs to be done validation tests using the Root Mean Square Error validation index (RMSE) and Mean Absolute Percentage Error (MAPE). The flowchart of system development and evaluation in this study is shown in Figure 2.

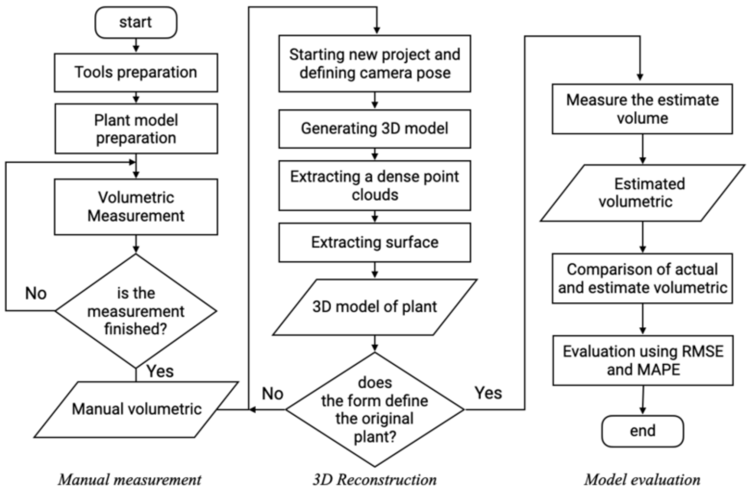

Figure 2. Flowchart of the system development and evaluation

Result and Discussion

Based on research about Three-Dimensional (3D) Reconstruction of Plant Using Close Range Photogrammetry for Leaf Type Variations that have been implemented, obtained the following results.

Calibration Result

Non-metric cameras have imperfect lenses, so shooting has errors. Therefore, it is necessary to calibrate to know the magnitude of the deviations that occur. Camera calibration is performed to determine the camera's internal parameters *(IOP)* including principal distance (c), photo fiducial center point (*X0*, *Y0*), lens distortion (*K1, K2, K3, P1*, and *P2*), as well as distortion due to scaling and orthogonal differences between the *X* and *Y* axes (*b1*, *b2*). The study was used to calibrate with grid calibration from Photo modeler Scanner software. In Table 1 you see a calibration result that displays an average RMS error value of 0.103 pixels. So, it can be stated if the camera is good for photogrammetry because the calibration result is not more than 1.

Table 1. Interior orientation parameters of DSLR camera calibration process

Parameters	value	Deviation
K1 (Radial Distortion)	1,639e-04	1.7e-06
K2 (Radial Distortion)	-1556e-07	2.1e-08
K3 (Radial Distortion)	0	0
P1 (Tangential Distortion)	-8237e-06	1.8e-06
P2 (Tangential Distortion)	-8743e-05	1.9e-06
Overall RMS	*0.103pixels*	-

DSLR cameras were chosen in this study because of the use of native plants so that it requires a camera that has a better sensor than a web-camera and fits the concept of this research that carries the concept of low-cost because it is easy to find. Shooting using a convergent axis captures shooting techniques.

Three-Dimensional Development Process in 3DF Zephyr Software Result

33DF Zephyr is a software used to reconstruct three dimensions. In this study, there are several stages. The first stage is to insert an image, the image is inputted in the new project and defining camera pose. In this section, it is useful to sort the images that have been taken. The next steps are the dense point cloud and mesh generation process. The last step is the editing process. The editing process sorts out the design used to measure the volume. In this process determine how the volume will be calculated. The thing that is eliminated at this stage of the process is the base and the part around the plant that reads for reconstruction.

Volume Capture and Measurement Results

The study was conducted with volumetric measurements of each variation with conventional volume measurement methods and volume measurements using 3DF Zephyr software. Conventional volume measurement by putting water into a prepared container and then dipping the plant into it. The increase in water that occurs in the container is then measured and expressed as the volume of the plant.

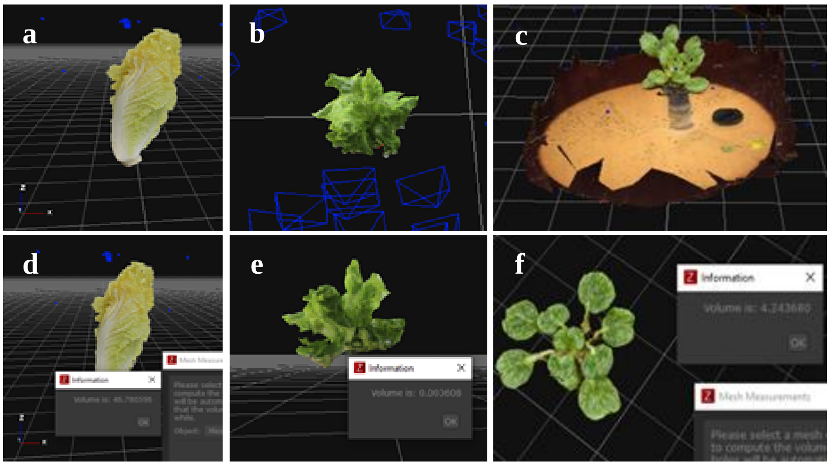

Figure 3. Volume measurement results using 3DF Zephyr software (a,b,c) before measurement (d,e,f) after measurement

While measurements using 3DF zephyr software can be seen in figure 3, three-dimensional objects will be given a useful control point as a reference in the computerized process of volume measurement to improve accuracy. After that, choose the part to be measured, to reduce the participation of the surrounding environment. The volume comparison results can be seen in Table 2.

Table 2. Volumetric Measurement Results

No Data	Chinese Cabbage		Lettuce		Tat Choy	
	Current	Zephyr	Current	Zephyr	Current	Zephyr
1	189	35	47	0,002	10	4,24
2	203	46,78	54	0,004	12	5,27
3	448	62,9	58	0,008	14	12,97
4	470	99,66	67	0,010	20	15,9
5	629	120,3	71	0,012	22	18,79
6	688	121,7	82	0,013	34	23,30

Volume Data Calibration Result

The comparison of conventional measurement results with the CRP method has a considerable difference, it is because 3DF Zephyr software has its criteria in volume measurement. The solution to knowing the pattern from each model variation can be done using calibration. The result of the coefficient of determination for each commodity shown in Figure 4. below.

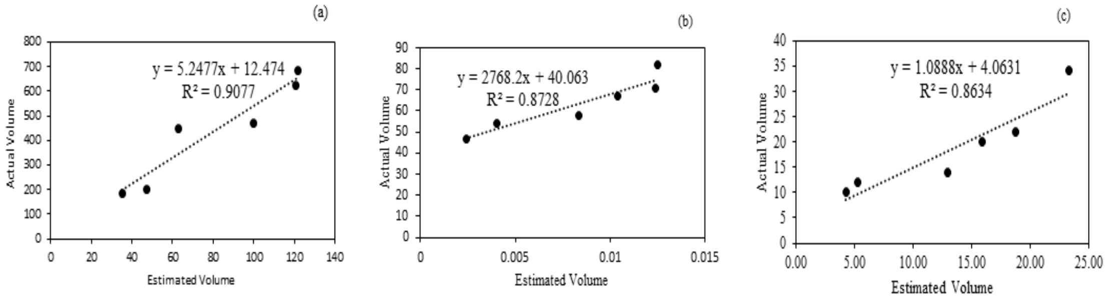

Figure 4. Coefficients Determination Result: (a) Chinese Cabbage; (b) Lettuce; (c) Tat Choy

Volume Comparison Validation Results

The study used 9 samples for each model, for 6 data used as calibrations to determine the value of deviations from volume measurements using Zephyr 3DF *software.* Known calibration equations:

$$y_{v\ Chinese\ Cabbage} = 5{,}2477x_{v\ Chinese\ Cabbage\ estimated} + 12{,}474 \quad \text{Equation 1}$$
$$y_{v\ Lettuce} = 2768{,}2x_{v\ Lettuce} + 40{,}63 \quad \text{Equation 2}$$
$$y_{v\ Tat\ Choy} = 1{,}0888x_{v\ Tat\ Choy} + 4{,}0631 \quad \text{Equation 3}$$

Where,
y: estimated volume (cm^3)
x: volume calculation by 3DF Zephyr(cm^3)

Based on the equation it can be stated that in the conversion of the value of the estimated volume to the actual volume. While the other three are used for evaluation using the RMSE and MAPE methods shown in Table 3. This evaluation aims to determine the value of errors in CRP measurements with conventional measurements. An RMSE value close to 0 indicates that the designed system is valid. However, this study found RMSE value for Chinese cabbage worth 27.65 cm3, lettuce 14.12 cm3, and pagoda 2.22 cm3. The acquisition of large results due to the overlap of large plant structures, in addition to the shape of the plant there are still many cavities that make misinterpretations.

Table 3. Volume Validation Comparison

Plant	RMSE (cm3)	MAPE (%)
Chinese cabbage	27,65	2,15
Lettuce	14,12	18,61
Pagoda	2,22	12,04

The MAPE shows the presentation error value of the system that can be used as a reference that the system designed is valid. In this study, Lettuce with the highest MAPE value is not recommended to use the CRP method in volume measurement. Although in 3D reconstruction lettuce was successful, volume measurements had the highest percentage of errors. Lettuce has a characteristic leaf that widens, hollows, and overlaps. In zephyr 3DF volume measurement, lettuce is less precise for volume measurement. It's the same with pagodas. Pagodas have the characteristics of many segments, and are short-lied so that there is a lot of overlap between leaves. Pagoda has a MAPE value of 12.04%. This value is not small when compared to the MAPE value of white mustard. Chinese cabbage had a MAPE value of 2.15%, the smallest value compared to the other two plant models. This is because the Chinese cabbage used has been more than 35 days old after planting so that the shape of the Chinese cabbage is oblong and solid. The characteristic shape of plants that have characteristics such as Chinese cabbage is highly recommended to be used in the measurement of CRP methods because the shape of plants is minimal with overlapping leaves and cavities so that volume measurement is easily recognized by the software. Although it is considered to have the most suitable characteristics, in this study Chinese cabbage still has a value of 2.15% due to the tip of the Chinese cabbage that is still hollow and abstract textured to cause errors in measurements.

Conclusion

This paper develops a non-destructive plant growth measurement system with three-dimensional modeling based on the Close-Range Photogrammetry method. Capture photo imagery data by scanning objects using a 360-degree orbital DSLR camera. 3D form processing is done using 3DFZephyr software so that actual plant visualizations are obtained. Data validation is done by testing three methods, namely linear regression, RMSE, and MAPE. For successive RMSE values of Chinese cabbage, lettuce and Tat Choy is 27.65 cm3 14.12 cm3, and 2.22 cm3, and MAPE is 2,15%, 27,65%, and 2,22%. Based on the monitoring system performance tests that have been conducted, it was obtained that Chinese cabbage has the best level of accuracy.

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References

Bps.go.id. (2020). Hasil Sensus Penduduk 2020. *Berita Resmi Statistik, 27*, 1–52. Retrieved from https://papua.bps.go.id/pressrelease/2018/05/07/336/indeks-pembangunan-manusia-provinsi-papua-tahun-2017.html

Gebbers, R. (2010). Precision Agriculture and Food Security. *Science, 327*(5967), 828-831. https://doi.org/10.1126/science.1183899

Khanal, S., Fulton, J., & Shearer, S. (2017). An overview of current and potential applications of thermal remote sensing in precision agriculture. *Computers and Electronics in Agriculture, 139*, 22–32.

https://doi.org/10.1016/j.compag.2017.05.001

Okayasu, T., Nugroho, A. P., Sakai, A., Arita, D., Yoshinaga, T., Taniguchi, R. I., Horimoto, M., Inoue, E., Hirai, Y. & Mitsuoka, M. (2017). Affordable Field Environmental Monitoring and Plant Growth Measurement System for Smart Agriculture. *In 2017 Eleventh International Conference on Sensing Technology (ICST)* (pp. 1-4). IEEE.

Arief, M.A.A., Nugroho, A.P., Putro, A.W., Dananta, D.H., Masithoh, R.E., Sutiarso, L. and Okayasu, T., (2021), April. Three-dimensional (3D) reconstruction for non-destructive plant growth observation system using close-range photogrammetry method. In *IOP Conference Series: Earth and Environmental Science* (Vol. 733, No. 1, p. 012028). IOP Publishing.

Rosell, J.R., Sanz, R., Llorens, J., Arnó, J., Escolà, A., Ribes-Dasi, M., Masip, J., Camp, F., Gràcia, F., Solanelles, F., Pallejà, T., Val, L., Planas, S., Gil, E. and Palacín, J., (2009). A Tractor Mounted Scanning LIDAR For the Non-Destructive Measurement of Vegetative Volume and Surface Area of Tree-Row Plantations: A Comparison with Conventional Destructive Measurements. *Biosystems Engineering*, 102: 128-134.

Wijanarko, A., Nugroho, A. P., Sutiarso, L., & Okayasu, T. (2019). Development of mobile RoboVision with stereo camera for automatic crop growth monitoring in plant factory. *In AIP Conference Proceedings* (Vol. 2202, No. 1, p. 020100). AIP Publishing LLC.

Ni, Z., Burks, T. F., & Lee, W. S. (2016). 3D Reconstruction of Plant/tree Canopy Using Monocular and Binocular Vision. *Journal of Imaging, 2*(4). https://doi.org/10.3390/jimaging2040028

Aguilar, M.A., Pozo, J.L., Aguilar, M.A., Garcia, A.M., Fernandez, I., Negreiros, J., Sánchez-Hermosilla, J. (2010). Application of Close-range Photogrammetry and Digital Photography Analysis for The Estimation of Leaf Area Index in a Greenhouse Tomato Culture. *International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, Vol. XXXVIII, Part 5 Commission V Symposium, Newcastle upon Tyne, UK. 2010

Cross, J.V., Walklate, P.J., Murray, R.A., Richardson, G.M. (2003). Spray Deposits and Losses in Different Sized Apple Trees from an Axial Fan Orchard Sprayer: 3. Effects of Air Volumetric Flow Rate. *Crop Protection,* 22, 381-394.

TAMANU OIL PRODUCTION USING SCREW-PRESSED METHOD

Linggar Setianingrum, Dhyas Tanjung Prabowo Putri*, Haryo Prasetyo Adi Andoyo,
Joko Nugroho Wahyu Karyadi, Makbul Hajad

Department of Agricultural and Biosystem Engineering, Faculty of Agricultural Technology,
Universitas Gadjah Mada, Yogyakarta 55281, Indonesia.
*dhyastanjung2018@mail.ugm.ac.id

Abstract

Indonesia is an agricultural country with many beaches that have many tamanu (*Calophyllum inophyllum* L) plants. The use of tamanu oil as oil for beauty is now in vogue. It is important to understand the physical characteristics of tamanu kernels and the characteristics of tamanu oil for further research because these are still rare. This study aims to determine the physical properties of tamanu kernels and to determine the characteristics of tamanu oil. Physical properties measured from tamanu kernels are measurements of the size (diameter and length), density, color, and water content (%db). Meanwhile, the properties measured from tamanu oil are measurements of density, degree of acidity (pH), color (visual), and viscosity. Based on the measurement of the characteristics of tamanu kernels that have been carried out, it can be concluded that the physical characteristics of tamanu kernels are round, pointed tip with a diameter of 1.6-1.8 cm and a length of 1.6-2.4 cm, have a density of 0.9-1 g/ml, yellow in color, and have a water content of 44.71%. Meanwhile, the characteristics of tamanu oil obtained were having a density of 0.984 g/ml, a degree of acidity (pH) of 5.88, dark green in color, and a viscosity at 28°C of 101.25 cp.

Keywords: *Calophyllum inophyllum* L; Characteristics; Physical properties; Tamanu kernels; Tamanu oil

Introduction

Tamanu (*Calophyllum inophyllum* L) is widely grown in Southeast Asia, especially in Indonesia (Bustomi, S. et al., 2008) and commonly known by the locals as Nyamplung or Bintangur (Sanjid, A. et al., 2013). The production of tamanu fruit in Indonesia according to the Research and Development Agency for Agriculture is 220 kg/tree/year from Banyuwangi, 60 to 110 kg/tree/year from the Ciamis area, 70-150 kg/tree/year from the Purworejo area, and 130 kg/tree/year. from Papua (Syakir, M. et al., 2011). Besides growing in Southeast Asia, tamanu is also widespread in Australia, India, Sri Lanka, and the South Pacific (Azad, A. K. et al., 2016). Different countries know the species by different vernacular names, some of which are presented in Table 1.

Table 1. Vernacular names for *Calophyllum inophyllum* (Ong, H. C. et al., 2011)

Country	Vernacular names	Country	Vernacular names
Bangladesh	Punnang	Malaysia	Penaga Laut, Bintangor
Cambodia	Khtung, Kchyong	Myanmar	Ponnyet
English	Alexandrian laurel, Borneo mahogany, Tamanu	Palau	Btaches
Hawaii	Kamani	Papua New Guinea	Beach calophyllum
India	Polanga, Sultan Champa	Philippines	Butalau, palo maria, bitaog
Indonesia	Nyamplung, Bintangur	Thailand	Krathing, saraphee (northern), naowakan (Nan)

Almost all parts of the tamanu plant can be used, such as the fruit, leaves, wood, flowers and tamanu sap because it contains oils that have various uses. However, those that contain the most oil are found in the fruit and tree sap. In addition to producing oil, the waste oil extraction process can be used as charcoal, liquid smoke for wood preservatives, and cake for animal feed, medicine and dye textiles of resin or sap, soap, etc. (Leksono, B. et al., 2014).

The oil content in fresh tamanu kernels is approximately 40-55%, while dry tamanu kernels are 70-73% (Heyne, K. et al., 987). The oil content in tamanu kernels is higher when compared to Jatropha (40 - 60%) and Palm (46-54%) (Leksono, B., et al.,2012). According to Trisnawati, S. et al. (2018), tamanu kernels contain 75% oil and the oil contains approximately 71% of unsaturated fatty acids. Oil produced from tamanu kernels has the potential as a raw material for biofuels (Leksono, B. et al., 2014). Tamanu oil also has potential for treatment because it contains steroids, flavonoids, saponins, and triterpenoids that have antibacterial effects so that they can function as medicine (Hasibuan, S. et al., 2013). In addition, Tamanu oil contains palmitic acid, oleic acid, stearic acid, linoleic acid, cyclohexanecarboxylic acid and eicosanedioic acid that can be used as pharmaceutical raw materials (cosmetics). The use of natural materials as raw materials for cosmetics is more interesting to the community because of the lower chance of side effects occurring compared to the use of synthetic chemicals (Artanti, A. N. et al., 2018).

Despite its high kernel oil content, the yield and characteristics of tamanu oil are affected by the extraction method (Fadhlullah, M. et al., 2015). Several extraction methods are used to extract oil from the kernels are mechanical extraction, chemical extraction and enzymatic extraction (Azad, A. K. et al., 2016). The oil extraction method commonly used in industry is mechanical extraction, one of which is the screw press (Jahirul M. I. et al., 2013). The oil from mechanical extraction can be affected by the kernel conditions, such as kernel moisture content and particle size (Orhevba B. A. et al., 2013). Mechanical pressing is used to extract oil with a range of oil content from 30-70% (Estrada, F. et al., 2007). Mechanical pressing commonly used is hydraulic pressing and expeller pressing (threaded pressing) or Screw press. Jairul et al. (2013) said that extracting tamanu seeds using the screw press method could extract more oil (68-80%) than ram press (60-65%). Given the effect of extraction methods and raw materials on the oil produced, this research analyzes the characteristics of raw materials and tamanu oil extracted using a mechanical method, namely screw press.

Materials and Methods

Tamanu fruits

This study used a sample of 38.18 Kg of tamanu kernels to produce tamanu oil where conducted at PT Sinergi Panggung Lestari. Tamanu kernels are produced from the process of stripping tamanu fruits conducted by the residents of Panggungharjo, Sewon, Bantul, Special Region of Yogyakarta. The raw material used is tamanu fruit that has fallen from tamanu trees for less than two weeks collected by farmer partners from PT Sinergi Panggung Lestari. The raw materials of tamanu fruit in PT Sinergi Panggung Lestari come from Madura, Purworejo, Magelang, and Banyuwangi.

Tamanu kernel physiological measurements

Physiological measurements of tamanu kernels consist of measuring the size (diameter and length), density, color (L, a*, b* or the respective values of lightness, green to red ratios, and blue to yellow ratios), as well as measurements of moisture content (%db). Measurement the size (diameter and length) of the kernels measured by electronic digital caliper. The density of tamanu kernels is measured by measuring glasses and analytical scales. The color of tamanu kernels is measured using Color Meter TES 135 A. Meanwhile, moisture content is measured using thermogravimetric measurement method with the help of Sanyo Laboratory Convection Oven MOV-212F.

Process of making tamanu oil

Tamanu fruits stripping process:

The stripping process is conducted to take the seed of tamanu commonly called the kernel of the tamanu fruit by stripping the skin and the pulp from the tamanu fruit. The stripping process is done manually with a hammer tool.

Tamanu kernel chopping process:

The chopping process aims to reduce the size of the tamanu kernels so the kernels can be dried quickly until the water content is ready to press (2.953%db). The chopping process is carried out with a chopping machine equipped with blades to chop. Chopped tamanu kernels then dried immediately to avoid the tamanu kernels oxidation.

Tamanu kernel drying process:

The drying process aims to inhibit the mushrooming of the tamanu kernels and to lower the water content of the tamanu kernels (44.712%db to 2.953%db) in order to maximize the production of the tamanu oil. This process is done by drying the kernels in the hot sun using a tarpaulin above the cement floor. During the drying process, the kernels are turned 3 times so the kernels can dry evenly. The drying time depends on the intensity of the sun, but usually the drying process takes 2 days.

Tamanu kernel extracting process:

The extracting process of the tamanu kernels uses a type of mechanical extraction that does not provide special heat treatment. The extracting process using a screw press machine with a single screw press type with a cold-press method. The principle of how the screw press works is that the chopped tamanu seeds will be pressed using the thrust of the rotating thread. The seeds will be pushed forward by itself along with the pressure from the thread so that the oil will drip out. Meanwhile, solid waste will come out at the end of the tool and fall into the solid waste outlet container. Tamanu kernels were mixed with rice husk in the pressing process to increase the oil yield during the extracting process (Atabani, A.E. et al., 2014). The disadvantage of the mechanical extraction method with a screw press is that the resulting oil requires further treatment such as screening and degumming (Jahirul M.I. et al., 2013). In addition, to obtain higher oil extraction yields, it is necessary to carry out a cooking process on the seeds. The increase in oil yield can occur up to 89% after single pass and 91% after dual pass (Atabani, A. E. et al., 2012)

Tamanu oil filtration process:

Tamanu oil filtration aims to separate the solids in the form of impurities in the oil. Filtering (filtration) of tamanu oil is carried out with a press filter machine consisting of a plate and an 8-frame (chamber). The filtration process uses a filter pressure machine and a filter cloth.

Tamanu oil packaging process:

The packaging process of tamanu oil is the last stage of processing tamanu kernels into tamanu oil. The packaging process is carried out after the tamanu oil is filtered, the oil flowed into the storage tank and then packaged by removing the oil from the tank faucet. Under certain conditions, the oil that comes out of the outlet pipe on the filter press machine will be directly packaged by flowing the oil into the derrigen or packer.

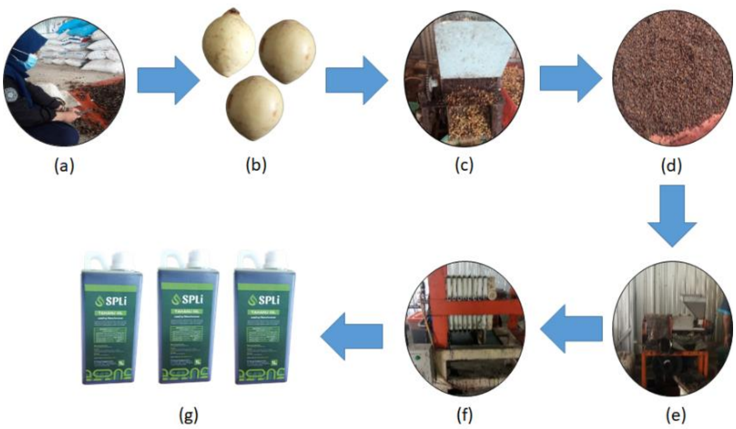

Figure 1. Process of making tamanu oil. (a) stripping process, (b) tamanu kernels, (c) chopping process, (d) drying process, (e) pressing process, (f) filtration process, (g) tamanu oil

Tamanu oil characteristic measurements

Characteristic measurements of tamanu oil consist of measurements of density, degree of acidity (pH), color (visual), and viscosity of tamanu oil. The density of tamanu oil was measured using a measuring cup and an analytical balance. The degree of acidity (pH) of tamanu oil was measured using a pH Meter ETI-8100. The color of tamanu oil is measured visually. Meanwhile, the viscosity of tamanu oil was measured using a Brookfield RVT analog viscometer.

Results and discussion

Tamanu kernel characteristics

The physical characteristics measurements performed on 5 samples of tamanu kernels then the measured data were analyzed by ANOVA to determine the sample group used had on average, the same or different, with a significance of $p < 0.05$. Table 2 shows that the samples of tamanu kernels used were significantly different in size (diameter and length) and color parameters at L* (Lightness) and a* (Redness). As for the density and color parameters in b* (Yellowness), the five samples were not significantly different or almost the same.

Table 2. The physical characteristics of tamanu kernels

Samples	Size		Density (g/ml)	Color				Moisture Content (%)
	Diameter (cm)	Length (cm)		L*	a*	b*	h°	
1	$1{,}61 \pm 0{,}01^{a}$	$1{,}61 \pm 0{,}01^{a}$	$1{,}00 \pm 0{,}05^{a}$	$11{,}49 \pm 2{,}87^{a}$	$-9{,}41 \pm 8{,}63^{a}$	$13{,}06 \pm 6{,}77^{a}$	-54,23	44,71 ± 2,71
2	$1{,}68 \pm 0{,}01^{b}$	$1{,}94 \pm 0{,}01^{b}$	$0{,}95 \pm 0{,}00^{a}$	$17{,}83 \pm 5{,}72^{a}$	$6{,}10 \pm 2{,}19^{bc}$	$6{,}59 \pm 3{,}56^{a}$	47,21	
3	$1{,}82 \pm 0{,}02^{d}$	$2{,}38 \pm 0{,}01^{c}$	$0{,}90 \pm 0{,}08^{a}$	$38{,}42 \pm 3{,}01^{b}$	$16{,}23 \pm 3{,}16^{c}$	$0{,}23 \pm 6{,}06^{a}$	0,81	
4	$1{,}67 \pm 0{,}02^{b}$	$2{,}26 \pm 0{,}01^{d}$	$0{,}94 \pm 0{,}09^{a}$	$8{,}45 \pm 1{,}64^{a}$	$0{,}60 \pm 3{,}06^{ab}$	$0{,}02 \pm 1{,}46^{a}$	1,91	
5	$1{,}71 \pm 0{,}01^{c}$	$1{,}73 \pm 0{,}01^{e}$	$0{,}91 \pm 0{,}10^{a}$	$14{,}53 \pm 4{,}21^{a}$	$5{,}88 \pm 7{,}93^{bc}$	$4{,}18 \pm 5{,}20^{a}$	35,41	

Description: In the same column, different superscripts indicate that significantly different parameters.

Table 2 shows that the average size of tamanu seeds is 1.6 - 1.8 cm in diameter and 1.6 - 2.4 cm in length. The results obtained are in line with the results of Fadhlullah, M. et al. (2015) that tamanu kernels have a diameter of 1-3 cm. The shape of some samples of tamanu kernels obtained from PT. Sinergi Panggung Lestari in Figure 1(b), which is round and has a sharp point at one end of the kernels. The results are according to those presented by Bustomi, S. et al. (2008) that tamanu kernels are round with a tapered tip. In addition, Table 2 also shows that the average density of tamanu kernels is in the range of 0.9 – 1 g/ml. So far, there have been no or not many studies that discuss the density of tamanu kernels, so that the measurement results obtained have not been compared between the results of other studies.

The water content of tamanu kernels shown in Table 2 is 44.71%. The water content value obtained is different from the results obtained by Andyna, N. (2009), namely tamanu kernels have a moisture content of 25-35%, and the results of Handayani, S. S. et al. (2020) where the water content of tamanu kernels is 32.45%. The difference in yield is because the water content of tamanu seeds can be affected by conditions or post-harvest treatment before being processed. According to Atabani, A. E. et al. (2014), the water content of tamanu kernels can be affected by the storage process carried out. Atabani, A. E. et al. (2013) stated that the ideal tamanu kernels storage condition is at a temperature of 26-27 °C with a humidity of 60-70%. The Tamanu kernels storage area must have good ventilation and the storage period is not too long so that the humidity conditions of the tamanu kernels are maintained.

Table 2 also shows the average value of L* which is 8.4 – 38.4, the value of a* is -9.5 – 16.2 and the value of b* ranges from 0 – 13, so that the average hue degree value of the whole sample tamanu kernels is obtained that is 51.14°. Based on the value of the degree of hue, the color of the measured tamanu kernels is close to yellow, because according to McGuire, R.G. (1992) the degree of hue indicates a value of 0° (red-purple), 90° (yellow), 180° (bluish green), 270° (blue). The results obtained are in line with those proposed by Azad, A. K. et al. (2016) that tamanu kernels are generally yellow in color.

Tamanu oil characteristics

Table 3 shows the density value of tamanu oil produced by mechanical extraction (Screw Press) is quite high, the average oil density value is 0.98 g/ml. The density of tamanu oil obtained in this study is close to Azad, A. K. et al. (2016) that the density is 0.97 g/ml and Atabani, A. E. et al. (2014), that the density of tamanu oil is 0.951 g/ml. However, when compared to tamanu oil obtained by the soxhlet extraction method which was the result of Silsia, D., and Yahya, R. (2019), the density of tamanu oil is different, namely 0.910 - 0.920 g/ml. The difference in the results shown may occur due to differences in the extraction process carried out so that the condition or quality of the oil will also be different. According to Fadhlullah, M. et al. (2015), the high density is due to the high natural impurities of the oil so that the quality of the oil will also be lower.

Table 3. Characteristics of tamanu oil

Charasteristics	Value
Density (g/ml)	0,98 ± 0,00
Viscosity (cp)	101,25 ± 0,00
pH	5,88 ± 0,05
Color	Dark Green

Table 3 also shows the viscosity value of tamanu oil, which is 101.25 cp as measured using RPM 20 at 28°C. The viscosity obtained in the analysis results is different from the results of Fadhlullah, M. et al. (2015) which showed the viscosity of tamanu oil at a temperature of 27°C was 108cp (20% seed moisture content) and 60cp (1.2% seed moisture content). Similarly, the results of research by Hartati, T. M. (2010) which shows the viscosity value of tamanu oil is 64cp at 30°C. Viscosity differences can be caused by differences in temperature and pressure at the time of measurement or in the production process. According to Zemansky, S. (2003) the magnitude of the viscosity is influenced by temperature, molecular size and weight, intermolecular forces and pressure. In addition, the high viscosity value can be caused by tamanu oil still containing sap because the degumming process is not carried out. According to Ketaren (1986), pure tamanu oil contains high resin and latex which will affect viscosity.

The degree of acidity (pH) of tamanu oil is 5.88 and the color of tamanu oil visually is green as shown in Table 3. The degree of acidity (pH) of tamanu oil obtained was different from the results of Atabani, A. E., and César, A. D. S. (2014) using the same extraction method (mechanical) of 4.60. This difference is caused by differences in the water content in the oil. Water is known to have a neutral pH of 7, if the oil contains more water the pH will be larger and closer to neutral. For the color of tamanu oil, the results are the same as those of Atabani, A. E. et al. (2013) which stated that tamanu oil has a dark green color.

Conclusion

The physical characteristics of tamanu kernels are yellow, round-shaped tapered ends with a diameter of 1.6-1.8 cm and a length of 1.6-2.4 cm, have a density of 0.9-1 g/ml, and a moisture content of 44.71%. Meanwhile, the properties of tamanu oil extracted with screw press method are dark green, density of 0.984 g/ml, a viscosity at a temperature of 28 °C of 101.25 cp, and have degree of acidity (pH) of 5.88.

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References

Bustomi, S., Rostiwati, T., Sudradjat, R., Leksono, B., Kosasih, A. S., Anggraeni, I., and Rahman, E. (2008). *Nyamplung (Calophyllum inophyllum L) sumber energi biofuel yang potensial*. Jakarta: Badan Penelitian and Pengembangan Kehutanan.

Sanjid, A., Masjuki, H. H., Kalam, M. A., Rahman, S. M. A., Abedin, M. J., and Palash, S. M. (2013). Impact of palm, mustard, waste cooking oil and Calophyllum inophyllum biofuels on performance and emission of CI engine. *Renewable and Sustainable Energy Reviews, 27*, 664–682.

Syakir, M., and Elna, Karmawati. (2011). *Tanaman Perkebunan Penghasil Bahan Bakar Nabati*. Jakarta: Badan Penelitian dan Pengembangan Pertanian.

Azad, A. K., Rasul, M. G., Khan, M. M. K., Sharma, S. C., Mofijur, M., and Bhuiya, M. M. K. (2016). Prospects, feedstocks and challenges of biodiesel production from beauty leaf oil and castor oil: A nonedible oil sources in Australia. *Renewable and Sustainable Energy Reviews, 61*, 302–318.

Ong, H.C., dan T.M.I Mahlia., H.H. Masjuki., and R.S. Norhasyima. (2011). Comparison of Palm Oil, Jatropha curcas and Calophyllum inophyllum for Biodiesel: A review. *Renewable and Sustainable Energy Reviews 15* (2011) 3501–3515.

Leksono, B., Windyarini, E., and Hasnah, T. N. (2014). Budidaya Nyamplung (Calophyllum inophyllum L.) Untuk Bioenergi Dan Prospek Pemanfaatan Lainnya. Bogor: IPB Press.

Heyne, K. (1987). *Tumbuhan Berguna Indonesia, Jilid III.* Translated by Badan Litbang Kehutanan.Yayasan SaranaWanajaya. Jakarta.

Leksono, B., & Putri, K. P. (2012). Variasi ukuran buah - biji dan sifat fisiko - kimia minyak nyamplung (C. Inophyllum L.) dari enam populasi di Jawa. In Prosiding Seminar Nasional HHBK. Mataram: BPTHHBK Mataram.

Trisnawati, S., and Siswani, E. D. (2018). Pemanfaatan Biji Nyamplung (*Calophyllum inophyllum L*) Sebagai Bahan Baku Biodiesel Dengan Variasi Suhu Dan Waktu Pada Proses Transesterifikasi. *Jurnal Kimia Dasar*, 7(2), 80–87.

Leksono, B., Windyarini, E., and Hasnah, T. N. (2014). Budidaya Nyamplung (*Calophyllum inophyllum L.*) Untuk Bioenergi Dan Prospek Pemanfaatan Lainnya. Bogor: IPB Press.

Hasibuan, S., Sahirman., and Yudawati, M. (2013). Karakteristik Fisiko Kimia dan Anti Bakteri Hasil Purifikasi Minyak Biji Nyamplung (*Calophyllum inophyllum L.*). *Agritech*, 33 (3).

Artanti, A. N., Rakhmawati, R., Hadi, S., and Prihapsara, F. (2018). IBM Peningkatan Produksi Minyak Nyamplung (Callophylum Inophyllum) sebagai Bahan Baku Kosmetik *Prosiding Seminar Nasional seri 8 " Mewujudkan Masyarakat Madani dan Lestari " Yogyakarta , 27 September 2018 Diseminasi Hasil-Hasil Pengabdian* .

Fadhlullah, M., Widiyanto, S. N. B., and Restiawaty, E. (2015). The potential of nyamplung (Calophyllum inophyllum L.) seed oil as biodiesel feedstock: Effect of seed moisture content and particle size on oil yield. *Energy Procedia, 68,* 177–185.

Azad, A. K., Rasul, M. G., Khan, M. M. K., Sharma, S. C., Mofijur, M., and Bhuiya, M. M. K. (2016). Prospects, feedstocks and challenges of biodiesel production from beauty leaf oil and castor oil: A nonedible oil sources in Australia. *Renewable and Sustainable Energy Reviews*, *61*, 302–318.

Jahirul MI, Brown JR, Senadeera W, Ashwath N, Laing C, and Leski-Taylor J. (2013). Optimisation of bio-oil extraction process from beauty leaf (Calophyllum Inophyllum) oil seed as a secondgeneration biodiesel source. *Procedia Eng, 56*(0), 619–24.

Orhevba B. A., Chukwu O., Osunde Z. E., and Ogwuagwu V. (2013). Studies on The Effect of Pressure on Yield of Mechanically Expressed Neem Seed Kernel Oil. *Global Journal of Engineering, Design & Technology, Vol. 2* (5), 20-4.

Atabani, A.E., dan Aldara da Silva César. Calophyllum inophyllum L. – A prospective non-edible biodiesel feedstock. Study of biodiesel production, properties, fatty acid composition, blending and engine performance. *Renewable and Sustainable Energy Reviews 37* (2014) 644–655.

Fadhlullah, M., Widiyanto, S. N. B., and Restiawaty, E. (2015). The potential of nyamplung (*Calophyllum inophyllum L.*) seed oil as biodiesel feedstock: Effect of seed moisture content and particle size on oil yield. *Energy Procedia*, *68*, 177–185.

Bustomi, S., Rostiwati, T., Sudradjat, R., Leksono, B., Kosasih, A. S., Anggraeni, I., and Rahman, E. (2008). *Nyamplung (Calophyllum inophyllum L) sumber energi biofuel yang potensial*. Jakarta: Badan Penelitian and Pengembangan Kehutanan.

Andyna, N. (2009). *Pembuatan Biodiesel Dari Minyak Biji Nyamplung (Calophyllum inophyllum)*. Bandung: Institut Teknologi Bandung.

Handayani, S. S., Gunawan, E. R., Suhendra, D., Murniati, M., and Aditha, I. M. (2020). Karakterisasi Sifat Fisiko Kimia Minyak Nyamplung Sebagai Bahan Baku Sabun Padat Transparan. *Jurnal Pijar Mipa*, *15*(4), 411.

Atabani, A. E., and César, A. D. S. (2014). *Calophyllum inophyllum L.* - A prospective non-edible biodiesel feedstock. Study of biodiesel production, properties, fatty acid composition, blending and engine performance. *Renewable and Sustainable Energy Reviews*, *37*, 644–655.

Atabani, A. E., Silitonga, A. S., and Ong HC. (2013). Non-Edible Vegetable Oils: A Critical Evaluation of Oil Extraction, Fatty Acid Compositions, Biodiesel Production, Characteristics, Engine Performance and Emissions Production. *Renewable and Sustainable Energy Reviews*, 18, 211–245.

McGuire, R.G. (1992). Reporting of Objective Color Measurements. *HortScience, 27*, 1254-1255.

Bustomi, S., Rostiwati, T., Sudradjat, R., Leksono, B., Kosasih, A. S., Anggraeni, I., and Rahman, E. (2008). *Nyamplung (Calophyllum inophyllum L) sumber energi biofuel yang potensial*. Jakarta: Badan Penelitian and Pengembangan Kehutanan.

Azad, A. K., Rasul, M. G., Khan, M. M. K., Sharma, S. C., Mofijur, M., and Bhuiya, M. M. K. (2016). Prospects, feedstocks and challenges of biodiesel production from beauty leaf oil and castor oil: A nonedible oil sources in Australia. *Renewable and Sustainable Energy Reviews*, *61*, 302–318.

Atabani, A. E., and César, A. D. S. (2014). *Calophyllum inophyllum L.* - A prospective non-edible biodiesel feedstock. Study of biodiesel production, properties, fatty acid composition, blending and engine performance. *Renewable and Sustainable Energy Reviews*, *37*, 644–655.

Silsia, D., and Yahya, R. (2019). Yields and Characteristics of Bintangur Oil From Enggano Island As Raw Material for Making Biodiesel. *Jurnal Agroindustri*, *9*(1), 1–7.

Prihanto, A., Pramudono, B., dan Santosa, H. (2013). Peningkatan Yield Biodiesel dari Minyak Biji Nyamplung melalui Transesterifikasi Dua Tahap. *Momentum*, *9*, 46–53.

Fadhlullah, M., Widiyanto, S. N. B., and Restiawaty, E. (2015). The potential of nyamplung (*Calophyllum inophyllum L.*) seed oil as biodiesel feedstock: Effect of seed moisture content and particle size on oil yield. *Energy Procedia*, *68*, 177–185.

Hartati, T. M. (2010). Study Content Nutrient Waste Plant Seeds Nyamplung (*Calophyllum inophyllum L.*) after Made as Biofuel. *Jurnal Perkebunan Dan Lahan Tropika*, 23–26.

Zemansky, Sears. (2003). Fisika Universitas. Edisi Kesepuluh. Jilid II. Jakarta: Erlangga.

Ketaren. (1986). *Pengantar Teknologi Minyak dan Lemak Pangan*. Jakarta: UI Press.

Atabani, A. E., and César, A. D. S. (2014). *Calophyllum inophyllum L.* - A prospective non-edible biodiesel feedstock. Study of biodiesel production, properties, fatty acid composition, blending and engine performance. *Renewable and Sustainable Energy Reviews*, *37*, 644–655.

Atabani, A. E., Silitonga, A. S., and Ong HC. (2013). Non-Edible Vegetable Oils: A Critical Evaluation of Oil Extraction, Fatty Acid Compositions, Biodiesel Production, Characteristics, Engine Performance and Emissions Production. *Renewable and Sustainable Energy Reviews*, 18, 211–245.

Estrada, F., Gusmao, R., Mudjijati, dan Indraswati, N. (2007). Pengambilan Minyak Kemiri dengan Cara Pengepresan dan Dilanjutkan Ekstrasi Cake Oil. *Widya Teknik, 6*(2), 121–130.

Atabani AE, Silitonga AS, Badruddin IA, Mahlia TMI, Masjuki HH, Mekhilef S.A. (2012). Comprehensive Review on Biodiesel as an Alternative Energy Resource and its Characteristics. *Renew Sustain Energy Rev, 16*(4), 70–93.

EVALUATION OF RICE TRANSPLANTER FOR "TAPAK MACAN" CROPPING PATTERN

Gigieh Henggar Jaya, Alfitra Widya Yubastama, Rafli Syaiful Fatah, Radi*, Bambang Purwantana
Department of Agricultural and Biosystem Engineering, Faculty of Agricultural Technology,
Universitas Gadjah Mada. Jln. Flora No.1 Bulaksumur, Yogyakarta 55281, Indonesia
*radi-tep@ugm.ac.id

Abstract

Rice is a commodity of rice-producing crops that has become a staple food of some of the world's population. To meet these needs, it is necessary to increase rice productivity. Efforts that can be made to increase rice productivity are due to application of technology. One of the technologies that is proven to be able to increase rice productivity is the "tapak macan" rice planting system. Even though the "tapak macan" has been implemented, is still experiencing constraints with planting workers. In order to overcome these obstacles, a prototype of "tapak macan" rice transplanter was created. However, the prototype still requires a lot of refinement to work properly. This research was conducted to evaluate the prototype design with variations in seed picking angle and planting locus based on prototype performance. Furthermore, this research is used to provide recommendations on setup and evaluating the design of the prototype. The research method used is direct observation. The tools used are prototypes of rice transplanter, seed trays, mobile phones, Adobe Premiere, 3DF Zephyr Pro, Solidworks, CorelDraw, and Microsoft Excel. The material used is rice seedlings. Furthermore, the research stage is divided into three stages. The first stage is the preparation, including seedling and prototype maintenance. The second stage is the collection of data on the number of seeds taken and the success of the retrieval. The last stage is data processing of the number of seeds taken and the percentage of success of retrieval. From the research that has been done, obtained the results of recommended variations by the author a variation of the seed picking angle 101.54º or a combination of 2 cm seed picking angle regulator and the arm of the corner at hole 2 with the result of the percentage of food success by 89% and the average number of seeds picked as much as 6.4 rice sticks for planting fork A1, 8 rice sticks for planting fork A2, and 6.2 rice sticks for the planting fork A3. For the recommendation of the prototype design that the author provided is a change in the shape of planting forks and pushing rods.

Keywords: Agriculture; Rice planting system; Rice transplanter.

Introduction

Agriculture is a type of activity required to fulfill the needs of human life through production activities based on the growth and development of plants and animals. One of the activities in the agricultural sector is the cultivation of rice crops. Rice is a commodity of rice-producing crops that has become a staple food of some of the world's population. In 2011, more than 7 billion people in the world consumed 445,084,000 tons of rice and in 2020 the world's population was over 7 billion and rice consumption was 504,309,000 tons (Shahbandeh, 2021). The annual level of rice consumption always increases as the number of human populations in the world increases. To fill up the needs and maintain the availability of rice, efforts to increase rice productivity are needed. Efforts can be made in the form of the application of technology at each stage of rice cultivation, ranging from preparatory activities, planting, maintenance, or harvesting.

One of the agricultural technologies in rice planting activities that are considered successful in improving rice productivity is the application that has been implemented by some farmers in Yogyakarta, Indonesia. The appropriate technology is the "tapak macan" rice planting system which is a modification of the System of Rice Intensification. System of Rice Intensification is a rice planting system that has a recommendation on the number of seedlings one stem per clump (Kasim, M., 2004). In the previous research conducted in

Ngaglik region Sleman, Yogyakarta in the 2014 growing season, the crop was able to increase the productivity of 15.7 tons/ha (Yuliska, 2018). As for the modifications made to meet the requirements of the "tapak macan" system planting system is in a clump consisting of three plants planted with a triangular pattern and 5-7cm with a distance between clumps 30cm or can be seen on Figure 1.

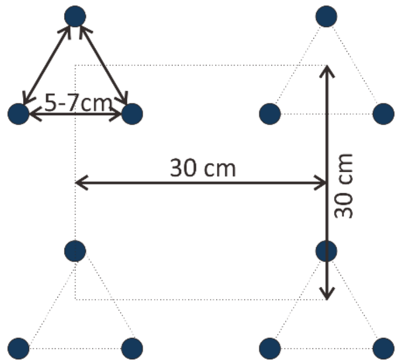

Figure 1. "Tapak macan" rice cropping pattern

Prototype of "tapak macan" rice transplanter was created as a support to help farmers to applicate the "tapak macan" rice planting system. In addition, the "tapak macan" rice transplanter is also intended to overcome labor shortages. However, the prototype still requires a lot of refinement to works properly. This research was conducted to evaluate the prototype technical performance with variations in seed picking angle based on the number of seeds picked and successful seeds picking. Furthermore, this research is used to provide recommendations on setup and evaluating the design of the prototype.

Materials and Methods

The research method used is direct observation. The tools used are prototypes of rice transplanter, seed trays, Adobe Premiere, 3DF Zephyr Pro, Solidworks, and MicrosoftExcel. Adobe Premiere to obtain slow-motion prototype movement videos. 3DF Zephyr Pro to process video into images at any given time frame. Solidworks to calculate the angle of seed picking formed.

Furthermore, the research stage is divided into three stages. The first stage is the preparation, including seedling on the seed trays and prototype maintenance. The second stage is the collection of data on the number of seeds taken and the success of the seeds picking. Variations are selected at the angle of seed picking because no setup produces the most optimal seed picking results. There are three variations, namely X1 for 101.54º, X2 for 97.6º, and X3 for 94.47º. Size of seed picking angle arranged through setting distance on the bolts. The specific angle of the seed picking, because the distance of the bolt can only change from 1.8 cm to 2 cm and to change the distanced smaller than 0.1cm is difficult. When the distance of the bolt was 2 cm obtained the angle of 101.54º, 1,9cm for 97.6º, and 1.8 cm for 44.47º. The components used to set the angle size of seed picking can be viewed in Figure 2 (a) and naming planting forks can be viewed in Figure 2 (b). The last stage is the evaluation of the number of seeds taken and the percentage of success of seed picking and decided the improvement needed to make the prototype works optimally.

(a) (b)

Figure 2. (a) Seeds Picking Angle Setup (b) Naming planting forks

Result and Discussion

Seedlings picked is the number of rice sticks picked at each planting fork point. The Percentage of successful seeds picked is a comparison of the success of the three points of planting forks in taking rice seedlings toward the total of picking that occurred. The results of the seedlings taken achieved are the number of stems taken close to 1 stem and the success of seed retrieval exceeds 70%. The data of seeds picked toward variations and the result of the percentage of successfully seeds picked are processed using Microsoft Excel. The result of seeds picked toward variations can be seen in Figure 4 and the result of percentage of successful seeds picked can be seen in Figure 3.

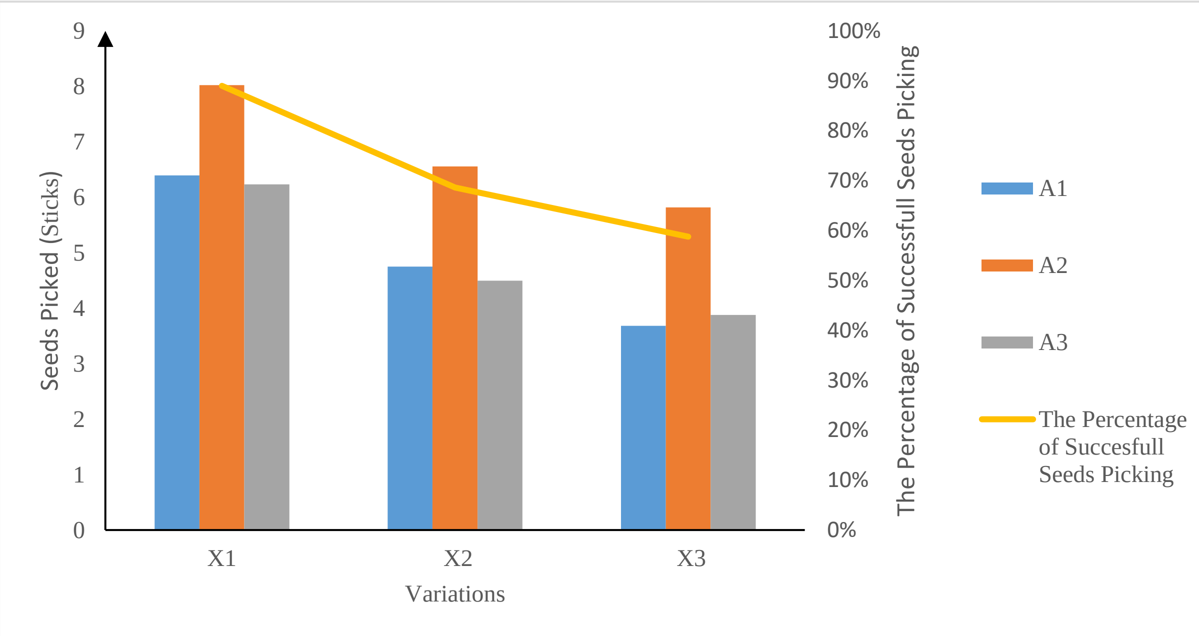

Figure 3. The Percentage of Successfull Seeds Picking and Seeds Picked Towards Variations on Every Planting Fork Points

The research obtained the results of the percentage of success of the seed picked and the number of seed picked matching the size of the angle of seed picking. From the research, also obtained the result of the percentage of seeds picked that passed the target only on the X1 variation. Therefore, the recommended variation is the X1 variation with the average seeds taken on the planting fork point A1 as much as 6.4 rice sticks, 8 rice sticks for point A2, and 6.2 rice sticks for point A3. In addition to these results, it can be known that the phenomenon of seedlings attracted by planting forks because pushing rods cannot push the seedlings to come off and make the seedlings pinched and make the seeds attracted down. From the result, given recommendations for repair design of planting forks include the replacement of the form of planting fork design and pushing rod.

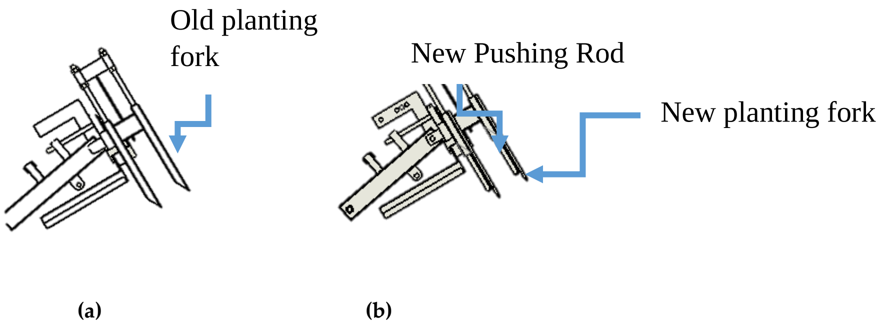

Figure 4. (a) Design of Old Planting Fork (b) Desain of New Planting Fork

Conclusion

Recommended variations by the author for use is a variation of the seed picking angle 101.54º or a combination of 2 cm seed picking angle regulator and the arm of the corner at hole 2 with the result of the percentage of food success by 89% and the average number of inedible seeds as much as 6.4 rice sticks for fork A1, 8 rice sticks for fork A2, and 6.2 rice sticks for the A3 fork. Recommendation of prototype design that the author provided is changes in the shape of planting forks and pushing rod.

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References

Kasim, M. (2004). Manajemen penggunaan air. Meminimalkan penggunaan air untuk meningkatkan produksi padi sawah melalui Sistem Intensifikasi padi (The System of Rice Intensification, SRI). *Makalah Pengukuhan Guru Besar* pada Universitas Andalas Padang

Shahbandeh. (2021). Total Global Rice Consumption 2008-2021. Retrieved from https://www.statista.com/statistics/255977/total-global-rice-consumption

Yuliska. (2018). Model Kewirausahaan Sosial di Lembaga. Agriculture Entrepreneur Clinics. *Jurnal Pemberdayaan Masyarakat: Media Pemikiran dan Dakwah Pembangunan.*2(1) 157-176

EXPLORATION OF THE POTENTIAL ROLE AND ECONOMIC VALUE OF AGRICULTURAL WASTE FOR BIOGENIC NANOSILICA PRODUCTION

Rafiq Usdiqa Maulana*, Riyanti Zhafirah Makrudi, Sania Isma Yanti
Department of Agricultural Product Technology, Faculty of Agricultural Technology,
Universitas Brawijaya, Indonesia
*rafiqusdiqa@gmail.com

Abstract

Increased research interest in the green industry is related to research development through the evaluation of bio-based by-products and waste materials in various applications. Silica nanoparticles have various applications based on their characteristic, including drug delivery, food, cosmetic and biomaterial. This work presented the results of the study on synthesis and potential economic value of nanosilica from rice husk, rice straw, and corn cob as the most increasing agricultural waste in Indonesia. Nanosilica was obtained by acid precipitation method with re-extraction and calcination at 700°C for 2 h, which is easier and cheaper than other methods. Several economic evaluation parameters were analyzed for informing the potential production of valuable material nanosilica from rice husk, rice straw, and corn cob. This research supports the availability of actual information and data regarding the amount of economic potential that can be obtained from agricultural waste and provide great economic gain. The result shows that agroindustrial waste has high economic potential with the profit of selling nanosilica from rice husk, rice straw, and corn cob in one month is Rp. 401,731, Rp. 863,655, and Rp. 1,437,048, respectively. Agricultural waste that initially has no economic value can be used as nanosilica so that it has a selling value in the global market.

Keywords: Corn cob; Gap economic; Nanosilica; Rice straw; Rice husk

Introduction

Indonesia's plantation area in 2019 is estimated to reach 390 million hectares and produce around 998 million tons of agricultural waste, of which 90-140 megatons are burned as fuel. The burning that is carried out can cause pollution and release gases that are harmful to the environment (Kauldhar and Yadav, 2018). National agro-industry commodities with continuous production levels which have increased are rice and corn. The high production rate is proportional to increase in the volume of waste biomass produced. Rice as a main agricultural commodity sector in Indonesia with production reaching 54.6 million tons/year in 2019 can produce rice husk waste biomass of 961 thousand tons BK/year and rice straw 124 million tons/year (BPS, 2020., and Purwandaru, 2013). The amount of corn production reaches 30 million tons and can produce cob corn waste biomass as much as 516 thousand tons BK/year (Kementerian Pertanian, 2018). The amount of waste biomass produced annually, with a limited level of management causes huge economic losses. Therefore, the use of agro-industrial waste biomass has a great opportunity to be further developed and explored in order to support the national economy.

On the other hand, another study reported that plant biomass contains SiO which is stored as phytolite, which consists of hydrated amorphous silica. Therefore, the biomass has the potential to extract its silica content, especially in the form of nanosilica (Sapawe et al, 2018., Patel et al, 2017, and Annuar et al, 2018). Research on nanosilica has attracted the interest of many researchers in recent years. Nanosilica is applied in various fields of medicine, food, cosmetics and biomaterials. In fact, nanosilica has consistently increasing demand every year with market growth predicted to reach 5 billion USD by 2025 (Al Ghurabi et al, 2020). The utilization of agricultural waste biomass that has low economic value as raw material for biogenic silica can be a promising solution. Production of biogenic nanosilica from agro-industrial waste can utilize waste that has low economic value and has the potential to pollute the environment into products with high economic value and a consistent increase in demand. In addition, biogenic nanosilica products can be an alternative source of synthetic nanosilica (such as TEOS) which is expensive and has potential toxicity. (Le et al, 2017). The extraction method of biogenic silica can be carried out using acid precipitation with re-extraction and calcination. According to Peerzada and Chidambaran (2020), the extraction process using this method can produce maximum yield, easy and cheap, has low energy consumption, and not excessive use of chemical compounds. It is also safe and environmentally friendly.

Aim and Scope

Based on the problems described, this study aims to utilize agro-industrial waste as a raw material for nanosilica production and to project the economic value of processing agricultural waste biomass in the biogenic nanosilica production. The scope of this research focuses on the processing of agro-industrial waste of rice husk, straw, and corncobs and their economic potential as a biogenic nano silica raw material.

Materials and Method

Materials

The materials used in this study were agricultural waste such as corn cobs, rice husks, rice straw, HCl, and aquades. Corn cobs, rice husks, and rice straw were obtained from East Java, Indonesia. The tools used in this study such as magnetic stirrer (VELP Scientifica), glassware (Iwaki), stirrer, furnace, scale analytics, and oven.

Method

The experimental design in this study was carried out using an empirical research approach with the following research stages :

1. Raw material preparation
2. Nanosilica extraction
3. Economic value analysis of nanosilica

Raw material preparation:

Agricultural waste in the form of corn cobs, rice husks, and rice straw were collected from the waste of a raw material processing plant. It was cleaned to remove impurities and dried under the sun. The dried raw materials are mechanically reduced in size and then placed in a porcelain dish to be heated using an electric stove to form biomass ash. After that, the ash was sieved using a sieve and weighed using an analytical balance.

Nanosilica extraction:

Biomass ash is weighed 25 grams. Then 200 mL of 1 N HCl was put into beaker glass. Beaker glass is placed on a stirrer then the biomass ash is added, the mixture is stirred for 2 hours at 90°C. The extraction results were left for 20 hours then filtered and rinsed using 200 mL of distilled water. The filtrate was then dried in the oven for 5 hours at 110℃ to form pretreated biomass ash. Pretreated biomass ash then calcined for 2 hours at 700℃ to form nanosilica.

Economic value analysis of nanosilica:

The evaluation of the potential for agro-industrial waste is carried out based on the yield data obtained from the extraction process, then the data is analyzed using Microsoft Excel software .

Result and Discussion

Agricultural waste is a product that has increased significantly every year. Agricultural waste has low economic value so it will usually be burned. This burning can result in air pollution and gases that are harmful to health. Silica (Si) or silicon dioxide (SiO2) is a chemical compound that belongs to the metalloid group and its presence is abundant in nature, which is above 70%. Silica can be found in crystalline and amorphous forms (Sharma et al, 2015). According to Kauldhar and Yadav (2018), plant biomass contains silicate oxide (SiO) which is stored as phytolite, which consists of hydrated amorphous silica. The use of silica in various fields is one of the enormous economic potentials given the high demand for the global silica market.

Several methods used to synthesize nanosilica such as flame synthesis, chemical vapour condensation, laser ablation, and reverse microemulsion. In flame synthesis, silica nanoparticles produced through high temperature flame decomposition of metal-organic precursors. The main disadvantage of flame synthesis is control over the particle size, phase composition, and morphology (Klabunde, 2001). The chemical vapour condensation method needs high temperatures, slower growth rates and it uses toxic reagents like Ni(CO)4 and B2H6. Some of these reagents are explosive and are also corrosive in nature (Karande et al, 2021). The laser ablation method has limitations such as efficiency and the characteristics of produced nano particles depend upon many parameters, including the wavelength of the laser impinging the metallic target, the duration of the laser pulses, the laser fluence, the ablation time duration and the effective liquid medium, with or without the presence of surfactants (Iravani et al, 2014). Reverse microemulsion method are high cost and difficulty in removing surfactants in the final product (Tan et al, 2011).

Silica is extracted from agricultural biomass using acid precipitation method and calcination. This method has advantages such as fast synthesis time, lower cost, and low toxicity (Tuan et al, 2017). The soaking process with acid is the extraction step as well as pre-treatment of biomass ash to remove other contaminant compounds (such as minerals and constituent components other than silica) so that the silica yield is purer, and the addition of acid serves to reduce the water content (Selvakumar et al, 2014) . The use of HCl solvent has advantages when compared to HNO_3 and $H2SO_4$, which allows maximum silica yield and moisture retention of only 4% (Ang et al, 2013). Re-extraction process is useful for increasing the yield obtained. The calcination process involving high temperatures and airtightness can make the size of the silica obtained to reach the nano size (Tuan et al, 2017).

This economic analysis is carried out from 1 month with the highest production per month is 3 kg nanosilica from all biomass.

Table 1. Economic Analysis of Biogenic Nanosilica Production

Analysis \ Nanosilica	Rice Husk	Rice Straw	Corn Cob
Initial Capital	Rp. 3,063,458	Rp. 2,670,220	Rp. 3,218,028
HPP (in gram)	**Rp. 268.00**	**Rp. 576.00**	**Rp. 319.00**
Production Cost	Rp. 803,462	Rp. 1,727,310	Rp. 958,032
Selling Price	**Rp. 402.00 / gram**	**Rp. 864.00 / gram**	**Rp. 479.00 / gram**
Total Income	Rp. 1,205,193	Rp. 2,590,965	Rp. 2,395,079
Profit	**Rp. 401,731**	**Rp. 863,655**	**Rp. 1,437,048**
Revenue/Cost (R/C)	Rp. 2.00	Rp. 2.00	Rp. 3.00
Pay Back Periode	**8 month**	**3 months**	**2 month**
Break Event Point (BEP)	Rp. 139,470	Rp. 172,286	Rp. 104,225

From these calculations, it can be seen that agroindustrial waste has high economic potential. Within one month, nanosilica from rice husk, rice straw, and corn cob can generate profit of Rp. 401,731, Rp. 863,655, and Rp. 1,437,048, respectively. The selling price for biogenic nanosilica is around Rp. 400-800 rupiah/gram. This price is cheaper than commercial nanosilica in the global market, which is Rp. 886 rupiah/gram. In addition, from the calculation of Revenue/Cost (R/C), the R/C value of all biomass is 2-3 rupiahs. This means that every 1 rupiah spent on production, generates revenue of 2-3 rupiahs. Waste that initially has no economic value can be used as nanosilica so that it has a selling value in the market.

Currently, there are high demands for nanosilica. Nanosilica is used widely in various applications. In cosmetic areas, nanosilica is used to enhance the effectiveness, shelf-life, and texture of cosmetic products. It adds absorbency and acts as an anti-caking agent (Fytianos et al, 2020). In biomedical areas, nanosilica can be used as a drug delivery component, cancer therapy, bioimaging, and biosensing. Its high drug loading capability, possibility to achieve local therapy, and even combination with other molecules, make it a promising alternative for developing advanced nanotherapy (Regi et al, 2018). In biomaterial areas, nanosilica can be applied as a filler for composite materials. It can improve durability and mechanical properties of high performance composite concrete materials (Indrasti et al, 2020).

These diverse applications can be economically advantageous because nanosilica raw materials are obtained from waste that previously had no economic value. This can be used to improve the economic welfare of the community and state. In addition to increasing economic value, the production of nanosilica from this waste can also reduce environmental damage due to waste combustion. It is hoped that this alternative solution can become a new study in further research and support the national economy.

Conclusion

Agricultural waste such as rice husks, rice straw, and corn cobs, can be used as a source of nanosilica. The isolation method used for the extraction of silica from agricultural waste biomass is acid precipitation with re-extraction and calcination. The results showed that agricultural waste can be used as an alternative nanosilica source. Nanosilica from agricultural waste will give some advantages, such as an inexpensive raw material, minimize the waste, and increase economic value because the nanosilica can be sold in the global market.

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References

Ang TN, Ngoh GC, Chua ASM. (2013). Comparative Study of Various Pretreatment Reagents on Rice Husk and Structural Changes Assessment of The Optimized Pretreated Rice Husk. *Bioresource Technology, 135*, 116–119.

Al-Ghurabi, E. H., Asif, M., Kumar, N. S., & Khan, S. A. (2020). Fluidization Dynamics of Hydrophobic Nano Silica with Velocity Step Changes. *Applied Sciences, 10*(22), 1-12.

Anuar, M. F., Fen, Y. W., Zaid, M. H. M., Matori, K. A., & Khaidir, R. E. M. (2018). Synthesis and Structural Properties of Coconut Husk as Potential Silica Source. *Results in Physics, 11*, 1-4.

Badan Pusat Statistik Republik Indonesia. (2020). Luas Panen dan Produksi Padi di Indonesia 2019. BPS RI. Jakarta.

Fytianos, G., Abbas, R., & George, Z. K. (2020). Nanomaterials in Cosmetics: Recent Updates. *Nanomaterials, 10*(979), 1-16.

Indrasti, N. S., Andes, I., Akhiruddin, M., & Sasongko, S. U. (2020). Synthesis of Nano-Silica from Boiler Ash In The Sugar Cane Industry Using The Precipitation Method. *International Journal of Technology, 11*(2), 422-435.

Iravani, S., Korbekandi, H., Mirmohammadi, S. V., and Zolfaghari, B. (2014). Synthesis of Silver Nanoparticles: Chemical, Physical and Biological Methods. *Res Pharm Sci, 9*(6), 385-406.

Karande, S. D., Sushilkumar, A. J., Harshada, B. G., Vilas, A. K., Shivaji, H. B., and Pramod, S. P. (2021). Green and Sustainable Synthesis of Silica Nanoparticles. *Nanotechnology for Environmental Engineering, 6*(29), 1-14.

Kauldhar, B. S., & Yadav, S. K. (2018). Turning Waste to Wealth: A Direct Process for Recovery of Nano-Silica and Lignin from Paddy Straw Agro-Waste. *Journal of Cleaner Production, 194*, 158-166.

Kementerian Pertanian Republik Indonesia. (2018). Produksi, Luas Panen serta Populasi Sub Sektor Kementerian Pertanian Selama Lima Tahun yaitu Tahun 2014-2018. Pusat Data dan Sistem Informasi Kementerian Pertanian. Jakarta.

Klabunde, K. J. (2001). *Nanoscale Materials in Chemistry*. Wiley-Interscience. New York, USA.

Le, N. A. T., Bui, D. D., Lai, T. K. D., Le, D. T. H., Nguyen, Q. H., & Dang, V. P. (2017). Preparation and Characterization of Nanosilica from Rice Husk Ash by Chemical Treatment Combined with Calcination. *Vietnam Journal of Chemistry*, *55*(4), 455-459.

Patel, K. G., Shettigar, R. R., & Misra, N. M. (2017). Recent Advance in Silica Production Technologies from Agricultural Waste Stream. *Journal of Advanced Agricultural Technologies, 4*(3), 274-279.

Peerzada, J.G. and Chidambaram, R., 2020. A Statistical Approach for Biogenic Synthesis of Nano-Silica from Different Agro-Wastes. *Silicon, 13*, 1-13.

Purwandaru, P. (2013). Pemanfaatan Jerami Untuk Produk Ramah Lingkungan UKM Melalui Proses Kempa. *Jurnal Teknologi Lingkungan, 14*(2), 83-88.

Regi, M. V., Montserrat, C., Isabel, I. B., & Miguel, M. (2018). Mesoporous Silica Nanoparticles for Drug Delivery: Current Insights. *Molecules, 23*(47), 1-29.

Sapawe, N., Osman, N. S., Zakaria, M. Z., Fikry, S. A. S. S. M., & Aris, M. A. M. (2018). Synthesis of Green Silica from Agricultural Waste by Sol-Gel Method. *Materials Today: Proceedings, 5*(10), 21861-21866.

Selvakumar KV, Umesh A, Ezhilkumar P, Gayatri S, Vinith P, Vignesh V. (2014). Extraction of Silica from Burnt Paddy Husk. *Int J ChemTech Res,* 6, 4455–4459.

Sharma, R.K. Shivani, S. Sriparna, D. Radek, Z. dan Manoj, B.G. 2015. Silicananosphere-Based Organic–Inorganic Hybrid Nanomaterials: Synthesis, Functionalization and Applications in Catalysis. *Green Chemistry*, 17, 3207−3230.

Tan, T. T. Y., Liu, S., Zhang, Y., Han, M. Y., and Selvan, S. V. (2011). Microemulsion Preparative Method (Overview). *Comprehensive Nanoscience and Technology, 5,* 399–441.

Tuan, L. N. A., Lai, T. K. D., Le, D. T. H., Nguyen, Q. H., Dang, V. P., and Bui, D. D. (2017). Preparation and Characterization of Nanosilica from Rice Husk Ash by Chemical Treatment Combined with Calcination. *Vietnam Journal of Chemistry*, *55*(4), 455-459.

PURIFICATION OF PROTEASE ENZYMES ON WASTE OF PAPAYA LEAVES TO INCREASE THE EFFECTIVENESS OF ANIMAL FOOD

Siti Miftachul Jannah*[1], Lilis Nur Fitriani[1], Dharma Abiyyu Allam[2], Freini Dessi Effendi[3]
[1]Department of Biotechnology, University of Brawijaya, Indonesia
[2]Departement of Electrical Engineering, University of Brawijaya, Indonesia
[3]Department of Agricultural Product Technology, University of Brawijaya, Indonesia
*miftachul705@gmail.com

Abstract

Papaya leaves contain many papain enzymes which have the ability to form new proteins or protein-like compounds called plastein, which is the result of proteinhydrolysis. Enzymes that play an important role in protein hydrolysis include theprotease enzyme which can break protein bonds into peptides, and peptidases which can break peptide bonds into amino acids. The addition of papain as an exogenous enzyme to feed can increase the hydrolysis of feed protein. The method of obtaining the protease enzyme (papain) is the partial purification method of the papain enzyme with the principle of salting out using ammonium sulfate. Based on the research and literature studies that have been done,it can be seen that protease enzyme (papain) can be used to increase the effectiveness of animal feed is theenzyme papain which is obtained from the purification results of the Calina papaya leaf extract. The enzyme work by increasing the digestibility of the protein in the feed.Therefore, this innovation is expected to be able to increase the use value ofpapaya leaves which are still underutilized and to optimizing the use value of papaya leaves which areagricultural waste.

Keywords: Animal feed; Papaya; Protease enzymes; Purification techniques

Introduction

Papaya *(Carica papaya L.)* is a plant originating from tropical America. Papaya has high nutritionalvalue and has benefits in every part ofthe plant. Papaya part can be used, starting from the leaves, roots, stems, fruit skins, fruit, and even the sap. However, the use of papaya fruit apartfrom the pulp is still very minimal andeven tends to be not used and becomes waste. The chemical contentin papaya plants that have potential as non-humic substances, one of which is the enzyme papain, chymopapain, papaya sap extract, alkaloids, saponins, flavonoids, and tannins. With this potential, other parts of the papaya plant can be used as additional good substances in other products.

Papaya leaves contain many papain enzymes which could form new proteins or protein-like compounds called plastein, which is the result of proteinhydrolysis (Hasanah, 2005). Papain enzyme is a proteolytic enzyme that is able to hydrolyze protein into amino acids orpeptides. This enzyme consists of 187amino acid residues and has a molecular weight of 21,000 (Amalia, 2013). Enzymes that play an important role in protein hydrolysis include theprotease enzyme which can break protein bonds into peptides, and peptidases which can break peptide bonds into amino acids (Yuniwati, 2008). The addition of papain as an exogenous enzyme to feed can increase the hydrolysis of feed protein. The method of obtaining the protease enzyme (papain) is the partial purification method of the papain enzyme with the principle of salting out using ammonium sulfate.

Therefore, this innovation is expected to increase the use-value of papaya leaves which are still underutilized and develop research results on animal feed and help improve community welfare in agriculture through optimizing the use value of papaya leaves which are agricultural waste.

Materials and Methods

Preparation of Tools and Materials

The enzyme purificationresearch has several preparation processes. First is to prepare papaya leaves. Then making a chemicalsolution of 1% casein, 5% TCA (w / v) (5% trichloro acetic acid, 9% sodium acetate, 9% acetic acid),tyrosine (0-100µg / mL), 0.5 M Na_2CO_3, Follin Ciocalteau 20%, 0.1 M Na-Phosphate buffer (pH 6.0-7.0), 0.1 M Tris-HCl Buffer (pH 7.0-9.0), 0.1 M $NaHCO_3$-NaOH buffer M (pH10.0), salt solutions of $CaCl_2$, $ZnCl_2$, $MgCl_2$, and $CuCl_2$, EDTA, organic solvents methanol, acetone, andtoluene.

Papaya Leaf Cleaning

The papaya leaves used are Calina papaya leaves, with the speciesname *Carica papaya L.* In this cleaning process, the papaya leaves are washed using clean water. This aims to remove dust and dirt that stillsticks to papaya leaves.

Production of Papaya Leaf Extract

Cleaned papaya leaves thenchopped and weighed as much as 100grams. The papaya leaves containing papain are added with 100 ml of water, then put in a blender until smooth. After that it is filtered using a sieve, then the rest of the pulp is discarded in order to produce papaya leaf extract. The results of the papayaleaf extract are deposited for 5 hours to extract starch. The last step is drying in an oven for 2 hours at a temperature of 65˚C.

Purification of Protease Enzymes (Papain)

The purification method was done following a procedure that has been described previously (Zusfahair, 2014), the papaya leaves of the Calina type in SambengDistrict, Lamongan Regency are taken as much as 100 g each poundedwith mortar in a cold state, then extracted the filtrate by squeezing with muslin cloth and adding 20 mL Phosphate buffer 0.1M pH 7. The insoluble parts that were still present in the filtrate were separated by centrifugation at 3500 rpm for 15 minutes at 4°C, obtained a supernatant containing crude extract of papain enzyme. The papaya leaf extract that has been obtained from the previous stage is then subjected toa purification process to obtain the papain enzyme. Papaya leaf extract isadded with ammonium sulfate. After that, the filtrate is stirred for 20 minutes at 4^oC until well blended.Then centrifuge at 8000 rpm for 7 minutes at 4^oC. The precipitate formed was dissolved with 0.5 ml of 0.05 phosphate buffer solution pH 7 and allowed to stand for 0, 12, 24, and36 hours.

Animal Feed Processing

In the processing of animal feed added papain enzyme that has been purified. The addition is done by mixing the enzyme with conventional rabbit feed. The experimental design was carried out with 4 types of comparisons between conventional feed and papain enzymes. Feed processing is carried out with 4 sample treatments, namely:

Control: Feed hydrolyzed by papain at a dose of 0%

Sample 1: Feed hydrolyzed bypapain at a dose of 0.75%.

Sample 2: Feed hydrolyzed by papainat a dose of 1.5%.

Sample 3: Feed hydrolyzed by papainat a dose of 2.25%.

Data Analysis

Data analysis was used to determine the effectiveness value of animal feed that has been tested for protein content. Data analysis was carried out by discussing the researchdata that had been obtained and compared with the literature study that had been collected.

Result and Discussion

The potential for increasingfeed digestibility with the addition ofpapain-type protease enzymes is very likely to be developed and implemented. Based on preliminary research that has been carried out by (Amalia, 2013) regarding the effect of using papain on the level of feed protein utilization and growth of African catfish (Clarias gariepinus), it can increase the value of EPP, PER and RGR. Based on this research, it can be seen that the data on the value of feed utilization efficiency (EPP) and Protein Efficiency Ratio (PER) from each sample can be seen in Figure 1.

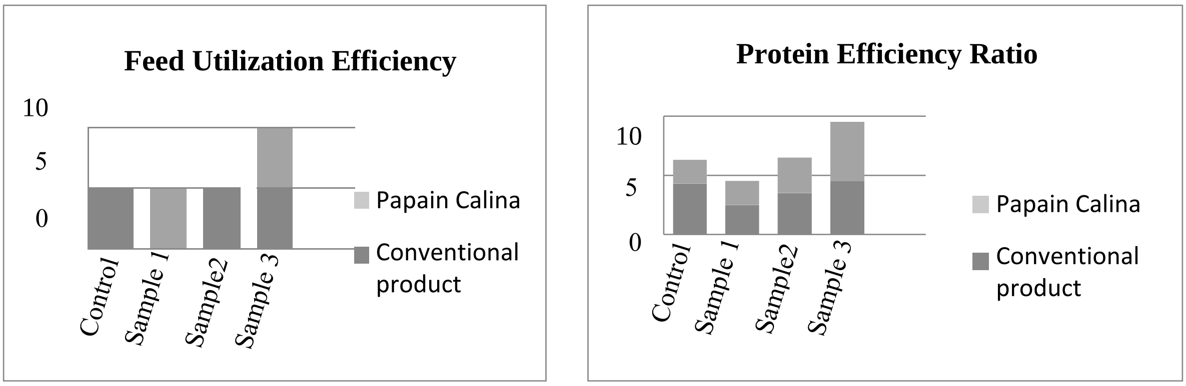

Figure 1. EPP and PER value

Conclusion

Based on the research and literature studies that have been done,it can be seen that protease enzyme (papain) can be used to increase the effectiveness of animal feed is theenzyme papain which is obtained from the purification results of theCalina papaya leaf extract. The enzyme work by increasing the digestibility of the protein in the feed.Therefore, this innovation is expectedto be able to increase the use value ofpapaya leaves which are still underutilized and to optimizing the use value of papaya leaves which areagricultural waste.

Based on the research that hasbeen done, several suggestions can be used todevelop this research, as follows: 1) Researchers can continue thisresearch with better research methodsto get more effective and more efficient results. 2) Farmers and society can be more participates in the processing and utilizing papayaleaves as rabbit feed with better quality so that it can add economic value.

Acknowledgement

The researchers would like to express gratitude to the research supervisor, Mrs Freini Dessi Effendi, S.TP., M.P., M.Sc., for allowing the researchers to do this research and for providing invaluable guidance and support throughout this research.

References

Amalia, Rosa S. (2013). The Effect of Papain on DietaryProtein Utility and Growth ofAfrican Catfish (Clarias gariepinus). *Journal of Aquaculture Management and Technology, 2*(1), 136-143.

Hasanah, E. 2005. Pengaruh Penambahan Antioksidan dan Pengkelat Logam Terhadap Aktifitas Proteolitik Enzim Papain. *Skripsi* Fakultas MIPA-IPB. Bogor.

Yuniwati, M, dkk. (2008). Pemanfaatan Enzim Papainsebagai Penggumpal dalamPembuatan Keju. (Jurnal) *Sains dan Teknologi*.

Zusfahair, Riana. (2014). Karakterisasi Papain Dari Daun Pepaya (Carica Papaya L.). *Molekul, 9*(1), 44-55.

PROXIMATE CHARACTERISTICS AND CALORIFIC VALUE OF BRIQUETTE FORMULATION FROM BIOMASS (DAIRY SLUDGE AND COCONUT SHELL) AND COAL AS AN ALTERNATIVE FUEL (CASE STUDY AT PT XYZ)

Tsamara Dhany Savira*, Dodyk Pranowo, Claudia Gadizza Perdani
Agroindustrial Technology, Universitas Brawijaya, Indonesia
*tsamaradhanysavira@gmail.com

Abstract

This study examines the proximate characteristics and calorific value of briquette. The aim of this study was to compare the feasibility of the formulated briquette with the Indonesian National Standard (SNI 01-6235-2000). The briquette formulation was obtained from linear programming with decision variables such as coal (X_1), dairy sludge charcoal (X_2), coconut shell charcoal (X_3), and adhesive (X_4) with the objective function is maximizing briquette calorific value. The optimal briquette formulation contains 10% coal, 10% dairy sludge charcoal, 75% coconut shell charcoal, and 5% adhesive. The calorific value obtained reached 9247.41 cal/gr, where the calorific value is quite high and has met the standard. However, the ash content does not meet the limit of the standard.

Keywords: Briquette; Calorific value; Linear programming; Proximate characteristics

Introduction

PT XYZ's activities as a dairy industry mostly utilize coal, especially in the boiler unit as a heat energy generator for steam. The non-renewable nature of coal encourages efforts to balance the use and consumption of coal through alternative fuels. PT XYZ produces 4 tons/day of dairy sludge waste. The abundance of organic material in dairy sludge is thought to have the potential to be used as an energy source. However, in order to increase the benefits and calorific value of the fuel later, it is necessary to add other biomass such as coconut shell. The fiber content in the coconut shell has the potential to be used as an ingredient in making briquette because it can increase the calorific value. In this study, coal is still used because there is a great hope that briquette can be scaled up in an effort to reduce the use of coal 100% at PT XYZ.

Briquettes are composed of charcoal made from biological waste through briquetting, which is the process of converting biomass energy sources into other forms of biomass by compressing the consistency to have an orderly shape. The biomass that makes up the briquette, such as dairy sludge and coconut shells, will undergo a composing process using the pyrolysis method. This study focus on the determination of briquette formulation using linear programming with the aim of maximizing calorific value and obtaining proximate characteristics (moisture content, ash content, volatile matter, fixed carbon) that meet SNI 01-6235-2000.

Aim and Scope

The aim of this study was to compare the feasibility of the formulated briquette with the Indonesian National Standard (SNI 01-6235-2000), especially on the calorific value. This research was only conducted on a laboratory scale.

Materials and Methods

The materials are coal, dairy sludge charcoal, coconut shell charcoal, tapioca flour, and water. The formulation method is linear programming, using POM-QM software. The output is the optimal formulation for each briquette component (X_1: coal; X_2: dairy sludge charcoal; X_3: coconut shell charcoal; X_4: tapioca adhesive). Figure 1. describes the steps in the briquetting process:

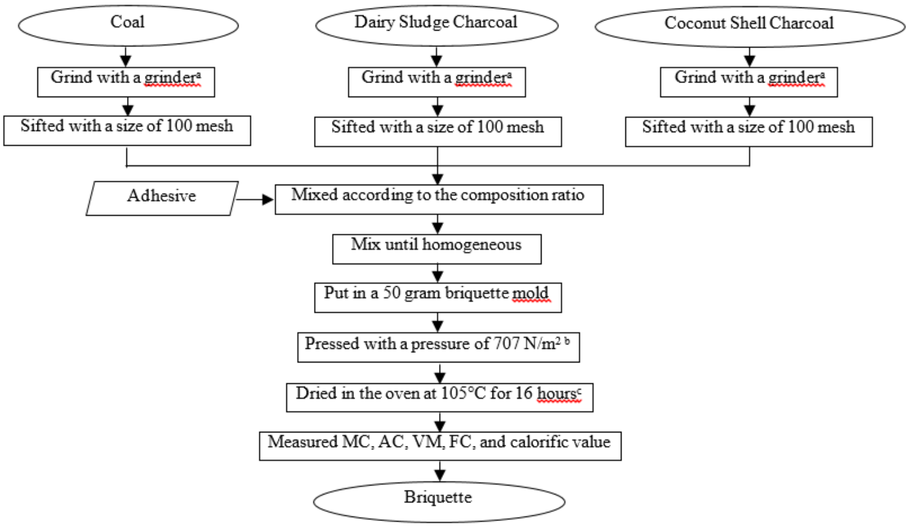

Figure 1. Briquetting Process, Source Modification [a](Hilmiati et al., 2018), [b](Nareswari, 2020), [c](Yuliansyah et al., 2019).

Results

Formulation

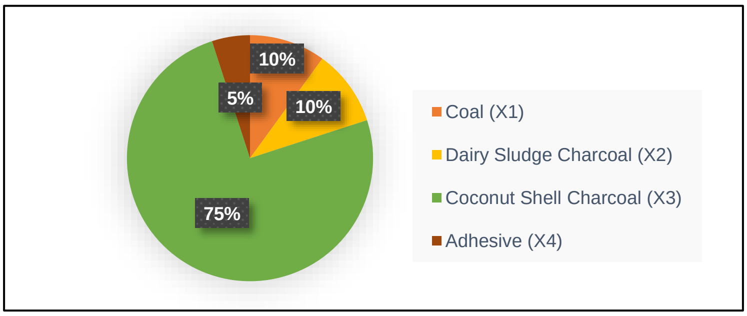

Figure 2. Briquette Formulation

The use of coal in this study is limited to 10-40%, while for the biomass used such as dairy sludge ≥10% and coconut shell charcoal ≥45%, because in order to reduce the use of coal and the utilization of biomass waste. In fact, the results show that the calorific value will be maximum when using the formulation of 10% coal, 10% dairy sludge charcoal, 75% coconut shell charcoal, and 5% adhesive.

Figure 3. Briquette

Based on the results of the formulation, Figure 3. shows that briquette are black and not easily broken. The shape of the briquette is a cylinder with a height of about 3cm and a diameter of 4.5cm.

Proximate Characteristics and Calorific Value of Briquette

The proximate characteristics and calorific value were compared with the estimated results on POM QM. It can be seen in Table 1.

Table 1. Comparison of Briquette Proximate Characteristics and Calorific Value

Analysis	Moisture Content (%)	Ash Content (%)	Volatile Matter (%)	Fixed Carbon (%)	Calorific Value (cal/gr)
Estimation	10,43	17,27	5,88	-	6204,25
Briquette	6	19	14	61	9247,41
SNI[a]	**≤8**	**≤8**	**≤15**	**≥69**	**≥5000**

Source: [a](Indonesia, 2000).

Moisture Content (MC)

The estimated moisture content is 10.43%, while in real conditions it is only 6%. The low water content in the resulting briquette was due to the drying treatment using an oven for 16 hours at a temperature of 105°C. The estimate of 10.43% is thought to be the water content when the briquette is wet, in the sense that before the drying process is carried out.

This is in accordance with research conducted by Sudarsono and Warmadewanthi (2010), that drying with an oven at a temperature >100°C tends to evaporate the material better. Then, the research of Kustiawan and Wijianti (2018) showed that the briquettes of their research that had been oven-dried for 16 hours at 80°C had a moisture content of 8.42%. Therefore, the formulated briquette that has been made in this study have a low true moisture content (6%) due to oven drying for 16 hours at a temperature of 105°C. Thus, the water content of the briquette in this study has met SNI 01-6235-2000 which is less than 8%.

Ash Content (AC)

The estimated water content is 17.27%, while in real conditions it is higher at 19%, both have a quite high value exceeds the limit. This means that the resulting briquette has almost the same ash content as expected. The high ash content of the briquette is caused by the materials used, mainly dominated by the use of dairy sludge charcoal because it has an ash content of 68%.

This condition is similar to the research conducted by Kwapinska and Leahy (2017) that ash is the main constituent of dairy sludge charcoal produced from the pyrolysis process of around 70-80%, so the ash content tends to be high. The study showed that the dairy sludge before pyrolysis had an ash content of 24.47% then increased after pyrolysis to 69.68%. This also happened in this study, where dry dairy sludge had an ash content of 28.5% and then increased after pyrolysis to 69.5%. The use of dairy sludge charcoal is one of the factors causing the high ash content in the briquette. Thus, the ash content of the briquette in this study did not meet the limits of SNI 01-6235-2000 because it was more than 8%.

Volatile Matter (VM)

The estimated volatile matter is 5.88%, while in real conditions it is higher at 14%. The high volatile matter in the resulting briquette was caused by the lower water content of the briquette when compared to estimates. The lower the water content will tend to increase the volatile matter, so the resulting briquette has a higher volatile matter than expected.

This is in accordance with the research conducted by Yuliah et al. (2017), that briquettes with a moisture content of 36.01% have a volatile matter of 21.88%, while briquettes with a moisture content of 28.56% have a volatile matter of 25.61%. This is what supports that the lower the water content will increase the volatile matter. In addition, Ristianingsih et al. (2015) argue that the high volatile matter can be influenced by the chemical components of charcoal such as impurities. However, the volatile matter of briquette in this study still meet SNI 01-6235-2000, which is less than 15%.

Fixed Carbon (FC)

The fixed carbon obtained is 61%. Fixed carbon is not formulated in POM-QM because the fixed carbon limit is not regulated in SNI 01-6235-2000. It would be nice when the percentage of fixed carbon could reach 69% because that number is a calculation of fixed carbon based on other proximate limits, where 100%-8%-8%-15%=69%. Therefore, fixed carbon is strongly influenced by water content, ash content, and volatile matter.

Research conducted by Ristianingsih et al. (2015), showed that high fixed carbon means it is composed of low volatile matter. In this study, briquette with 26.85% fixed carbon had 46.3% volatile matter, while briquette with 54.96% fixed carbon had 24% volatile matter. Thus, the materials used also greatly affect the proximate characteristics produced. If the proximate characteristics other than bound carbon can be controlled properly, then the bound carbon produced will be more maximal, it can even reach 69%.

Calorific Value

The estimated calorific value is 6204.25 cal/gr, while in real conditions it is higher at 9247.41 cal/gr. The high calorific value is due to the good formulation of the materials used. The cause of the high calorific value is the use of coconut shell charcoal by 75% which tends to dominate and the addition of coal by 10% also increases the calorific value.

In addition, water content is a proximate characteristic that has a very strong influence on the calorific value. The same thing also happened in research conducted by Kustiawan and Wijianti (2018) which showed that briquettes with a moisture content of 8.42% had a calorific value of 6512.13 cal/gr, while briquettes with a water content of 17.12% had a calorific value of 5531.43%, both use the same tapioca adhesive ratio of 10%. Therefore, the actual condition of the higher calorific value of the briquette that has been made when compared to the estimate is due to the low water content. Thus, the calorific value of briquette in this study has met SNI 01-6235-2000 which is more than 5000 cal/gr.

Conclusions

The results showed that the optimal briquette formulations were 10% coal, 10% dairy sludge charcoal, 10% coconut shell charcoal, and 5% adhesive. Based on the formulation, overall the briquette have complied with SNI 01-6235-2000 and are suitable to be used as fuel, but the ash content produced cannot meet the limit because one of the ingredients in the briquette that causes the high ash content is dairy sludge. The high ash content indeed indicates that the minerals contained in the dairy sludge are also quite high, where the relationship between the two is that the higher the mineral, the more ash increases, but this is not crucial in this study, but the volatile matter is one of the targets that is quite important because the higher the volatile matter will be dangerous, in contrast to the ash content which only leaves inorganic material (ash) after combustion. When compared with coal, the briquette produced in this study have much better characteristics and are even feasible to produce because they have a lower economic value when compared to commercial briquettes.

Acknowledgement

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References

Hilmiati, Husraini L, Zamhuri A. (2018). Densification of Product Torrefaction from Coconut Coir to Bio-briquette as Renewable Energy that Environmentally. *Environmental Research & Clean Energy, 12*(1), 13–16.

Indonesia SN. (2000). Briket Arang Kayu. Badan Standardisasi Nasional. Jakarta. 1-8.

Kustiawan E, Wijianti ES. (2018). Karakteristik Briket Berbahan Campuran Cangkang Buah Karet dan Batang Senggani dengan Tekanan Pencetakan 90 PSI. *Teknik Mesin, 4*(1), 29–33.

Kwapinska M, Leahy JJ. (2017). Pyrolysis – A Way of Recovering Energy from Wastewater Sludge from Milk Processing Factories 5 th International Conference on Sustainable Solid Waste Management. 5 th Int. Conf. Sustain. Solid Waste Manag, 1–12.

Nareswari MP. (2020). Karakterisasi Sifat Fisiko Kimia Arang dan Briket Arang Hasil Pirolisis Serabut Nipah (*Nypa Fruticans Wurmb.*). Universitas Brawijaya.

Ristianingsih Y, Ulfa A, Syafitri R. (2015). Pengaruh Suhu dan Konsentrasi Perekat terhadap Karakteristik Briket Bioarang Berbahan Baku Tandan Kosong Kelapa Sawit dengan Proses Pirolisis. *Konversi, 4*(2): 45–51.

Sudarsono PER, Warmadewanthi I. (2010). Eco-briquette dari Komposit Kulit Kopi, Lumpur IPAL PT SIER, dan Sampah Plastik LDPE. Seminar Nasional Manajemen Teknologi, XI, 1–9.

Yuliah Y, Suryaningsih S, Ulfi K. (2017). Penentuan Kadar Air Hilang dan Volatile Matter pada Bio-briket dari Campuran Arang Sekam Padi dan Batok Kelapa. *Ilmu dan Inovasi Fisika, 1*(1), 51–57.

Yuliansyah AT, Hidayat M, Annas A, Faez, Putra PW, Kuswandi CT. (2019). Preparation and Characterization of Bio-Coal Briquettes from Pyrolyzed Biomass-Coal Blends. *Engineering Science and Technology, 14*(1), 3569–3581.

MANAGING SAGO HAMPAS AND DECANTER CAKE THROUGH STABILIZATION USING BLACK SOLDIER FLY (*HERMETIA ILLUCENS*) LARVAE

Visvini Lohananthan[1], Latifah Omar*[1,2], Ahmed Osumanu Haruna[1,2], Kurk Wei Jie[1],
Mohd Hasyrin Hassan[1]
[1]Faculty of Agricultural Science and Forestry, Universiti Putra Malaysia Bintulu Sarawak Campus,
Nyabau Road, 97008 Bintulu, Sarawak, Malaysia
[2]Institut Ekosains Borneo (IEB), Universiti Putra Malaysia Bintulu Sarawak Campus,
Nyabau Road, 97008 Bintulu, Sarawak, Malaysia
*latifahomar@upm.edu.my

Abstract

Disposal of agro-industrial wastes such as sago hampas and decanter cake may cause various adverse effects on the environment if they are not treated properly. Sago hampas and decanter cake could be managed through stabilization using black soldier fly larvae (BSFL) to produce frass. Frass is the larvae excretion which include the leftover substrate during the rearing process of BSFL. The eggs of black soldier fly were obtained from BSF Farming and Trading, Bintulu, Sarawak, Malaysia and hatched in the trays whereby starter feeds such as leftover bread, rejected sago starch, and rice were fed to the BSFL at day one to day 14 of larvae age. After 14 days, sago hampas and decanter cake were fed to the BSFL as main substrates for rearing larvae until the BSFL reached to pupae stage at days 45. The frass of each substrate was analyzed for some selected physico-chemical properties and germination test to ascertain the quality of the BSFL frass to be used as organic fertilizer. The pH of BSFL frasses produced from sago hampas and decanter cake as rearing substrates were 5.09 and 7.03, respectively. Electrical conductivities of the sago hampas BSFL frass (1.34 mS/cm) and decanter cake BSFL frass (2.21 mS/cm) were in the range of permissible level for their uses as organic fertilizers. Ammonium content was high (9380.50 ppm) in the BSFL frass of decanter cake because the ammonium is released due to the biodegradation process of the organic substrates as observed in the lower content of total organic matter (31.33%) and organic C (18.17%) of decanter cake BSFL frass. Total organic matter, organic C, and C/N ratio of BSFL frass from sago hampas were 89.73%, 52.04%, and 62:1, respectively which resulted in toxic for radish seeds germination regardless of the frass extractant. Total N of the BSFL frass of sago hampas and decanter cake were 0.82% and 1.48%. Decanter cake as feeding substrate for BSFL showed better quality of frass in terms of texture, colour, nutrients content, and germination test. Toxic effects of BSFL frass produced from sago hampas were related to the immature or incomplete degradation of organic matter in the sago hampas. Thus, BSFL frass produced from sago hampas need to be further decomposed for maturity and stabilization to avoid phytotoxicity effects in plant. Decanter cake could be used as rearing substrate for BSFL to produce a good quality frass based on the appropriate pH, EC, ammonium content, total organic matter, total organic C, low C/N ratio, and preferable amount of N.

Keywords: Agro-industrial wastes**;** Bio decomposer; Eutrophication; Frass; Insect larvae

Introduction

In Malaysia, 1.2 million tonnes of agricultural waste are disposed into landfills annually which may cause various adverse effects on the environment if they are not treated properly. For example, disposal of sago wastes and palm oil residue (decanter cake) into nearest rivers polluted water bodies and endangered aquatic and human life. It is important to adopt proper and safe methods to manage sago hampas and decanter cake by turning them into valuable product that could be reusable. One of the proper approaches is to use sago hampas and decanter cake as substrates for rearing black soldier fly larvae (BSFL) to produce frass. Frass is an excrement of the insect larvae which obtained through the digestive system of the larvae when the dry matter of feedstocks had been digested (Lalander *et al*., 2017). Owing to the high carbon (C) and nitrogen (N) contents of sago hampas and decanter cake, decomposer agents need to be introduced in the feedstocks to fasten the decomposition and to ascertain the maturity and stability of the frass (Omar *et* *al*., 2021). The BSFL (*Hermetia illucens* L.) are considered as one of the most efficient insect-based bio converters because BSFL are voracious consumers on organic waste such as crop, animal, and human wastes (Lalander *et al.*, 2017; Manurung *et al*., 2016). Frass has high major nutrients such as N, phosphorus (P), and potassium (K) with an analysis of 5-2-2 thus, it could be used as an organic fertilizer for soil and plant productivity improvement (Vickerson *et al*., 2017). Applying BSFL frass in soil had been proven to improve soil fertility by providing essential plant nutrients such as N, P, and K (Kebli & Sinaj, 2017).

However, quality of the frass depends on the nature of the organic wastes consumed by the BSFL and the stabilization during the degradation process which involved biological, physical, and chemical factors. According to Ndambi *et al*. (2019), the organic wastes with low nutritional quality such as sewage sludge led to ammonia volatilization which caused the significant loss of N in frass (Lalander *et al*., 2015). Whereas Oonincx *et al*. (2015) reported the N loss of approximately 23 to 78% in frass produced from the degradation of BSFL on livestock wastes. The mixing of organic matters and coffee grounds has been reported as booster for BSFL metabolism due to the caffeine content in the coffee grounds (Bullock *et al*., 2013). Fruit and vegetables leftovers are appropriate for BSFL rearing substrate because of high nutrients content for BSFL growth apart from readily availability and easily obtained from the fruit and vegetables processing industries (Nguyen *et al*., 2015; Paz *et al*., 2015). Leftover fruits such as banana, pineapples, avocados, and watermelons provide nutrients for the BSFL due to the high N free extract (Paz *et al*., 2015).

The degree of stability and maturity of the BSFL frass must be determined to ascertain the safety use of frass as organic fertilizer and not toxic to plants. Stability and maturity of the growing media refers to no adverse effects such as phytotoxic substances to the seed germination and plant growth from any organic fertilizers such as composts or frass from BSFL (Sullivan and Miller, 2001). In this study, the changes of colour, odour, temperature, and electrical conductivity (EC) were recorded during the stabilization of frass production from BSFL after being fed on sago hampas and decanter cake. Whereas the chemical properties such as the pH, organic matter (OM), carbon (C), C/N ratio, ammonium, nitrate, and total N were also analyzed to confirm the maturity of the BSFL frass. For agronomy purpose, successful germination could confirm the absence of phytotoxic substances such as phenolic acids and volatile fatty acids within the immature feedstock (Omar *et al*., 2021). Therefore, the maturity and stability of BSFL frass after being fed on problematic wastes such sago hampas and decanter cake need to be determined because sago hampas are high in lignin dan fibrous in nature. Whereas decanter cake is greasy and high in moisture content (Ramli *et al*., 2012). In this study, attempts were to utilize sago hampas and decanter cake as rearing substrates for BSFL to produce frass. It is hypothesized that managing sago hampas and decanter cake using BSFL as decomposer agent could produce frass which safe to be used as growing media or organic fertilizer. However, the use of BSFL frass as growing media or organic fertilizer is scarcely explored. Research questions that need to be explored in this study are: (i) what is the physico-chemical properties of frass excreted by BSFL after being fed on sago hampas and decanter cake? and (ii) does BSFL frass produced from sago hampas and decanter cake have toxic effects on seed germination? To overcome the afore stated research questions, this study was carried out to determine the selected physico-chemical properties of the BSFL frass and to ascertain the maturity and stability of the BSFL frass. The implications of this study could provide an alternative approach of managing agro-industrial wastes such as sago hampas and decanter cake using BSFL as decomposer agent, develop organic fertilizer (BSFL frass) from BSFL after being fed on sago hampas and decanter cake, and confirm the benefits of BSFL frass as growing media or organic fertilizer.

Materials and Methods

Rearing Black Soldier Fly Larvae for Frass Production

The eggs of the BSF and decanter cake were obtained from the BSF Farming and Trading Bintulu, Sarawak, Malaysia. Sago hampas was collected from Sago Link Sdn. Bhd., Mukah, Sarawak, Malaysia. A 10 gram of BSF eggs were laid in the plastic tray size of 65 cm length x 37 cm width x 15 cm depth (Figure 1). After hatched, the BSFL were fed at day one to day seven with leftover foods (bread crumbs, rice, and rejected sago starch) which were obtained from food courts in Universiti Putra Malaysia Bintulu Sarawak Campus, Malaysia. The starter diet was fed to an early age of the BSFL until day 14 because at the larvae could not digest the fibrous and greasy nature of feeds as characterized by sago hampas and decanter cake. After the BSFL were fed on starter diet for 14 days, 3 kg of sago hampas and decanter cake were placed in the feeding trays and the rearing of the BSFL continued for another 31 days (Figure 1). It must be noted that, the rearing of BSFL using sago hampas and decanter were carried out separately with three replications (Figure 1). During the rearing progress, the substrates were sprinkled with 20 mL of water to maintain moisture content, humidity, and low temperature of the substrates. The temperatures of the substrates were taken daily to avoid increase of the temperature that could restricted the growth of BSFL. At day 45, the colour of both sago hampas and decanter cake were compared using Munshell Colour Chart (Figure 1). The separation of the pupae from the frass was carried out using the hand sieve after which the frass was further analyzed for physico-chemical properties using standard procedures (Tan, 2005) and phytotoxicity test.

a) Sago hampas as main substrate; b) Black soldier fly eggs were laid in the trays; c) Black soldier fly eggs hatched and fed with starter diet (leftover food); d) Growth of insect was monitored; e) Frass produced at 45 days when larvae turn to pupae

a) Decanter cake as main substrate; b) Fly eggs were incubated, hatched and fed with starter diet; c) At day 7, fly larvae were added to decanter cake; d) Larvae turn to pupae; e) Matured frass

Figure 1. Procedures of frass production from rearing black soldier fly larvae using sago hampas and decanter cake

Selected Physico-chemical Characterization of Black Soldier Fly Larvae Frass

The temperature of substrates was recorded from the beginning until the end of the BSFL rearing processes (day one to day 45) whereby the BSFL completed larvae stage and turn into pupae. The pH and EC of the frass were determined in distilled water using a ratio of 1:10 (w/v) (Tan, 2005). The colours of frass were compared based on colour categories outlined in Munshell Colour Chart. Total C and OM of the frass were determined using loss-on-ignition method (Tan, 2005). Total N was determined using Kjedhal method (Bremner, 1965). The method described by Keeney and Nelson (1982) was used to extract exchangeable ammonium and available nitrate in the frass after which the ions were determined using steam distillation (Tan, 2005).

Phytotoxicity Test on Black Soldier Fly Larvae Frass

The plant bioassays method was used for phytotoxicity test of BSFL frass in which the seed germination rate and the seeds elongation were determined under controlled conditions (Sullivan & Miller, 2001). The BSFL frass extracts were prepared by diluting 5 g of BSFL frass with 50 mL of distilled water (1:10, w/v) and shaken at 180 rpm for one hour. The samples were filtered through Whatman filter paper no. 2 and then diluted according to the dilution series of 10, 100 and 1000 times, respectively. The radish seeds (*Raphanus sativus*) were used as a test crop whereby the 10 seeds were placed on the petri dishes laid with the filter papers after which moistened with 5 mL BSFL frass extract from each dilution. The petri dishes contain of radish seeds were kept in the dark room under controlled environment for 72 hours at 25 °C. The similar procedures were repeated for distilled water which serves as the positive control that used for the comparison against the BSFL frass extracted at three different series. After 72 hours, the germinated seeds were recorded, and their radicle or root lengths were measured. The germination index (GI) was calculated using the equation 1. The RSG (%) is the relative seed germination was calculated as given in the equation 2 whereas RRG (%) is the relative root growth and determined following the equation 3.

GI = (RSG% x RRG%) / 100 Equation 1
RSG = (Number of seeds germinated in BSFL frass extracts / Number of seeds germinated in distilled water) x 100 Equation 2
RRG = (Root length mean in BSFL frass extracts / Root length mean in distilled water) x 100 Equation 3

It is noted that if the value of radish seeds germinated in the BSFL frass extracts below than 50%, it is considered as highly phytotoxic, germination under 50% and 80% are moderately phytotoxic, and if the GI value more than 80%, the BSFL frass considered as not toxic to plant (Teresa *et al*., 2011; Emino *et al*., 2004).

Experimental Design and Statistical Analysis

The rearing trays were arranged in a completely randomized design (CRD) with three replications. Data analyses for all variables involved in this study were in triplicates (replicated three times). Analysis of variance (ANOVA) was used to compare the treatment effects and Tukey's test was used to compare treatment means at P ≤ 0.05 using the Statistical Analysis System software version 9.4.

Results and Discussion

Some Selected Physico-chemical Properties of Black Soldier Fly Larvae Frass

The daily temperature of both rearing substrates (sago hampas and decanter cake) was 27 °C and it is the optimum temperature that help in increasing the efficiency of BSFL to digest the substrates (Sheppard *et al*., 2002). The daily temperature is important to be monitored because BSFL could not tolerate to high temperature for example above 30 °C. According to Zhang *et al*. (2010), 45 °C is the maximum temperature that inhibit survival of the BSFL. If the temperatures are less than 10 °C and higher than 45 °C, the BSFL become inactive and reduce their survival rates. The BSFL have completed larvae stage at 45 days after which the larvae had turn into pre-pupae and some of them turn into pupae. The slight changes in the colour and texture of BSFL frass from sago hampas were because of the high fibrous and lignin content of the sago hampas resulted in difficulties for BSFL to digest the substrate (Figure 2a, b, c). In addition, the completion stage of BSFL at 45 days and turn into pupae contributed to the incomplete degradation of sago hampas. In contrast to decanter cake, the dark colour and crumble texture of BSFL frass after being fed on decanter cake suggested that the BSFL frass was stabilized and reached to pupae stage (Figure 3a, b, c). In the pupae stage, the BSFL exoskeleton begins to turn darkens and a pupa develops within two weeks (Hall & Gerhardt, 2002). Both BSFL frasses did not emits unpleasant odours whereby odourless degraded product is one of the maturity indicators (McCrory & Hobbs, 2001). Instead of unpleasant odour, both BSFL frasses were slightly earthy and inoffensive smell in terms of odour.

a) Sago hampas as rearing substrate at seven days of black soldier fly larvae age
b) Colour was slightly changed at 30 days of black soldier fly larvae age
c) The frass at 45 days of black soldier fly larvae age

Figure 2. Colour profiles of frass from stabilization of sago hampas using black soldier fly larvae as degrading agent

a) Decanter cake as rearing substrate at seven days of black soldier fly larvae age

b) Decanter cake became clumpy at 30 days of black soldier fly larvae age

c) The dark colour of frass at day 45 of black soldier fly larvae

Figure 3. Colour profiles of frass from stabilization of decanter cake using black soldier fly larvae as degrading agent

High moisture content of the decanter cake as rearing substrate is one of the determinant factors that contribute to the stabilized frass excreted by the BSFL after being fed on decanter cake (Figure 3c).

The pH of the BSFL frass from decanter cake as rearing substrate was neutral (Table 1), whereas BSFL frass from sago hampas as rearing substrate was acidic (Table 1). The neutral pH of BSFL frass from decanter cake was due to the releasing of ammonia through deamination of protein from decanter cake (Baroso et al., 2017). Besides, the pH of the BSFL frass which were around 7 achieved the standard that most of the organic amendments such as composts whereby near to neutral or slightly alkaline pH with a high buffering capacity (Ko et al., 2008). For BSFL frass derived from sago hampas, the low pH was related to the digestion of sago hampas into in the guts of BSFL secreted the organic acids that can reduce the pH of frass (David et al., 2014). Electrical conductivities (EC) of the BSFL frasses were 1.34 and 2.21 mS/cm (Table 1) and those EC values are in the range of permissible level for organic fertilizer. According to Moore et al. (2010) recommended EC values between 2.0 and 3.5 mS/cm are optimal to be used as organic fertilizer. The amount of ammonium increased when BSFL fed on sago hampas because of the decomposition of proteins by microbes. However, the amount of nitrate is greater than that of ammonium in BSFL frass of sago hampas was due to nitrification occurred along the feeding progress which contribute to the conversion of ammonium to nitrate (Kristine & Daryl, 2010). In addition, when the substrate for rearing BSFL was matured, the low temperature associates with low microbial activity favours the production of nitrate rather than loss of N through denitrification. The higher total organic matter and C in BSFL frass from sago hampas suggested that incomplete degradation of the substrate. Well decomposed organic materials attributed by the lower organic matter and C as observed in BSFL frass produced from decanter cake in which related to the degradation of organic matter and released carbon dioxide and water as by product. Total nitrogen (1.48%) of the frass from decanter cake is considered high as most of the soil organic amendment produced from plant and animal wastes are commonly below 1% (Latifah et al., 2017). The C/N ratio of the BSFL frass from decanter cake is in the range of decomposed materials and the high C/N ratio of BSFL frass excreted from sago hampas suggested that the frass need to be further decomposed (Table 1).

Table 1. Physico-chemical properties of black soldier fly larvae frass after fed on sago hampas and decanter cake. Means are followed with ± standard error (SE).

Properties	BSFL frass from sago hampas	BSFL frass from decanter cake
Colour (Munsell colour chart)	Brown	Black (10YR 2/1)
pH_{dw}	5.09 ± 0.009	7.03 ± 0.040
EC (mS/cm)	1.34 ± 0.778	2.21 ± 0.068
Exchangeable Ammonium (ppm)	30.355 ± 2.335	9380.50 ± 0.698
Available Nitrate (ppm)	32.690 ± 2.335	7512.50 ± 0.346
Total Organic Matter (%)	89.733 ± 0.333	31.33 ± 0.033
Total Organic Carbon (%)	52.045 ± 0.193	18.17 ± 0.667
Total Nitrogen (%)	0.827 ± 0.000	1.48 ± 0.167
C/N Ratio	62:1	12:1 ± 1.65

Germination Bioassay Test of Black Soldier Fly Larvae frass

Radish seeds (Raphanus sativus) were used as a test crop for germination bioassay test in the frass extractants from BSFL frass of sago hampas were toxic irrespective of dilution time (Table 2) and the unsuccessful of radish seeds germination was related to the immature BSFL frass of sago hampas which were reflected by high organic matter, organic C, and C/N ratio. The germination index (GI) of the distilled water and BSFL frass extractants from decanter cake regardless of dilution series were greater than 80% which indicates the frass was stabilized, matured, and not toxic to the radish seed germination (Table 2). The GI values between 80% to 100% was proved as free from plant toxicity (Zucconi et al., 1985).

Table 2. Germination bioassay tests of black soldier fly larvae frass after being fed on sago hampas and decanter cake

Treatment	Dilution	Root (cm)	Shoot (cm)	RRG%	RSG%	GI (%)	Remark
Distilled water	None	2.45	2.75	100	100	100	Not toxic
Sago hampas	10x	2.83	3.67	12.82	14.84	3.08	Toxic
	100x	1.00	1.67	4.52	6.75	0.34	Toxic
	1000x	2.47	2.87	11.16	11.61	1.74	Toxic
Decanter cake	10x	5.70	5.70	95.89	100	95.89	Not toxic
	100x	5.78	5.78	97.18	100	100	Not toxic
	1000x	5.70	5.70	95.90	88.89	85.25	Not toxic

Conclusions

The pH of BSFL frasses produced from sago hampas and decanter cake as rearing substrates were 5.09 and 7.03, respectively. Electrical conductivities of the sago hampas BSFL frass (1.34 mS/cm) and decanter cake BSFL frass (2.21 mS/cm) were in the range of permissible level for their uses as organic fertilizers. Ammonium content was high (9380.50 ppm) in the BSFL frass of decanter cake because the ammonium is released due to the biodegradation process of the organic substrates as observed in the lower content of total organic matter (31.33%) and organic C (18.17%) of decanter cake BSFL frass. Total organic matter, organic C, and C/N ratio of BSFL frass from sago hampas were 89.73%, 52.04%, and 62:1, respectively which resulted in toxic for radish seeds germination regardless of the frass extractant. Total N of the BSFL frass of sago hampas and decanter cake were 0.82% and 1.48%. Decanter cake as feeding substrate for BSFL showed better quality of frass in terms of texture, colour, nutrients content, and germination test. Toxic effects of BSFL frass produced from sago hampas were related to the immature or incomplete degradation of organic matter in the sago hampas. Thus, BSFL frass produced from sago hampas need to be further decomposed for maturity and stabilization to avoid phytotoxicity effects in plant. Decanter cake could be used as rearing substrate for BSFL to produce a good quality frass based on the appropriate pH, EC, ammonium content, total organic matter, total organic C, low C/N ratio, and preferable amount of N.

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References

Barroso, F.G., Sánchez-Muros, M., Ramos, R., Segura, M., Morote, E., Guil, J.L., & Torres, A. (2017). Insects as food: Enrichment of Larvae of *Hermetia illucens* with Omega 3 Fatty Acids by Means of Dietary Modifications. Journal of Food Composition Analysis, (62), 8–13.

Bio Logic. (2001). Report on assessing compost maturity. A Final Report for the Nova Scotia Department of Environment and Labour, Bio-Logic Environmental Systems, Dartmouth, Canada.

Bremner, J.M. (1965). Total Nitrogen. In Methods of Soil Analysis; Black, C.A., Evans, D.D., Ensminger, L.E., White, J.L., Clark, F.F., Dinauer, R.C., (Eds) American Society of Agronomy: Madison, WI, United States of America.

Brinton, W. F. (2000). Compost quality standards and guidelines. Woods End Research Laboratory, prepared for New York State Association of Recyclers.

Bullock, N., Chapin, E., Elder, B., Evans, A., Givens, M., Jeffay, N., Pierce, B., Robinson, W., & Mattox, J. (2013). Implementation of Black Soldier Fly Breeding and Chicken Feed Production at Pickard's Mountain Eco-Institute.

David, L. A., Maurice, C. F., Carmody, R. N., Gootenberg, D. B., Button, J. E., & Wolfe, B. E. (2014). Diet Rapidly and Reproducibly Alters the Human Gut Microbiome. *Nature,* (505), 559–563.

Emino, E.R & Warman P.R. (2004). Biological assay for compost quality. *Compost Science and Utilization*, 12(4),342–348.

Hall, D.C. & Gerhardt, R.R. (2002). Flies (Diptera). In Mullen, G. & Durden, L. (eds). Medical and Veterinary Entomology. Academic Press. San Diego, California.

Isibika, A., Vinnerås, B., Kibazohi, O., Zurbrügg, C. & Lalander, C. (2019). Pre-treatment of banana peel to improve composting by black soldier fly (*Hermetia illucens* (L.), Diptera: Stratiomyidae) larvae. *Waste Management Research*, 100, 151–160.

Keeney, D.R. & Nelson, D.W. (1982). Nitrogen-inorganic forms. In Methods of Soil Analysis, Part 2, 2nd ed.; Page, A.G., Keeney, D.R., Baker, D.E., Miller, R.H., Rhoades, J.D. (Eds) American Society of Agronomy: Madison, Wisconsin, United States of America.

Kebli, H. & Sinaj, S. (2017). Agronomic Potential of a Natural Fertiliser Based on Fly Larvae Frass. *Recherche Agronomique Suisse,* (3), 88-95.

Ko, H.J., Kim, H.T., Kim, C.N. & Umeda, M. (2008). Evaluation of Maturity Parameters and Heavy Metal Contents in Composts Made from Animal Manure. *Waste Management*, 28(5), 813–820.

Kristine & M. Daryl. (2010). Compost Stability and Maturity Evaluation - A Literature Review. *Canadian Journal of Civil Engineering*, (37), 1505-1523.

Lalander, C., Nordberg, Å., & Vinnerås, B. (2017). A Comparison in Product-Value Potential in Four Treatment Strategies for Food Waste and Faeces—Assessing Composting, Fly Larvae Composting and Anaerobic Digestion. *GCB Bioenergy*, (2017), 1–8.

Lalander, C.H., Fidjeland, J, Diener, S., Eriksson, S., & Vinnerås B. (2015). High Waste-To-Biomass Conversion and Efficient Salmonella Spp. Reduction Using Black Soldier Fly for Waste Recycling. *Agronomy Sustainable Development*, 35(1), 261–271.

Omar, L., V., Lohanathan, & O. H. Ahmed. (2021). Frass Production from Rearing Black Soldier Fly Larvae with Decanter Cake and Palm Kernel Expeller. Ways of development of science in modern crisis conditions: theses add. II International Scientific and Practical Internet Conference, June 3-4, 2021 – Dnipro, Ukraine.

Latifah, O., Ahmed, O.H. & Majid, N.M.A. (2017). Enhancing Nutrients Use Efficiency and Grain Yield of *Zea Mays* L. Cultivated on A Tropical Acid Soil Using Paddy Husk Compost and Clinoptilolite Zeolite. *Bulgarian Journal of Agricultural Science,* 23(3), 418-428.

Manurung, R., Supriatna, A. & Esyanthi, RR. (2016). Bioconversion of Rice Straw Waste by Black Soldier Fly Larvae (*Hermetia illucens* L.): Optimal Feed Rate for Biomass Production. *Journal of Entomology and Zoology Study,* 4(4), 1036–41.

McCrory, D.F.& Hobbs, P.J. (2001). Additives To Reduce Ammonia and Odour Emissions from Livestock Wastes. Journal of Environmental Quality, (30),345–355.

Moore, J. C., DeVries, J.W., Lipp, M., Grif, J.C. & Abernethy, D.R. (2010). Total Protein Methods and Their Potential Utility to Reduce the Risk of Food Protein Adulteration. Comprehensive Revision of Food Science and Food Safety, (9), 330–357.

Ndambi, O.A., Pelster, D.E., Owino, J.O., de Buisonjé, F. & Vellinga T. (2019). Manure Management Practices and Policies in Sub-Saharan Africa: Implications on Manure Quality as a Fertilizer. Frontier in Sustainable Food System, (3),1–14.

Nguyen, T.T., Tomberlin, J.K., & Vanlaerhoven, S. (2015). Ability of Black Soldier Fly (Diptera: Stratiomyidae) Larvae to Recycle Food Waste. Environmental and Entomology, (44), 406–410.

Oonincx, D., Huis, A. & van Loon, J. (2015). Nutrient Utilisation by Black Soldier Flies Fed with Chicken, Pig, Or Cow Manure. *Journal of Insects as Food and Feed*, (1), 131-139.

Paz, A.S.P., Carrejo, N.S., & Rodríguez, C.H.G., (2015). Effects Of Larval Density and Feeding Rates on The Bioconversion of Vegetable Waste Using Black Soldier Fly Larvae (*Hermetia illucens* (L.) (Diptera: Stratiomyidae). *Waste Biomass Valorization,* (6), 1059– 1065.

Ramli, A., Singh, R.P., & Ibrahim, M.H. (2012). Use of Decanter Cake from Palm Oil Mill as Fertilizer Supplement: The pattern of Macronutrients Accumulation in Oil and Plant with The Amendment of Decanter Cake. UMT 11th Inter. Annual Symposium on Sustainability Sciene and Management. Universiti Malaysia Terengganu, Malaysia.

Sheppard et al. (2002). Selected Life-History Traits of Black Soldier Flies (Diptera: Stratiomydae) Reared on Three Artificial Diets. *Entomology Society of America*, 95(3), 379-386.

Sullivan, D.M., & Miller, R.O. (2001). Compost Quality Attributes, Measurements, And Variability. In Compost Utilization in Horticultural Cropping Systems. Edited by P.J. Stofella and B.A. Kahn. Lewis Publishers, Boca Raton, Florida, United States of America.

Tan, K.H. (2005). Soil Sampling, Preparation, and Analysis. 2nd ed.; CRC Press: Boca Raton, Florida, United States of America.

Teresa, M, & Remigio B. (2011). A Review on the Use of Phytotoxicity as a Compost Quality Indicator. Dynamic Soil, *Dynamic Plant Glob Sci Books. 5*(2), 36–44.

Vickerson, et al. (2017). Test Methods for the Examination of Composting and Compost. In: W.H. Thompson, P.B. Leege, P.D. Millner, and M.E. Wilson. (Editor), United States Department of Agriculture, and Composting Council Research and Education Foundation, Holbrook, New York, United States of America.

Zmora-Nahum, S., Markovitch, O., Tarchitzky, J., & Chen, Y. (2005). Dissolved Organic Carbon (DOC) As A Parameter of Compost Maturity. *Soil Biology and Biochemistry*, 37(11), 2109– 2116.

Zucconi, F., Monaco, A. & Forte, M. (1985). Phytotoxins during the stabilization of organic matter. In: Gasser J. K. R. (Editor), Composting of Agricultural and other Wastes, Elsevier Applied Science Publication, New York, United States of America.

Zhang, J., Huang, L., He, J., Tomberlin, J.K., Li, J., & Lei, C. (2010). An Artificial Light Source Influences Mating and Oviposition of Black Soldier Flies, *Hermetia illucens*. *Journal of Insect Science*, 10(202), 1–7.

DEVELOPMENT OF BIOFILM FROM SAGO STARCH AND RED CABBAGE AND ITS APPLICATION ON FRESH-CUT TOMATOES AND RED APPLES

Nurul Husna Che Hamzah[1], Dayangku Nurshahirah Awang Wahab[1,3], Mohammad Sobri Merais[1], Nozieana Khairuddin[*1,2]
[1]Department of Science and Technology, Faculty of Humanities, Management and Science; and
[2]Institut Ekosains Borneo, Universiti Putra Malaysia Bintulu Sarawak Campus, Sarawak, Malaysia
[3]Faculty of Engineering, Computing and Science, Swinburne University of Technology Sarawak Campus, Kuching, Sarawak, Malaysia
*nozieana@upm.edu.my

Introduction

Biodegradable, smart, edible, non-toxic films are the new trends in the packaging industry (Adel, A. M. et al., 2019, Salvucci, E. et al., 2019) Biofilms made from renewable sources, such as polysaccharides, proteins, and lipids, or a mixture of them are used as coatings in packaging to minimize serious environmental concerns by reducing the usage of plastic packaging (Thakur, R. et al., 2016). Currently, there has been a surge of interest in developing novel and underutilized starchy crops for various applications. When it comes to developing packaging biofilms, starch is frequently selected because it is abundant, cheap, edible, and biodegradable. Among the starches consumed by humans, less attention has been paid to the starch extracted from sago crops (*Metroxylon Sagu*). This crop is one of the potential underutilized food palms that grow well in the tropical rain forests of Southeast Asia. The sago palm tree is remarkably resistant to unfavorable environmental circumstances such as drought, flood, strong wind, and fire.

The starch biofilms can be added with functional ingredients, for instance, antimicrobial and antioxidant agents, nutraceuticals, or color and flavor ingredients. Usage of glycerol as plasticizer provides the pliability and flexibility to modify the physical characteristics of starch-based films and coatings (Das, D. K. et al., 2013). Films prepared with starch are colorless, odorless, and have adequate barrier properties against oxygen. Furthermore, the films become rigid and relatively durable due to the linear chains that tend to interact through hydrogen bonding (Yan, Q. et al., 2012). Among the antioxidants added in active packages, the phenolic compound can delay the oxidative process and stimulate an increase in the shelf life of perishable foods. Anthocyanins can be incorporated in biodegradable starch films as it supplies functional properties, such as those of a pH indicator (Eskandarabadi, S. M. et al., 2019). Anthocyanins and phenolic compounds commonly found in red cabbage (*Brassica Oleracea*) have been studied as antioxidant and antimicrobial agents in various reports (Prietto, L. et al., 2017, Chu, M. et al., 2020, Freitas, P. A. et al., 2020, Gennadios, A. et al., 1993). Besides, anthocyanin from red cabbage also provides a wide spectrum color when reacting with different pH solutions. Thus, anthocyanin-rich films are considered as promising intelligent pH indicators to monitor the freshness of food since the process of food spoilage is usually accompanied by pH changes. For instance, the films have shown the spoilage point of pork samples (Choi, I. et al., 2017) and milk (Pereira, V. A. et al., 2015).

Tomato or scientifically known as *Lycopersicon esculentum* is a seasonal vegetable high in vitamins and minerals. Tomatoes tend to deteriorate rapidly during storage and transportation which is a crucial post-harvest issue for traders. Hence, biofilms may have the potential to delay the rapid degradation of harvested tomatoes (Das, D. K. et al., 2013). Red apples or *Malus domestica* is a highly nutritious fruit to be consumed for daily diet. One of the major challenges for the fresh-cut fruit industry is the browning effect that evolves due to the polyphenol oxidase activity that occurs after peeling and diet which exists in a wide variety of fresh-cut fruits and vegetables (Zepon, K. M. et al., 2019). There are several ways to predict the shelf life of food such as by using spectroscopy, imaging, chemical analysis, and temperature. Therefore, this research aims to develop a biofilm-based on sago starch, red cabbage, and glycerol as the plasticizer to prolong the shelf-life of fresh-cuts of tomatoes and red apples. Furthermore, color response efficiency, colorimetric test, and moisture content test will also be analyzed.

Keywords: Bioplastic; Packaging; Red cabbage; Sago starch; Shelf-life

Materials and Methods

Materials

Sago starch, red cabbage, ripe tomato, and red apples were purchased from a local supermarket. Ethanol absolute denatured and glycerin 99.7% were obtained from HMBG, Germany. Distilled water was used as the solvent.

Preparation of biofilm

A sample of approximately 150 g of red cabbage was crushed and macerated with 20% ethanol in 150 ml distilled water for 24 hours. The solid to the liquid ratio used was 1:1. Then, the prepared solution was filtered using Whatman No. 1 filter paper and stored in the chiller at the temperature of 4℃ before being further incorporated in sago starch-based film. After that, a sample of 100 ml of red cabbage extract was heated on the stirring hot plate (Model HS0707V2; Favorit, Chicago, IL, USA) with continuous stirring before an amount of 5 g of sago starch was added into the solution. Later, about 3.5 ml glycerin as the plasticizer was added and stirred homogeneously. The heating process continues until 70℃ with a constant stirring on the stirring hot plate. Figure 1a) shows the final solution before it was cast on the petri dish. The film was then dried in a convection oven for about 2 hours at 60℃ as shown on Figure 1b). The final product was shown in Figure 1c) below.

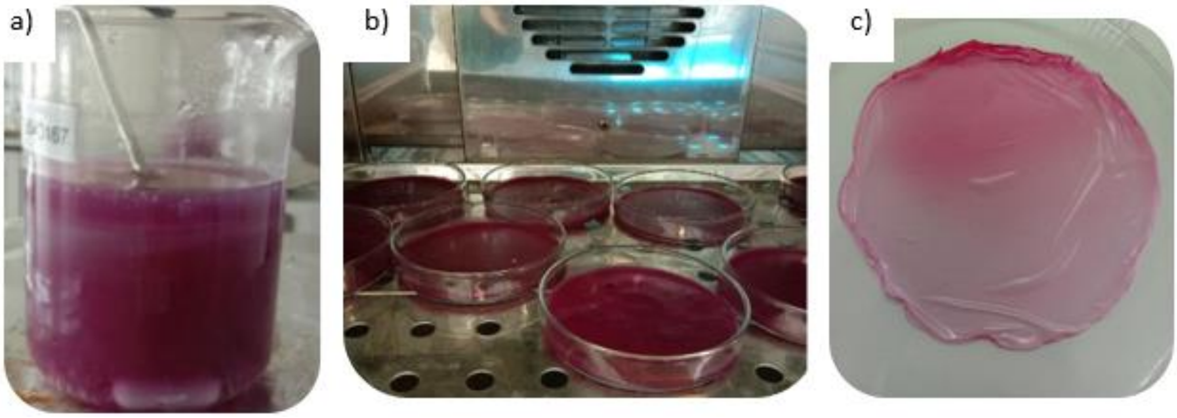

Figure 1. a) Gelatinization of sago starch with red cabbage anthocyanin; b) drying process of the biofilms and c) dried product of biofilm

Color response efficiency and colorimetric test

Color response efficiency and colorimetric analysis were done by adding 5 ml of buffer solution from pH 1 to 13 into a separate petri dish. Then, 5 ml of anthocyanin solution was added into each petri dish which had already been filled with buffer solution previously. The color changes were monitored and recorded using Color Reader CR10 (Konica Minolta CR10, Japan) for its L, a, and b reading. The L values indicate the lightness, whereas the a and b values indicate the green to red and blue to yellow respectively.

Food wrapping test

To determine the performance of the biofilm on fresh-cut apples and tomatoes, the biofilm was tested to wrap the samples as shown in Figure 2. Three layers of biofilm and cling wrap were used to wrap the samples before they were stored in the chiller at 4℃. After 5 days of storage, the samples were taken out for observation. Visual observation such as the outer condition of the samples and moisture content before and after the storage was recorded in Figure 2.

Moisture content test

To determine the moisture content (MC), the films were dried to an equilibrium weight at 105 ℃ in an oven. MC was calculated according to the following equation:

$$MC\ (\%) = 100 \times (M_i - M_f)/M_i \quad \text{Equation 1}$$

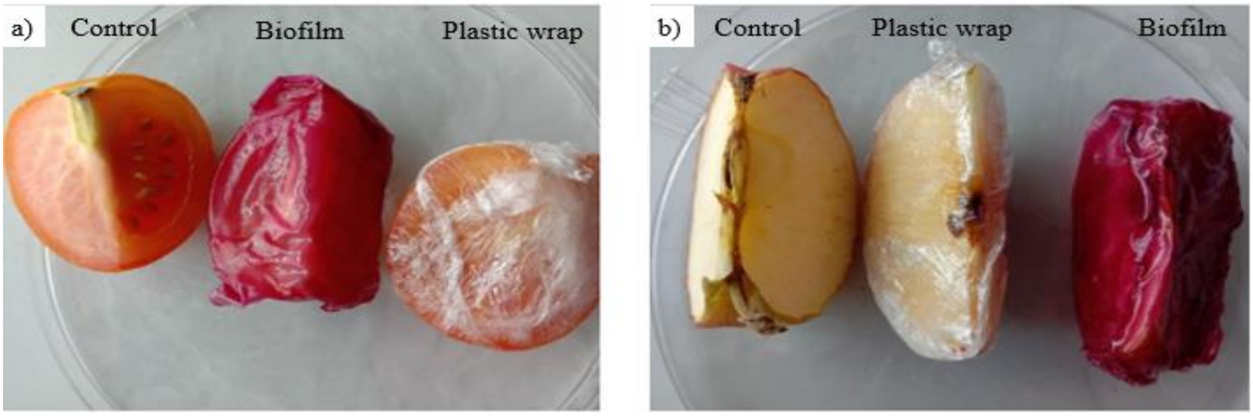

Figure 2. Wrapping the samples with biofilm, plastic wrap, and control (without any wrap) for samples: a) tomatoes; and b) apples

Result and Discussion

Color response efficiency and colorimetric analysis

It was observed that the anthocyanin solution extracted from red cabbage can change colors when it reacts with different pH solutions. The color of the biofilm solution completely changed from its original color (purple) to different color when in contact with buffer solution from pH 1 until 13 as displayed in Figure 3. This result proves that this biofilm can act as smart packaging film since it can communicate with human beings when the spoilage of the food or drinks occurs through direct visual changes, mainly alterations in color.

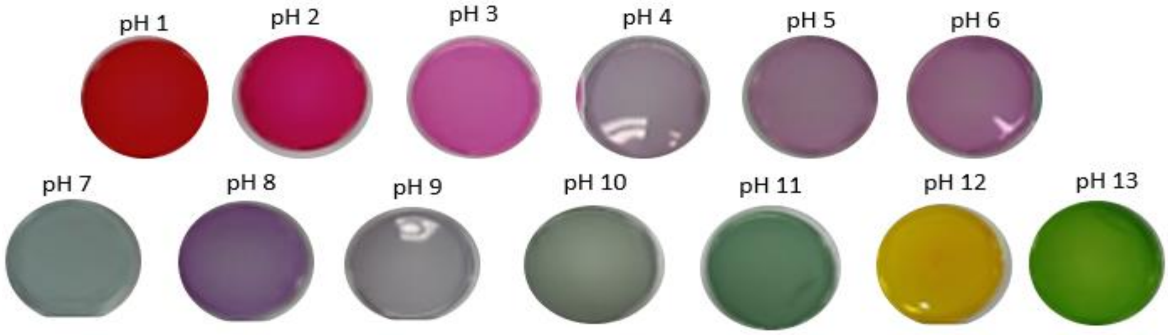

Figure 3. Color change of red cabbage anthocyanin

The color of anthocyanins is highly dependent on the pH of the solution. This is due to the molecular structure of anthocyanins that possesses an ionic nature. Generally, anthocyanins presented different structures at different pH values: flavylium cation (red, at strong acidic conditions), carbinol pseudobase (colorless, at weak acidic conditions), quinoidal base (blue, at weak alkaline conditions), and chalcone (yellow, at strong alkaline conditions) (Zhai, X. et al., 2017, Zhang, K. et al., 2020).

Table 1 summarizes the results of the color properties of red cabbage anthocyanin in a different buffer solution that shows the lightness of the solution has increased from acidic to basic buffer solution. This result was confirmed by the visual observation in Figure 3. The a* values and b* values of red cabbage anthocyanin also have different trends based on the pH of the buffer solution.

Table 1. Color properties of red cabbage anthocyanin in different buffer solution

Color properties	the pH of buffer solution				
	2	5	7	9	13
L*	43.9	45.1	45.6	45.7	46.6
a*	9.1	3.5	3.7	5	1
b*	-0.4	-0.9	-1	-1.1	8.7

Physical properties of the biofilm

The biofilm produced is translucent, durable, and stretchable as compared to plastic wrap. The red color did not change its color due to the low surrounding temperature.

Application of biofilm wrap for fresh-cut tomatoes and apples

The samples were analyzed visually using human eyes. After the biofilm was used to wrap the samples, it was observed that the biofilm did not change its color and the size has also shrunken as the samples were kept at a cold temperature inside the chiller. The resulted samples after 5 days of storage were shown in Figure 4 below.

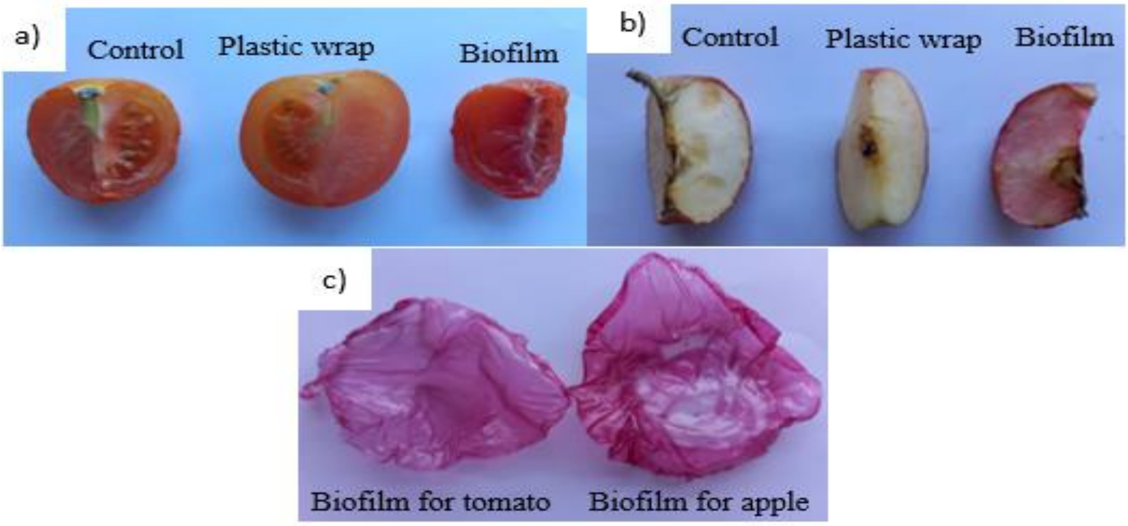

Figure 4. Samples observation after 5 days; a) tomatoes; b) apples; c) biofilms

After 5 days, as for plastic wrap, the samples still appear moist and fresh since the samples were kept in the refrigerator at 4°C. On the other hand, the control samples (without plastic wrap or biofilm) have lost their moisture after 5 days stored in the chiller. Then, it was observed that the samples have lost their moisture content after being wrapped with biofilm since starch is a hydrophilic substance and it will absorb moisture from the samples. This is also due to the hygroscopic nature of glycerol as a plasticizer. A significant factor concerning the films is their sensibility to environmental circumstances, such as temperature and relative humidity, since these films are hygroscopic materials, and thereby, highly vulnerable to water vapor (Abral, H. et al., 2019). In hygroscopic materials such as foods and edible films, the amount of water in the material is usually the most important factor. The biofilm also did not change its color after 5 days of storage due to the cold temperature that causes no pH changes as shown in Figure 4. It was also observed that the biofilm manages to prevent microbial attack due to the low storage temperature. However, if the samples were left at room temperature, a microbial attack may occur. The moisture content has lost significantly after several days of storage. This is clearly shown by the data recorded in Table 2 below.

Table 2. The moisture content of apples and tomatoes

Samples	Moisture content (%)			
	S1	**S2**	**S3**	**Average**
Apples	86.909	87.654	86.376	86.980
Tomatoes	95.775	93.433	93.372	94.193

The moisture content of tomatoes is slightly higher compared to the apples with a difference of 7.213%. Both samples have a very high moisture content which is more than 80% since apples are usually extracted for drinking juice whereas tomatoes are usually used as tomatoes ketchup and sauce. Therefore, both are susceptible to microbial attack due to moisture and need protection using packaging films. Barriers to oxygen, moisture, and light offer good protection for the most sensitive foods (Mousavi Khaneghah, A. et al., 2018).

The moisture loss of apples and tomatoes after 5 days of storage in the chiller at the temperature of 4°C suggested that the control samples (without wrap and biofilm) showed the highest moisture loss with apples and tomatoes are 81.34% and 69.14% respectively. The biofilm showed a slightly lower moisture loss as compared to the control. This result indicates that biofilm could not act as an oxygen and moisture barrier due to the poor sealing which has caused leakage of moisture and oxygen. A study by Abral, H. et al. (2019) reported that sago starch biofilms can be sealed by using Vaseline.

Due to its hydrophilic nature, polysaccharide-based coatings such as sago starch may provide only a minimal moisture barrier. Hence, a high moisture content food is not suitable to be used for the starch biofilm packaging since the biofilm is easily torn and melted when in contact with moisture from fruits. Fresh-cut produce has a much larger cut surface and consequently a much shorter shelf-life. Loss of quality characteristics such as color, firmness, juiciness, flavor, and significant moisture loss results in a shorter shelf life, which increases the likelihood of consumers rejecting the product.

Conclusion

In conclusion, red cabbage anthocyanin can be incorporated in sago starch-based film because of its compatibility with the starch. The biofilms are quite durable, stretchable, and suitable for dry food. However, it is not suitable for wrapping wet foods since starch film easily absorbs moisture from the wet food. For future works, the authors recommend using the biofilm as a packaging cover instead of wrapping it directly on the food. Besides, the food samples can be placed at room temperature to analyze the shelf life of the food. On top of that, the biofilm should be replaced with coating films to secure the freshness and moisture content of the apples and tomatoes. In addition, the biofilm needs to be sealed for preventing the leakage of moisture through exposed biofilm corners.

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References

Adel, A. M., Ibrahim, A. A., El-Shafei, A. M., & Al-Shemy, M. T. (2019). Inclusion complex of clove oil with chitosan/β-cyclodextrin citrate/oxidized nanocellulose biocomposite for active food packaging. *Food Packaging and Shelf Life, 20*, 100307.

Zambrano-Zaragoza, M. L., Gutiérrez-Cortez, E., Del Real, A., González-Reza, R. M., Galindo-Pérez, M. J., & Quintanar-Guerrero, D. (2014). Fresh-cut red delicious apples coating using tocopherol/mucilage nanoemulsion: Effect of coating on polyphenol oxidase and pectin methylesterase activities. *Food Research International, 62*, 974–983. https://doi.org/10.1016/j.foodres.2014.05.011

Choi, I., Lee, J. Y., Lacroix, M., & Han, J. (2017). Intelligent pH indicator film composed of agar/potato starch and anthocyanin extracts from purple sweet potato. *Food Chemistry, 218,* 122–128. https://doi.org/10.1016/j.foodchem.2016.09.050

Chu, M., Feng, N., An, H., You, G., Mo, C., Zhong, H., & Hu, D. (2020). Design and validation of antibacterial and pH response of cationic guar gum film by combining hydroxyethyl cellulose and red cabbage pigment. *International Journal of Biological Macromolecules, 162*, 1311-1322.

Das, D. K., Dutta, H., & Mahanta, C. L. (2013). Development of a rice starch-based coating with antioxidant and microbe-barrier properties and study of its effect on tomatoes stored at room temperature. *LWT-Food Science and Technology, 50*(1), 272-278.

Eskandarabadi, S. M., Mahmoudian, M., Farah, K. R., Abdali, A., Nozad, E., & Enayati, M. (2019). Active intelligent packaging film based on ethylene vinyl acetate nanocomposite containing extracted anthocyanin, rosemary extract and ZnO/Fe-MMT nanoparticles. *Food Packaging and Shelf Life, 22*, 100389.

Freitas, P. A., Silva, R. R., de Oliveira, T. V., Soares, R. R., Junior, N. S., Moraes, A. R., & Soares, N. F. (2020). Development and characterization of intelligent cellulose acetate-based films using red cabbage extract for visual detection of volatile bases. *Lwt, 132*, 109780.

Mousavi Khaneghah, A., Hashemi, S. M. B., & Limbo, S. (2018). Antimicrobial agents and packaging systems in antimicrobial active food packaging: An overview of approaches and interactions. *Food and Bioproducts Processing, 111*, 1–19. https://doi.org/10.1016/j.fbp.2018.05.001

Pereira, V. A., de Arruda, I. N. Q., & Stefani, R. (2015). Active chitosan/PVA films with anthocyanins from Brassica oleraceae (Red Cabbage) as Time-Temperature Indicators for application in intelligent food packaging. *Food Hydrocolloids, 43*, 180–188. https://doi.org/10.1016/j.foodhyd.2014.05.014

Prietto, L., Mirapalhete, T. C., Pinto, V. Z., Hoffmann, J. F., Vanier, N. L., Lim, L. T., & da Rosa Zavareze, E. (2017). pH-sensitive films containing anthocyanins extracted from black bean seed coat and red cabbage. *Lwt, 80*, 492-500.

Salvucci, E., Rossi, M., Colombo, A., Pérez, G., Borneo, R., & Aguirre, A. (2019). Triticale flour films added with bacteriocin-like substance (BLIS) for active food packaging applications. *Food Packaging and Shelf Life, 19*, 193-199.

Thakur, R., Saberi, B., Pristijono, P., Golding, J., Stathopoulos, C., Scarlett, C., & Vuong, Q. (2016). Characterization of rice starch-ι-carrageenan biodegradable edible film. Effect of stearic acid on the film properties. *International Journal of Biological Macromolecules, 93*, 952-960.

Yan, Q., Hou, H., Guo, P., & Dong, H. (2012). Effects of extrusion and glycerol content on properties of oxidized and acetylated corn starch-based films. *Carbohydrate Polymers, 87*(1), 707-712.

Zepon, K. M., Martins, M. M., Marques, M. S., Heckler, J. M., Morisso, F. D. P., Moreira, M. G., Ziulkoski & Kanis, L. A. (2019). Smart wound dressing based on κ–carrageenan/locust bean gum/cranberry extract for monitoring bacterial infections. *Carbohydrate polymers, 206*, 362-370.

Zhai, X., Shi, J., Zou, X., Wang, S., Jiang, C., Zhang, J., Huang, X., Zhang, W. & Holmes, M. (2017). Novel colorimetric films based on starch/polyvinyl alcohol incorporated with roselle anthocyanins for fish freshness monitoring. *Food Hydrocolloids, 69*, 308-317.

Zhang, K., Huang, T. S., Yan, H., Hu, X., & Ren, T. (2020). Novel pH-sensitive films based on starch/polyvinyl alcohol and food anthocyanins as a visual indicator of shrimp deterioration. *International Journal of Biological Macromolecules, 145*, 768-776.

Gennadios, A., Park, H. J., & Weller, C. L. (1993). Relative humidity and temperature effects on tensile strength of edible protein and cellulose ether films. *Transactions of the ASAE, 36*, 1867.

Abral, H., Basri, A., Muhammad, F., Fernando, Y., Hafizulhaq, F., Mahardika, M., Sugiarti, E., Sapuan, S. M., Ilyas, R. A., & Stephane, I. (2019). A simple method for improving the properties of the sago starch films prepared by using ultrasonication treatment. *Food Hydrocolloids*, *93*(February), 276–283. https://doi.org/10.1016/j.foodhyd.2019.02.012

FLEXURAL AND WATER ABSORPTION PROPERTIES OF BANANA/GLASS FIBRE REINFORCED POLYESTER COMPOSITES

Nor Hanifawati Inai*[a], Azizul Hakim Lahuri*[b], Jamie Lazaroo, Nur Khairunnisa Mohd Kamaruzaman, Logeswary Muniandy
Department of Science and Technology, University Putra Malaysia Bintulu Campus, Nyabau Road, 97008 Bintulu, Sarawak, Malaysia
*[a]hanifawati@upm.edu.my and *[b]azizulhakim@upm.edu.my

Abstract

Banana fibre is obtained from pseudostem after the crop harvest. Banana pseudostem fibre was the chosen material due to its abundance and relative cheapness. Researchers are looking at the possibilities of combining bio fibres such as banana fibre with polymer matrices to form composite materials to make the biocomposite revolution a reality Natural fibre-based thermoset composites are generally lower in strength performance compared to synthetic thermoset composites. Incoorporation with some amount of synthetic fibre enhanced the properties of the composites. Banana/glass fibre composites were fabricated using the hand lay-up method followed by compression moulding. Different volume ratios of banana to glass fibre were prepared and tested using flexural and water absorption tests. Results showed that both mechanical and physical properties show great enhancement by introducing a slight amount of glass fibre to the banana fibre polyester matrix.

Keywords: Banana fibre; Flexural strength; Glass fibre; Unsaturated polyester; Water absorption

Introduction

Advances in science and technology pose new challenges in relation to certain environmental issues, such as renewability, biodegradability, recyclability, and eco-friendliness, that need to be addressed to help preserve and protect our environment. Natural fibres are produced from renewable resources, biodegradable, and their specific properties are excellent. The density and cost are low, and the fibres are relatively non-abrasive, which gives processing advantages (Motaung & Linganiso, 2018).

Though several researches have been carried out on the potential use of natural fibre, there are some disadvantages of using natural fibre as reinforcement of composites. The primary weakness of natural fibre is its low modulus and strength comparable to synthetic fibre. Another drawback of natural fibre is its poor moisture resistance, high biodegradability when exposed to the environment and limited thermal stability.

The hydrophilic nature of lignocellulosic fibre also leads to low compatibility with hydrophobic polymer matrices and poor adhesion between fibres and matrices. Many studies have been carried out on the potential of the natural fibres as reinforcements for composites, and in several cases, the results show that the natural fibre composites own good stiffness, but the composites do not reach the same level of strength as glass fibre composites (Bax and Mussig, 2008; Oksman et al., 2003).

The study of hybrid composites has become an active area in composite material research in the past few decades (Rodrigues, LPS, 2020; John and Thomas, 2008). Hybrid biocomposites can be designed by combining synthetic fibre and natural fibre (bio fibre) in a matrix or combining two natural fibres/bio fibres in a matrix. Hybridization of low-cost lignocellulosic fibre with moisture- and corrosion-resistant synthetic fibres is one technique to enhance the strength, stiffness, and moisture resistance of the resulting hybrid fibre composites. In hybrid composites that contain two or more fibre types, the advantages of one type of fibre could compensate for the disadvantages of the other. As a consequence, a balance in properties, cost and environment can be achieved.

In this study, the reinforcing fibre used is derived from the banana trunk (pseudostem). The banana plant (*Musa sepientum*) is an annual crop and has been an important source of natural fibre for composites and other industrial applications. In this research, banana pseudostem, glass fibre and polyester are used as the main constituents to develop a natural fibre-polymer composite. The composites with fibre loading 10, 20, 30 and 40% of volume fraction were chosen. It is known that varying the amount of fibre in a composites material will affect the properties of the composites. Changing on physical and mechanical properties proportional with fibre loading were reported in previous researches (Idicula et al, 2009, Rozman et al, 1999, Abdul Khalil et al, 2007). However, at high fibre concentrations, the mechanical properties start to decrease, possibly due to increased fibre-to-fibre interactions and dispersion. This study focused on the determination of flexural and physical properties of hybrid banana pseudostem/glass fibre reinforced polyester composites. A flexural test was employed to evaluate the mechanical properties of banana/glass hybrid polyester composites, and a water absorption test was done to investigate the water absorption property of the composites. The effects of fibre loading on the flexural and water absorption properties of the composites are also studied.

Materials

Banana (*Musaceae*) fibres were obtained from Baala Bharat Agri Industries, Andhra Pradesh, India. The glass fibre (GF) with an average fibre length of 30 mm was obtained from Berjaya Bintang Timur Sdn. Bhd. Cheras, Kuala Lumpur. Unsaturated polyester acted as a matrix while methyl ethyl ketone peroxide (MEKP) was a hardener, both supplied by Berjaya Bintang Timur Sdn. Bhd. Cheras, Kuala Lumpur. The mixing ratio used was 99:1.

Methods

The composites with fibre loading 10, 20, 30 and 40% of volume fraction were fabricated using hand lay-up followed by compression moulding. Banana fibres were cut into an optimum length of about 30-40mm. Figures 1 (a) and (b) showed the bundle of glass and banana pseudostem fibre. Hybrid banana and glass fibre in the ratio of 100/0, 75/25, 50/50, 25/75 and 0/100 were evenly arranged in the mould and covered with the matrix. The composite was compressed at a constant pressure (10kg/cm^2) at room temperature to eliminate the bubbles in the composites and cured for 24 h. The samples were denoted as xB/yG, where x/y is banana fibre/glass fibre ratio, B is banana fibre, and G is glass fibre.

Figure 1: (a) Chopped glass fibres and (b) banana fibres

Flexural Test

The test specimens were cut as per ASTM D790 specifications. The tests were measured by employing a universal testing machine (UTM), INSTRON model 5566. The crosshead speed for flexural tests was maintained at 5 mm/min. In each case, five samples were tested, and the average values were reported.

Water Absorption Test

Water absorption studies were performed following the ASTM D570-98, Standard Test Method for Water Absorption of Plastic. This standard covers the determination of the relative rate of water absorption by the plastic when immersed in water.

The test specimens were prepared in a bar 50 mm x 25.4 mm x 3 mm. The test specimens are conditioned in an oven for 2 hours at 105°C. The sample is weighed, and thickness is measured before being immersed horizontally in distilled water for 24 hours. Mass uptake of the samples was measured periodically by removing them from the water bath. The samples were wiped off with tissue paper to remove excess water. The water absorption and thickness swelling have been calculated using Equation 1.

$$\text{Water absorption, WA\%} = \frac{W_2 - W_1}{W_1} \times 100, \qquad \text{Equation 1}$$

Where W_1 and W_2 are the weight of test specimens before immersion (g) and the weight of test specimens after immersion (g) respectively.

Results and Discussion

Flexural Properties

Flexural strength (FS) of composites were analyzed to study the effect of banana and glass fibre ratio on the flexural properties of hybrid banana pseudostem/glass fibre reinforced polyester composites. From Figure 2, it was observed that the addition of glass fibre significantly improves the flexural strength of banana/polyester composite. In 40 vol% fibre contents, the FS of the composites at 0 vol% of glass fibre and 100 vol% of banana fibre loading is 19.46 MPa. The addition of about 25 vol% of glass fibre to the banana/polyester composites increases its FS by 515%, and when both fibre fraction (banana and glass) is about 50 vol% each, the increment is about 598%. The incorporation of glass fibre along with natural fibre leads to composites having good flexural performance is expected as the glass fibre is stronger and stiffer than natural fibre. As a result of the increased glass fibre content, the FS increases due to the increased resistance to shearing of the composites due to the inclusion of rigid glass fibre (Mishra et al., 2003). According to Kalaprasad et al., (2004), the addition of glass fibres helps to attain a uniform dispersion of the banana fibre and prevent fibre-to-fibre contact in the matrix.

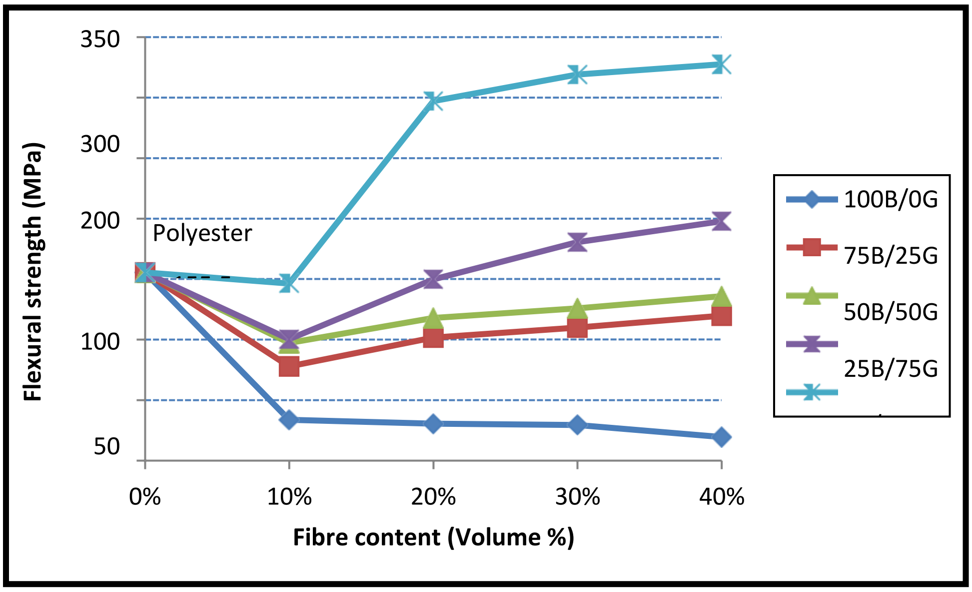

Figure 2: FS of banana/polyester, glass/polyester and hybrid banana/glass polyester composites at different fibre loadings

Water Absorption Properties

Water absorption behaviour of biocomposites received considerable attention due to the increase in the usage of composites for automotive and transportation applications. The water absorption property of the composites depends on fibre content, fibre orientation, the permeability of fibres, void content, and hydrophilicity of the individual component (Sreekumar et al., 2008).

Figure 3 shows the variation of water absorption by banana/polyester composites, glass/polyester composites and hybrid banana/glass polyester composites at 40 vol% of total fibre loading. According to Pothan and Thomas (2004), the water permeability of an overall composite is decided mainly by the nature of fibres. As expected, banana/polyester composites samples exhibited the highest water absorption, whereas glass/polyester composites showed the lowest properties. This is due to the hydrophilic character of natural fibres, therefore a higher content on banana fibre leads to a higher amount of water absorbed.

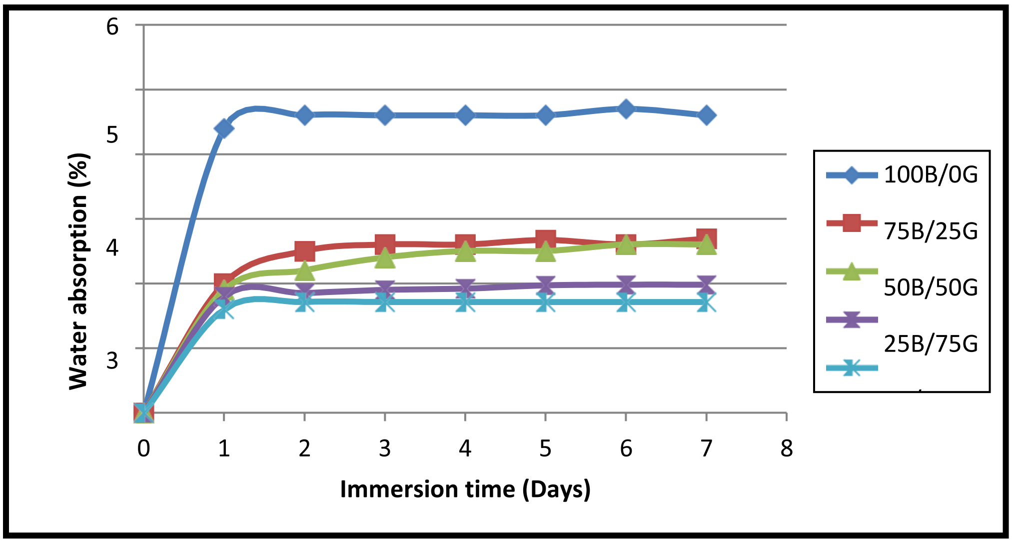

Figure 3: Water absorption of banana/polyester, glass/polyester and hybrid banana/glass polyester composites at 40 vol% fibre loading

Other than hydrophilicity nature of the banana fibre, the factor like poor fibre–matrix adhesion and presence of gap or void between banana fibre and matrix in the composites might have affected the water uptake characteristics of the composite. This is because the fibres in the composites are not completely embedded with the matrix, resulting in the appearance of voids in the structure of the polymerized natural fibres composites, which could increase the water absorption rate (Lasilla et al., 2002). Interestingly, the addition of only 25 vol.% glass fibre decreased the maximum water content in the composites by 130% and shows a steady decrease with the further addition of glass fibre. This observation is mainly due to water-impermeable glass fibre, which acts as a barrier to the banana fibre, preventing direct contact with water (Samal et al., 2009).

Conclusion

In general, banana/polyester composites have the lowest mechanical and physical properties among the composites. However, with the addition of a small fraction of glass fibre, these properties are improved significantly. This proves that the presence of glass fibre can greatly improve the physical properties of the composites and increase the potential use of biohybrid composites for outdoor applications. In conclusion, it is clearly shown that hybrid banana pseudostem/glass fibre had a positive effect on its composites' mechanical and physical properties.

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References

Abdul Khalil, H. P. S., Hanida, S., Kang, C. W, and Nik Fuaad, N. A. (2007). Agro-hybrid composites: The effects on mechanical and physical properties of oil palm fibre (EFB)/glass hybrid reinforced polyester composites. *Journal of Reinforced Plastics and Composites,* 26, 203- 218.

ASTM D 790 (2000). Standard test methods for flexural properties of unreinforced and reinforced plastics and electrical insulating materials. American Society for Testing Materials

ASTM D 570 (1998). Standard test methods for water absorption of plastics. American Society for Testing Materials.

Bax, B. and Mussig, J. (2008). Impact and tensile properties of PLA/Cordenka and PLA/flax composites. *Composites Science and Technology,* 68, 1601-1607.

Idicula, M., Sreekumar, P.A., Joseph, K., and Thomas, S. (2009). Natural fiber hybrid composites – A comparison between compression molding and resin transfer molding. *Polymer Composites* 30:1417-1425.

John, M. J. and Thomas, S. (2008). Biofibres and biocomposites. *Carbohydrate Polymers 71*(3), 343-364.

Kalaprasad, G., Francis, B., Thomas, S, Kumar, C.R., Pavithra, C., Groeninckx, G. and Thomas, S. (2004). Effect of fibre length and chemical modifications on the tensile properties of intimately mixed short sisal/glass hybrid fibre reinforced low density polyethylene composites. *Polymer International* 53: 624–1638.

Lassila, L. V, Nohrström, T. and Vallittu, P. K. (2002). The influence of short-term water storage on the flexural properties of unidirectional glass fiber-reinforced composites. *Biomaterials,* 23(10), 2221-2229.

Motaung, T. E, & Linganiso, L. Z. (2018). Critical review on agrowaste cellulose applications for biopolymers. In *International Journal of Plastics Technology* (Vol. 22, Issue 2). Springer India. https://doi.org/10.1007/s12588-018-9219-6.

Mishra, S., Mohanty, A.K., Drzal, L.T., Misra, M., Pari Ja, S., Nayak, S.K. and Triphaty, S.S. (2003). Studies on mechanical performance of biofibre/glass reinforced polyester hybrid composites. *Composite Science and Technology* 63:1377-1385.

Oksman, K, Skrivars, M. and Selin, J.F. (2003). Natural fibres as reinforcement in polyactic acid (PLA) composites. *Composite Science and Technology,* 63, 1317-1324.

Pothan, L. A. and Thomas, S. (2004). Effect of hybridization and chemical modification on the water-absorption behavior of banana fiber-reinforced polyester composites. *Journal of Applied Polymer Science,* 91, 3856-3865

Rodrigues, L. P. S, Silva, R. V, Aquino, E. M. F. (2020) Hybrid composites with glass fiber and natural fibers of sisal, coir, and luffa sponge. *Journal of Composites Material*, 46, 2055–2064.

Rodrigues, L. P. S, Silva, R. V, Aquino, E. M. F. Effect of accelerated environmental aging on mechanical behavior of curaua/glass hybrid composite. *Journal of Composites Material*, 46, 2055–2064.

Rozman, H.D., Tay, G.S., Kumar, R.N., Abubakar, A., Ismail, H., and Mohd. Ishak, Z.A. (1999) Polypropylene hybrid composites: A preliminary study on the use of glass and coconut fiber as reinforcement in polypropylene composites. *Polymer-Plastic Technology and Engineering* 38(5):997-1011.

Samal, S. K, Mohanty, S. and Nayak, S.K. (2009). Banana/glass fiber-reinforced polypropylene hybrid composites: Fabrication and performance evaluation. *Polymer-Plastics Technology and Engineering,* 48(4), 397-414.

Sreekumar, P. A, Albert P, Unnikrishnan, G, Joseph, K., Thomas, S. (2008). Mechanical and water sorption studies of eco-friendly banana fiber-reinforced polyester composites fabricated by RTM. *Journal of Applied Polymer Science,* 109, 1547-1555.

PRODUCTION OF BIO BRIQUETTES USING COFFEE RESIDUE WASTE, COCONUT SHELL CHARCOAL, AND PAPER AS ADHESIVES FOR COMMUNITY USE

Patrick Gani*, Jaromansen Damanik, Danni Dwiki Tampubolon, Radi, Chandra Setyawan
Department of Agricultural and Biosystems Engineering, Faculty of Agricultural Technology, Universitas Gadjah Mada Jln. Flora No.1 Bulaksumur, Yogyakarta 55281, Indonesia.
*patrickgani@mail.ugm.ac.id

Abstract

Coconut shells and coffee residue are two of the many biomass wastes that have not been utilized optimally. Both biomass materials have the potential to be used as alternative energy such as briquettes, then there are also papers that also have the potential to be used as adhesive material. The briquettes variations composition of coconut shell, coffee waste, and paper that were used in this research are 80%:20%:0%, 80%:10%:10%, 60%:40%:0%, and 60%:20%:20%. The materials used in this study are coffee residue waste, coconut shell and paper waste used as an adhesive material and water used as a solvent. The tools used in this study include a bomb calorimeter, analytical balance, oven, furnace, 100 mesh sieve, crusher, desiccator, press tool, and carbonization drum. The briquette quality analysis includes density, the proximate test (the moisture content uses ASTM D3173, the volatile matter content uses ISO 562:2010(E), ash content uses ASTM D3174-11 and ISO 1171:2010 (E), fixed carbon uses ASTM D 3172), and the calorific value is tested according to ASTM D5865-13. The study found density ranged from 1.095 g/cm3-0.763 g/cm3. The water content ranged from 5.813%-7.247%. The ash content produced ranged from 4.437%-7.167%, the volatile matter content was found to be between 5.132 & -8.377%, the fixed carbon range is between 84.617%-77.209%. The variation of the caloric value obtained from the experiment has a range between 7082.9 cal/g - 8070.213 cal/g. This study shows that the physical properties of briquettes are influenced by the composition of coffee residue, coconut shells, and paper, coffee residue waste can be used up to 20% to get maximum results. All variations of briquettes were found to meet Indonesia, Japan, US, and UK standards. The best variation that have the best performance are the 80%:20%:0% as it has the highest calorific value. But the best variation that can solve environmental problems is the 60%:20%:20% this is due to this variant utilizes environmental waste that human created and also this variation meet all of the standards of Indonesia, Japan, US, and UK.

Keywords: Agricultural waste; Briquettes; Calorific value; Physical properties of briquettes

Introduction

Indonesia is the largest coconut producing country in the world, with 16.6 million tons in 2019 (FAOSTAT, 2019), as the largest coconut producing country in the world. Indonesia is also one of the countries with the largest coconut consumption in the world and waste from coconut have not been utilized optimally, Coconut waste is often used as coconut shell charcoal which is relatively cheap and easy. Besides being used as coconut shell charcoal, coconut shell is a waste product of coconut and is one of the materials commonly found in the manufacture of biomass briquettes. Coconut shells also have a high calorific value of 5258 cal/g (Vidian, F., 2008) but only few use coconut shells as raw material for making charcoal and briquettes. Also one of the agricultural commodities wastes that have not been utilized optimally is coffee residue. Coffee residue waste itself is still very abundant. So far, only a few coffee processing factories utilize coffee waste as animal feed, plant fertilizer, and biogas. Coffee residue waste has a fairly high calorific value of 7360 cal/g (Tangmankongworakoon, N., 2019) making it suitable as a raw material for briquettes. Briquettes generally require binders to improve the physical properties of the briquettes. Generally, adding an appropriate amount of binder during the briquetting process will increase the calorific value of the briquette (Ismayana, A. et al., 2014). The hypothesis of this research is bio-briquettes can be made from biomass waste, and using the correct type and percentage of binder will produce better quality briquettes. Difference in binder type and percentage will produce briquettes with different characteristics, moisture content, volatile content, ash content, carbon content, and calorific value. In this investigation, the type of adhesive used was waste paper pulp. Paper is made from cellulose, pure wood fibers, binders, and other chemicals. The composition of the briquettes used in this study is based on Ministerial Regulation No. EMR 047 of 2006 on the guidelines for the manufacture and use of coal and solid coal-based fuels. In this study, the effect of ratio of different variations of coconut shells, coffee residue, and paper adhesive toward the physical properties of the resulting briquettes were studied

Materials and Methods

Materials and tools

The materials used in this study are coffee residue waste, coconut shell and paper waste used as an adhesive material and water used as a solvent. The tools used in this study include a bomb calorimeter, analytical balance, oven, furnace, 100 mesh sieve, crusher, desiccator, press tool, and carbonization drum.

Briquettes making procedures

The following Briquettes making procedures can be seen in the research flow diagram in Figure 1.

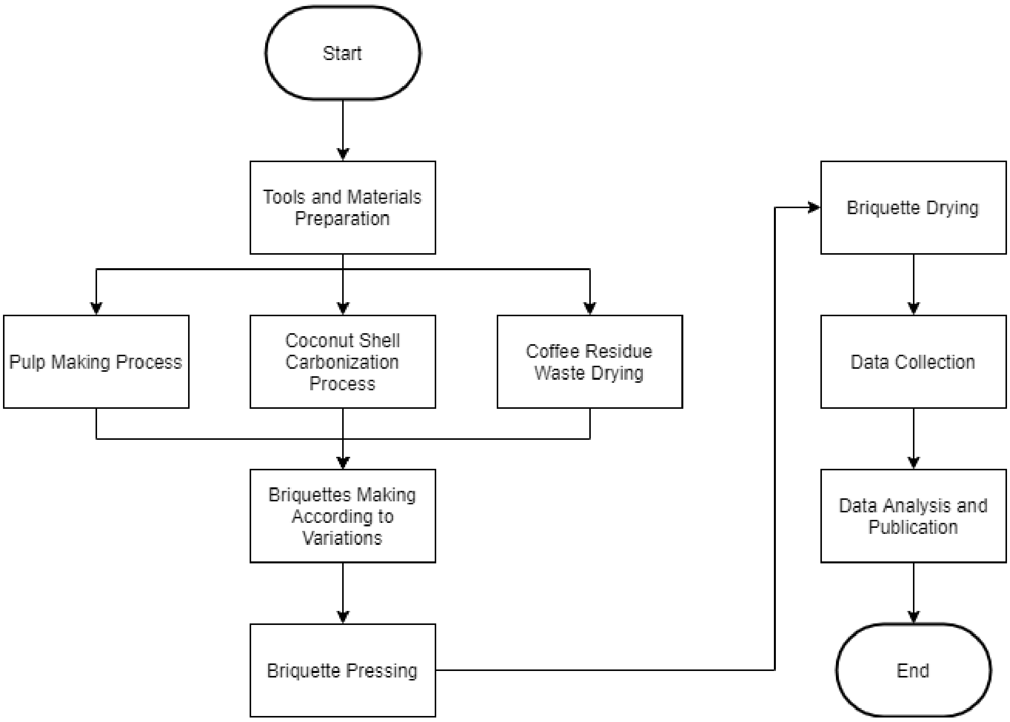

Figure 1. Research Diagram

The procedures starts with the material preparation followed by carbonation and from there crushing and sieving of 100 mesh sizes, adding coffee residue waste, and binder mixing process. The briquettes composition of coconut shell, coffee waste, and paper used were 80%:20%:0%, 80%:10%:10%, 60%:40%:0%, and 60%:20%:20%. Binder paper waste pulp is made by shredding the newspaper into pieces and soaking them in water overnight, then the drain the water and mashed to be pulp. As we can see from figure 1, in the briquette pressing process we use a cylindrical mold of 5 cm in diameter. The mold pressed using a pressing machine. The briquette then removed from the mold, and dried in the oven at 50 °C for 300 minutes.

Determination of Physical Properties of Briquettes

The briquette quality analysis includes density, the proximate test (the moisture content uses ASTM D3173, the volatile matter content uses ISO 562:2010(E), ash content uses ASTM D3174-11 and ISO 1171:2010 (E), fixed carbon uses ASTM D 3172), and the calorific value is tested according to ASTM D5865-13.

Results and Discussion

Briquettes Density

Preliminary test begins with a density test to determine the density of briquettes. By dividing the mass and volume of briquettes, the density of briquettes is shown in Table 1.

Tabel 1. Briquettes Density

No	Variation (%) Shell:Coffee: paper	Density (g/cm^3)
1	100%:0%:0%	1.095
2	80%:20%:0%	0.947
3	80%:10%:10%	0.934
4	60%:40%:0%	0.763
5	60%:20%:20%	0.948

From Table 1, we can see that the highest density value is from the control experiment which is coconut charcoal briquettes with average 1.095 g/cm^3. The density in this study ranged from 1.095 g/cm^3-0.763 g/cm^3 and it can be seen that along with the increase in coffee and paper, the density value decreases. This also occurs in the 60%:40% variation where the density value is only 0.763 g/cm^3 attributed to the low value of the coffee residue density, which is only 0.387 g/cm^3 (Mohamed, G. and Djamila, B., 2018). All variants of briquettes have higher density value than commercial charcoal briquettes (0.44 g/cm^3) and all variations except 60%:40% have a density value equivalent to wood briquettes (0.88-1.04 g/cm^3) (Sumangat, D. and Broto, W., 2009).

Determination of Physical Properties of Briquettes

To determine the quality of the briquettes produced, it is necessary to do a proximate test, which tests the moisture content, ash content, volatile matter content, and fixed carbon content. The results of the briquette proximate test are shown in Table 2.

Table 2. Physical Properties of the Briquettes

No	Variation (%) Shell:Coffee: paper	Water Content (%)	Ash Content (%)	Volatile Matter (%)	Fixed Cabon (%)
1	100%:0%:0%	5.813	4.437	5.132	84.617
2	80%:20%:0%	6.283	4.767	7.086	81.864
3	80%:10%:10%	7.127	5.633	7.881	79.359
4	60%:40%:0%	7.127	5.567	7.649	79.658
5	60%:20%:20%	7.247	7.167	8.377	77.209

The water content of the briquettes should be as low as possible because the lower the water content of the briquettes, the higher the calorific value of the briquettes (Venter, P. and Naude, N., 2015) as seen from Table 2. The water content produced in this study ranged from 5.813% - 7.247%. The increasing content of coffee and paper increases the water content is caused by the water content of coffee and paper which is quite high compared to control briquettes. Therefore, the water content increases with the addition of paper and water content. Determination of ash content is intended to determine the unburned part that no longer has the element of carbon after the briquettes are burned. The ash content is proportional to the content of inorganic materials contained in the briquettes. The ash content produced in this study ranged from 4.437%-7.167%. There is an increase in ash content along with the addition of variations of paper and coffee. For the addition of coffee, the addition of ash content is not too significant while for the addition of paper there is a significant addition as paper contains magnesium silicate. Volatile matter are the result of the decomposition of the compounds in material. When the briquettes are ignited, the high volatile matter briquettes produce more smoke. This is due to the reaction between carbon monoxide and alcohol derivatives (Hendra, D. et al., 2000). In this study, the volatile matter content was found to be between 5.132 & -8.377%, the same as the previous 3 experiments, this experiment also got an increase in ash content along with the addition of water and coffee content. This is caused by compounds in coffee such as carbonyl, alicyclic sulfur aromatic benzene, and heterocyclic compounds. Also, on paper that has a substance such as cellulose that gives coffee more volatile matter levels. Fixed carbon is the main heat source in the combustion process. Fixed carbon is influenced by the value of ash content and volatile matter, the content will be of high value if the water content, ash content, and volatile matter are low. From this research, the fixed carbon range is between 84.617% - 77.209%. Carbon content continues to decrease with the addition of coffee and paper content as well. However, the fixed carbon content obtained by all variations meets Indonesia, UK, Japan, and US standard.

The Calorific Value of Briquettes

From this study, the variation of the caloric value obtained from the experiment has a range between 7082.9 cal/g - 8070.213 cal/g. The calorific value of the briquettes can be seen in Figure 2.

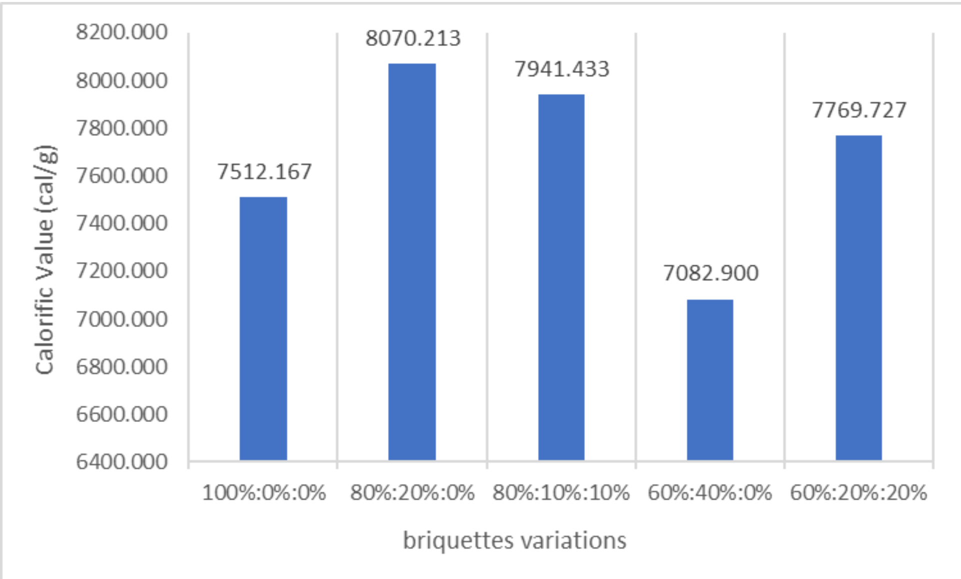

Figure 2. Briquettes Calorific Value

The results of this study indicate that the addition of coffee provides a significant calorific value with the addition of 20% coffee. This happens because coffee grounds waste has a fairly high calorific value of 7360 cal/g and also because of the high carbon content in coffee, which is 77.77%. The addition of paper also increases the calorific value. but if the variation of 60%:40% there is a decrease in the calorific value, this is because the resulting density is much lower than the other variations, this is due to the density affecting the calorific value, the greater the density, the greater the calorific value produced.

Conclusion

This study shows that the physical properties of briquettes are influenced by the composition of coffee residue, coconut shells, and paper, coffee residue waste can be used up to 20% to get maximum results. All variations of briquettes meet Indonesia, Japan, US, and UK standards. The highest calorific value is the 80%:20% variation, with a calorific value of 8070.21 cal/g with fixed carbon 81.864% the second highest is, 80%:10%:10% with a calorific value of 7941.43 cal/g, and fixed carbon 79.359%, followed by 60%:20%:20% with a calorific value of 7769.72 cal/g and fixed carbon 77.209%, and the lowest calorific value is the variation of 60%:40% with a calorific value of 7082.9 cal/g and 79.658% fixed carbon. The best variation that have the best performance are the 80%:20%:0%, as the 80%:20%:0% have the highest calorific value. But the best variation that can solve environmental problems is the 60%:20%:20% as this variant use a lot of the environmental waste that human created and also this variation meet all of the standards of Indonesia, Japan, US, and UK.

Acknowledgement

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References

FAOSTAT (2019). http://faostat.fao.org/site/567/Desktop Default.aspx?PageID= 567#ancor (Accessed: 10 May 2021)

Vidian, F. (2008). Gasifikasi tempurung kelapa menggunakan updraft gasifier pada beberapa variasi laju alir udara pembakaran. *Jurnal Teknik Mesin*, *10*(2), 88-93.

Tangmankongworakoon, N. (2019). An approach to produce biochar from coffee residue for fuel and soil amendment purpose. *International Journal of Recycling of Organic Waste in Agriculture*, *8*(1), 37-44.

Ismayana, A., Indrasti, N. S., & Erica, N. (2014). Pengaruh rasio C/N awal dan laju aerasi pada proses co-composting blotong dan abu ketel. *Jurnal Bumi Lestari*, *14*(1), 39-45.

Mohamed, G., & Djamila, B. (2018). Properties of dune sand concrete containing coffee waste. In *MATEC Web of Conferences* (Vol. 149, p. 01039). EDP Sciences.

Sumangat, D., & Broto, W. (2009). Kajian teknis dan ekonomis pengolahan briket bungkil biji jarak pagar sebagai bahan bakar tungku. Buletin Teknologi Pasca Panen, 5(1), 18-26.

Venter, P., & Naude, N. (2015). Evaluation of some optimum moisture and binder conditions for coal fines briquetting. Journal of The Southern African Institute of Mining and Metallurgy, 115(4), 329-333.

Hendra, D., & Pari, G. (2000). Penyempurnaan Teknologi Pengolahan Arang. Laporan Hasil Penelitian Pusat Penelitian dan Pengembangan Hasil Hutan. Balai Penelitian dan Pengembangan Kehutan, Bogor.

CRISPR/CAS9 (CLUSTERED REGULARLY INTERSPACED SHORT PALINDROMIC REPEAT/ASSOCIATED PROTEIN-9) TECHNOLOGY AS GENETIC THERAPY OF TYPE 1 DIABETES MELLITUS PATIENTS

Lilis Nur Fitriani*[1], Siti Miftachul Jannah[1], Kresna Purwandaru[2], Mochamad Nurcholis[3]
[1]Department of Biotechnology, University of Brawijaya, Indonesia
[2]Department of Chemical Engineering, University of Brawijaya, Indonesia
[3]Department of Agricultural Product Technology, University of Brawijaya, Indonesia
*lilisnurfitriani23@gmail.com

Abstract

The prevalence of patients with diabetes in Indonesia reaches 6.2 percent, which means that there are more than 10.8 million people suffering from diabetes in the year 2020. Diabetes mellitus is a metabolic disorder that can be caused by various etiologies, accompanied by the presence of chronic hyperglycemia due to impaired insulin secretion or impaired insulin action, or both. Meanwhile, Diabetes mellitus (DM) type 1 is a metabolic disorder caused by an autoimmune reaction, causing damage to pancreatic cells characterized by chronic hyperglycemia due to severe insulin deficiency. With the latest CRISPR technology, researchers are able to instantly change the DNA sequence of nearly any organism. The process of altering the hPSCs gene associated with T1D is the reduction of hiPSCs from patients with T1D, triggering improved isogenous control, and differentiation into pancreatic cells. The repair process of pancreatic cells can help in the regulation of insulin in the body. Thus, it can help patients in treating type 1 diabetes. One of the mechanisms of action of CRISPR/Cas9 is to produce DSB (Double Stranded DNA Breaks). DSB will be quickly repaired if through the NHEJ mechanism that triggers cell deletion. Induction of pluripotent stem cells (hiPSCs) obtained from patients was carried out by considering the genotypic factors. Then based on the previous research, total clones analyzed (n=300) were compared with Nocodazole cells and the results were 54.64% showing a significant increase in the use of the CRISPR editing method compared to the TALENT editing method. Based on the results of the questionnaire, there are 68.6% of respondents think that the CRISPR/Cas9 innovation is effective to be implemented as a therapy for Type 1 Diabetes Mellitus patients. It means that the community has a positive response to this innovation shows that it has a great opportunity to be developed and implemented in the long term.

Keywords: DNA; Genetic engineering; Insulin

Introduction

The International Diabetes Federation (IDF) states that Indonesia has diabetes alert status because it ranks 7th out of 10 countries with the highest number of diabetic patients. The prevalence of patients with diabetes in Indonesia reaches 6.2 percent, which means that there are more than 10.8 million people suffering from diabetes. The Chairperson of the Indonesian Endocrinology Association (Perkeni), Prof. Dr. Ketut Suastika said that this figure was estimated increased to 16.7 million patients in the year 2045. With this year's data, 1 in 25 Indonesians or 10 percent of Indonesia's population has diabetes. Diabetes mellitus is a metabolic disorder that can be caused by various etiologies, accompanied by the presence of chronic hyperglycemia due to impaired insulin secretion or impaired insulin action, or both. Meanwhile, Type 1 Diabetes Mellitus is caused by reduced insulin secretion due to damage to pancreatic cells based on an autoimmune process. The term diabetes mellitus comes from the Greek, namely diabetes which means "siphon" indicating excessive urine formation, and mellitus comes from the word "meli" which means honey. Diabetes mellitus (DM) type 1 is a metabolic disorder caused by an autoimmune reaction, causing damage to pancreatic cells characterized by chronic hyperglycemia due to severe insulin deficiency.

Blood sugar levels are controlled by the hormone insulin, which is produced by the pancreas, an organ located behind the stomach. In diabetics, the pancreas is unable to produce insulin according to the body's needs. Without insulin, the body's cells cannot absorb and process glucose into energy. In general, diabetes is divided into two types, namely type 1 and type 2 diabetes. Type 1 diabetes occurs when the patient's immune system attacks and destroys the pancreatic cells that produce insulin. This results in an increase in blood glucose levels, resulting in damage to the body's organs. Type 1 diabetes is also known as autoimmune diabetes. The trigger for this autoimmune condition is still not known with certainty. The strongest suspicion is that it is caused by genetic factors from the patient who are also influenced by environmental factors. Type 1 diabetes can develop quickly within a few weeks, even a few days. In most cases, Type 1 Diabetes Mellitus also has more severe risks and symptoms compared to Type 2. Therefore, it is necessary to have new innovations in the treatment and healing steps as well as therapy for Type 1 Diabetes Mellitus patients.

On the other hand, starting with genetic engineering, there have been advances in gene engineering technology that have sparked new enthusiasm and revolution. With the latest CRISPR technology, researchers are able to instantly change the DNA sequence of nearly any organism, thereby enabling the explanation of genetic function at the system level, as well as identifying the genetic causes of a condition or disease. Even a small change in a person's genes will fundamentally change the function of the cell. CRISPR technology has supported researchers with tools like never before. CRISPR/CAS9 is known to be effective in altering human pluripotent stem cell (hPSCs) genes. The process of altering the hPSCs gene associated with T1D is the reduction of hiPSCs from patients with T1D, triggering improved isogenous control, and differentiation into pancreatic cells (Kee et al., 2015). The repair process of pancreatic cells can help in the regulation of insulin in the body. Thus, it can help patients in treating type 1 diabetes.

Method

Data Collection Techniques

This study used a random sampling data collection technique through a questionnaire. Where the questionnaire will be used to measure the level of public interest in the use of CRISPR in general. The use of CRISPR aims to be a substitute or alternative for the treatment of Type 1 Diabetes Mellitus, where previously there was treatment using injection in the form of insulin.

The questionnaires that we distribute use the Likert Summated Rating (LSR) and Semantic Differential (SD) measurement techniques, both in the form of open-ended questions, as well as 1-5 response weighting questions. In making the questionnaire, we used the Google Form platform, then the time for filling out the questionnaire was from 23 May - 5 June 2021. Regarding the distribution of the questionnaire, it was carried out among the general public, both students and non-students.

Research Method

This research uses qualitative research methods with data/information collection methods using survey methods through questionnaires with the target respondents being all people in Indonesia. In addition, it also uses library research methods that refer to several existing research journals.

This research applies several stages of research work, as follows. First is the identification of problems, in which Indonesia is currently on diabetes alert status because it 7th out of 10 countries with the highest number of diabetic patients. The prevalence of patients with diabetes in Indonesia reaches 6.2 percent, which means that there are more than 10.8 million people suffering from diabetes in the year 2020. With regards to that, this research initiated an innovation for the therapy of Type 1 Diabetes Mellitus patients using CRISPR/Cas9. The second stage is formulation of the problem, which is viewed from the existing problems related to the importance of acting and acting to deal with diabetics, where the percentage is getting higher every year. The third stage is literature search in the form of journals and previous research on the use of CRISPR/Cas9. The next stage focusing on the research design. This paper is designed to create a useful idea to treat people with Type 1 Diabetes Mellitus. In terms of the process of collecting data and information, this research uses a survey method by distributing questionnaires to students and non-students. In addition to these methods, the authors also use library research methods. The next stage is data processing and analysis. The data from questionnaire will then be processed to become supporting data, whether this CRISPR/Cas9 innovation can be accepted or not by the public.

Data Analysis Techniques

The analysis in this study was carried out by processing the data that had been obtained from the previously distributed questionnaires. In the questionnaire there are several questions in the form of yes or no choices, as well as weighting questions on a scale of 1-5. So based on the data obtained from various respondents, a graph is plotted that include the summary of all the questions. From the graph, the development potential of this research is discussed.

Result and Discussion

CRISPR/Cas9

CRISPR associated proteins abbreviated to Cas are endonuclease enzymes produced by the gene from the "cas operon". There are two classes of Cas genes, namely class 1 which is a complex system for cutting foreign genetic material, while class 2 only uses a single protein with the same purpose. Each of these classes is further subdivided into Cas types (Staals et al., 2013). The protein component of Cas9 is composed of four components consisting of two main protein domains, namely REC and RuvC (Figure 2). REC and RuvC are linked by regions rich in the amino acid arginine (blue). While the next two components are HNH and PAM (Protospacer Adjacent Motif) which are DNA sequences composed of 2-6 bp (Song et al. 2016). The function of each component of Cas9, namely REC and NHN, functions as an endonuclease (cutting DNA); RuvC functions as a recognition site; PAM functions to insert the target DNA sequence immediately when Cas9 recognizes the foreign DNA being targeted. PAM is also a key in the process of the CRISPR/Cas9 system (Song et al., 2016).

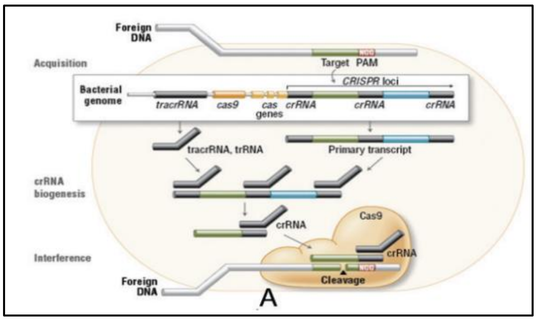


Figure 1. CRISPR/Cas9

Applications and Prospects of CRISPR/Cas9

CRISPR is a mechanism that allows cells to record, over time, their virus. Bits of DNA are passed on to progeny cells, so that cells are protected from viruses in not just one generation, but many generations of cells. This allows the cell to keep a record of infection, CRISPR is the effective locus of the genetic vaccination card in cells. So far, the development of CRISPR is still ongoing, various biotechnology researchers around the world are working on the application of CRISPR. In the next 10 years or so, CRISPR technology has the possibility to be used commercially. Clinical trials and therapies might even be possible, which is a very interesting thing to think about. But we must also consider that CRISPR technology can be used for things like enhancements. Prospective CRISPR could be futuristically used to edit human genes with enhanced properties, such as stronger bones, or lower susceptibility to cardiovascular disease or even having a different eye color or being taller.

Induction of Human Pluripotent Stem Cells (hPSCs)

Type 1 diabetes mellitus is a disease that requires gene component modifiers in its treatment (Otonkoski, 2016). Human pluripotent stem cells (hPSCs) are used because they can be obtained from diabetic patients easily and are able to differentiate into other cell types, namely pancreatic beta cells, muscle myocytes, adipocytes, and hepatocytes. Then CRISPR was used to become an important tool in increasing differentiation because it has been tested for its ability in the treatment of muscular dystrophy, and hematopoietic stem cells in treating sickle cell disease. Recent studies have shown that CRISPR can be used to correct deleterious mutations. One of the mechanisms of action of CRISPR/Cas9 is to produce DSB (Double Stranded DNA Breaks). DSB will be quickly repaired if through the NHEJ mechanism that triggers cell deletion. Induction of pluripotent stem cells (hiPSCs) obtained from patients was carried out by considering the genotypic factors. Then the hiPSCs differentiate into the relevant cell types, such as pancreatic islet cells, hepatocytes, and other cells (Otonkoski, 2016).

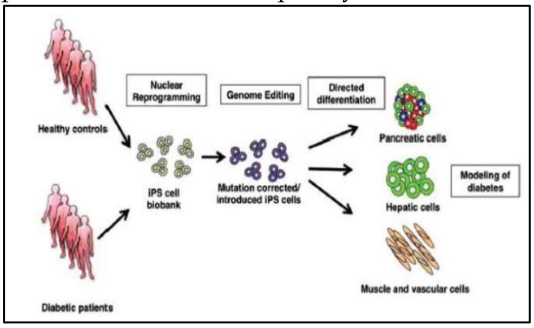


Figure 2. Use of Cell Repetition and Gene Alteration

Gene Editing of Pancreatic Progenitor Cells (hPSCs)

There are 3 types of pancreatic progenitor cells (hPSCs) which are known to produce insulin, namely NKX6.1-GFP HUES8 cells, H1 cells, and Nocodazole cells. One of the markers of in vitro differentiation in CRISPR is the presence of GFP. GFP is the result of improvements from DSB which was carried out with the presence of NHEJ donors on the use of CRISPR/Cas9. GFP plays a role in the derivation of pancreatic progenitor cells (NKX6.1-GFP HUES8 cells) (Yang et al., 2016). GFP specifically increased as much as 47.6% of the total cells expressing eGFP, so that Hues8 cells were used as a target for cell repair to produce insulin using CRISPR S.Pyogene. In addition, trials with other cells, namely H1 cells, showed a difference. The difference between H1 cells and CRISPR shows the number 17. 77% of the clones were positive for the two PCR outcomes by establishing the correct integration of the knockout and selection genes. Then the total clones analyzed (n=300) were compared with Nocodazole cells and the results were 54.64% showing a significant increase in the use of the CRISPR editing method compared to the TALENT editing method (Yang et al., 2016).

CRISPR Technique

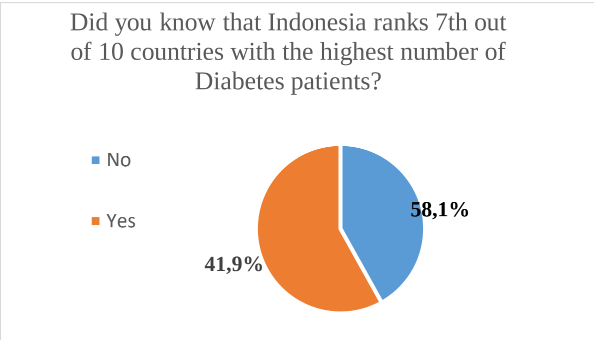
CRISPR able to change, repair, replace, delete, or insert parts of DNA in cells and living things. The two main components of this system require the enzyme Cas9 (CRISPR-associated protein-9 nuclease), namely an endonuclease (molecular scissors), and a guide RNA (guide RNA), which is usually a gRNA or sgRNA. The guiding RNA looks for the threatening and dangerous DNA nucleic acid sequence code (target DNA), then guides Cas9 to the location of the specific sequence to be changed. 3-5,13 The way CRISPR works is likened to a computer's find, cut, and paste system. Cas9 action depends on the presence of PAM (Protospacer Adjacent Motif) sequences on the target DNA.

CRISPR Results

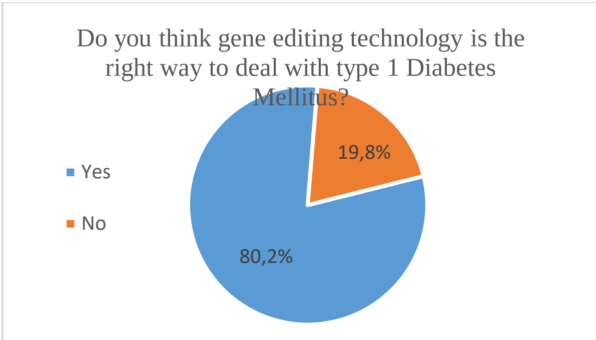
Based on previous research that has been done, CRISPR-Cas9 technology has been widely used as a research tool, and what is very interesting is the development of CRISPR-Cas9 as a therapeutic technology. Although studies on eukaryotic cells have only been around for the last three years, many potential applications of CRIPSR-Cas9 for human diseases including genetic disorders, cancer and viruses have been discovered. So far, CRISPR/Cas9 has been applied to four human viruses HPV, HBV, EBV and HIV. For monogenic recessive disorders due to loss-off-function mutations (such as Huntington's disease, cystic fibrosis, sickle cell anemia, or Duchenne muscular dystrophy), Cas9 can be used to correct the mutations causing these diseases (Hsu et al., 2014; Shin et al., 2016). Research conducted by Harel et al. (2015) found that the use of CRISPR-Cas9 technology to edit and knock out genes related to aging and degenerative diseases in turquoise killifish significantly increased lifespan indicating that the use of CRISPR-Cas9 technology can effectively increase life expectancy and prevent the aging process (Harel et al. 2015). Thus, it can be concluded that CRISPR/Cas9 has the potential to be used in the treatment of type 1 Diabetes Mellitus patients.

Questionnaire Analysis

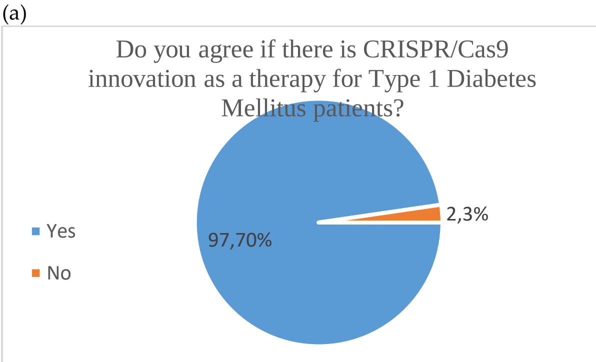
Based on the research survey questionnaire that was distributed from 23 May - 5 June 2021, there are total of 86 respondents with an age distribution of 18 to 24 years. Based on Figure 3a, it can be seen that there are 41.9% of respondents who still unaware of the fact that Indonesia ranks 7th out of 10 countries with the highest number of Diabetes patients. This shows that public knowledge and awareness regarding diabetes is still quite low. Even though diabetes is not a severe problem yet, there are more than 10.8 million people suffering from diabetes in the year 2020. The development of gene editing technology is the solution proposed by this study, and according to Figure 3b, 80.2% of respondents believe it is appropriate for overcoming the problem of diabetic Mellitus type 1. On the other hand, Figure 3c shows that 97.7% of respondents agreed that the CRISPR/Cas9 innovation should be used as a therapy for Type 1 Diabetes Mellitus patients, after respondents were given a brief summary of CRISPR/Cas9. Then, as indicated in the bar chart Figure 3d, 68.6% of respondents believe that the CRISPR/Cas9 innovation is effective enough to be used as a therapy for Type 1 Diabetes Mellitus patients. In Figure 3e, 65.9% of respondents believe that the CRISPR innovation/Cas9 kite will be utilised as a long-term therapy for patients with type 1 Diabetes Mellitus.



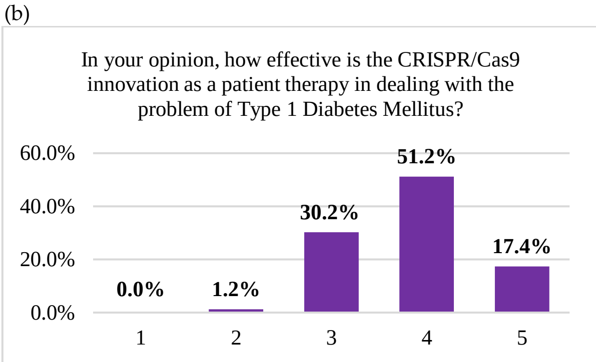
(a)



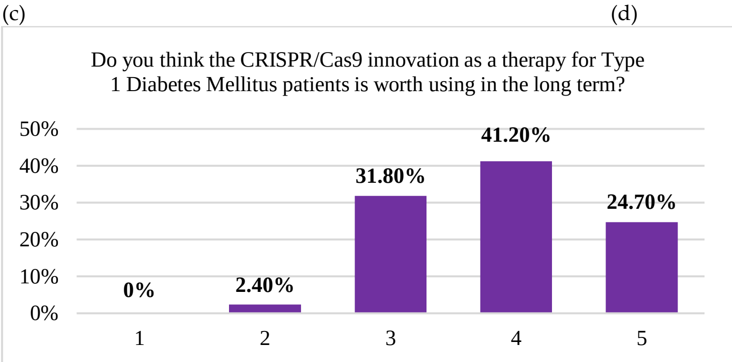
(b)



(c)



(d)



(e)

Figure 3. Survey Results using Questionnaires

Conclusion

Diabetes mellitus (DM) is a metabolic disease consisting of Type 1 DM caused by an autoimmune reaction of pancreatic cells, and Type 2 DM due to the body's inability to use insulin optimally. Type 1 diabetes mellitus is a disease that requires gene editing in its treatment. CRISPR/Cas9 is present in bacteria and archaea that play a role in adaptive immunity. The process of repairing pancreatic cells helps regulate the body's insulin as well as treats Type 1 DM. Based on the results of the questionnaire, the community has a positive response to the CRISPR/Cas9 innovation as a therapy for type 1 Diabetes Mellitus patients and shows that this innovation has a great opportunity to be developed and implemented in the long term.

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References

Harel, I. et al. (2015). A Platform for Rapid Exploration of Aging and Diseases in a Naturally Short-Lived Vertebrate *Cell, 160* (5), 1013–1026.

Hsu P. Et Al. (2014). Development and applications of CRISPR-Cas9 for genome engineering. *Cell, 157*(6), 1262-1278.

Kee, A. et al. (2015). Dissecting Diabetes/Metabolic Disease Mechanisms Using Pluripotent Stem Cells and Genome Editing Tools. *Molecular Metabolism, 4*(9), 593–604.

Otonkoski, T. (2016). New Tools for Experimental Diabetes Research: Cellular Reprogramming and Genome Editing.

Song, G. et al. (2016). Crispr/Cas9: A Powerful Tool for Crop Genome Editing. *The Crop Journal, 4*(2), 75–82.

Staals, RHJ et al. (2013). Structure And Activity of The Rna-Targeting Type III-B Crispr-Cas Complex of Thermus Thermophilus. *Molecular Cells, 52*(1), 135–145.

Yang, D. et al. (2016). Enrichment Of G2/M Cell Cycle Phase in Human Pluripotent Stem Cells Enhances Hdr-Mediated Gene Repair with Customizable Endonucleases. *Scientific Reports, 6*(February), 21264.

Shin, S. et al. (2016). CRISPR/Cas9-induced knockout and knock-in mutations in Chlamydomonas reinhardtii. *NCBI, 13*(6).

LACTAID "FAST ACT LACTOSE INTOLERANCE RELIEF" DAIRY FROM MUNG BEAN *(VIGNA RADIATA, L.)* TEMPEH WITH CHOCOLATE FLAVOUR FOR LACTOSE INTOLERANCE PEOPLE

Haida Setyani*, Noveria Anggi Nurrahmah, Yesica Meiliana Widiastuti, Siti Mariyam, Joko Nugroho
Department of Agricultural and Biosystems Engineering, Faculty of Agricultural Technology, Universitas Gadjah Mada, Jln. Flora No.1 Bulaksumur, Yogyakarta 55281, Indonesia.
*haidasetyani@mail.ugm.ac.id

Abstract

Milk is a white liquid from the milking process of mammals that contains several dissolved compounds such as water, milk sugar (lactose), protein, fat, calcium, iron, vitamins, and phosphorus. Cow's milk has a lot of nutrient content and benefits, but not everyone can consume it. Cow's milk can cause some diseases in people with lactose intolerance. Lactose intolerance is a condition where there is no or insufficient amount of the enzyme lactase in human body. The innovative solution to help people with lactose intolerance is milk from vegetable ingredients, such as mung bean tempeh. The benefit of consuming mung beans is nutritional support for humans and helps fill vitamin B1 and thiamine needs. The methods of this research are conducting a literature review on journals about the materials such as milk, mung beans, and the fermentation process of tempeh which is made from soybeans. The research results showed that mung beans are one of the vegetables that contain high protein and have good nutritional value. Fermentation processing in tempeh can increase digestibility and some levels of vitamin B. Tempeh milk is an innovation in tempeh processing which is carried out by the extraction process. The viscosity values between soybean and mung bean tempeh milk are not much different, thus, the manufacture of mung bean milk can be developed because the resulting product can be normal categorized as existed in the market. Milk powder production is one way to maintain shelf life of the milk. The addition of flavours improves the products to be more attractive and accepted, one of which is the taste of chocolate. The use of mung beans into mung bean tempeh milk powder with chocolate flavour needs to be developed to increase food diversification.

Keywords: Lactose intolerance; Milk; Mung beans; Tempeh

Introduction

Milk is a fat emulsion in water that contains several dissolved compounds. Milk contains 87.5% water, 5% milk sugar (lactose), 3.5% protein, and 3-4% fat. The content in milk can be used as a source of calcium, phosphorus, and vitamin A. Milk protein serves as an emulsifier so that the fat and water in the milk are not easily separated. The milk protein quality is comparable in value to meat and egg protein, especially high in lysine. Lysine is one of the essential amino acids that the body needs (Widodo, 2002).

Based on The Central Bureau of Statistics, total milk production in 2017-2019 has increased along with the increase in the number of cattle populations. Milk production in 2017 was 132.222,76 litres meanwhile in 2019 increased to 165.775,02liter (BPS, 2019). The cow's milk has a lot of nutrients content and benefits. However, cow's milk could not be taken by those of lactose intolerance. For people with lactose intolerance, cow's milk can cause diseases such as nausea and vomiting, headaches, sore throat, and joint pain. Lactose intolerance is a condition where there is not enough enzyme lactase in the body because the small intestine could not produce enough of enzyme lactase to digest milk sugar or lactose (Matthews et al, 2005). Because of that, there is a need for manipulation of cow's milk substitute for people with lactose intolerance, such as extracting milk products from non-animal source for example tempeh. The use of mung bean seeds in tempeh is to increase the protein content in tempeh. The fermentation process throughout tempeh production is for cohesion and adhesion of the mung bean.

Mung beans are one of the commodities that have a great opportunity to be developed as an export commodity. This is because mung beans are in great demand by various countries. Mung bean is the second ranked at 19.82% after corn exports which was 63, 34%. The benefit of consuming mung beans is as a nutritional supplement for humans because the content is good for the body and provides vitamin B1 and thiamine (Belinda, 2009). In addition, consuming mung beans can prevent heart disease, prevent cancer, a source of protein, increase immunity, improve digestion, and so on.

The benefits and high production of mung bean seeds need to be balanced with food processing diversity or diversification in order that people can consume and get the benefits of mung bean seeds. The diversity of food processing from mung beans seeds is relatively limited, for example the consumption is limited to mung beans seeds porridge and mung bean seeds ice. Tempeh is a product that utilizes biotechnology because it applies the principles of science and engineering in its processing (Mahadi, 2016). Tempeh has a short shelf life, so innovation is needed to extend the shelf life of tempeh, one of them is processing it into a milk powder. Therefore, this research was conducted to give information and new innovation on the use of mung bean seeds. The results of this research are expected to provide knowledge about alternative nutrition that can be accessed by all society at an affordable price but has good nutrition comparable to cow's milk. Hence, mung bean seeds milk powder processing can be carried out in a sustainable manner to meet the nutritional content for people with lactose intolerance.

Materials and Methods

Study Literature

Likewise, what the authors did in this study, the steps are conducting a literature review on journals which discuss the material, such as milk, red beans, and fermentation process of tempeh which is made from soybeans. The obtained data from this literature review will be used as references to make and develop a milk from mung beans. Literature review using some journals from reputable sources, such as Sumarto and Ani Radiati (2016) about Analysis of Physical Properties, Organoleptic Properties, and Nutritional Values of Tempeh from Non-Soybean Legumes. Based on the Filiyanti's research (2013), the process of making tempeh milk starts form tempeh that have been aged of 2 days are cut with a size of 1,5 x 1,5 x 1,5 cm and steamed for 10 minutes. After that, tempeh then mashed using blender with added water at a ratio of 1:2 tempeh and water to obtain tempeh porridge. Next, the tempeh porridge is done filtering with a filter cloth to separate between tempeh dregs and tempeh milk. After that, to making tempeh milk become powder, we use freeze dryer.

Results and Discussion

Mung Bean Seeds

Mung bean (*Vigna radiata*, L.) is a type of leguminous plant that has the third rank in Indonesia after soybeans and peanuts. According to Evita (2009), every 100 grams of mung bean seeds contain 345 calories, 22 grams of protein, 1.2 grams of fat, 62.9 grams of carbohydrates, 125 milligrams of calcium, 320 milligrams of phosphorus, 6.7 milligrams of iron, 157 milligrams of vitamins. A, 0.64 milligrams of vitamin B, 1.6 milligrams of vitamin C, and 10 grams of water. Meanwhile, according to research by Wijaningsih (2008), 100 grams of mung beans contain 22 grams of protein which is rich in the amino acid lysine (7.94%). In addition, mung beans also contain 1.2 grams fat lower than soybeans, i.e 15.6 grams in 100 grams fat. Therefore, mung beans are very good for people who avoid high fat consumption.

Mung beans have very important benefits because they have good nutritional value. Mung beans contain other anti-nutrients, namely hemagglutinin and phytic acid. The carbohydrate content in mung beans is 62.5% so that it can be used as an energy source. Mung beans contain hemagglutinin which can agglomerate red blood cells which are toxic. Fermentation process can increase the availability of iron elements for the body which can prevent anaemia (Astawan, 2004). According to research conducted by Misrawati and Marliah in 2019, mung bean juice can be useful for improving haemoglobin levels.

Tempeh

Tempeh is a traditional Indonesian fermented food which uses fungi, particularly *Rhizopus* sp. This process can increase soluble proteins and carbohydrates. Furthermore, it is possible to significantly decrease antinutritional factors, such as protease inhibitors, phytic acid, tannin content, and flatulence producing factors (Ferial, et al. 2014). Fungi that grow on the basic ingredients for making tempeh can hydrolyze complex compounds, such as carbohydrates, fats, and proteins into simple compounds in the form of glucose, fatty acids, and alpha amino acids, which are easily digested by human body (Alrasyid, 2007). Tempeh is a processed product that utilizes the fermentation process. Fermentation processing can increase digestibility and some levels of vitamin B. The mold that grows on tempeh is able to produce several enzymes such as protease enzymes to break down the protein into shorter peptides and free amino acids, lipase enzymes to break down fats into fatty acids, and amylase enzymes to break down complex carbohydrates into simpler compounds (Sumarto, 2016). The process of making mung bean tempe is the stages of soaking, boiling, soaking in acid, and fermenting molds (Maknun, 2015). Based on research conducted by Sumarto in 2016, the following (Table 1) is a comparison of the content between soybean tempeh and mung beans in 100 grams:

Table 1. Comparison of The Content Between Soybean Tempeh and Mung Bean Tempeh

Type of Beans	Energy Content (kal)	Carbohydrate Content (g)	Proteint Content (g)	Fat Content (g)
Soybean	400	32	35,1	17,7
Mung Bean	345	62,9	22,2	1,2

Based on the table, it is found that mung beans have a lower energy content than soybeans. This is due to the lower protein content and fat content but higher carbohydrate content than soybeans. This high carbohydrate content shows that mung beans can be used as a source of energy. Therefore, these mung beans have the potential to be developed as raw material for tempeh.

Based on the research conducted by Ani Radiati and Sumarto (2016), mung bean tempeh has a water content of 56,19%. The value obtained indicates that mung bean tempeh has met the Indonesia National Standard 3144:2009 which is the maximum water content of 65% (BSN, 2009). The relatively high-water content in tempeh makes tempeh prone to being overgrown by other microorganisms that will cause damage to the tempeh. The organoleptic test for mung bean tempeh conducted by Sumarto (2016) included color, aroma, taste, and texture. The organoleptic test results for mung bean tempeh were 2,8/5 for color 3,3/5, for taste, 3/5 for aroma, and 2,8/5 for texture. Based on the result, mung bean tempeh has color, taste, aroma, and texture lower than soybean tempeh. Therefore, it is necessary to process mung bean tempeh that can improve the color, taste, aroma, and texture so that panelists and consumers can accept it, one of which is making mung bean tempeh milk. Making plant-based milk from mung beans has the same process as other plant-based milks. Based on research conducted by Supriyono (2008), the results showed that mung bean milk contains a number of antioxidants and can scavenge (brittle) free radicals by 24,28% so that mung bean milk is good for consumption.

Based on research by Siti Maryam (2015), the presence of vitamin E levels in mung bean tempeh is caused by fermentation. Fermentation occurs due to the activity of traditional inoculum in the form of a mixture of several *rhizopus* such as *Rhizopus oligosporus*, *Rhizopus oryzae*, *Rhizopus stolonifer* and *Rhizopus arrhizus*, which are found in hibiscus leaves. Vitamin E is an organic compound that functions as an antioxidant. The function of vitamin E as an antioxidant is due to the presence of a double bond in the structure of vitamin E. The presence of this double bond will result in electron delocalization and will ultimately have the ability to capture or reduce free radicals generated or formed as a result of the oxidative stress process. The ability to capture free radicals is what causes a substance containing vitamin E to act as an antioxidant or free radical scavenger (Wijaya, 2007). Making tempeh with mung beans is an innovation that can increase the efficiency of tempe utilization and encourage people to be able to meet nutritional needs. In addition, the antioxidants contained in mung bean tempeh indicate that mung bean tempeh can be used as a functional food and is safe for consumption by all groups. Utilization or processing of tempeh into milk is one way that can be used to help lactose intolerance people to continue to consume milk.

Fermentation Process in Tempeh

Mung beans tempeh is processed by fermenting *Rhizopus* mold. The molds that are often used in making tempeh are *Rhizopus microsporus* and *Rhizopus oryzae*. The two molds had different β-glucosidase enzyme activities. The activity of the β-glucosidase enzyme *Rhizopus microsporus var. chinensis* is stronger than *Rhizopus oryzae* (Purwoko et al., 2001). *Rhizopus microsporus* which is often used as tempeh mold, is *Rhizopus microsporus var. oligosporus.* According to Schipper and Stalpers (1994), *Rhizopus microsporus var. oligosporus* is a revised result of *Rhizopus oligosporus*.

Making tempeh consists of 2 steps. The steps are soaking and fermentation. In the soaking stage, the mung beans are immersed in water, so that the release of the thin skin of soybeans is easier and causes the mold to ferment the soybeans without the skin. At that time there was fermentation by bacteria that live around soybeans. In the fermentation stage, large organic molecules are degraded into smaller organic molecules, so that soybeans, which were originally relatively hard, become soft and easy to digest. In both stages, the process of hydrolysis of isoflavone glycosides into isoflavone aglycones takes place. Making tempeh begins by soaking soy mung beans in water. Because mung beans are soaked in water, the mung beans conditions are anaerobic. Microbes that live around soybeans carry out fermentation activities. In general, these microbes perform lactic acid fermentation.

Lactose Intolerance People

Lactose intolerance is a condition where there is no or insufficient amount of the enzyme lactase in a person's body. Lactase enzyme is an enzyme whose job is to break down the sugar lactose into simpler sugars, namely glucose and galactose. Compared to lactose, which is a disaccharide, glucose and galactose are monosaccharides that can be digested and absorbed by the intestines for metabolic processes. The absence of the enzyme lactase causes diarrhea, murus, or nausea symptoms sometime after drinking milk. Drinking milk can also cause allergies. This is known as protein intolerance. One type of protein in milk is lactoglobulin, which in the body of certain people can act as a very strong antigen that can cause allergies.

Zero Lactose Powder from Tempeh

Tempeh milk is a new innovation in tempeh processing which is carried out by the extraction process. The content of isoflavone, real phytoestrogens, lecithin, saponin, vitamin A, and vitamin C in tempeh milk is higher than cow's milk. Tempeh milk contains Vitamin B12 which is not contained in soy milk and does not contain cholesterol, but the calcium content of tempeh milk is lower than cow's milk (Galeaz and Navis, 1999). Based on the research of Herlin Santoso et al. (2017) about An Analysis of Tempe Milk Quality with Variation of Beans and Stabilizer, it was found that the viscosity value of mung bean milk was not much different from the viscosity of soybean tempeh milk. The viscosity value of peanut tempeh milk based on the Herlin's research is as shown in Table 2.

Table 2. The Value Viscosity of Bean Tempeh Milk

Type of Nuts	Stability		
	CMC (carboxy methyl cellulose)	Arabic Gum	Without Stability
Soybean	$37{,}05 \times 10^{-3b}$	$6{,}84 \times 10^{-3d}$	$6{,}30 \times 10^{-3d}$
Mung Bean	$34{,}85 \times 10^{-3a}$	$6{,}60 \times 10^{-3b}$	$6{,}33 \times 10^{-3d}$

The viscosity value of tempeh milk is influenced by the stabilizer inclusion, besides that the fiber and starch content in the beans also affects the viscosity. The viscosity value between soybean and mung bean tempeh milk is not much different, that manufacture of mung bean milk can be developed because the resulting product can be categorized as existed product available in the market. Based on Herlin's research, the protein content in soybean tempeh milk was 7.57% and in the mung bean tempeh milk was 15.75%. The protein content of mung bean tempeh milk is higher than that of soybean tempeh milk. In contrast to Sumarto's research which states that the protein content of soybeans is greater than that of mung beans. One of the factors that affect the amount of protein content is during the fermentation process of making tempeh.

The organoleptic analysis of the colour and aroma of peanut milk conducted by Herlin (2017) shows insignificant different of colour and aroma of mung bean tempeh milk and soybean tempeh. Tempeh milk has a distinctive tempeh aroma because of the degradation of the components in tempeh during the fermentation process (Kasmidjo, 1990). The processing of mung bean tempeh milk in liquid form; therefore, this paper compiled the ideas or innovations about processing milk in powder form. Dairy products in dry powder form have a longer lifespan, lower transportation, and storage costs, and will be easier for transportation. Thus, a process is needed to produce dry powdered milk that is easily soluble without losing its nutrients. The use of a freeze dryer to produce powder is an alternative, besides, the addition of chocolate flavour will provide a more varied and more delicious taste for consumption. The addition of chocolate flavour is also to reduce the dominant tempeh taste and aroma.

Conclusion

Based on the readily availability potential number of mung beans in Indonesia and the benefits of the beans, the other use of mung beans such as for powder milk production needs to be developed. There are several studies regarding the manufacture of milk from mung beans and the manufacture of tempeh from mung beans but production of milk from mung bean tempeh in powder milk is scarcely described. Therefore, the use of mung beans into tempeh milk powder with chocolate flavour needs to be developed to increase food diversification.

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References

Alrasyid H. (2007). Peranan isoflavon tempe kedelai, fokus pada obesitas dan komorbil, Majalah kedokteran nusantara, Vol 40(3)

Astawan, M. (2004). Tetap Sehat dengan Produk Makanan Olahan. *Tiga Serangkai.* Solo

Astawan, M. (2009). *Sehat dengan Hidangan Kacang dan Biji-bijian*. Jakarta: Penebar Swadaya.

Badan Pusat Statistik Indonesia. (2019). Retrieved from https://www.bps.go.id/indicator/24/376/1/produksi-susu-perusahaan-sapi-perah.html.

Badan Pusat Statistik Indonesia. (2020). Retrieved from https://www.bps.go.id/indicator/55/61/1/produksi-tanaman-sayuran.html

Badan Pusat Statistik. (2012). *Survei Sosial Ekonomi Nasional Buku 1: Pengeluaran untuk konsumsi penduduk Indonesia*. Jakarta, Indonesia: Badan Pusat Statistik.

Belinda. (2009). Evaluasi Mutu Cookies Campuran Tepung Kacang Hijau Dan Beras (Oryza sativa) Sebagai Pangan Tambahan Bagi Ibu Hamil. [Skripsi]. Bogor: Fakultas Teknologi Pertanian, IPB. Hal: 32

Evita. (2009). Pengaruh Beberapa Dosis Kompos Sampah Kota terhadap Pertumbuhan dan Hasil Kacang Hijau. *Jurnal Agronomi.* 2(13): 5-8

Ferial M. Abu-Salem, Rasha K, Mohamed, Ahmed Y. Gibriel, Nagwa M. H. Rasmy. (2014). Levels of Some Antinutritional Factors in Tempeh Produced from Some Legumes and Jojobas Seeds. *International Journal of Biological, Agricultural, Biosystems, Life Science and Engineering* Vol:8 No:3, 2014

Galeaz, R. D and Navis, S.R. (1999). Soymilk-Drink Up, *Soyfoods USA*. Vol 4(8) BSN, B.S.N., 2009. SNI 3144:2009 - Tempe Kedelai, Indonesia

Kasmidjo, R.B. (1990). *Tempe:* Mikrobiologi dan Biokimia Pengolahan serta Pemanfaatannya. PAU Pangan dan Gizi. UGM. Yogyakarta

Mahadi, imam; Darmawati; Apriyanti. (2016). Pengaruh Lama Fermentasi Terhadap Kualitas Susu Tempe Bubuk Sebagai Pengembangan LKM (Lembar Kerja Mahasiswa) Materi Bioteknologi Pangan. *Jurnal Biogenesis.* Vol. 13(1): 1-10

Maknun, L. (2015). Pengaruh Jenis Inokulum dan Waktu Inkubasi Terhadap Sifat Fisiko-Kimia Tempe Kacang Merah (Phaseolus vulgaris L.). [*Skripsi*]. Bogor (ID). Institut Pertanian Bogor.

Maryam, Siti. (2015). Potensi Tempe Kacang Hijau (Vigna Radiata) Hasil Fermentasi Menggunakan Inokulum Tradisional Sebagai Pangan Fungsional. *Jurnal Sains dan Teknologi.* Vol 4(2)

Purwoko, T. (2001). Biotransformasi Isoflavon oleh Rhizopus oryzae UICC 524 dan Rhisopus microsporus var. chinensis UICC 521 pada Fermentasi Tempe dan Aktivitas Antioksidan Isoflavon Aglikon terhadap Oksidasi Minyak Kedelai. [*Tesis*]. Depok: Universitas Indonesia.

S. B. Matthews, J. P. Waud, A. G. Roberts, A. K. Campbell. (2005). Systemic Lactose Intolerance: A New Perspective on An Old Problem. *Postgrad Med J*. 81:167–173. Retrieved from https://pmj.bmj.com/content/81/953/167.short pada Hari Kamis, 10 Juni 2021.

Santoso, H. and Moulina, M. A. (2017). An Analysis of Tempeh Milk Quality with Variations of Beans and Stabilizers. *Agritepa J. 8*:38-52

Schipper, M.A.A. and J.A. Stalpers. (1994). A Revision of the genus Rhizopus II. The Rhizopus microsporus group. *Studies in Mycology. 25*: 20-34.

Sumarto, Ani Radiati. (2016). Analisis Sifat Fisik, Sifat Organoleptik, dan Kandungan Gizi pada Produk Tempe dari Kacang Non-Kedelai. *Jurnal Aplikasi Teknologi Pangan* 5 (1)

Widodo, Wahyu. (2002). *Bioteknologi Fermentasi Susu*. Pusat Pengembangan Bioteknologi Universitas Muhammadiyah Malang. Malang.

Wijaningsih, W. (2008). Aktivitas Antibakteri In Vitro dan Sifat Kimia Kefir Susu Kacang Hijau (Vignradiata) oleh Pengaruh Jumlah Starter dan Lama Fermentasi. (*Tesis*). Semarang: Universitas Diponegoro.

Wijaya H. (2007). *Pangan fungsional dan kontribusinya bagi kesehatan*. seminar online charisma ke 2

FUNCTIONAL CaO CATALYST IMPREGNATED WITH TRANSITION METAL FROM WASTE EGGSHELL AS SUPPORT FOR BIODIESEL PRODUCTION VIA TRANSESTERIFICATION

Nur Afiqah Ali [1], Nor Shafinaz Azman [1], Nozieana Khairuddin*[1,2]
[1]Department of Science and Technology, Faculty of Humanities, Management and Science, Universiti Putra Malaysia Bintulu Sarawak Campus, 97008 Sarawak, Malaysia
[2]Institut Ekosains Borneo, Universiti Putra Malaysia Bintulu Sarawak Campus, 97008 Sarawak, Malaysia
*nozieana@upm.edu.my

Abstract

Biodiesel is renewable energy that can be processed from waste cooking oil where it is more environmentally friendly and an alternative to fossil fuel. The eggshell consists of calcium carbonate ($CaCO_3$) that can be converted to calcium oxide (CaO) under high temperatures and can be used as a catalyst. The objective of this study is to observe the capability of CaO impregnated with nickel (II) nitrate hexahydrate ($Ni (NO_3)_2{\cdot}6H_2O$) and ammonium molybdate ($(NH_4)_6Mo_7O_{24}{\cdot}4H_2O$). The catalyst loadings employed in this study were 0.2wt%, 0.3wt%, 0.4wt%, 0.5wt%, 0.6wt%, 0.7wt%, 0.8wt%, 0.9wt%and 1.0wt%. The yield of biodiesel impacts the reaction variables, including the amount of catalyst that is utilised. This study shows that 0.5wt% give yield 90% compare to the others. The outcome shows that CaO can be corporated with metals successfully and shows that waste cooking oil can convert to biodiesel.

Keywords: Biodiesel; Transesterification; Waste cooking oil (WCO); Waste eggshell (WES); Wet impregnation method

Introduction

In the current era of globalization, the demand for diesel is increasing every year. Diesel is non-renewable energy that will run out and cause environmental pollution, where diesel is widely used in the industrial sector and vehicles. Furthermore, the increased demand for energy (non-renewable) jeopardizes environmental sustainability and impairs biodiesel production's energetic balance (Bharti et al. 2020). Furthermore, fossil fuels are regarded as environmentally detrimental because they contribute to various issues such as global warming and climate change by releasing greenhouse gases into the atmosphere, either indirectly or directly (Ling et al. 2019). Biodiesel, renewable energy, is one of the alternative fuels to deal with the non-renewable energy resource shortage (Putra et al. 2018 and Fadhil et al. 2016). Biodiesel is one of the most environmentally friendly energy sources since it is non-toxic and emits fewer greenhouse gases (Ullah et al. 2016). It can be made from a variety of oils, including soybean oil, corn oil, palm oil, and others (Chuah et al. 2017). The most popular way to make biodiesel is to use a homogeneous or heterogeneous catalyst in a transesterification reaction (Ling et al. 2019). Aside from that, waste cooking oil (WCO) has the potential to be an economically viable oil feedstock for biodiesel production (Chung et al. 2019). To counter the high capital cost of materials, studies have suggested that using WCO as an alternative feedstock can eventually lower the cost of biodiesel because it has a cheaper rate and is more readily available than palm oil and soybean oil as pure refined vegetable oil which requires an additional purification process (Chung et al. 2019). In spite of this, the use of waste catalysts in the production of biodiesel has the potential to make it a more cost-effective and environmentally friendly resources (Chung et al. 2019). CaO is the most widely used alkali earth oxide catalyst, and this is due to the fact that it is readily available in nature, is inexpensive, has a long lifetime, has the highest activity under mild reaction conditions, and has high activity (Chung et al. 2019 and Mazaheri et al. 2018). CaO is a frequently used catalyst for feedstock transesterification where a variety of waste materials contain large concentrations of Ca and are readily available at a low cost since CaO is excellent catalyst support as it has an enormous surface area and a large number of pores (Marwaha et al. 2018). Figure 1 shows that Throughout Peninsular Malaysia, the production of chicken eggs has steadily increased, and the eggshell waste, which contains valuable sources of CaO, may be readily obtained from various sources, including restaurants (Kavitha et al. 2019). There have been a plethora of earlier studies on the effects of dopants on the performance of chemicals. The addition of metal dopants enhances and increases a catalyst's catalytic activity, which gives a positive outcome (Kamarullah et al. 2019 and Dey et al. 2017). As reported by a previous study by Guo et al. (2015) proves that a method of increasing the catalytic activity of a catalyst is to dope the metal substrate on which it is supported. According to Azman et al. (2021) the bimetallic Ni-Mo/AC catalyst promotes more excellent coke formation resistance than other catalysts. Nickel catalysts are highly effective in catalytic processes because of the abundant nickel supply and the inexpensive cost of nickel (Dantas et al. 2017). According to Azman et al. (2021), the bimetallic Ni-Mo/AC catalyst promotes more excellent coke formation resistance than other catalysts, and because of its extended life and ability to be reused, it has the potential to improve catalyst stability and provide opportunities for further application at the pilot-scale. Till today, no study has yet shown that the two transition metals incorporated with CaO from waste eggshells. Due to the energetic interaction between the active acidic promoter (Ni-Mo) and the large surface area of the AC support, the great activity of Ni-Mo/AC is achieving (Azman et al. 2021) and promising when CaO impregnates with the transition metal. Therefore, this study aims to observe the performance of waste eggshell (WES) impregnated with transition metal for biodiesel production via the transesterification process. Moreover, to compare the output of biodiesel yield % obtained in the catalytic performance between plain CaO catalyst and impregnated Cao in transesterification and to find out the catalyst stability and its capability to be reused.

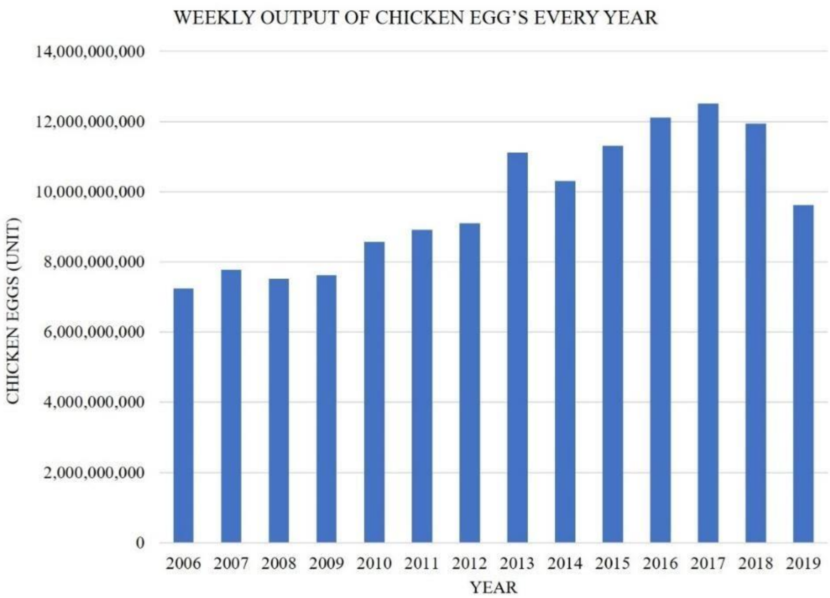

Figure 1: Weekly output of chicken eggs (Industry statistics, 2020).

Materials and Methods

Materials

The support catalyst was derived from the waste eggshell obtained from the selected bakeries in Bintulu with the appearance of the 0.8 mm mesh support. The nickel (II) nitrate hexahydrate (Ni $(NO_3)_2{\cdot}6H_2O$) with molecular weight 290.79 g/mol and ammonium molybdate ($(NH_4)_6Mo_7O_{24}{\cdot}4H_2O$) with molecular weight 1235.86 g/mol were purchased from HmbG Chemicals. The liquid product used was phosphoric acid (lab-grade standard in 85%) from the Reagent brand. The WCO feedstock which is palm oil-based was obtained from registered food premises in Bintulu town.

Catalyst Synthesis

Catalyst preparation for this this research was prepared by referring the method of Khalit et al. (2020) with minor modification which the activated carbon (AC) was replaced with CaO eggshell as support. The waste eggshell (WES) was washed thoroughly using distilled water to remove contaminants and dirts before being dried in an oven for 100^{0}C in 24 hours. Then, the dried waste eggshell was grinded into powder form screened using 0.8mm mesh size. Later, the powder was calcined using normal furnace with setting temperature of 900^{0}C in 3 hours. Next, the calcined powder was then impregnated with transition metal species to synthesize the NiO: MoO: WES with ration of 10:10:80 % of the molar mass, by constant stirring for six (6) hours. The impregnated metals on the (WES) catalyst support was subsequently desiccated at 100°C for 24 hours for cooling down. Afterwards, AC doped with the metals was calcined under O_2 gas flow at 900°C for 3 hours.

Catalyst Performance Evaluation

Simultaneous transesterification of Waste Cooking Oil (WCO)

The transesterification of WCO was performed in a 250 mL mechanically stirred, semi-batch reactor, as shown in Figure 2. Table 1 shows for each run, was using methanol to oil ratio of 1: 10 and synthesized catalyst loading of 0.5, 0.4, 0.3, and 0.2wt.% were placed in the reactor with fixed setting temperature of 75^{0}C during the heating process and run-time of 1 hour and RPM 300. Next, the transesterified liquid was poured and keep into filter funnel and let to settle down and form 4 layer indicates spent catalyst followed by glycerol in the bottom, middle part is unreacted methanol and upper part is biodiesel. The spent catalyst was discharged and washed using n-hexane to remove unreacted methanol and triglyceride and oven dried in an oven for next cycle experiment. Lastly, the products yield % were recorded for further analytical testing.

Table 1. Different catalyst weight percentage

Catalyst loading (wt.%)	Time of reaction (minutes)	Methanol to oil ratio
0.2		
0.3		
0.4		
0.5		
0.6	60	1:10
0.7		
0.8		
0.9		
1.0		

Free Fatty Acid Value assessmenet of waste cooking oil (WCO)

Van Gerpen et al. (2004) highlighted the number of carboxylic acid groups such as fatty acids in a mixture of chemical compounds. Typically, a fixed amount of a sample is diluted in an organic solvent (usually isopropanol) and titrated with KOH (potassium hydroxide), using phenolphthalein as an essential colour indicator. Furthermore, the acid number measures the acidity of any substance, such as biodiesel. The volume of KOH (in mg) required to neutralize the acidic constituents is 1 g of the sample. In this study, the three (3) WCO samples, and the acid values of their liquid oil products are shown in Table 2. The acidic and FFA values are expressed in Equations below:

$$Acid\ Value = \frac{(Volume\ of\ 0.01\ M\ KOH \times 0.01 \times 56.1)}{Weight\ of\ oil\ (g)} \qquad \text{Equation 1}$$

$$FFA = \frac{Acid\ value}{2} \qquad \text{Equation 2}$$

Results and Discussion

WCO Assessment as Biodiesel Feedstock

The production of FAME reached 60% and above for the waste cooking oils used; nevertheless, the free fatty acids and water present in the waste cooking oil were responsible for the degradation of the CaO catalyst (Kouzu et al. 2017). In contrast, the reduction in FFA conversion after the optimum temperature was due to the lack of methanol at high temperatures (Bet-Moushoul et al. 2016). When the water content of WCO-based biodiesel was increased from 0.6% to 2.5%, the yield dropped (Mazaheri et al. 2021). However, increasing the temperature from 65°C to 75°C resulted in a decrease in FFA conversion, where can be explained by the fact that increasing the temperature would increase the reaction rate and equilibrium constant for an endothermic reaction (Bet-Moushoul et al. 2016).

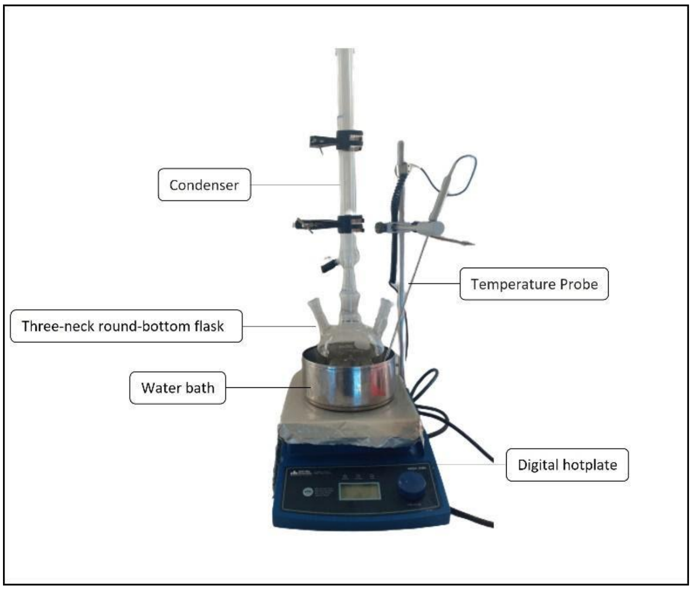

Figure 2: Transesterification process.

Table 2. Properties of WCO

Properties	WCO	Standard
A. Acid value	i.8.936 ii.5.905 iii.4.265	ASTM D974
B. FFA	i.4.468 ii.2.953 iii.2.133	

Biodiesel turnout by weight percentage of catalyst loading

Based on the experiment conducted, biodiesel yield obtained shows predominate performance towards the WES/NiMo catalyst. Catalyst loading of 0.5 wt% gives maximum yield 90% compared to others due to its relevant mass and prepared material methanol to oil ratio in reactor size. Furthermore, this is because larger quantities of the catalyst (0.5 wt%) provide a greater number of catalytically active sites. The higher the FAME yield of the product, the more efficient the interactions between both reactants and catalytically active sites are in the applied reaction conditions (Kamarullah et al. 2019 and Marinkovic et al. 2016). It is suggested that, as the catalyst amount decrease, the yield produced will also reduce. Nevertheless, at comparable reaction conditions, when the catalyst loading grew over 0.5wt %, the pure FAME content yield began to decline. Meanwhile, the higher the catalyst amount (> 0.9%) consume will lead to reduction in yield due to concentrated suspension form in the catalytic reaction thus slower the stirring rate during transesterification reaction. Additionally, a rise in the viscosity of the reaction medium resulted from the creation of dense slurry from the catalyst powder and the WCO, which made homogeneous mixing of the reactants difficult and, as a result, decreased the contact between the catalyst and reaction component (Rabie et al. 2019 and Negm et al. 2017).

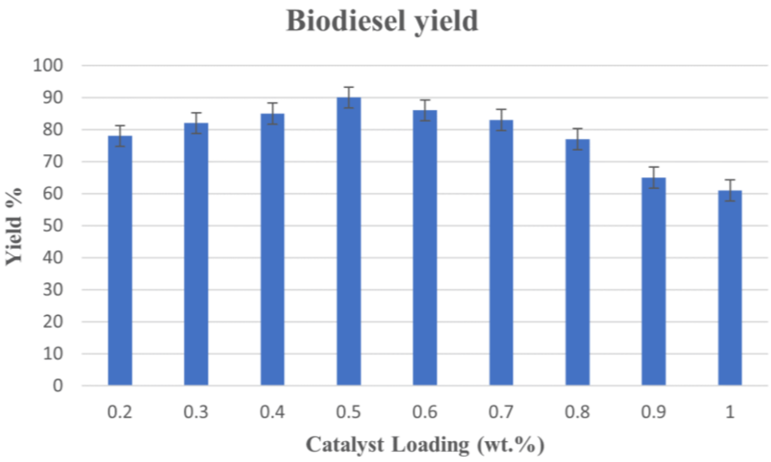

Figure 3:Biodiesel yield over varies catalyst loading (wt.%).

Conclusion

The different weight percentages of CaO catalysts impregnated with transition metal used the highest biodiesel production at 90% by using 0.5wt% catalyst loading is the optimum. CaO impregnated with high transition metals Ni-Mo is directly linked to these findings. The established catalyst was used to develop biodiesel using the transesterification method. The compatibility of CaO impregnated with a transition metal and WCO as a potential candidate for biodiesel production in pilot scale was found to be promising. More research is needed on reaction time, catalyst loading and reusability of catalyst to determine the propriety of Ni-Mo/CaO as biodiesel catalysts. Thus, it may aid biodiesel production by improving product quality and reducing purification procedures and waste.

Acknowledgment

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References

Azman, N. S., Marliza, T. S., Yun Hin, T. Y., & Khairuddin, N. (2021). Production of Biodiesel from Waste Cooking Oil via Deoxygenation Using Ni-Mo/Ac Catalyst. *Processes, 9*(5), 750.

Bet-Moushoul, E., Farhadi, K., Mansourpanah, Y., Nikbakht, A. M., Molaei, R., & Forough, M. (2016). Application of CaO-based/Au nanoparticles as heterogeneous nanocatalysts in biodiesel production. *Fuel, 164*, 119-127.

Bharti, R., Guldhe, A., Kumar, D., & Singh, B. (2020). Solar irradiation assisted synthesis of biodiesel from waste cooking oil using calcium oxide derived from chicken eggshell. *Fuel, 273*, 117778.

Chuah, L.F., Klemeš, J.J., Yusup, S., Bokhari, A., Akbar, M.M., 2017. A review of cleaner intensification technologies in biodiesel production. *J. Cleaner Prod. 146*, 181-193.

Chung, Z. L., Tan, Y. H., Chan, Y. S., Kansedo, J., Mubarak, N. M., Ghasemi, M., & Abdullah, M. O. (2019). Life cycle assessment of waste cooking oil for biodiesel production using waste chicken eggshell derived CaO as catalyst via transesterification. *Biocatalysis and Agricultural Biotechnology, 21*, 101317. doi: 10.1016/j.bcab.2019.101317

Dantas, J., Leal, E., Mapossa, A. B., Cornejo, D. R., & Costa, A. C. F. M. (2017). Magnetic nanocatalysts of Ni0. 5Zn0. 5Fe2O4 doped with Cu and performance evaluation in transesterification reaction for biodiesel production. *Fuel, 191*, 463-471.

Dey, S., Dhal, G. C., Prasad, R. &Mohan, D. (2017). Effects of doping on the performance of CuMnOx Catalyst for CO oxidation.*Bulletin of Chemical Reaction Engineering & Catalysis,12*(3), 370-383.

Fadhil, A.B., Aziz, A.M., Altamer, M.H., 2016. Potassium acetate supported on activated carbon for transesterification of new non-edible oil, bitter almond oil. *Fuel 170,* 130-140.

Guo, N., Xi, Y., Liu, S. &Zhang, C. (2015). Greatly enhancing catalytic activity of graphene by doping the underlying metal substrate.*Scientific reports,5*, 12058

Industry statistics. (n.d.). Retrieved from http://flfam.org.my/index.php/industry-statistics.

Kamarullah, S. H. K., Razak, Z. K. A., Shohaimi, N. A. M., Zuply, K. F., & Azri, N. S. (2019). Production of biodiesel from palm oil using alumina supported potassium iodide catalyst with nickel dopant. Gading *Journal of Science and Technology* (e-ISSN: 2637-0018), 2(02), 26-33.

Kavitha, V., Geetha, V., & Jacqueline, P. J. (2019). Production of biodiesel from dairy waste scum using eggshell waste. *Process Safety and Environmental Protection, 125*, 279-287.

Khalit, W. N. A. W., Marliza, T. S., Asikin-Mijan, N., Gamal, M. S., Saiman, M. I., Ibrahim, M. L., & Taufiq-Yap, Y. H. (2020). Development of bimetallic nickel-based catalysts supported on activated carbon for green fuel production. *RSC Advances, 10*(61), 37218-37232.

Kouzu, M., Fujimori, A., Suzuki, T., Koshi, K., & Moriyasu, H. (2017). Industrial feasibility of powdery CaO catalyst for production of biodiesel. *Fuel Processing Technology, 165*, 94-101.

Ling, J. S. J., Tan, Y. H., Mubarak, N. M., Kansedo, J., Saptoro, A., & Nolasco-Hipolito, C. (2019). A review of heterogeneous calcium oxide-based catalyst from waste for biodiesel synthesis. *SN Applied Sciences, 1*(8). doi:10.1007/s42452-019-0843-3

Marwaha, A., Rosha, P., Mohapatra, S. K., Mahla, S. K., & Dhir, A. (2018). Waste materials as potential catalysts for biodiesel production: Current state and future scope. *Fuel processing technology, 181*, 175-186.

Mazaheri, H., Ong, H. C., Masjuki, H. H., Amini, Z., Harrison, M. D., Wang, C. T. & Alwi, A. (2018). Rice bran oil-based biodiesel production using calcium oxide catalyst derived from Chicoreus brunneus shell. *Energy, 144*, 10-19.

Mazaheri, H., Ong, H.C., Amini, Z., Masjuki, H.H., Mofijur, M., Su, C.H., Anjum Badruddin, I. and Khan, T.M., 2021. An Overview of Biodiesel Production via Calcium Oxide Based Catalysts: Current State and Perspective. *Energies, 14*(13), 3950.

Negm, N. A., Sayed, G. H., Habib, O. I., Yehia, F. Z., & Mohamed, E. A. (2017). Heterogeneous catalytic transformation of vegetable oils into biodiesel in one-step reaction using super acidic sulfonated modified mica catalyst. *Journal of Molecular Liquids, 237*, 38-45.

Putra, M. D., Irawan, C., Udiantoro, Ristianingsih, Y., & Nata, I. F. (2018). A cleaner process for biodiesel production from waste cooking oil using waste materials as a heterogeneous catalyst and its kinetic study. *Journal of Cleaner Production, 195*, 1249–1258. doi: 10.1016/j.jclepro.2018.06.010

Rabie, A. M., Shaban, M., Abukhadra, M. R., Hosny, R., Ahmed, S. A., & Negm, N. A. (2019). Diatomite supported by CaO/MgO nanocomposite as heterogeneous catalyst for biodiesel production from waste cooking oil. *Journal of Molecular Liquids, 279*, 224-231.

Ullah, F., Dong, L., Bano, A., Peng, Q., Huang, J., 2016. Current advances in catalysis toward sustainable biodiesel production. *J. Energy Inst. 89*, 282-292.

Van Gerpen, J., Shanks, B., Pruszko, R., Clements, D., & Knothe, G. (2004). Biodiesel Analytical Methods: August 2002-January 2004 (No. NREL/SR-510-36240). National Renewable Energy Lab., Golden, CO (US).

OPTIMIZATION OF DRYING TIME AND FOAM THICKNESS ON THE PRODUCTION OF MICROWAVE-DRIED EGG WHITE POWDER

Desy Putri Utami*, Sukardi, Claudia Gadizza Perdani
Department of Agroindustrial Technology, Faculty of Agricultural Technology, Universitas Brawijaya
Jl. Veteran, Malang, East Java, Indonesia 65141
*desyputriutami@student.ub.ac.id

Abstract

The present study aimed to determine the optimum foam thickness (2, 3, 4 g/mm) and drying time (270, 350, 430 s) in order to obtain foam mat dried egg white powder with low browning index, high solubility, and high drying rate. Optimization was carried out using central composite design and model verification was done in triplicates. The egg white foam was dried in a household microwave oven at constant power of 400 W. The optimum conditions with 58,8% desirability of 2,545 g/mm foam thickness and drying time of 270 s predicted 9,317 browning index, 48,980% solubility and 0,067 g/s drying rate. The experimental results were fitted into linear models to describe the response quality of browning index and solubility, and a quadratic model to predict that of drying rate. The egg white powder obtained has a pH of 7.75, 8.74% moisture content, 17.225% protein, and 0,0015% reducing sugar. In addition, it was observed that protein exposed to microwave has a stretched and exposed hydrophobic and hydrophilic group which enables them to reach a higher emulsion ability (34.5%), stability (36.6%), as well as foam stability (40%).

Keywords: Drying; Egg white powder; Foam mat; Microwave

Introduction

Egg white, the clear and viscous liquid of an egg, is widely known to be incorporated as a food ingredient due to its high protein content that enables it to have a good gelling and foaming ability. Several components that make up an egg white includes ovalbumin (54%), ovotransferrin (12%), ovomucoid (11%), ovomucin (3.5%), and lysozyme (Awwaly, 2017). The functionality of egg white is accounted by the high number of sulfhydryl (SH) groups, which are very sensitive to pH and temperature changes (Gharbi & Labbafi, 2018). Egg white powder is one form of egg derivatives with a long shelf life and is extensively used in industries as premix for ice cream, pastry, doughs, and surimi (Bhandari et al., 2013). Several studies have shown that egg white powder can be produced through pan drying (Nahariah et al., 2018), freeze drying (Quan & Benjakul, 2019), and most commonly through spray drying atomization (Blech, 2009).

Foam mat is a process which facilitates the drying of foodstuffs at a relatively lower temperature. Foam, which is a colloidal dispersion, is spread as a thin layer onto a pan or mat, dried as it is exposed to hot air, scraped and ground into fine powder (Mujumdar & Xiao, 2020). This method is known to be an economical alternative and suitable for the drying of products which are viscous, sticky and heat-sensitive in nature (Sangamithra et al., 2015). When coupled with other method such as microwave drying, drying process can be carried out at even a lower cost as it is faster and requires less energy on the long run. Microwave drying involves the radiation of electromagnetic waves with a range of frequency of 300 MHZ – 300 GHz to oscillate water molecules due to excitation. Çalışkan Koç and Çabuk (2019) stated that this hybrid advances allows the drying of materials to be done in a shorter time and faster rate, hence producing an end product with higher retention of nutrition and quality. However, although can be compensated by the short drying rate, this hybrid method is limited to the minimum amount of throughput or feed of materials that can be dried in one batch (Ratti & Kudra, 2006).

In relation to the drying of egg white, similar studies previously have examined different drying techniques such as follows. Prior desugarization of quail egg white with yeast (0.1 – 0.4%) was recommended to avoid Maillard reaction through the removal of reducing sugar (Nusa et al., 2017). Another study regarding the drying of egg white foam at different microwave powers (120 – 720 W) showed that drying kinetics was most fitted into Page model as it exhibits the highest R^2 values (Koç & Çabuk, 2020). However, there is a paucity of studies conducted to investigate the most optimum drying time which is suitable for a given range of foam thickness in order to obtain egg white powder with the most desirable qualities, such as low browning index, high degree of solubility as well as drying rate.

Materials and Methods

Materials

77 fresh whole eggs of ages 1-2 days were purchased from Candra Telor Farm, Pakis, Malang. Other material and chemicals include Saf-instant yeast, egg white powder (SKM Egg Products Export), soybean oil (Sania), citric acid (Merck), distilled water, glucose anhydrous (Merck), nelson A and B, Kjeldahl tablets (Merck), concentrated H_2SO_4 (Merck), NaOH (PA), boric acid (Merck), HCl 0.1 N, NaCl p.a (Merck), and arsenomolybdate. Pieces of laboratory equipment used were glassware, stand mixer (Kirin KSM-388, 200 W, Indonesia), mortar and pestle, desiccator (NS 24/29, Duran, Germany), stopwatch, analytical balances (EntriS224-1S, EntriS5201-1S, Sartorius Stedim Biotech, France), infrared thermometer (Extech Instruments, USA), microwave-safe plastic plate (115 mm diameter), 60 mesh sieve, microwave (Sanyo EM-S2612S, 400 W, 2450 Hz, Indonesia), microtube (Eppendorf, Germany), colorimeter (PCE-CSM4, PCE Instruments, UK), centrifuge (Z326K, Hermle Labortechnik, Germany), oven (UN55, Memmert, USA), fume hood (FH1200, Biobase, China), automatic distillation unit (UDK 149, VELP Scientifica, Italy), vortex mixer (50-60 Hz, Thermo Fisher Scientific, USA), homogenizer (T25, IKA Process, Malaysia), and UV-Vis spectrophotometer (UV-1280, Shimadzu, Japan).

Methods

Before foaming, egg white was separated from whole egg and pasteurized using the double wall heating at 60 °C for 3.5 minutes according to the USDA method (USDA, 1969). Two metal pots were filled with water and egg white separately, water was then heated until it reached 60 °C, and the pot containing egg white was put on top of the warm water. After cooling, 5% citric acid was then slowly added until the pH reaches 6.00. The egg white mixture was left to desugarize with 0.4% m/v instant yeast at room temperature (approximately 28 – 30 °C) for 24 hours, and then kept in the fridge (4 °C) to prevent further desugarization. Foaming was done using mixer with level 2 speed for 15 minutes. Egg white foam was then poured onto the plastic plate and weighed accordingly to reach certain foam thicknesses, which was regarded as the product of foam density and the area of plastic plate used, with a diameter of 115 mm and height of 8 mm (Dehghannya et al., 2018). Drying was carried out at constant power of 400, dried sample was then ground into fine powder, sieved, and stored in clear plastic clips for further analysis.

Analysis

A central composite design (CCD) with 13 runs was used for optimization with three replications for verification. Browning index which indicates the degree of Maillard reaction was calculated using the CIELAB color space approach according to Diamante *et al.* (2010). Solubility of egg white powder was determined using a modified procedure described by Nahariah *et al.* (2018). For this purpose, one gram of egg white powder was diluted with 7 mL of warm distilled water (40 °C), and centrifuged for 15 minutes with a speed of 3500 rpm. The powder that remained insoluble was then determined for its dry mass after drying in the oven at 120 °C for 2 hours. Solubility was determined as the ratio of mass of dried insoluble powder to the initial mass before dilution. Drying rate was determined as change of mass in a period of time in line with the method proposed by Hakim *et al*. (2020). Effective moisture diffusivity (D_{eff}) was calculated using the gradient obtained from the logarithmic moisture ratio curve (Dehghannya et al., 2018).

Proximate analysis for protein and moisture content was done in accordance with SNI 01-4323-1996 (Indonesian National Standard for commercial egg white powder) using the micro Kjeldahl and gravimetry methods. Emulsion ability and stability were determined in line with the method previously done by Yasumatsu *et al.* (1972). However, some modification was made where the first homogenization was done under a speed of 10,000 rpm for 2 minutes, and proceeded by centrifugation at speed of 1,300 g for 5 minutes. Water holding capacity was done according to the method of Pokora *et al.* (2013) with a modification where centrifugation was carried out under speed of 2,800 g for 30 minutes. At last, foaming ability was determined in accordance to Stadelman *et al.* (2017) with a modification in the whipping method which uses homogenizer set at 3,200 rpm for 2 minutes. The data obtained were then analyzed using Design Expert 10.0.1 to find the best fitted model which expresses the response variable as a function of previously mentioned independent variables through an equation. The characteristics obtained from experimental egg white powder (EWP) was then compared to a commercial grade EWP under the brand SKM.

Table 1. CCD obtained from RSM and experimental values of responses

Run	Parameters		Responses		
	Foam thickness (g/mm)	Drying time (s)	Browning index	Solubility (%)	Drying rate (g/s)
1	3	237	6.97	49.36	0.0885
2	3	350	10.40	52.79	0.0597
3	1.586	350	10.01	55.04	0.0316
4	3	350	11.06	44.61	0.0598
5	3	350	11.12	47.18	0.0595
6	2	430	11.00	45.31	0.0324
7	3	463	11.02	45.18	0.0451
8	2	270	8.70	46.36	0.0516
9	4	270	13.19	42.70	0.102
10	4.414	350	14.56	41.38	0.0877
11	4	430	15.81	43.27	0.0646
12	3	350	13.26	48.32	0.0597
13	3	350	12.97	46.34	0.0599

Results and Discussion

Model Fitting

Table 1 lists the experimental data in terms of responses of browning index, solubility, and drying rate obtained under different conditions. The most suitable model is selected based on the lowest p-value ($p<0.05$), highest R-squared values, lowest standard deviation and lowest PRESS (Myers & Montgomery, 1995). The following polynomial equations are used to predict each response in terms of coded variables:

$$Y1 = 11{,}54 + 1{,}97A + 1{,}33B \quad \text{Equation 1}$$
$$Y2 = +46{,}76 - 3{,}13A - 0{,}80B \quad \text{Equation 2}$$
$$Y3 = +0{,}060 + 0{,}020A - 0{,}015B - 4{,}550\times10^{-3}\, AB - 1{,}787\times10^{-4}\, A^2 + 3{,}396\times10^{-3}\, B^2 \quad \text{Equation 3}$$

where,
Y1 = *browning index,* Y2 = solubility (%), Y3 = drying rate (g/s), A = foam thickness (g/mm), and B = drying time (s).

Effect of Process Parameters

It can be deduced that browning index and solubility were predicted to have a linear model, while drying rate to have a quadratic model as presented in Figure 1. Browning index can be indicated by the degree of Maillard reaction that happened between cephalin of amino group and aldehyde from reducing sugar molecules. This reaction is unwanted as it may produce off-flavor and end product with a yellowish color (Quan & Benjakul, 2019). From Figure 1(A), as foam thickness increased and drying proceed, it can be seen that browning index increased as well. For Maillard reaction to proceed, a relatively low a_w of 0.3 – 0.7 must be achieved to allow the first step of reaction to occur, namely the Hines and Amadori rearrangement (Gómez-Narváez et al., 2019). On the other hand, as drying proceeded, the lightness of powder produced (L^*) was getting lower. A similar result was observed from the microwave drying of okra (Dadali et al., 2007). A longer residence time may result in a distinct change of color of end product (Liu et al., 2020). In comparison, SKM egg white powder produced through spray drying has a low browning index of 7.19, while that of powder obtained by microwave drying had a fairly higher value of 8.70 – 15.81. Desugarization was said to be significant in decreasing browning index (Quan & Benjakul, 2019). Although liquid egg white has been desugared prior to drying which results in a reduction of reducing sugar content from 0.0754% to 0.0067%, Maillard reaction may still happen between nitrogenous and organic acid compounds (Cernîşev, 2010), leading to the relatively higher browning index.

From Figure 1(B), it can be deduced that higher foam thickness and drying time both results in a low solubility of egg white powder. This may be caused by a higher remaining moisture content after drying of samples with thicker foam, in which foam thicknesses of 4.414 and 3 g/mm already had a difference of initial moisture content of 0.4227 g H_2O/g DM. Powder with a high remaining moisture tend to agglomerate, causing them to have a longer dissolution time (Muzaffar & Kumar, 2015). The length of drying time was predicted to be in line with the degree of denaturation and coagulation of protein which causes them to be more insoluble. Ovotransferrin may lose its tertiary structure during the first step of coagulation at 61.5 – 62.5 °C (Campbell et al., 2003), this was bound to happen as the drying of sample for 270 s was later found to reach a temperature of 64.9 – 73.7 °C. Another factor that may produce an end product with low solubility (41.38 – 55.04%) is desugarization, in which the removal of reducing sugar reduces the number of hydrophilic interactions, causing particles to form larger aggregates and thus lowers the solubility of powder when rehydrated.

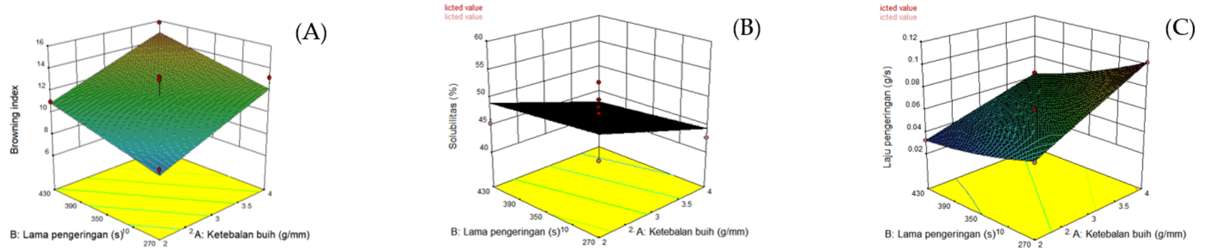

Figure 1. Response surface and 3D contour plot for browning index (A), solubility (B), and drying rate (C)

The experimental results showed that foam thickness is directly proportional to drying rate, however it was inversely proportional as observed in a previous study conducted by Dehghannya *et al.* (2018). This discrepancy might be observed due to samples with thin foams, which were shown to have lower initial moisture content. This decreases the ability of water molecules to absorb microwave power thus resulting in a lower drying rate (Çalışkan Koç & Çabuk, 2019). Samples with thin foams are shallow, it cannot be fully penetrated by electromagnetic waves and tends bounce off into the microwave cavity (Hakim *et al.*, 2020). The contour on Figure 1(C) with a hillside type of response surface shows that high foam thickness and short drying time will result in a high drying rate.

Optimization and Verification

This study aims to search for the optimum process parameters for minimum browning index, maximum solubility and maximum drying rate of egg white powder obtained from microwave drying. Table 2 shows the predicted optimum condition at 2.545 g/mm foam thickness and 270 s drying time to achieve a desirability level of 58.8%. Three experiments were done under the recommended optimum condition in order to verify the model. Under this condition, the egg white powder obtained has an average browning index of 10.467, solubility of 50.788%, and drying rate of 0.066 g/s. The experimental results and residual in comparison to predicted values are presented in the following table. Other than browning index, solubility and drying rate both have <5% error, which indicates that the model is robust (Tian *et al.*, 2021). A relatively high error of 12.3% is obtained from browning index because its value is a result of x (raw calculated number from colorimeter) multiplied by 100 and then divided by 0.17 (Diamante et al., 2010). Hence, a small difference from predicted and experimental values will significantly impact the margin of error.

Table 2. Predicted and experimental values of each response at optimum conditions for microwave-dried egg white powder

Values	Parameters		Responses		
	Foam thickness (g/mm)	Drying time (s)	Browning index	Solubility (%)	Drying rate (g/s)
Predicted	2.545	270	9.317	48.980	0.067
Experimental	2.545	270	10.467	50.788	0.066
RSD (%)			0.631	15.543	0.717
Residual			1.1500	1.8080	0.001
Error (%)			12.3%	3.69%	1.49%

Drying Behavior

Microwave drying is also known to be volumetric heating facilitated by electromagnetic radiation, which causes the internal part of material to heat up faster in comparison to its surface area. The intensity of electromagnetic wave being radiated depends on the capacity of magnetron to produce oscillation, which is then converted into energy absorbed by material (Çalışkan Koç & Çabuk, 2019). As drying proceeds, water molecules become more vigorous due to the energy being absorbed, and thus causes a temperature change. It was observed that the drying of optimum sample at 400 W with foam thickness of 2.545 g/mm when dried within 270 s, experienced a temperature change from 22.1 °C to 64.9 – 73.7 °C.

Figure 2 illustrates the changes of drying rate of sample dried under optimum condition. Drying rate initially rose up in the first 30 s, slows down, and experienced a steady increase until it reaches a maximum drying rate of 0.09141 g/s at the 150 s mark. The immense rise of drying rate at the start of drying, namely the heat up period, was caused by the rapid decrease of moisture from 7.8438 g H_2O/g db. At the 150 s mark and onwards, when moisture content was 2.13 g/g db, drying rate was observed to rather slow down as the movement of water molecules from internal part of material to the surface was slower in comparison to the evaporation rate of water molecules to the surrounding air. This phenomenon was referred to as the first falling rate period, as it was observed in previous study regarding the foam mat drying of honeysuckle berry (Sun et al., 2012). At 180 – 210 s, drying rate dropped significantly from 0.0893 g/s to 0.0767 g/s due to the faster evaporation of water molecules due to a decrease in foam thickness. At this phase, foam structure has mostly ruptured, making the sample more porous and thus facilitating water molecules to evaporate at a faster rate (Kudra & Ratti, 2006).

From this graph, a logarithmic function of moisture ratio was derived in order to calculate the effective moisture diffusivity (D_{eff}), which can be used to evaluate the internal movement of water molecules during drying. A D_{eff} value of 2.074 x 10^{-8} m^2/s was obtained from the drying of sample under the suggested optimum condition. The calculated value was close enough to the forementioned study with D_{eff} of 9.5501 x 10^{-8} m^2/s. High D_{eff} value can be referred to as high drying rate, and can be increased by drying samples with thinner foam as well as increasing microwave power (Dehghannya et al., 2018).

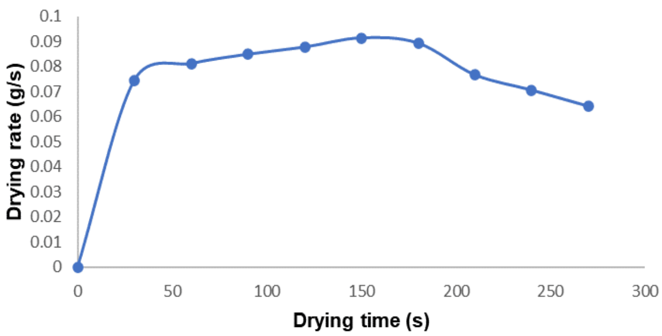

Figure 2. Drying rate curve

Proximate and Functional Characteristics

From a series of proximate and functional analysis as tabled on Table 3, it can be concluded that the experimental powder has fairly acceptable pH and moisture. The reducing sugar content was much lower than standard (0.0015%) due to fermentative desugarization prior to drying. The protein content of experimental EWP, which is 17.225%, is far below the minimum standard of 75%. Martins *et al.* (2001) stated that Maillard reaction may inhibit the digestibility of protein and inactivate amino acids. The product of this reaction may cause crosslinking with another protein molecules, making it harder for protein and amino acids to be measured during the semimicro Kjeldahl procedure. Besides, microwave radiation possibly accelerates the folding and denaturation of protein as it was suggested by Bohr and Bohr (2000) in a previous study regarding the radiation of β-lactoglobulin (2.45 GHz, 400 W).

It can be inferred from Table 3 that experimental EWP has a higher emulsifying ability and stability. Exposure towards microwave radiation causes the hydrophobic and hydrophilic parts of a protein molecule to be more stretched out. A higher stability (36.6%) suggests that protein molecule is flexible enough to be able to form a stable layer at the interface. Emulsion stability increases with exposure towards microwave radiation, making the structure of EWP to be more porous hence allowing oil molecules to be easily absorbed (Liu et al., 2020). It is predicted that microwave radiation changes the distribution of charged molecules and the electrical conductivity of protein molecules. This changes the ability of EWP to form foams upon rehydration with water (Zhou et al., 2014). Furthermore, Wang *et al.* (2020) also stated that dry heating of egg white using microwave radiation may cause them to form smaller foam surrounded with thicker lamella, which accounts for a higher foam stability.

Table 3. Proximate and functional analysis of experimental and commercial grade egg white powder (EWP)

Parameter	SNI 01-2891-1992	Experimental EWP	SKM EWP*
pH	6.3 – 7.5	7.75	7.42
Moisture (%)	Maximum of 8	8.74	12.46
Protein (%)	Minimum of 75	17.225	80
Reducing sugar (%)	Maximum of 0.5	0.0015	0.0716
Emulsifying ability (%)	-	34.5	31.4
Emulsifying stability (%)	-	36.6	34.9
Water holding capacity (%)	-	76.7	86.3
Foaming ability (%)	-	40	56

** SKM is a brand of commercial grade egg white powder produced by SKM Egg Products Export (India) Limited*

Implication of Findings

The findings of this study facilitated the understanding regarding the optimal process conditions of egg white powder dried under electromagnetic radiation. However, there is a need for further studies regarding the implication of the suggested processing conditions on an upscaled production.

Conclusions

The optimization of microwave-dried egg white powder was well generated using a response surface methodology (RSM) with a central composite design. With an increase in foam thickness, solubility decreases while browning index and drying rate increases. On the other hand, the increase of drying time results in a higher browning index and lower solubility of end product. The suggested model to predict the responses of browning index and solubility was linear, while of drying rate was quadratic. The optimum process condition involves drying of sample with 2.545 g/mm foam thickness for 270 s, this condition generates a desirability of 58.8%. The suggested models were then validated by comparing experimental results to the predicted responses, it was concluded that there was a fair correspondence between both results. Results from this study suggests that egg white powder obtained by foam mat microwave drying has an acceptable pH and moisture, and possesses a better emulsifying ability and foaming stability in comparison to that of commercial grade produced through spray drying. Microwave radiation may cause inactivation and denaturation of protein, but at the same time it stretches out the hydrophobic and hydrophilic moieties of protein molecules, which in turn resulted in better emulsifying ability.

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References

Awwaly, K. U. Al. (2017). *Protein Pangan Hasil Ternak dan Aplikasinya*. Universitas Brawijaya Press.

Bhandari, B., Bansal, N., Zhang, M., & Schuck, P. (2013). Handbook of Food Powders: Processes and Properties. In *Handbook of Food Powders: Processes and Properties*. Woodhead Publishing. https://doi.org/10.1533/9780857098672

Blech, Z. Y. (2009). Kosher Food Production: Second Edition. In *Kosher Food Production: Second Edition*. Willey Blackwell. https://doi.org/10.1002/9780813804750

Bohr, H., & Bohr, J. (2000). Microwave-enhanced folding and denaturation of globular proteins. *Physical Review E - Statistical Physics, Plasmas, Fluids, and Related Interdisciplinary Topics*, *61*(4), 4310–4316. https://doi.org/10.1103/PhysRevE.61.4310

Çalışkan Koç, G., & Çabuk, B. (2019). The Effect of Different Microwave Powers on the Drying Kinetics and Powder Properties of Foam-Mat Dried Egg White Powder. *Gida / the Journal of Food*, *44*(2), 328–339.

Campbell, L., Raikos, V., & Euston, S. R. (2003). Modification of functional properties of egg-white proteins. *Nahrung - Food*, *47*, 369–376. https://doi.org/10.1002/food.200390084

Cernîşev, S. (2010). Effects of conventional and multistage drying processing on non-enzymatic browning in tomato. *Journal of Food Engineering*, *96*, 114–118. https://doi.org/10.1016/j.jfoodeng.2009.07.002

Dadali, G., Apar, D. K., & Özbek, B. (2007). Color change kinetics of okra undergoing microwave drying. *Drying Technology*, *25*(5), 925–936. https://doi.org/10.1080/07373930701372296

Dehghannya, J., Pourahmad, M., Ghanbarzadeh, B., & Ghaffari, H. (2018). Influence of foam thickness on production of lime juice powder during foam-mat drying: Experimental and numerical investigation. *Powder Technology*, *328*, 470–484. https://doi.org/10.1016/j.powtec.2018.01.034

Diamante, L., Durand, M., Savage, G., & Vanhanen, L. (2010). Effect of temperature on the drying characteristics, colour and ascorbic acid content of green and gold kiwifruits. *International Food Research Journal*, *17*, 441–451.

Gharbi, N., & Labbafi, M. (2018). Effect of processing on aggregation mechanism of egg white proteins. *Food Chemistry*, 1–32. https://doi.org/10.1016/j.foodchem.2018.01.088

Gómez-Narváez, F., Contreras-Calderón, J., & Pérez-Martínez, L. (2019). Usefulness of some Maillard reaction indicators for monitoring the heat damage of whey powder under conditions applicable to spray drying. *International Dairy Journal*, *99*, 1–8. https://doi.org/10.1016/j.idairyj.2019.104553

Hakim, A. R.; Handoyo, W. T.; Prasetyo, A. W. (2020). Performa dan analisis konsumsi energi pengeringan rumput laut menggunakan energi gelombang mikro. *JPB Kelautan Dan Perikanan*, *15*(1), 85–98. https://doi.org/http://dx.doi.org/10.15578/jpbkp.v15i1.639

Koç, G. Ç., & Çabuk, B. (2020). Characterization of the Foam-Mat Dried Egg White Powder. *The Journal of Food*, *45*(1), 150–160.

Kudra, T., & Ratti, C. (2006). Foam-mat drying: Energy and cost analyses. *Canadian Biosystems Engineering / Le Genie Des Biosystems Au Canada*, *48*, 327–333.

Liu, L., Dai, X., Kang, H., Xu, Y., & Hao, W. (2020). Structural and functional properties of hydrolyzed/glycosylated ovalbumin under spray drying and microwave freeze drying. *Food Science and Human Wellness*, *9*, 80–87. https://doi.org/10.1016/j.fshw.2020.01.003

Martins, S., Jongen, W., Boekel, V., & Martinus, A. (2001). A review of Maillard reaction in food and implications to kinetic modelling. *Trends in Food Science and Technology*, *11*, 364–373.

Mujumdar, A. S., & Xiao, H. W. (2020). *Advanced Drying Technologies for Foods*. CRC Press.

Muzaffar, K., & Kumar, P. (2015). Parameter optimization for spray drying of tamarind pulp using response surface methodology. *Powder Technology*, *279*, 179–184. https://doi.org/10.1016/j.powtec.2015.04.010

Myers, R. H., & Montgomery, D. C. (1995). *Response surface methodology: Process and product optimization using designed experiments*. John Wiley & Sons.

Nahariah, N., Legowo, A. M., Abustam, E., Hintono, A., & Hikmah, H. (2018). Functional characteristics of fermented egg white powder after pan-drying at different temperatures and times. *International Journal of Poultry Science*, *17*(3), 134–139. https://doi.org/10.3923/ijps.2018.134.139

Nusa, I. M., Suarti, B., & Marbun, R. A. (2017). Penambahan Ragi Tempe dan Lama Fermentasi Terhadap Sifat Mutu Tepung Albumin Telur Puyuh. *Agrium*, *20*(3), 211–222.

Pokora, M., Eckert, E., Zambrowicz, A., Bobak, Ł., Szołtysik, M., Dąbrowska, A., Chrzanowska, J., Polanowski, A., & Trziszka, T. (2013). Biological and functional properties of proteolytic enzyme-modified egg protein by-products. *Food Science and Nutrition*, 1–12. https://doi.org/10.1002/fsn3.27

Quan, T. H., & Benjakul, S. (2019). Impacts of desugarization and drying methods on physicochemical and functional properties of duck albumen powder. *Drying Technology*, 1–13. https://doi.org/10.1080/07373937.2018.1469509

Ratti, C., & Kudra, T. (2006). Drying of foamed biological materials: Opportunities and challenges. *Drying Technology*, 1101–1108. https://doi.org/10.1080/07373930600778213

Sangamithra, A., Venkatachalam, S., John, S. G., & Kuppuswamy, K. (2015). Foam Mat Drying of Food Materials: A Review. *Journal of Food Processing and Preservation*, 1–10. https://doi.org/10.1111/jfpp.12421

Stadelman, W., Newkirk, D., & Newby, L. (2017). Egg Science and Technology, Fourth Edition. In *Egg Science and Technology, Fourth Edition*. CRC Press. https://doi.org/10.1201/9780203758878

Sun, Y., Zheng, X., Xu, X., Liu, C., Li, Q., & Zhang, Q. (2012). Drying properties and parameters of blue honeysuckles pulp under foam assisted microwave drying conditions. *International Journal of Food Engineering*, *8*(2), 1–23. https://doi.org/10.1515/1556-3758.2540

Tian, Z; Zhang, Z; Zhang, K; Tang, X; Huang, S. (2021). Statistical modeling and multi-objective optimization of roadgeopolymer grouting material via RSM and MOPSO. *Construction and Building Materials*, *271*(121534), 1–13. https://doi.org/https://doi.org/10.1016/j.conbuildmat.2020.121534

USDA. (1969). *Egg Pasteurization Manual*. https://naldc.nal.usda.gov/download/CAIN709025458/PDF

Wang, X., Gu, L., Su, Y., Li, J., Yang, Y., & Chang, C. (2020). Microwave technology as a new strategy to induce structural transition and foaming properties improvement of egg white powder. *Food Hydrocolloids*, *101*, 1–8. https://doi.org/10.1016/j.foodhyd.2019.105530

Yasumatsu, K., Sawada, K., Moritaka, S., Misaki, M., Toda, J., Wada, T., Ishii, K., Toda, J. U., & Ada, T. W. (1972). Whipping and Emulsifying Properties of Soybean Products. *Agricultural and Biological ChemistryAgr. Bioi. Chern*, *36*(5), 719–727. https://doi.org/10.1080/00021369.1972.10860321

Zhou, B., Zhang, M., Fang, Z., & Liu, Y. (2014). A Combination of Freeze Drying and Microwave Vacuum Drying of Duck Egg White Protein Powders. *Drying Technology*, *32*(15), 1840–1847. https://doi.org/10.1080/07373937.2014.952380

THE REVIEW OF 3D-PRINTED MEAT ANALOGUE WITH BROAD BEANS TO MAINTAIN ASEAN FOOD SECURITY

I Nyoman Anggie Pratistha*[1], I Putu Fadya Rachmawan[2], Gusti Putu Surya Govinda Atmaja[3], Manikharda[1], Andriati Ningrum[1]
[1]Department of Food and Agricultural Products Technology, Universitas Gadjah Mada
[2]Department of Electrical Engineering and Informatics, Vocational College, Universitas Gadjah Mada
[3]Department of Mechanical and Industrial Engineering, Universitas Gadjah Mada, Indonesia
*inyomananggi22@mail.ugm.ac.id

Abstract

Southeast Asian countries are big players in agricultural products contributors in the world with total exports of 129 million tons of rice, 40 million tons of corn, 171 million tons of sugarcane, 1.44 million tons of soybean, and 70.34 million tons of cassava. However, with the high number of agricultural product exports, Southeast Asian countries still have problems dealing with hunger and food waste. Future Directions International stated that 25 percent of the total food waste in the world comes from East Asia and Southeast Asia. This problem is further exacerbated, especially the throughout the Southeast Asian population indicating the Global Hunger Index range of 44-83. Despite the issues, the Southeast Asian region have a variety of native food commodities that have not been fully utilized. These native food commodities, for example broad beans, having comparable protein content as other known regular food commodities. Therefore, this study provides general overview of the application of additive manufacturing technologies in food engineering. This paper reviewed the development of meat analogue by means of additive manufacturing technology, generally known as 3D printing, using a native Southeast Asian food commodities. Social acceptance, manufacturing technologies, and local culture remain the main hurdle of the meat analogue introduction, especially in the Southeast Asian population. Compared to regular meat, analogue meat in general has a lower carbon footprint and lower food waste. The use of native commodities also helps farmers in Southeast Asian to add value to their products and improve food security across Southeast Asian nations. Eventually, this study also examined theoretical products called All Can Eat Meat that is developed using 3D printing process and used broad bean as the main ingredients. All Can Eat Meat also use ASEAN variants and flavors such as Rendang, Laksa, Curry, and others so that they can be accepted by the people of Southeast Asia and the form of processing and packaging using biodegradable bioplastics and edible films from seaweed that are environmentally friendly and low waste can minimize the food waste number in Southeast Asia.

Keywords: 3D printing; ASEAN; Broad beans; Food waste; Meat analogue

Introduction

ASEAN or Association of Southeast Asian Nations is a collective body solving issues concerning the region and synchronizing the country member in the Southeast Asian region. The purpose of the establishment of ASEAN is to accelerate economic growth, social progress, and cultural development in Southeast Asia (ASEAN, 2020). With a total population approximately between 667 million in 2021, and US$3,355.7 in 2021. ASEAN was also one of the most productive agricultural baskets in the world. In 2012, the region produced 129 million tons of rice, 40 million tons of corn, 171 million tons of sugarcane, 1.44 million tons of soybean, and 70.34 million tons of cassava Rice production this year is forecast to increase by 3% to 132.87 million tons (ASEAN, 2018; O'Neill, 2021a). Rice exports, domestic utilization, and self-sufficiency ratio are all expected to increase in 2013. ASEAN was likely to increase exports to 18.28 million tons (ASEAN, 2018). While domestic utilization was projected to increase to 114.57 million from 113.04 million tons in 2012, self-sufficiency (production to domestic utilization) ratio is still assured at 116% (ASEAN, 2020; O'Neill, 2021b).

The problem that occurred in ASEAN especially in food sectors are food security and food waste. The Future Directions International (FDI), a non-profit strategic research institute, South and Southeast Asia accounts for 25 percent of the world's food waste. Singapore's National Environment Agency (NEA) reported that in 2017, over 809,800 tons of food was thrown out. Meanwhile, Malaysia generates 38,000 tons of waste per day, of which 3,000 tons are edible and could have fed at least two million people (Gustafsson et al., 2013; Team, 2019). Based on a 2017 Economist Intelligence Unit (EIU) report, 'Fixing Food', Indonesia was the world's second-largest food waster, throwing out 300 kilograms (kg) of food per person each year. The food security issue implies that the number of soybean import in ASEAN is quite high (Gustafsson et al., 2013). The increase occurred from 2018 of 3,225.9 million USD to 3,421.6 million USD in 2019. The high number of imports shows that the population's consumption of protein rich products is quite high. However, the movement of protein consumption will continue to increase so that soybeans as a source of protein needed will continue to be highly demanded. In the future, if the demand for soybean conditions is not met, it will create serious problems for food security in ASEAN countries.

The people in the region had high awareness concerning the Industrial Revolution 4.0 (Readiness Index showed 81% of awareness score). This index shows that ASEAN inhabitants are prepared for the Industrial Revolution in various sectors like food engineering and manufacturing including 3D-printing in manufacturing and food processing (Arbulu et al., 2018; R. Kumar & Kumar, 2020; Schwab, 2019). However, the food processing industry that offers cheap-to-eat and fast-to-eat food using up to date technology is rarely seen in ASEAN countries itself. This paper reviewed several studies concerning the development of meat analogue by means of additive manufacturing technology, generally known as 3D printing, using a native Southeast Asian food commodity, especially broad beans. In this paper, sustainability, manufacturing techniques, ingredients, social acceptance, safety, and nutritional value of analogue meat is reviewed thoroughly. In conclusion, this paper also includes examination of theoretical 3D printing products called All Can Eat Meat.

Sustainability Perspective of Meat Analogue

As one of the economic hotspots, with large middle-class, Southeast Asian encountered an ever-increasing demand of high protein food products, especially meat (ASEAN, 2018). However, the meat supply around the world is very limited. Moreover, the intensive meat production often led to unintended problem of greenhouse gas emission, forest clearance, land degradation, and other environmental related issue (Galanakis, 2019; Kowalski, 2019; S. Kumar et al., 2020; Malav et al., 2015; Ong et al., 2018; Schwab, 2019). The growing consumption of meat also had huge impact in the climate. Meat production account for 20% of the world greenhouse gases emissions (FAO, 2015). Furthermore, the meat production and the following supply chain uses nearly 50–70% of the total freshwater consumption by agricultural sector, which accounts for 70–80% of the world's freshwater consumption (Kowalski, 2019).

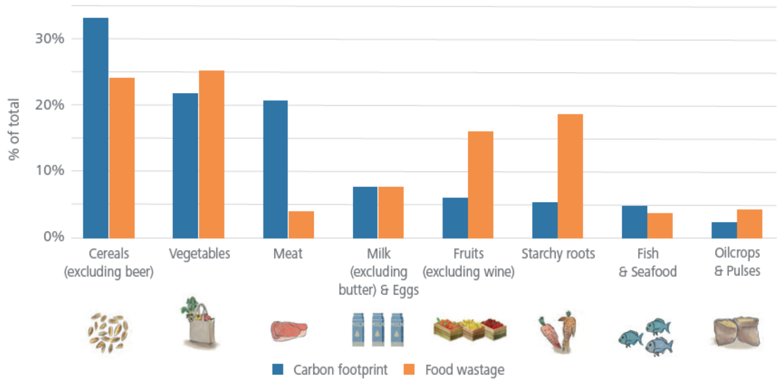

Figure 1. Carbon footprint of various food commodities (FAO, 2015; Karwowska et al., 2021)

Additionally, around 10–20% of the food produced was currently becoming unusable wastes. Inappropriate supply chain, especially in Southeast Asian and Africa region, became one of the big contributors of food waste production in developing countries. This condition is greatly influence by underdeveloped infrastructure for transportation in most developing countries. However, situation is in contrast with the developed countries. Most of the food waste production in developed countries comes from the consumption phases. This condition relates with the tendencies of high-income individuals to store excess food to prepare for unpredictable events. However, tendency to throw away unpalatable food in favor of more delicious one or experimental food that turn out to be inedible is on the rise in developed countries as the food culture grow more complex and intertwined

With current growth rate of food consumption and food waste production, in 2030 the condition will likely become unsustainable (Galanakis, 2019; Kowalski, 2019; S. Kumar et al., 2020; Malav et al., 2015; Ong et al., 2018; Schwab, 2019) because the number of resources in the earth is predicted to be insufficient to satisfy the growing demand for high-protein food like meat (FAO, 2015, 2016). Accordingly, famine would be widespread. In this case, the development of meat analogue as substituted of real meat is believed to be a great way to improve human health, conserve natural resources, and maintain animal welfare (Galanakis, 2019; Kowalski, 2019; S. Kumar et al., 2020; Malav et al., 2015; Ong et al., 2018; Schwab, 2019).. Moreover, the ability to modify the nutritional content of meat analogues could be a great tool to increase the acceptance of the products and also the general health, as the meat analogues could be designed to have custom nutritional content for every individual (Galanakis, 2019; Kowalski, 2019; S. Kumar et al., 2020; Malav et al., 2015; Ong et al., 2018; Schwab, 2019).. Eventually, the production of meat analogue could potentially reduce the food waste production, as the meat analogue could be produced relatively fast and have customable flavor and textures (Galanakis, 2019; Kowalski, 2019; S. Kumar et al., 2020; Malav et al., 2015; Ong et al., 2018; Schwab, 2019).

3D Printing Techniques

3D printed food has gained a lot of attention in the last few years. The high customizability of the 3D printed food products greatly contributed to its popularities. Moreover, the smaller number of wastes produced, the ability to create various shape, and shorter manufacturing time is the main reason in 3D printing implementation in food production, including meat analogue production (Galanakis, 2019; Godoi et al., 2016; R. Kumar & Kumar, 2020; Saldanha et al., 2021; C. Sun et al., 2021; J. Sun et al., 2015; Yang et al., 2017). In addition, food production through 3D printing also has the potential to prevent food waste and substitute the rare known ingredients of the food with abundant, less known ones, improving the food securities in the region (Godoi et al., 2019; Galanakis, 2019; Roman & Russell, 2009).

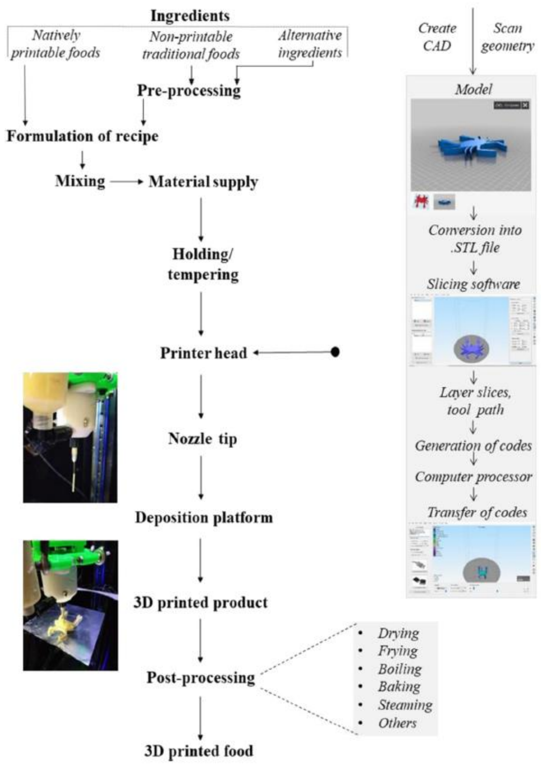

Figure 2. Schematic flow diagram of a typical extrusion-based food 3D printing process. Adapted from (Nachal et al., 2019)

There are several 3D printing techniques that could be used to produce food products, especially plant-based food products. There extrusion process, inkjet printing process, power binding deposition, and bio printing (Godoi et al., 2016; R. Kumar & Kumar, 2020; Liu et al., 2017; Nachal et al., 2019; J. Sun et al., 2015). Eventhoug every technique has unique approach and working mechanism, they follow the same basic principle. 3D printed food techniques employ the same pre-processing, printing process, and finalizing process or post-processing step (Godoi et al., 2016; R. Kumar & Kumar, 2020; Liu et al., 2017; Nachal et al., 2019; J. Sun et al., 2015).

In the pre-processing phases, the food ingredients will be sorted and processed by mixing, chopping, and reacting the ingredients chemically with chemical agent before the ingredient mixture could enter the next step (Nachal et al., 2019). The mixture characteristics are different across various printing techniques. In the extrusion technique, the material will be turned into semi-solid mixture that retain its rheological properties (Godoi et al., 2016; R. Kumar & Kumar, 2020; Liu et al., 2017; Nachal et al., 2019; J. Sun et al., 2015). In the inkjet printing technique, the material is turned into powder (Godoi et al., 2016; R. Kumar & Kumar, 2020; Liu et al., 2017; Nachal et al., 2019; J. Sun et al., 2015). . In the power binding technique, the material is mixed with binding agent, or the material is designed so that it will form crosslinking or dissolutions if it is exposed to the heat sources (Godoi et al., 2016; R. Kumar & Kumar, 2020; Liu et al., 2017; Nachal et al., 2019; J. Sun et al., 2015). Lastly, in the bioprinting technique, the material used is cultivated cell that is assembled into mold or scaffold (Godoi et al., 2019; Schwab, 2019).

The printing technique involves shaping of the food to the intended design, layer by layer (Nachal et al., 2019). Initially, the to be printed food must be designed using computer aided design software. After that, the corresponding model will undergo the slicing procedure in slicing software (Nachal et al., 2019). This slicing software also generates printing path and printing code that will be transferred to the printing device (Nachal et al., 2019). The printing device will read the code, then the printing process is executed according to the code. In the extrusion technique, the material will be extruded. In the inkjet printing technique, the material will be heated slightly or sintered. In the power binding technique, the material will be exposed to heat to melt or alter the structure of the material. In bioprinting technique, the material will be assembled just like arranging Lego blocks (Godoi et al., 2019; Schwab, 2019).

The post-printing process could involve drying, frying, baking, steaming, boiling, and so on (Godoi et al., 2019; Schwab, 2019). The goal of the last process is to sterilize the meat analogue products and prepare them to be cooked like regular meat. After this process, meat analogue could be packed, stored, and distributed to the customer for consumption.

Meat Analogue Ingredients of All Can Eat Meat

There are two main components in the meat analogue, there are protein sources and other substantial ingredients. Each of the component will be studied thoroughly in the following section

Protein source

The protein component is the most important component for the identification of imitation meat products. Protein plays a role in solubility, flavor binding, emulsification, viscosity, gelation, texture, and dough formation (Bohrer, 2019; Meade et al., 2005). The protein source of meat analog based broad beans. Broad beans belong to the family legumes. The broad beans used in meat analog are the sword broad beans (Meade et al., 2005).

Broad beans are easy to find in Indonesia and have affordable price. This legume has a protein content of 28.6 %, fat content of 2.26%, and carbohydrate content of 50.6 % (Susanti et al., 2013). While soybean is the most used ingredient and in the form of soy concentrate contains about 70% protein. Soybeans are also rich in fat and carbohydrates, fibers content, macronutrients, micronutrients, and vitamins. Currently, the number of soybeans produced in Southeast Asian countries is still lower than their demand, especially in Indonesia (Susanti et al., 2013). This problem could be solved with utilization of broad beans as a potential substitute.The use of broad beans is a guideline for all can eat meat products or analog meats made from broad beans.

Table 1. Sword broad beans content (Susanti et al., 2013)

Parameter	Level
Water (%)	15.7
Protein (%)	28.6
Fat (%)	2.26
Carbohydrate (%)	50.6

Other Materials

Beside protein, the other ingredients in meat analog products are fat, carbohydrate, water, coloring agents, binding agents, and flavor (Bohrer, 2019). The role of fats/oils with sunflower oil will contribute to mouthfeel, juiciness, and flavor release of the product. Sunflower oil contains 13g/100g saturated fat. The use of sunflower oil with low saturated fat makes meat analog healthier (Vadivel & Janardhanan, 2001). The carbohydrates from broad beans in the meat analogue is expected to improve the interaction between the other ingredients, such as lipid, protein, and water components. Coloring agent used is soy leghemoglobin, a heme-an iron-containing compound found in most living organism (Fraser et al., 2018; Kyriakopoulou et al., 2019). Water is the component with the highest percentage in meat analog and plays a role in ingredient distribution, emulsification, juiciness. Binding agents are components that play a role in water binding and determine production processing conditions. In meat analog, egg white is an ingredient for binding agents (Malav et al., 2015; Ponnampalam et al., 2019).

Social Acceptance, Safety, and Nutritional Aspect

Meat is rarely the central focus of a Southeast Asian meal, and many dishes make use of only a small quantity of pork, beef, or chicken in a recipe. The taste of meat is not featured except in grilled meats. When meat is available, the whole animal is used, and often guts and brains are considered delicacies and are just as expensive as muscle meat, particularly in Chinese dishes. In the past, dishes like pig entrails in blood were a common breakfast dish. Lao dishes such as *laap* contain intestines, as do many other soups and specialties found in rural areas. Chicken, goose, and duck feet were used to flavor soups and stews. However, this does not mean that poor households prefer the taste of chicken feet to chicken legs (Peters, 2015, p. 48,56,61,69)

From the social overview in the Southeast Asia which are consist of food culture, ingredient used, and spice used. This product will be more potential in the Southeast Asian market if the ingredients that form this artificial meat comes from Southeast Asian cuisine. However, in the current market, several products are successful as plant-based meat analogues and seem to provide sufficient number of proteins to our diet as meat alternatives. Bohrer (Bohrer, 2019) investigated the nutritional contents in four major types (beef burger products, beef meatballs, pork ham, and chicken nuggets) of traditional meat and plant-based meat analogues in market. They found that each beef patty in a burger contains 23.33 g of protein, whereas a meat analogue patty has approximately 19.46 g of protein However, plant-based meat analogues have less cholesterol and more dietary fiber, which can be appealing to consumers.

The market potential in the Asia-Pacific (Kamble & Deshmukh, 2021) dominated the cultured meat market in 2021, and is expected to sustain its dominance throughout the cultured meat market forecast period. India and China have been identified as prominent countries to conduct consumer surveys on cultured meat. This is not only attributed to growing population but also rising economies, thereby increasing the meat consumption and consumer affordability for premium products. In Southeast Asia, the food bowl of Asia, covers 11 countries, that are Brunei, Cambodia, East Timor, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Thailand, and Vietnam. The new generation of plant-based meat alternatives such as the Impossible Burger and Beyond Burger are becoming increasingly popular with consumers.

Their success has led other international food companies including traditional meat companies to invest in their own product versions (Sha & Xiong, 2020). The global plant-based meat alternative sector has experienced substantial growth and is projected to increase from $11.6 billion in 2019 to $30.9 billion by 2026 with a compound annual growth rate (CAGR) of 15%. In contrast, the meat sector is expecting a CAGR of 3.9% during this time and to reach a market value of $1142.9 billion by 2023(Wunsch, 2020).

A commercially available plant-based alternative closely matches the Nutrition Facts panel of beef as shown in Figure 4, and to consumers reading nutritional labels they may appear nutritionally interchangeable (International Food Information Council, 2019). Nonetheless, food sources have considerable complexity and contain a wide variety of nutrients, for example phenols, antioxidants, peptides, amino acids, fatty acids, biogenic amines etc., the majority of which do not appear on nutrition labels, but can have potential health implications (Barabási et al., 2019). Important nutritional differences may exist between beef and novel plant-based alternatives; however, this has not been thoroughly assessed.

A schematic representation of the study flow is provided in Figure 6. Eighteen different packages (340 g or 12 oz each) of a commercially available plant-based meat alternative was purchased from a local grocery store in Raleigh, NC, USA. Ground beef from eighteen grass-fed, black angus cattle (454 g or 16 oz each) was purchased from Alderspring Ranch (May, ID) and matched for total fat content to the plant-based alternative, which was confirmed using proximate analysis (method AOAC 960.39; Microbac Laboratories, Warrendale, PA). The macronutrient composition and energy content of 113 g (4 oz) grass-fed beef was 24 g of protein, 0 g of carbohydrates, 14 g of fat (5 g saturated fat), and 220 kcal. The macronutrient composition and energy content of 113 g (4 oz) the soy-based meat alternative was 19 g of protein, 9 g of carbohydrates, 14 g of fat (8 g saturated fat), and 250 kcal. The plant-based alternative is fortified with iron (from soy leghemoglobin), ascorbic acid (vitamin C), thiamin, riboflavin, niacin, vitamin B6, vitamin B12, and zinc. The micronutrients within grass-fed beef are part of the natural food matrix (van Vliet et al., 2021)

Result and Discussion

The manufacture of this meat analogue uses ingredients derived from plants. The impact given will make this meat analogue eat will not contain cholesterol. The use of sunflower oil on meat analogue will give the real meat taste. Then, this oil will have a good impact on health. That is because the saturated fat content of sunflower oil is low. The resulting meat analogue will have as much as 50.4 grams of protein. This amount is high so that it can meet the protein needs of the body. Then, every 300 grams of meat analogue can provide energy for the body as much as 637.17 kcal. Based on all its contents, the nutrients in meat analogue products are certainly able to meet the nutritional and nutritional intake needed by someone who cannot eat real meat. For people who are on a vegan diet, this product can certainly be the right choice. The nutritional content of All Can Eat Meat is presented in Table 2.

In addition, in product packaging, the use of edible packaging is useful as one of the early prevention efforts against food waste and the use of plastic. Edible food packaging eliminates the typical waste cycle and does not require any recycling. Since most edible packaging can be eaten or composted, it is very biodegradable and will not fill up landfills or recycling centers. Second, this type of packaging can be applied to a variety of uses –with food packaging and food saving. Edible packaging is used most for refrigerated and single serve products (Pooja Saklani, nath, Kishor Das, & Singh, 2019). But there are some shortcomings to edible packaging. The idea that it is water soluble is both an advantage and disadvantage. If the packaging is too water soluble it will not hold up in humid climates. It would also break down faster if kept cold and then exposed to condensation effects once removed from the refrigerator. Another downside is that some edible packaging would not be as sanitary when it is exposed to different environments and during shipping. Some edible packaging will still require outer packaging to protect it from contaminants and keep it safe for consumption. The outer packaging would not be biodegradable and still made from original packaging substances making it not as eco-friendly.

Table 2. Nutritional composition of All Can Eat Meat Analogue with reference to (Vadivel & Janardhanan, 2001) and team analysis

Nutrient Specifications	Level (/300g)	Nutrient Specifications	Level (/300g)
Energy Value	637.17kcal	**Dietary Fiber**	7.95g
Protein	50.4g	**Cholesterol**	0.00g
Fat	36.90g	**Carbohydrates**	23.88g
Saturated Fat	9.87g	**Sodium**	18.00g

**Product standardized to a 300g serving*

Future Perspective

The manufacture of this meat analog uses plant-derived ingredients. The impact given will make this meat analog eat will not contain cholesterol. The use of sunflower oil on meat analog will give the real meat taste. Then, this oil will have a good impact on health because sunflower oil has a low saturated fat content, and the vegetarian will be interested to consume meat analogs. Then, the use of 3dz printing machine makes meat analog prices tend to be cheaper than real meat and meat products get many fans in the market. Finally, vegetable proteins will be a source of protein for humans in the future (Nurhartadi et al., 2014).

Figure 3. All Can Eat Meat product based on the team analysis

Based on these 3D printing proprietary technology and materials guidelines. Later, all can eat meat products can be realized. All can eat meat is an analog meat product made from broad beans.

Conclusion

As a result of this research, it is possible to accelerate product development cycles. The goal of this study, then, is to design a fast-to-make and cheap-to-eat product in order to fulfil the sustainable development goals of minimising the hunger index, achieving zero hunger, and resolving the food waste and food security issues in ASEAN. Due to the importing crisis, other alternative products such as Broad Beans are being utilized to reduce the use of soybeans. Finally, the additional goal is to shift the sources of profit, develop new food engineering capabilities, and create an all-can-eat-meat ecosystem.

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References

Godoi, F. C., Zhang, M., Bhandari, B. R., & Prakash, S. (2019). *Fundamentals of 3D Food Printing and Applications*.

Arbulu, I., Lath, V., Mancini, M., Patel, A., & Tonby, O. (2018). *Reinvigorating ASEAN Manufacturing for the Future*. McKinsey&Company. http://files/141/Arbulu et al. - Reinvigorating ASEAN Manufacturing for the Future.pdf

ASEAN. (2018). *Agriculture | ASEAN Investment*. Retrieved from http://investasean.asean.org/index.php/page/view/agriculture

ASEAN. (2020). *Overview - ASEAN | ONE VISION ONE IDENTITY ONE COMMUNITY*. https://asean.org/asean/about-asean/overview/

Bohrer, B. M. (2019). An investigation of the formulation and nutritional composition of modern meat analogue products. *Food Science and Human Wellness*, *8*(4), 320–329. https://doi.org/10.1016/j.fshw.2019.11.006

FAO. (2015). Food wastage footprint & Climate Change. *Food Wastage Footprint & Climate Change*, *1*, 1–4. http://www.fao.org/3/a-bb144e.pdf

FAO. (2016). *FAO Outlook*. http://www.fao.org/3/a-BO103e.pdf

Fraser, R. Z., Shitut, M., Agrawal, P., Mendes, O., & Klapholz, S. (2018). Safety Evaluation of Soy Leghemoglobin Protein Preparation Derived From Pichia pastoris, Intended for Use as a Flavor Catalyst in Plant-Based Meat. *International Journal of Toxicology*, *37*(3), 241–262. https://doi.org/10.1177/1091581818766318

Galanakis, C. M. (2019). *Sustainable Meat Production and Processing* (Issue January 2018). Elsevier. https://doi.org/10.1016/C2017-0-02230-9

Godoi, F. C., Prakash, S., & Bhandari, B. R. (2016). 3d printing technologies applied for food design: Status and prospects. *Journal of Food Engineering*, *179*, 44–54. https://doi.org/10.1016/j.jfoodeng.2016.01.025

Gustafsson, J., Cederberg, C., & Sonesson, U. (2013). *The methodology of the FAO study: Global Food Losses and Food Waste-extent, causes and prevention"-FAO, 2011*. https://www.diva-portal.org/smash/get/diva2:944159/FULLTEXT01.pdf

International Food Information Council. (2019). *A Consumer Survey on Plant Alternatives to Animal Meat*. 1–29. https://foodinsight.org/consumer-survey-plant-alternatives-to-meat/

Karwowska, M., Łaba, S., & Szczepański, K. (2021). Food loss and waste in meat sector—why the consumption stage generates the most losses? *Sustainability (Switzerland)*, *13*(11). https://doi.org/10.3390/su13116227

Kowalski, R. J. (2019). Sustainability Impacts of Pulses in Meat-Analogue Food Products. *Cereal Foods World*, *64*(5). https://doi.org/10.1094/CFW-64-5-0052

Kumar, R., & Kumar, R. (2020). Materials Today : Proceedings 3D printing of food materials : A state of art review and future applications. *Materials Today: Proceedings*, *33*, 1463–1467. https://doi.org/10.1016/j.matpr.2020.02.005

Kumar, S., Kumar, V., Sharma, R., Paul, A. A., Suthar, P., & Saini, R. (2020). Plant Proteins as Healthy, Sustainable and Integrative Meat Alternates. *Veganism - a Fashion Trend or Food as a Medicine*. https://doi.org/10.5772/INTECHOPEN.94094

Kyriakopoulou, K., Dekkers, B., & van der Goot, A. J. (2019). Plant-Based Meat Analogues. In *Sustainable Meat Production and Processing* (pp. 103–126). Elsevier. https://doi.org/10.1016/B978-0-12-814874-7.00006-7

Liu, Z., Zhang, M., Bhandari, B., & Wang, Y. (2017). Trends in Food Science & Technology 3D printing : Printing precision and application in food sector. *Trends in Food Science & Technology*, *69*, 83–94. https://doi.org/10.1016/j.tifs.2017.08.018

Malav, O. P., Talukder, S., Gokulakrishnan, P., & Chand, S. (2015). Meat Analog: A Review. *Critical Reviews in Food Science and Nutrition*, *55*(9), 1241–1245. https://doi.org/10.1080/10408398.2012.689381

Meade, S. J., Reid, E. A., & Gerrard, J. A. (2005). The impact of processing on the nutritional quality of food proteins. *Journal of AOAC International*, *88*(3), 904–922. https://doi.org/10.1093/jaoac/88.3.904

Nachal, N., Moses, J. A., Karthik, P., & Anandharamakrishnan, C. (2019). Applications of 3D Printing in Food Processing. *Food Engineering Reviews*, *11*(3), 123–141. https://doi.org/10.1007/s12393-019-09199-8

Nurhartadi, E., Anam, C., Ishartani, D., Parnanto, N. H., Laily, R. A., & Suminar, N. (2014). Meat analog dari protein curd kacang merah (phaseolus vulgaris l) dengan tepung biji kecipir (psophocarpus tetragonolobus) sebagai bahan pengisi : sifat fisikokimia meat. *Jurnal Teknologi Hasil Pertanian*, *VII*(1), 12–19.

O'Neill, A. (2021a). • *ASEAN countries GDP 2021 | Statista*. https://www.statista.com/statistics/796245/gdp-of-the-asean-countries/

O'Neill, A. (2021b). *Total population of the ASEAN countries 2011-2021 | Statista*. https://www.statista.com/statistics/796222/total-population-of-the-asean-countries/

Ong, K. L., Kaur, G., Pensupa, N., Uisan, K., & Lin, C. S. K. (2018). Trends in food waste valorization for the production of chemicals, materials and fuels: Case study South and Southeast Asia. *Bioresource Technology*, *248*, 100–112. https://doi.org/10.1016/j.biortech.2017.06.076

Ponnampalam, E. N., Bekhit, A. E. D., Bruce, H., Scollan, N. D., Muchenje, V., Silva, P., & Jacobs, J. L. (2019). Production Strategies and Processing Systems of Meat. In *Sustainable Meat Production and Processing* (pp. 17–44). Elsevier. https://doi.org/10.1016/B978-0-12-814874-7.00002-X

Roman, B., & Russell, S. (2009). *Southeast Asian Food and Culture*. Retrieved from http://131.156.68.45/outreach/SEAFood&Culture.htm

S Vliet, S. K. F. P. (2020). Plant-based meats, human health, and climate change. *Front. Sust. Food. Syst.*, *4*. https://doi.org/10.3389/fsufs.2020.00128

Saldanha, C., Halvor, S., Malizia, G., Dessev, T., Geny, A., Zobel, H., Myhrer, K. S., Varela, P., & Sahlstrøm, S. (2021). *Meat analogues from a faba bean concentrate can be generated by high moisture extrusion*. *3*(January). https://doi.org/10.1016/j.fufo.2021.100014

Schwab, K. (2019). *Sustainable 3D Printing with Soy-derived Bioink*.

Sun, C., Ge, J., He, J., Gan, R., & Fang, Y. (2021). Processing , Quality , Safety , and Acceptance of Meat Analogue Products. *Engineering*, *7*(5), 674–678. https://doi.org/10.1016/j.eng.2020.10.011

Sun, J., Zhou, W., Huang, D., Fuh, J. Y. H., & Hong, G. S. (2015). *An Overview of 3D Printing Technologies for Food Fabrication*. 1605–1615. https://doi.org/10.1007/s11947-015-1528-6

Susanti, I., Siregar, N., & Supriatna, D. (2013).). Potensi kacang koro pedang (canavila ensiformis dc) sebagai sumber protein produk pangan. In *Indonesian Journal of Industrial Research* (Vol. 7, Issue 1, pp. 1–13).

Team, T. A. P. (2019). ASEAN Start-Ups Are Tackling Food Waste. In *The ASEAN Post*. https://theaseanpost.com/article/asean-start-ups-are-tackling-food-waste

Vadivel, V., & Janardhanan, K. (2001). Diversity in nutritional composition of wild jack bean (Canavalia ensiformis L. DC) seeds collected from south India. *Food Chemistry*, *74*(4), 507–511. https://doi.org/10.1016/S0308-8146(01)00175-3

Wunsch, N.-G. (2020). *Meat substitutes market in the U.S. - Statistics and Facts | Statista*. https://www.statista.com/topics/6057/meat-substitutes-market-in-the-us/

Yang, F., Zhang, M., & Bhandari, B. (2017). *Recent development in 3D food printing*. *8398*. https://doi.org/10.1080/10408398.2015.1094732

EFFECT OF GIBBERELLIC ACID AND CHITOSAN FOLIAR APPLICATION ON THE GROWTH AND YIELD OF SPINACH (*Spinacia oleracea*) USING NUTRIENT FILM TECHNIQUE (NFT) HYDROPONIC SYSTEM

Norhafizah Md Zain*[1,2,3], Nadzirah Adnan[1], Zainah Md Zain[4]
[1]Faculty of Agro-Based Industry, University Malaysia Kelantan, Jeli Campus, 17600 Jeli, Kelantan, Malaysia
[2]Institute of Food Security and Sustainable Agriculture (IFSSA), University Malaysia Kelantan, Jeli Campus, 17600 Jeli, Kelantan, Malaysia
[3]Institute for Poverty Research and Management (InsPeK), Universiti Malaysia Kelantan, 16300 Bachok, Kelantan Malaysia
[4]Faculty of Electrical and Electronics Engineering, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia
*norhafizah.mz@umk.edu.my

Abstract

Plant hormone and inorganic chemicals such as gibberellic acid (GA_3) and chitosan (CTS) were used to increase the plant growth and act as bio stimulant in agriculture. However, their application as foliar application in the smart planting technique by using hydroponic system not fully studied. Thus, this study was conducted to determine the efficacy of different concentration of GA_3 and CTS foliar application on the growth and yield of spinach ((*Spinacia oleracea*) as bioassay species. The spinach was treated with GA_3 and chitosan CTS at **T0**: 0 ppm GA_3 + 0.0% CTS, **T1**: 50 ppm GA_3 + 2.5% CTS, **T2**: 100 ppm GA_3 + 2.5% CTS and **T3**: 200 ppm GA_3 + 2.5% CTS at 15 and 25 days of plant cultivation. After 30 days of cultivation, the plant growth data such as plant height, number of leaves, fresh weight (yield) and chlorophyll content were measured. From the study, GA_3 and CTS foliar application at **T1** and **T2** significantly enhanced the chlorophyll content and the plant fresh weight by approximately 19% and 68%, respectively. However, all the treated spinach does not give any significant difference in term of the leaves number and plant height. Even though not significant, **T1** shows higher mean values for all growth and yield parameters, suggesting that combination of 50ppm GA_3 + 2.5% CTS at **T1** was the most optimum rate in promoting the production of spinach plants under Nutrient Film Technique (NFT) hydroponic system.

Keywords: Chitosan; Gibberellic acid; Growth performance; Hydroponic; Spinach (*Spinacia oleracea*)

Introduction

Spinach (*Spinacia oleracea*) is one of the leafy vegetables that has high demand and are popular among Malaysian growers (Husna et al., 2019). The total area cultivated by spinach was 2474 ha which is the 4th largest planted area among lowland vegetables in Malaysia (Saleh, M. M. 2010). In 2019, round cabbage recorded the highest Per capita consumption (PCC) with consumption of 5.3 kilograms per year, followed by mustard (4.4 kg /year), tomato (3.6 kg/year), cucumber (2.8 kg/year) and spinach (2.1 kg/ year) (DOSM, 2020). However, it was reported that the price transmission of spinach is higher than other vegetables. There is 0.6% increase in spinach retail price for every 1% increase of spinach wholesale price.

Nowadays, spinach growers faced a variety of challenges, including issues of failure in seed germination, which might be caused by water stress (Chen, K. et al., 2010). According to Sharma et al. (2018), the spinach seeds will germinate faster in hydroponics or aquaponics systems and any soilless media as compared to the conventional methods because it has low to medium nutrients requirement for the plant growth. Besides, previous study conducted by Al-Qumboz and Abu-Naser (2019) showed that soil fungal pathogens would be the main problem in spinach production. The pathogens cause many severe diseases and had reduce the spinach yield and commercial value. They suggested that the using of planting media (soilless potting mix), should be practiced in spinach production to prevent soil borne diseases.

Various studies reported the effect of gibberellic acid (GA_3) and chitosan (CTS) on selected plant yield and quality. For example, GA_3 was found to shortened period from planting to harvest and increased yield of seed grown artichoke [*Cynara cardunculus* L. var. *scolymus* (L.) Fiori] (Calabrese, N. and Bianco, V.V. (2000). Meanwhile, the chitosan, an N-acetylated derivative of the polysaccharide chitin has been reported to stimulate plants immunity against microorganisms (Gornik, K. et al., 2008) and increased the vegetative growth, yield and quality of some vegetable crops by foliar spray application (Kamal et al., 2011 and Fawzy et al., 2012). Thus, the smart planting technique by using hydroponic system together with the application of phytohormone, gibberellic acid (GA_3) with natural compound of chitosan (CTS) would be an ideal solution to enhance the spinach production. The present study investigates the effect of different foliar sprays of GA_3 and CTS concentrations on vegetative growth and yield of spinach (*Spinacia oleracea*) under Nutrient Film Technique (NFT) hydroponic system for local consumption.

Materials and Methods

Plant Material and Growth Conditions

The study was conducted in a shelter house of Agro Techno Park, University Malaysia Kelantan (UMK), Jeli Campus, Kelantan, Malaysia during October to December 2020. Spinach (*Spinacia oleracea*) were grown under NFT hydroponic system with the temperature ranging from 25 to 30^oC and 80-90% relative humidity.

Treatments

Gibberellic acid (GA_3) at the rate of 50, 100 and 200 ppm and and 2.5% of chitosan (CTS) were applied as foliar application. The GA_3 solution was prepared by dissolving it with absolute alcohol and water (alcohol/water: 1/1000 v/v). Meanwhile, the optimum concentration of 2.5% CTS was prepared by using distilled water and acetic acid based on the modified method of Rinaudo et al. (1999). The combination of treatments as shown in Table 1.

Table 1. Treatments applied to the spinach under NFT hydroponic system

Treatment	Application rate
T0 (Control)	0 ppm GA_3 + 0.0% CTS
T1	50 ppm GA_3 + 2.5% CTS
T2	100 ppm GA_3 + 2.5% CTS
T3	200 ppm GA_3 + 2.5% CTS

Note: GA_3: Gibberellic acid; CTS: Chitosan

Plant Growth Experiment

The spinach seeds were sown in sowing sponge at 3-4 mm depths. Then, the sponge was immersed in the water and covered with black plastic to stimulate the seed germination. Sowing sponge that contains spinach seeds were monitored daily to make sure the sowing sponge always in moist condition. After 1-2 days, the seed coat begins to break and then the roots and leaves begin to come out of the seeds. Then, at day 10-11, the spinach seedlings together with the sowing sponge were ready to be transplanted into hydropots for growth and development under NFT hydroponic system (Figure 1). The plants were fertilized with hydroponic AB fertilizer containing complete nutrient solution of macronutrients and micronutrients: N, P_2O_5, K_2O, Ca, Mg, S, Fe, Mn, Mo and Cu (Treftz, C. and Omaye, S.T., 2015). Before that, the AB fertilizer was diluted into water with the ratio of 1:1 until reach the desired concentration level.

At the beginning (day 10-15), the plants were fertilized with AB fertilizer at nutrient concentration of 800 ppm for the first week of planting. The portable EC meter was used to monitor the amount soluble salts content (electrical conductivity) of the water solution. Then, the EC reading was increased to 1000 ppm at day 16-23 and 1200 ppm at day 24-30 (harvesting period), due to the increase of nutrients requirement for the plant growth. The AB fertilizer solution was circulated 24 hours every day by using water pump. The GA_3 and CTS combination treatments at different level of concentration (**T0**: 0 ppm GA_3 + 0.0% CTS, **T1**: 50 ppm GA_3 + 2.5% CTS, **T2**: 100 ppm GA_3 + 2.5% CTS and **T3**: 200 ppm GA_3 + 2.5% CTS) were applied as foliar application with spraying volume of 160 L/ha (equivalent to 45 ml per plant). The treatments were applied at day 15 and day 25 of planting. Untreated plants were left as a control and sprayed with distilled water. The NFT hydroponic system and the bioassay plants were monitored continuously to ensure the availability of nutrients solution uptake by the plants.

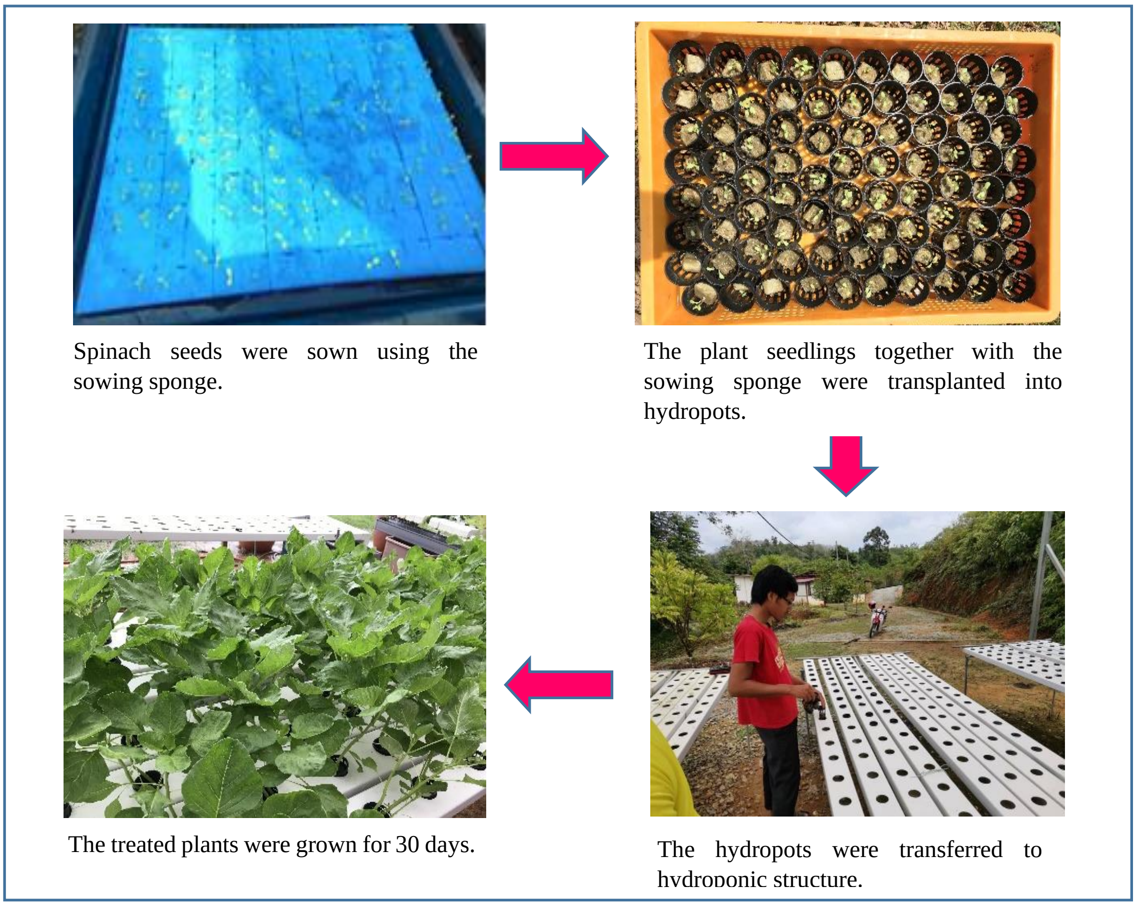

Figure 1. The experimental setup for the plant growth experiment.

Measurements

After 30 days of cultivation, the plant height, number of leaves, chlorophyll content and the fresh weight of spinach plants were measured. Plant height was measured by using the measuring tape, while the number of spinach leaves (excluding the young leaves) was manually counted and recorded. The chlorophyll content of the plants further was measured by using the SPAD meter (model SPAD-502) and the fresh weight (yield) was measured by using weighing scale.

Statistical Analysis

Experiment was arranged in a completely randomized design (CRD) with three replications. All data were subjected to one-way ANOVA analysis. The Tukey HSD was used to compare mean among the treatments. Differences regarded as a significant when the p-values were less that 0.05 ($p<0.05$).

Results and Discussion

Plant Height

Figure 2A shows the effect of GA_3 enriched with CTS on the plant height of hydroponically grown spinach. Regardless of any concentration used, spinach plants showed no significant increase in plant height. However, GA_3 at 50 ppm (**T1**) and 100 ppm (**T2**) showed higher mean values of plant height with 25.83cm and 24.61cm, respectively. The results in this current study were similar with the study conducted by Llanes et al. (2019), where the application of exogenously applied GA_3 with other phytohormones at lowest concentration on soybean (*Glycine max*) and maize (*Zea mays*) showed significant improvement on shoot growth in both species. Furthermore, the positive stimulating effect of GA_3 on plant height also have been reported by other researchers (El-Greadly, N. H. M., 1994 and Sharaf-Eldin, M. A. A., 2003). In this study, CTS may interact with GA_3 to stimulate the plant height by enhance the increase of water and nutrient solution uptake through the hydroponic system.

Number of leaves

Spraying plants with **T2** (100 ppm GA + 2.5% CTS) resulted in a significant increase ($P \leq 0.05$) in number of leaves of spinach with the mean value of 11.83 as compared to the control (**T0**) (Figure 2B). This current finding was in line with a study conducted by Elsharkawy and Ghoneim (2019), who investigated that the interaction treatments between spraying artichoke plants (*Cynara scolymus* L.) two times with GA_3 and CTS at 0.015% gave the highest mean values of leaf length and width. These results might be explained by the role of CTS in photosynthesis by enhanced the plant growth and induces syntheses of plant hormones such as gibberellins (Gornik et al., 2008 and Mondal et al., 2012). Another study conducted by Dastjerd et al. (2013) found that the shoots of in vitro cultured M26 apple rootstock had increased in 0.1 or 0.3 mgL^{-1} GA_3 in combination with 120 mgL^{-1} CTS, indicating the role of CTS as an efficient growth stimulator in combination with a minimum amount of GA_3.

Chlorophyll content

It was noticed that application of GA_3 at 50 ppm (**T1**) and 100 ppm (**T2**) together with CTS at the rate of 2.5% produced the best interaction which had significant effect on the chlorophyll content of spinach (Figure 2C). In contrast, Mondal et al. [17] found that foliar application of 0.01-0.0125% CTS every 15 days increased okra fruit (*Abelmoschus esculentus*) production, as well as plant height, leaf number, relative growth rate, and photosynthesis rate, but had no effect on the chlorophyll content. Such findings might be due through elicitation and signaling of different physiological and metabolically processes in the plants. In other side, Ahmad et al. (2019) demonstrated that the foliar application of both GA_3 and irradiated chitosan significantly increased the total chlorophyll content of peppermint (*Mentha piperita* L.). They suggest that the reasons of the increment in chlorophyll content might be due to radiation processed of chitosan that can have synergistic effect on photosynthesis resulting in enhanced growth of the tested plant.

Fresh Weight

Similar trend was also observed for the fresh weight (yield) of spinach plants where both concentration of GA_3 at 150 and 100 ppm exhibit largest significant values with mean of 27.0 g and 24.6 g, respectively (Figure 2D). It could be observed that the increment of fresh weight at low concentration may be explained as a result of favorable stimulatory effects between GA_3 and CTS on vegetative growth characters and enhanced photosynthetic apparatus [13]. Even though there is no significant difference was observed between **T1** (50 ppm GA3 + 2.5% CTS) and **T2** (100 ppm GA3 + 2.5% CTS) in all vegetative growth and yield of spinach, but **T1** appears to be the optimum rate in promoting the production of spinach plants under NFT hydroponic system. Miceli et al. (2019) reported that plants of leaf lettuce (*Lactuca sativa* L. var. *Crispa*) and rocket (*Eruca sativa* L.) cultivated in a hydroponic floating system using nutrient solutions showed an increase in total fresh biomass after treated with low concentration of 10^{-6} M GA_3. However, they observed that the marketability of plants was lost when higher concentration of 10^{-4} M GA_3 was added to the mineral nutrient solution, suggesting that the addition of 10^{-4} M GA_3 exceeded the acceptable threshold for use in hydroponics production systems.

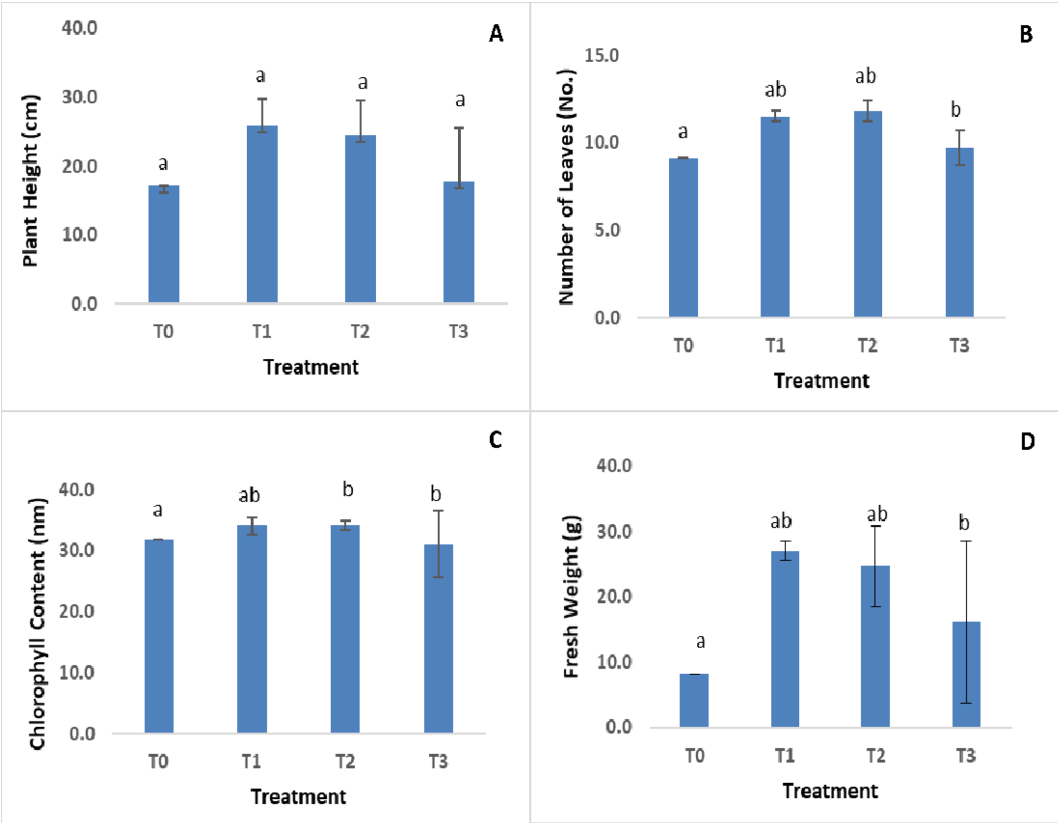

Figure 2. The effect of gibberellic acid (GA_3) and chitosan (CTS) on the plant height (A), number of leaves (B), chlorophyll content (C) and fresh weight (D) of spinach (*Spinacia oleracea*). Vertical error bars represent standard deviation (s.d) of the mean. T0: 0 ppm GA_3 + 0.0% CTS, T1: 50 ppm GA_3 + 2.5% CTS, T2: 100 ppm GA_3 + 2.5% CTS and T_3: 200 ppm GA_3 + 2.5% CTS.

Conclusion

Vegetative growth and yield of spinach plants were influence by the different level of GA_3 foliar spray application. The addition of CTS as foliar spray showed positive impact on the plants as it increased their morphology for marketability during harvest. The enhancement in the plant's growth could be associated with an optimal selectivity of GA_3 and CTS nutrition concentration. Finally, this study suggested that the application of foliar spray of GA_3 and CTS at **T1** (50 ppm GA3 + 2.5% CTS) on hydroponically grown spinach can promote the vegetative growth and yield of spinach.

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References

Nurfarah Husna, M. H., Shafirah, S, Suzana, Y. and Nurul Aini, A. (2019). *Journal of Science and Technology, 2*, 23–31.

Salleh, M. M. (2010). Tropical fruits and vegetables in Malaysia : Production and impact on health. Fruits and Vegetables for Health Workshop. 15-16 August 2006, Seoul, Korea, 1–5

Department of Statistic Malaysia (DOSM), Press Release, BERNAMA (18 August 2020).

Chen, K., Arora, R. and Arora, U. (2010). Osmopriming of spinach (*Spinacia oleracea* L. cv. Bloomsdale) seeds and germination performance under temperature and water stress. 45–57.

Sharma, N., Acharya, S., and Kumar, K., Singh, N. and Chaurasia, O. M. (2018). Hydroponics as an advanced technique for vegetable production : An overview. *Journal of Soil and Water Conservation. 17*(4), 364-371.

Al-Qumboz, M. N. A. and Abu-Naser, S. S. (2019). Spinach expert system : Diseases and symptoms. *International Journal of Academic Information Systems Research. 3*(3), 16–22.

Calabrese, N. and Bianco, V.V. (2000). Effect of gibberellic acid on yield and quality of seed grown artichoke (*Cynara cardunculus* L. var. scolymus (L.) Fiori). *Acta Horticulturae, 514*, 25–32.

Gornik, K., Grzesik, M. and Duda, B.R. (2008) The effect of chitosan on rooting of gravevine cuttings and on subsequent plant growth under drought and temperature stress. *Journal of Fruit and Ornamental Plant Research. 16*, 333-343.

Kamal, A. M. and Ghanem, K.M. (2011). Response of cape gooseberry plants (*Physalis peruviana* L.) To some organic amendments and foliar spray with chitosan. *Journal of Plant Production Mansoura University. 2* (12), 1741 – 1759.

Fawzy, Z.F., El-Shal, Z.S., Yunsheng, L., Zhu, O. and Sawan, O. M. (2012). Response of Garlic (*Allium sativum* L.). Plants to foliar spraying of some biostimulants under sandy soil condition. *Journal of Applied Sciences Research. 8* (2), 770- 776.

Rinaudo, M., Pavlov, G. and Desbrie, J. (1999). Influence of acetic acid concentration on the solubilization of chitosan. *Polymer. 40* (25), 7029–7032.

Treftz, C. and Omaye, S. T. (2015). Comparison between hydroponic- and soil-grown raspberries (*Rubus idaeus*): Vi-ability and sensory traits. *International Journal of Agricultural Extension. Food and Nutrition Sciences. 6*, 1533-1540.

Llanes, A., Iparraguirre, J., Masciarelli, O., Maria, N. and Luna, V. (2019). Foliar application of phytohormones enhances growth of maize and soybean seedlings. *Trabajos En Prensa. 44* (1).

El-Greadly, N.H.M. (1994). Effect of some chemical substances on earliness, productivity and endogenous substances of globe artichoke, *Ph.D. Thesis,* Faculty of Agriculture, Cairo University.

Sharaf-Eldin, M.A.A. (2003) Studies on the effect of some agricultural treatments on growth and productivity ofartichoke

(*Cynara cardunculus* var. *scolymus* (L.) Fiori) and their relation to earliness and physical and chemical characters of heads. Ph.D. Student, Chair of Vegetable Science, Technische Universität München, Freising Weihenstephan, Germany. Soltani.

Elsharkawy, G. A. and Ghoneim, I. M. (2019). Effect of chitosan and gibberellic acid applications on yield, quality and yield pattern of globe artichoke (*Cynara scolymus* L.). *Egyptian Journal of Horticulture. 46*(1), 95–106.

Mondal, M.M.A., Malek, M.A. Puteh, A.B. Ismail, M.R. Ashrafuzzaman, M. and Naher, L. (2012). Effect of foliar application of chitosan on growth and yield in okra. *Australian Journal of Crop Science. 6* (5), 918-921.

Dastjerd, Z.H., Jabbarzadeh, Z. and Marandi, R.J. (2013). Interaction effects of chitosan, benzyladenine, and gibberellic acid on in vitro proliferation of M26 apple rootstock. *Horticulture, Environment, and Biotechnology. 54*, 538–547.

Ahmad, B., Jaleel, H., Shabbir, A., Khan, M. M. A. and Sadiq, Y. (2019). Concomitant application of depolymerized chitosan and GA_3 modulates photosynthesis, essential oil and menthol production in peppermint (*Mentha piperita* L.). *Scientia Horticulturae. 246*, 371-379

Miceli, A., Moncada, A., Sabatino, L. and Vetrano, F. (2019). Effect of gibberellic acid on growth, yield, and quality of leaf lettuce and rocket grown in a floating system. *Agronomy. 9*(7), 382.

EFFECT OF ORGANIC MULCHES ON THE GROWTH OF LETTUCE (*LACTUCA SATIVA* L.) – DO TYPES AND FORMS OF MULCHING MATERIALS MATTER?

Dk. Nasriah Rabiatul Adawiyah Pg Abdul Karim, Amanda Liew Wei Yi,
Nurul Aqilah Asyahirah Abd Aziz, Faizah Metali*,
Environmental and Life Sciences Programme, Faculty of Science, Universiti Brunei Darussalam,
Jalan Tungku Link, BE1410, Brunei Darussalam
faizah.metali@ubd.edu.bn

Abstract

Plastic mulches offer numerous agricultural benefits, but their extensive use has generated a huge amount of plastic waste that might pollute the environment. Therefore, organic mulches are commonly used nowadays to provide farmers with cost-effective and environmentally friendly alternatives to traditional plastic mulching. In addition to investigating selected physicochemical properties of organic mulches (two seaweed species, *Padina australis* and *Ulva intestinalis* and the leaves of jackfruit trees, *Artocarpus heterophyllus*), the study also evaluated the effects of different types (seaweeds, jackfruit leaves and plastic mulch) and forms (dry, milled vs. fresh, shredded mulches) of mulching treatments on the growth of *Lactuca sativa* L. (lettuce). It was reported that the pH of *U. intestinalis* (pH 6.95) was significantly lower than *P. australis* (pH 7.56), but both were not significantly different from *A. heterophyllus* (pH 7.21). The moisture contents of seaweeds were significantly greater (180% in *P. australis* and 171% in *U. intestinalis*) than *A. heterophyllus* leaves. However, *P. australis* had significantly lower organic matter content (61.4%) than *U. intestinalis* and *A. heterophyllu*s (71.7% and 67.9%, respectively). In terms of total macronutrient content, *U. intestinalis* and *A. heterophyllus* had significantly the highest concentration of nitrogen (N) and phosphorus (P), respectively. The mean relative growth rate (RGR) of lettuce was significantly greater in dry, milled seaweed (MS) mulching treatments than in fresh, shredded leaf (FL) mulching treatment by 50-66% but not significantly different from the control treatment. The fresh *P. australis* and milled *U. intestinalis* treatments showed significantly larger mean total leaf surface area (LSA) than milled leaf mulching treatments. In terms of chlorophyll content index (CCI), only milled *P. australis* showed significantly higher values than other mulching treatments, including control by 57%. The findings suggest that dry, milled seaweed mulch, regardless of seaweed species, might be a potential organic mulching treatment that could improve the growth of lettuce. This study is valuable as it provides more insight into organic mulching in Brunei Darussalam, which is feasible, easy to implement and promotes sustainable agriculture.

Keywords: *Lactuca sativa;* Organic mulching; *Padina australis;* RGR; *Ulva intestinalis*

Introduction

Mulches are materials that are applied on the soil surface and around the plant to minimize moisture loss and soil erosion, reduce weed growth, enhance seed germination, and improve crop growth and yield (Chalker-Scott, 2007; Iqbal et al., 2020). Black plastic film is a commonly used mulching material, but its extensive use may cause land and marine pollution (Chae & An, 2018). The green solution to this pollution issue is to use biodegradable, organic mulches such as seaweeds and leaves (Shit & Shah, 2014; Ni et al., 2016).

Since farmers rely heavily on synthetic fertilizers to meet global food demand, there is a need to explore organic alternatives that can also be utilized to boost agricultural productivity. Many studies on organic mulch have demonstrated its beneficial impacts on soil quality, notably in terms of increasing soil nutrients levels due to biodegradation and decomposition of organic residues (Iqbal et al., 2020; Wang et al., 2021). Different types of organic mulch have been proven to be effective in vegetable growth (Ngala et al., 2019; Gheshm & Brown, 2020; Iqbal et al., 2020). For example, seaweed mulch and neem leaves mulch were reported to improve leaf area, stem diameter, height, and fresh and dry weights of *Amaranthus* species (Ngala et al., 2019), however, Gheshm and Brown (2020) demonstrated that compost mulch, derived from a mixture of feedstocks including seaweed and leaves, and black plastic mulch enhanced yield of lettuce but not dried, shredded leaf mulch. Among many organic feedstocks, seaweed has tremendous potential as an organic fertilizer, making it excellent for use on a range of crops to boost yield and quality (Baweja et al., 2019). Seaweed contains bioactive compounds, such as essential minerals, growth hormones, vitamins, and amino acids, which all could contribute to plant growth, development, quality, and yield (Paulert et al., 2009; Peres et al., 2012; Baweja et al., 2019). Seaweeds have also been reported to control pests, boost disease resistance, and improve the overall quality of the plant (Novello & de Palma, 2008).

Since seaweeds are diverse in Brunei Darussalam, exploring their potential as an organic mulch and biofertilizer holds great promise for diversifying Brunei's economy and encouraging organic and sustainable agriculture. Thus, this research project aims to investigate the effects of different types (seaweed and leaf mulches) and forms (dry, milled vs. fresh, shredded mulches) of organic mulches on the growth of *Lactuca sativa* L. (lettuce). This study also included black plastic film mulching, and no mulching as additional mulching treatments. Simultaneously, selected physicochemical properties of dried seaweed and jackfruit leaf mulches were analyzed and reported. This study will address the following research questions:

1. Are there significant differences in the physicochemical properties (pH and, moisture, organic matter, and macronutrient contents) of dried seaweed species (*Padina australis* and *Ulva intestinalis*) and leaves of jackfruit trees (*Artocarpus heterophyllus*) used as organic mulch?

2. Do the types and forms of organic mulch significantly affect the growth of lettuce compared to plastic mulch and no mulch treatments?

Materials and Methods

Organic Mulching Sampling and Preparation

Padina australis Huak (Ochrophyta) and *Ulva intestinalis* Linnaeus (Chlorophyta) were chosen because they were abundant and commonly found on the rocks at Tanjung Batu in Brunei Darussalam (5°02'19.6"N, 115°03'42.3"E). Approximately 1 kg of fresh seaweed per species was collected, rinsed with seawater, and stored inside plastic bags containing seawater before transported to the laboratory. The samples were rewashed using distilled water before storing in a freezer (-15°C). The leaf mulch was prepared using leaves from jackfruit trees, *Artocarpus heterophyllus* (Moraceae) sampled from Kampung Kulapis in Brunei Darussalam (4°51.612'N, 114°49.413'E). This fruit tree species was chosen because it existed at a high density near the plant shade.

For dry, milled seaweed and leaf mulch preparation, fresh samples were sundried for 2 h before oven-drying (60°C) for 24 h (Kaladharan et al., 2019). The oven-dried samples were ground, and the milled samples were stored in airtight containers before further use. The frozen seaweed was thawed and used immediately for the fresh, shredded seaweed mulching treatment. The fresh samples were cut roughly into 5 cm in length and spread onto the soil surface following Gheshm and Brown (2020).

Physicochemical Properties of Seaweed and Leaf Mulches

Fresh samples were mixed with distilled water (1:8 respectively) following Perez-Harguindeguy et al. (2013) and the pH was measured using a pH bench meter (Orion Star TM A211, Thermo scientific, USA). Approximately 10 g of fresh sample was weighed (W0) in a crucible, followed by oven-drying at 105°C for 2 days before re-weighing it to obtain the oven-dried mass (W1). The percentage moisture content (%) based on wet mass was calculated following Horwitz (2000): [(W0-W1)/W0]x100%

The ash content (%) was determined following the incineration method by Horwitz (2000). The oven-dried samples were placed in a muffle furnace at 550°C for 18 h until samples turned to ashes. The samples were then re-weighed (W2). Ash content (%) and organic matter content (%) were determined as follows: Ash content (%) = (W2/W1)x100% and organic matter content (%) = 100%-Ash content(%)

Approximately 0.2 g of each sample (oven-dried at 60°C for 2 days and milled) was used to determine total N and P concentrations following a modified method of Allen et al. (1989). The samples were placed into separate digestion tubes which contain a Kjeltab tablet and 5 mL of concentrated H_2SO_4 each. The tubes were placed inside a preheated digestion block (BD-46 Block Digestor, LACHAT, USA) for 90 mins. The diluted samples (50 mL) were analysed for total N and P concentrations using the Flow Injector (FIAstar 5000, Hoganas, Sweden). All analyses were performed in triplicate.

Plant Bioassay Experiment

Approximately 200 lettuce seeds, purchased from the Rimba Garden Central, Gadong, were germinated in a plastic container lined with a wet paper towel. Once the seedlings had grown at least two leaves (~3 cm shoot length), three seedlings were randomly selected and transplanted into each plastic pot (18 cm width by 20 cm height; 36 pots), containing 100 g of autoclaved potting soils (Free Peat BV, Vriezenveen, The Netherlands). The potting soil has the following properties: loamy sand with 86.9% sand, 8.7% silt and 4.4% clay, pH 4.43, bulk density of 0.24 g cm^{-3}, moisture content of 35.8%, ash content of 8.3%, organic matter content of 91.7%, total N of 47.9 mg g^{-1} and total P of 11.4 mg g^{-1} (n = 3).

The seedlings were acclimatized for 1 day before any treatments were carried out. This study was conducted in a plant shade at Kg Kulapis, Brunei-Muara (4°51.612'N, 114°49.413'E), with mean air temperature, relative humidity, and light intensity of 32.4 ± 1.2°C, 71.2 ± 0.4% and 525 μmol m^2 s^{-1}, respectively (n = 8, except for light intensity). The pot experiment was conducted in a randomized complete block design with 3 blocks of 6 different mulching treatments including a control treatment per seaweed species following a modified experiment by Ngala et al. (2019). Each treatment per block was represented by a pot with three lettuce seedlings, thus the experiment had 18 pots and 54 seedlings per seaweed species mulch. Two seaweed species were used in this study, resulting in 36 pots with 108 seedlings in total. The following were the details of the experimental treatments that were conducted per seaweed species:

T0: No mulching (control treatment),

T1: Mulching using black plastic film

T2: Mulching using fresh, shredded seaweed (either *Padina australis* or *Ulva intestinalis*)

T3: Mulching using dry, milled seaweed (either *Padina australis* or *Ulva intestinalis*)

T4: Mulching using fresh, shredded leaves of jackfruit trees, *Artocarpus heterophyllus*

T5: Mulching using dry, milled leaves of jackfruit trees, *Artocarpus heterophyllus*

For T2 and T4 treatments, fresh seaweed, and leaves were laid uniformly (~3 to 5 cm thick) to cover the soil surface, which was equivalent to 10 g of seaweed or leaves per pot. A total of 10 g of dry, milled seaweed was added to cover the soil surface for T3 and T5 treatments. For T1, the soil surface was covered with black plastic mulching, which was normally adopted by local farmers in their agricultural farms (*pers. obs.*). The seaweed and leaf mulching treatments (T2 to T5) were reapplied twice (7th day and 21st day after transplanting). Once a week, all pots received equal amounts of water (~50 mL) and their positions were randomized to reduce environmental variation. The plants were harvested after 30 days.

Data and Statistical Analysis

The total seedling height was measured at the start of the experiment and at the final harvest to compute relative growth rate (RGR) of each seedling over 30 days following Hunt et al. (2002): Relative Growth Rate = ln(G2) − ln(G1) / (t2 − t1), where G2 and G1 were the final and initial mean of total height (cm), respectively and t2 – t1 are 30 days. Additional parameters that were measured at the final harvest were Chlorophyll Content Index (CCI), total leaf surface area (LSA) and total foliar N and P concentrations of lettuce. One leaf per block was chosen at random and measured for every treatment, resulting in 3 seedlings per treatment. The CCI was measured using a chlorophyll content meter (CCM-200, Opti Sciences, USA), while the total LSA was measured using a mobile application called 'Easy Leaf Area', which used colour ratios of each pixel to distinguish leaves (green) and red calibration area (Easlon & Bloom, 2014). Total counts of green leaf and red calibration pixels were used to estimate leaf area: Leaf area = (green pixel count) x (calibration area/red pixel count). Total foliar N and P contents of lettuce were determined using the acid-digestion method and a flow injector analyser as described above.

The statistical analyses were performed using R4.0.3 software (R Core Team, 2020). The data for all analyses were checked for normality using Shapiro-Wilk test and homogeneity of variances using Levene's test. Data were first transformed using log_{10} transformation, where necessary, except data that were presented in percentages, which were arcsine transformed. The mean differences in physicochemical properties of the seaweed and leaf samples, growth bioassay parameters and, foliar N and P concentrations of lettuce between all mulching treatments for each seaweed species were determined using one-way analysis of variance (ANOVA), followed by TukeyHSD test. If the ANOVA test assumptions were still violated, non-parametric tests which include Kruskal-Wallis test and pairwise Wilcox comparison test were conducted.

Results

Physicochemical Properties of Seaweed and Leaf Mulches

U. intestinalis had significantly lower pH value than *P. australis*, but the pH values of both seaweed species were not significantly different from *A. heterophyllus* ($P < 0.01$; Table 1). The moisture contents of both seaweeds were significantly greater (180% in *P. australis* and 171% in *U. intestinalis*) than *A. heterophyllus* ($P < 0.001$). However, *P. australis* had significantly lower organic matter content than *U. intestinalis* and *A. heterophyllus* ($P < 0.01$). In terms of total macronutrient content, *U. intestinalis* and *A. heterophyllus* had significantly the highest concentration of N ($P < 0.05$) and P ($P < 0.001$), respectively.

Table 1. Mean differences in physicochemical properties between two seaweed species; *Padina australis* (Ochrophyta), *Ulva intestinalis* (Chlorophyta) and the jackfruit leaf, *Artocarpus heterophyllus* (Moraceae). Values are mean ± standard error, SE (*n* = 3 replicates). Different letters within a row indicate significant differences between species as obtained from one-way ANOVA and TukeyHSD tests at 5% significance level.

Properties	Seaweed		Leaf	P values
	P. australis	*U. intestinalis*	*A. heterophyllus*	
pH	7.56 ± 0.11[a]	6.95 ± 0.05[b]	7.21 ± 0.12[ab]	< 0.01
Moisture Content (%)	84.7 ± 0.21[a]	81.8 ± 0.22[a]	30.2 ± 2.08[b]	< 0.001
Organic Matter (%)	61.4 ± 0.29[a]	71.7 ± 0.27[b]	67.9 ± 0.25[b]	< 0.01
N (mg g^{-1})	10.6 ± 0.31[ab]	15.1 ± 1.80[a]	8.9 ± 0.26[b]	< 0.05
P (mg g^{-1})	0.77 ± 0.03[a]	0.93 ± 0.07[a]	2.2 ±0.03[b]	< 0.01

Effects of Mulching Treatments on the Growth of Lactuca sativa

The experiment showed that the mulching treatment using dry, milled *P. australis* and *U. intestinalis* (MS) were significantly greater in mean RGR of lettuce than fresh, shredded leaf treatment (FL) by 66% and 50%, respectively ($P < 0.01$; Figure 1) but not significantly different from control treatment. The fresh *P. australis* and milled *U. intestinalis* treatment showed significantly larger mean total LSA than milled leaf treatment ($P < 0.01$). In terms of CCI, only milled *P. australis* showed significantly higher values than other mulching treatments, including control by 57% ($P < 0.05$).

Discussion

The physicochemical properties of both seaweeds and *A. heterophyllus* suggested that they have the potential to be used as organic mulches and biofertilizers (both seaweeds for moisture content, *U. intestinalis* and *A. heterophyllus* for organic matter content, *U. intestinalis* for total N and *A. heterophyllus* for total P). The pH values of organic mulches were not significantly different, and they ranged from pH 6.95

to 7.56, indicating that the pH is not too acidic and toxic to cause damage to the leaves and roots of the vegetables (Long et al., 2019). The moisture content for *P. australis* and *U. intestinalis* (84.7% and 81.8%, respectively). These findings were comparable to those of Maharany et al. (2017), who found that *P. australis* had a similar moisture content and lower ash content in their study, but not Peasura et al. (2015), who reported a much lower moisture content and ash content in *U. intestinalis*.

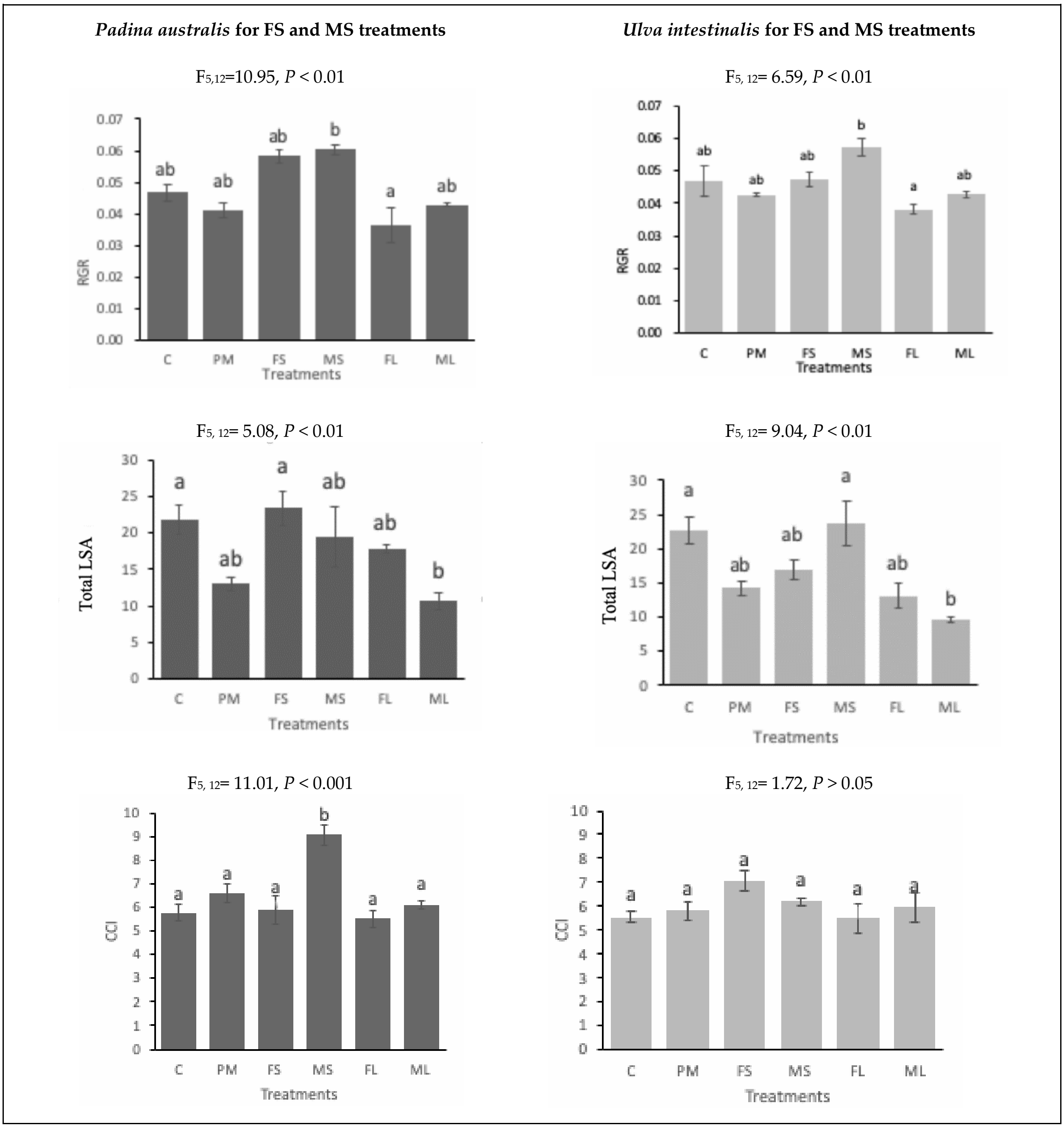

Figure 1. Effects of mulching treatments on the mean relative growth rate ($RGR_{total\ height}$, cm cm^{-1} day^{-1}), mean total leaf surface area (LSA, cm^2) and Chlorophyll Content Index (CCI) of *Lactuca sativa*. The mulching treatments are: control (C), plastic mulching (PM), fresh, shredded (FS) and dry, milled (MS) of *Padina australis* (black bar) or *Ulva intestinalis* (grey bar), fresh, shredded (FL) and dry, milled leaf (ML) of *Artocarpus heterophyllus*. Values are mean ± standard error, SE (*n* = 3 replicates). The different letters indicate significant differences between mulching treatments as obtained from one-way ANOVA and TukeyHSD tests at 5% significance level.

The overall high organic matter content of the seaweed species (61-71%) may improve water holding capacity, nutrient retention, aeration and heat and pH buffering of the soils (Brady & Weil, 2002). In this study, high organic matter content in seaweed was seemed to be associated to total N rather than total P content, especially in *U. intestinalis*. Therefore, it could be proposed that both seaweeds have the potential to supply minerals to plants, especially if there are any shortages of minerals in the soils. This was evident from this study, in which, in general seaweed was reported to show greater mean RGR, total LSA and CCI compared to other mulching treatments, including the jackfruit leaf treatment.

In terms of seaweed and leaf mulching treatments, milled seaweed mulches exhibited greater mean RGR, mean total LSA (*U. intestinalis* only) and mean CCI (*P. australis* only) in lettuce compared to other mulching treatments, particularly the fresh, shredded leaf treatment. These findings were comparable to those of Ngala et al. (2019) and Gheshm and Brown (2020), who reported that applying seaweed mulch to vegetables increased growth. When compared to a fresh, shredded sample, milled seaweed mulch has a higher surface area to volume ratio, which allows it to cover the topsoil more efficiently (Manikandan et al., 2013). Since seaweeds also had higher moisture content, the milled seaweed samples should be able to effectively reduce soil evaporation, resulting in high water and nutrient retention. In comparison to the other mulching treatments, lettuce takes up N and P much better under milled mulches, according to this study.

Although this preliminary study used seaweed gathered from the wild, adequate management and sustainable harvesting are required to prevent the loss of marine biodiversity. It would be even better if the seaweed used for mulching were derived from seaweed waste, such as kelp waste residues after alginate extraction in China (Zheng et al., 2016). Reusing seaweed waste has great promise for addressing issues related to waste pollution and management, as well as promoting organic, sustainable, and green agriculture.

Conclusion

In comparison to plastic or leaf mulches, both seaweed species, *Padina australis* and *Ulva intestinalis*, have the potential to be used as organic mulches and biofertilizers to promote better growth of agricultural crops. This study provided preliminary evidence that irrespective of the seaweed species, dry, milled seaweeds had significantly improved RGR, total LSA and CCI of lettuce. However, it is recommended that this potting experiment be expanded to include field trials to get a comprehensive understanding of the impacts of seaweed mulches under natural conditions and to promote organic and green agriculture.

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References

Allen, S.E., Grimshaw, H.M., Parkinson, J.A., Quarmby, C. (1989). *Chemical Analysis of Ecological Materials.* Oxford, UK: Blackwell Scientific Publications.

Baweja, P., Kumar, S., Kumar, G. (2019). Organic Fertilizer from Algae: A Novel Approach Towards Sustainable Agriculture. In: Giri, B., Prasad, R., Wu, Q.S., Varma, A. (eds.) Biofertilizers for Sustainable Agriculture and Environment. *Soil Biology, 55*, 353–370. https://doi.org/10.1007/978-3-030-18933-4_16

Brady, N.C., Weil, R.R. (2002). *The Nature and Properties of Soils* (13th ed.). New Jersey, USA: Pearson Education, Inc.

Chae, Y., An, Y. (2018). Current Research Trends on Plastic Pollution and Ecological Impacts on the Soil Ecosystem: A review. *Environmental Pollution, 240*, 387–395.

Chalker-Scott, L. (2007). Impact of Mulches on Landscape of Plants and the Environment - A Review. *Journal of Environmental Horticulture, 25*(4), 239–249.

Easlon, H., Bloom, A. (2014). Easy Leaf Area: Automated Digital Image Analysis for Rapid and Accurate Measurement of Leaf Area. *Applications in Plant Sciences, 2*(7), 1400033.

Gheshm, R., Brown, R. (2020). Compost and Black Polyethylene Mulches Improve Spring Production of Romaine Lettuce in Southern New England. *HortTechnology, 30*(4), 510–518.

Horwitz, W. (2000). *Official Methods of Analysis of AOAC International*. Virginia, USA: AOAC International.

Hunt, R., Causton, D.R., Shipley, B., Askew, A.P. (2002). A Modern Tool for Classical Plant Growth Analysis. *Annals of Botany, 90*(4): 485–488.

Iqbal, R., Raza, M.A.S., Valipour, M., Saleem, M.F., Zaheer, M.S., Ahmad, S. et al. (2020). Potential Agricultural and Environmental Benefits of Mulches – A Review. *Bulletin of the National Research Centre, 44*, 75.

Kaladharan, E., Sathianandan, S., Edison, S., Shahana, T., Vysakhan, P. (2019). Effects of Basal Application of Mulch and Foliar Spray of *Sargassum wightii* Extract on Certain Vegetable Crops. *Fishery Technology, 56*, 44 – 48.

Long, A., Huang, W., Qi, Y., Yang, L., Lai, N., Guo, J., Chen, L. (2019). Low pH Effects on Reactive Oxygen Species and Methylglyoxal Metabolisms in Citrus Roots and Leaves. *BMC Plant Biology, 19,* 477. https://doi.org/10.1186/s12870-019-2103-5.

Maharany, F., Nurjanah, N., Suwandi, R., Anwar, E., Hidayat, T. (2017). Bioactive Compounds of Seaweed *Padina australis* and *Eucheuma cottonii* as Sunscreen Raw Materials. *Jurnal Pengolahan Hasil Perikanan Indonesia, 20*(1), 10–17.

Manikandan, A., Subramanian, K. Kannaiyan. P. (2013). Effect of High Energy Ball Milling on Particle Size and Surface Area of Adsorbents for Efficient Loading of Fertilizer. *Asian Journal of Soil Science, 8*, 249–254.

Ngala, J.M, Ndiso, J.B., Muindi, E.M. (2019). Effect of selected organic mulches on growth and yield of *Amaranthus* in Kilifi county. *International Journal of Agriculture, Environment and Bioresearch, 4*(6), 229–236.

Ni, X., Song, W., Zhang, H., Yang, X., Wang, L. (2020). Effects of Mulching on Soil Properties and Growth of Tea Olive (*Osmanthus fragrans*). *PLoS ONE, 11*(8), e0158228.

Novello, V., de Palma, L. (2008). Growing Grapes under Cover. *Acta Horticulturae, 785,* 353–362.

Paulert, R., Talamini, V., Cassolato, J., Duarte, M., Noseda, M., Smania, A., Stadnik, M. (2009). Effects of Sulfated Polysaccharide and Alcoholic Extracts from Green Seaweed *Ulva fasciata* on Anthracnose Severity and Growth of Common Beans (*Phaseolus vulgaris* L.). *Journal of Plant Diseases and Protection, 116*(6), 263–270.

Peasura, N., Laohakunjit, N., Kerdchoechuen, O., Wanlapa, S. (2015). Characteristics and Antioxidant of *Ulva intestinalis* Sulphated Polysaccharides Extracted with Different Solvents. *International Journal of Biological Macromolecules, 81*, 912–919.

Peres, J., Carvalho, L., Gonçalez, E., Berian, L., Felicio, J. (2012). Evaluation of Antifungal Activity of Seaweed Extracts. *Ciência E Agrotecnologia, 36*(3), 294–299.

Pérez-Harguindeguy, N., Díaz, S., Garnier, E., Lavorel, S., Poorter, H., Jaureguiberry, P. et al. (2013). New handbook for standardised measurement of plant functional traits worldwide. *Australian Journal of Botany, 61*(3), 191–192.

R Core Team. (2021). R: A Language and Environment for Statistical Computing. *R Foundation for Statistical Computing*, Vienna, Austria.

Shit, S.C, Shah, P.M. (2014). Edible Polymers: Challenges and Opportunities. *Journal of Polymers*, Article ID 427259, https://doi.org/10.1155/2014/427259

Wang, B., Niu, J., Berndtsson, R., Zhang, L., Chen, X., Li, X, Zhu, Z. (2020). Effects of Organic Mulch Thickness for Soil and Water Conservation in Urban Areas. *Scientific Reports*, 116259.

Zheng, S., Jiang, J., He, M., Zou, S., Wang, C. (2016). Effect of Kelp Waste Extracts on the Growth and Development of Pakchoi (*Brassica chinensis* L.). *Scientific Reports, 6*(1), 38683.

CROP-WASTE HYDROGEL FACTORY MANAGEMENT UTILIZING IOT SYSTEM FOR SUSTAINABLE WATER SCARCITY SOLUTION

Meutia Cahya Kusuma[1], Nadya Hafidzatun Nisa[1], Esti Krisjulianingrum[2], Aryanis Mutia Zahra*[1], Radi[1]
[1]Department of Agriculture and Biosystem Engineering, Faculty of Agricultural Technology, Universitas Gadjah Mada, Indonesia
[2]Department of Agronomic, Faculty of Agriculture, Universitas Gadjah Mada, Indonesia
*aryanismutiazahra@ugm.ac.id

Abstract

Hydrogel production from crop waste biopolymer is the optimal solution for conserving irrigation water, resolving environmental issues, and averting water crises and drought. Unfortunately, hydrogels derived from agricultural waste biopolymers are still relatively unknown and challenging. This study was aimed to incorporate IoT technology advancements such as mobile app integration, drones, and artificial intelligence (AI) robot's involvement in industrial waste processing systems into hydrogels to facilitate the production, distribution, and application processes on land. As a result, a cost-effective manufacturing and distribution process was established. Data access is facilitated by integration with the user-friendly mobile app. Drones and artificial intelligence (AI) robots shorten the distribution chain and ensure efficient irrigation by responding to the land's needs. Irrigation water savings are known at up to 40%, and crop waste reductions of up to 50% are possible if implemented sustainably.

Keywords: Crop waste; Hydrogel; Irrigation; Manufacturing; Water saving

Introduction

The development of hydrogel technology-based crop waste biopolymer engineering is the right solution to overcome the complex problems regarding water, food, and environmental crises due to climate change. Crop waste contains cellulose and hemicellulose, which can be synthesized into biodegradable hydrogels (Li and Chen, 2020). Hydrogel is a bonded hydrophilic polymer chain macromolecule that can absorb water. The ability of hydrogels to absorb water is applicable as a substitute for crop irrigation, which generally requires abundant water. Applying hydrogel to arid land will increase irrigation efficiency, which will positively impact high levels of crop productivity (Abobatta, 2018). Furthermore, hydrogels can reduce the amount of water used in the agricultural production process (Neethu et al., 2018 and Bairwa et al., 2020). However, because hydrogels based on biopolymer engineering are not widely known and difficult to manufacture, a system is required to regulate and facilitate the processing and distribution of hydrogels and hydrogels.

Advances in internet-based technology have been widely developed and implemented in all aspects of life, including the agricultural industry. Internet of Things (IoT) applications in the agricultural industry are critical in revolutionizing the industrial process to become more accessible and more efficient. IoT is a system that can connect an object to the internet network to be controlled, monitored, and accessed using the internet network remotely. The operational principle of this system is that the data collected from the sensor will be transmitted to a database server via the Wireless Sensor Network (WSN) so that it can be accessed using the internet through an application on a smartphone (Atmaja et al., 2021). The monitoring system can be applied to agricultural tools and machinery, for example, in measuring soil moisture content to increase the effectiveness of irrigation. IoT can be applied in various agricultural and industrial processes because it facilitates high-precision automation and monitoring systems to increase resource use effectiveness (Pillai and Sivathanu, 2020).

This paper aims to apply IoT capabilities to the industrial processing system of crop waste-based hydrogel to streamline the production, distribution, and application of hydrogel on land. The application of IoT in this crop waste-based hydrogel processing system called ‘Crop Waste Hydrogel Factory Management System’ or CWH-Fams will create a sustainable agricultural system with zero waste to not give up any waste. Moreover, this system is expected to help prevent water scarcity and drought, as the designed agricultural system aims to save irrigation water.

Methodology

The development of CWH-Fams is carried out using the System Development Life Cycle (SDLC) technique approach. SDLC is very suitable for developing complex systems such as production and distribution hydrogel system. With the SDLC method, the changes that occur in the cycle are easy to observe and regulate (Mustaquim and Nystrom, 2015). System development using SDLC can also improve time efficiency and reduce the risk of system implementation failure. Several systems that have been successfully developed using SDLC are the development of a home health system at a regional hospital (NASA, 2020), the development of a company accounting information system (Hwe, 2016), and the development of a smart traceability system for the rice agroindustry supply chain in Indonesia (Purwandoko et al., 2019).

Crop Waste Based Hydrogel Treatment Process

The hydrogel production process begins with collecting crop waste such as rice straw, corn cobs, husks, and rice bran. Furthermore, cellulose extraction is performed, with one type of cellulose being hydrophilic CMC (Carboxymethyl Cellulose), which can absorb water and be used as a raw material to produce hydrogels. CMC is then reacted using a polymerization technique with developer material such as N, N'-methylene bisacrylamide (MBA). MBA acts as a crosslinker between the monomers of the hydrogel matrix. Next, the mixture is dried and molded before being prepared for distribution and irrigation application. The hydrogel is delivered to participating stores through pickup trucks, which are used in the distribution process. Only then can farmers purchase the hydrogel in the shop. The hydrogel is used to irrigate rice fields by farmers by spreading it onto the soil in the vicinity of the plant's root system.

Crop Waste Hydrogel Factory Management System (CWH-Fams)

CWH-Fams were designed to facilitate using the hydrogel on farmland for all parties involved in the production, distribution, and process. The hydrogel treatment developed in this system is described as being conducted in a factory. Crop waste used as raw processing of hydrogel production comes from farmers' territory where hydrogels are employed. The processing data from factories and fields in CWH-Fams is integrated into a mobile application. Meanwhile, drones and AI robots are involved in the waste collection and distribution process. Robots and drones are integrated and implemented to streamline the use of hydrogels on farmland. In addition, it is also used to minimize human labor required. The system architecture is used to manage the complex information requirements, system components, and all supporting technology for the hydrogel production in CWH-Fams, which will be used to process agricultural waste. Figure 1 explains the architecture of the CWH-Fams system.

Mobile App Integration

CWH-Fams is designed to integrate crop waste treatment systems into hydrogels in a 'Crow-gel' mobile application that facilitates collecting agricultural waste and applying hydrogels to farmland by users (farmers). The 'Crow-gel' application was developed with a cloud-based database system that provides factories and farmers with direct and real-time access to data. Accessible data include waste quantity, location, land area, land conditions, and hydrogel for land requirements. This data will be used by a server at the factory to control the hydrogel delivery, allowing the dose to be adjusted directly in response to the area's and terrain's conditions. Furthermore, localization information makes it easier for farmers to collect crop waste and distribute hydrogels to their farmland.

The Involvement of Drones and AI Robot

The process of collecting crop waste in CWH-Fams is carried out to minimize the performance of farmers, who must make efforts to collect crop waste from their land and bring it to the hydrogel processing plant.

A large area of agricultural land will undoubtedly produce a significant amount of agricultural waste, which can be used as a raw material for hydrogel production. In CWH-Fams, the process of transporting crop waste will be replaced by an AI robot specially designed to detect the location of waste, collect and accommodate crop waste to the hydrogel treatment site. The mechanism for the distribution of hydrogel processed in CWH-Fams no longer uses conventional trucks. In CWH-Fams, the hydrogel is distributed by drone while facilitating farmers' irrigation of their land with hydrogel. The distribution of hydrogel involves a drone equipped with a camera that can capture the condition and area of the farmland. The AI robots and drones used in CWH-Fams are integrated into the 'Crow-gel' application, which allows for continuous monitoring of every process. Furthermore, land data stored and processed by a server in the factory allows the process to run more accurately and according to land area and farmland conditions.

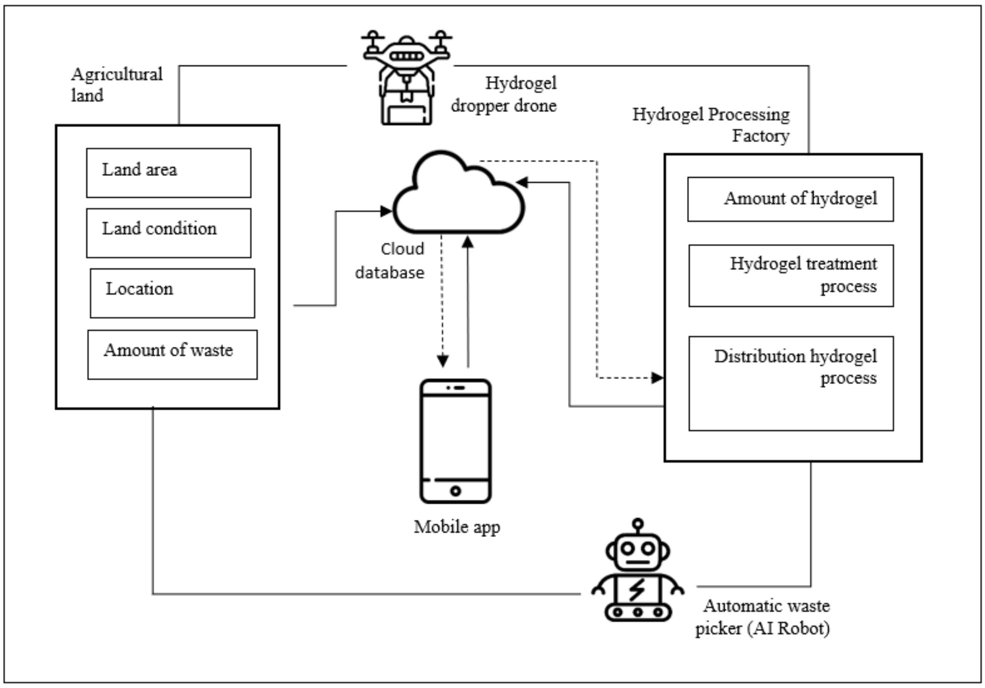

Figure 1. System architecture

System Implementation

'Crow-gel' application development is accomplished by integrating a cloud database with a hydrogel processing factory server. MySQL is used as a cloud database in the "Crow-gel" software application. MySQL is used because the data storage system for a variety of programming languages is quite flexible. System configuration in the application requires a server, and the Apache Tomcat application server is used in this application, which can be directly connected to the MySQL cloud. The application is developed using the programming language of Golang. Golang (Go language) is a programming language with a lightweight and powerful syntax based on the principle of "reduce typing" developed by Google (Kristanto et al., 2020). Although relatively new, Golang can build programs with many mobile applications such as Tokopedia and Bukalapak. An illustration of the user interface for the fully developed 'Crow-gel' application can be found in Figure 2.

An artificial intelligence (AI) robot used in CWH-Fams can detect the presence of crop waste on the land and retrieve it as soon as an order from the processing plant's server has been received. These capabilities are stored in an AI processor database, housed in a chip, and embedded within the robot's body. The hydrogel transport drone is installed with a location tracking system and land condition analysis system to transport hydrogels. This location tracking system is based on Google Maps (Gmaps) installed and activated on the user's smartphone to track the user's location (farmer). The ADC Snaps camera was used to capture the condition of the land and analyze the real-time condition. The ADC Snaps camera is a high-resolution camera specially designed for mounting on unmanned aerial vehicles (UAV). One of its capabilities is to perform imaging based on NDVI values. The ADC Snaps camera will be installed on the hydrogel transport drone to analyze the land-based state on the NDVI value simultaneously. Plants reflect different amounts of visible light and near-infrared light, and the ratio of these values represents their NDVI value formula as shown in the function below (Costa et al., 2020).

$$NDVI = \frac{NIR-Red}{NIR+Red} \quad \text{Equation 1}$$

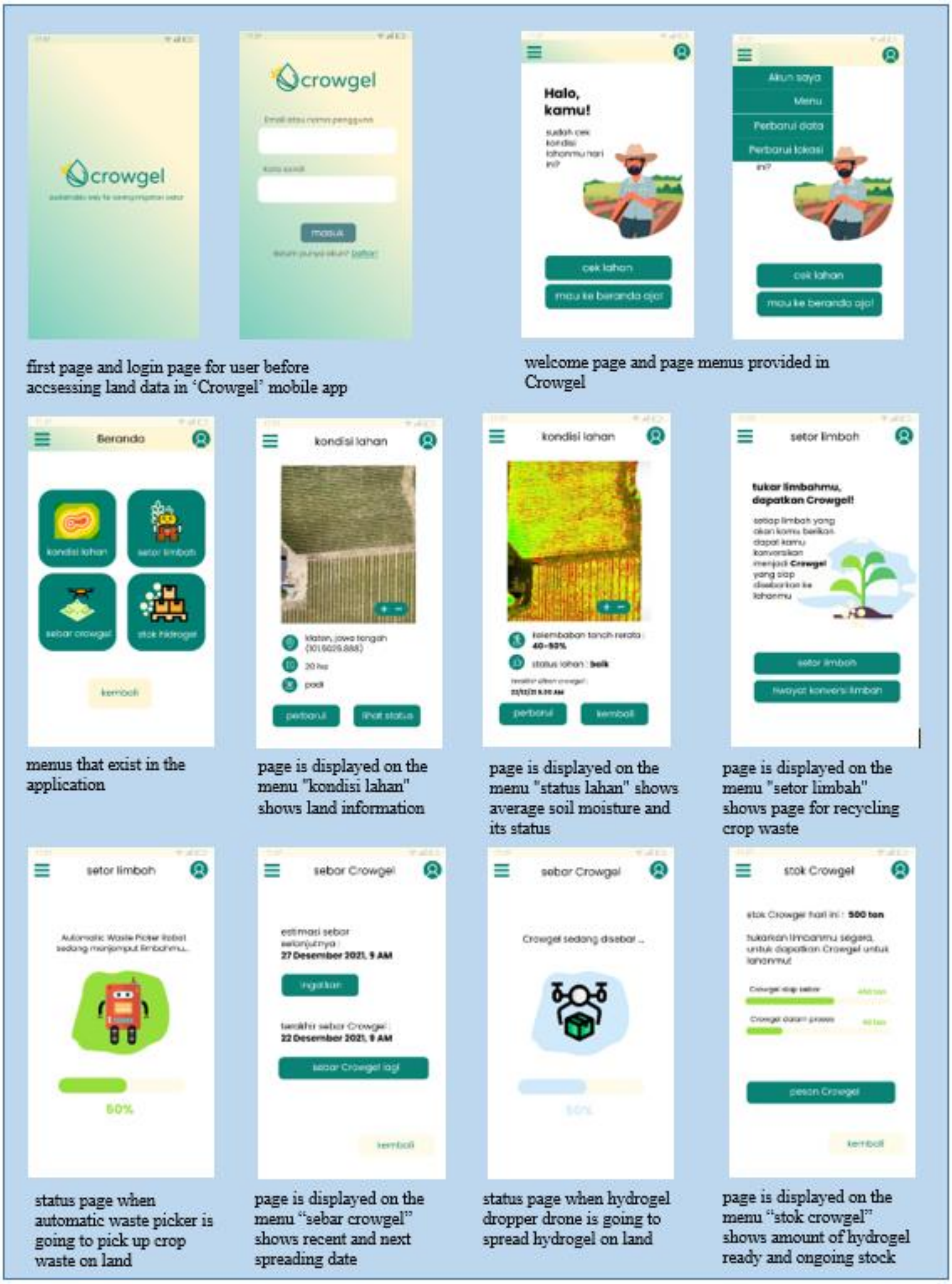

Figure 2. User interface for the fully developed 'Crow-gel' application

The NDVI value ranges from -1 to +1, with the closer the number is to -1, the redder the color imaged tends to be, and the closer the number is to +1, the greener the color image tends to be (in the red-yellow-green palette as shown in Figure 3) (Kraetzig, 2020). The red color indicates the condition of the plants on the land tends to be dry, and green indicates the plants and land are in good condition (NASA, 2020). This NDVI can represent the condition of the plant at that time because plants in good condition with a large amount of chlorophyll generally absorb more red light and emit infrared light and vice versa for the diseased plant. Because of this, it is possible to use NDVI readings to detect differences between arable and arid land types. NDVI analysis on the camera mounted on the drone is very useful for predicting the need for hydrogel to be spread on the land. Thus, the hydrogel that is spread on the land as needed is not excessive or insufficient. The NDVI value can represent the soil moisture value of the land properly. Research states that the correlation reached 0.94, where the value is quite close to 1, meaning that the NDVI value is sufficient to represent the soil moisture value of the imaged land (Bai et al., 2020).

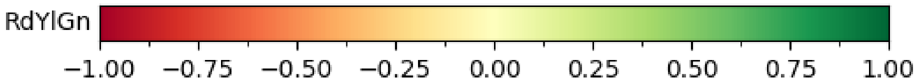

Figure 3. Color (red-yellow-green) palette based NDVI value

System Implication

The application of IoT on CWH-Fams is expected to facilitate the system for taking raw materials, processing, and distributing hydrogels. Integrating all systems in an application is expected to inform and make it easier for farmers and processing factories to access all the data needed in real-time. Research on the use of IoT for monitoring electrical energy use, sensors installed in a building integrated with a web allows access to energy consumption data in real-time (Purwandoko et al., 2019). Also, the GPS integrated into the mobile app will make it easier to access data to find and navigate targets (Wahab et al., 2018). In addition, the integration in a mobile app is expected to maintain the security and orderliness of the data of farmers and processing plants.

The hydrogel distribution process using a hydrogel dropper drone will cut the distribution chain while saving distribution time. Based on the results of a study on the development of a quadcopter drone design that spreads pesticides in rice fields using drones with an area of 1 ha only takes 12.5 hours, whereas conventionally, it takes about 20 hours (Yudhana and Wardani, 2017). The efficiency in using drones as a distribution medium also increases 40 times higher than the conventional method (Ikhwana and Hapsari, 2019). Several other studies also mention how effective the use of drones is on agricultural lands, such as the UAV-imagery to assess crop vigor and yields in Sub-Saharan Africa (SSA) (Wahab et al., 2018), monitoring corn and barley fields in the Czech Republic (Raeva et al., 2019), and to quantify upland rice growth and water use efficiency (WUE) after biochar application in a Costa Rican dry region (Jin et al., 2021). Potentially, the use of a hydrogel drone dropper in this system will also make the process more effective and faster in its application to land.

The ability of hydrogels to increase water holding capacity by more than 50% can save irrigation water use. It is known that the hydrogel of 2-2.5 grams/plant that is applied can save 40% of the use of irrigation water or about 155.44 mm of water (Fernandez et al., 2016). Saving irrigation water is expected to maintain water availability and reduce the potential for drought in areas with minimal water sources.

This agricultural waste-based hydrogel processing certainly has an impact on reducing the amount of abandoned crop waste. It is known that 561-706 tons of cellulose can be extracted from 1,468 tons of global crop waste (Li and Chen, 2020). If the cellulose-based hydrogel processing of crop waste is optimal, the amount of waste may be reduced by 50% or even more. The processing of agricultural waste from agricultural land is also very possible to create a zero-waste agricultural system so that the process in the agricultural system and efforts to save irrigation water is sustainable.

Conclusion

System integration in the mobile app is relatively easy to access data in real-time. Drones applied to distribute hydrogel reduce distribution chain time and length-likewise, AI robots in waste collection. The application of NDVI value-based cameras mounted on drones increases the efficiency of hydrogel deployment. Irrigation water savings with hydrogel substitution reached 40%, and about 50% can reduce crop waste. This system's benefits and convenience make it a potential solution for saving irrigation water to prevent water scarcity and drought in a sustainable way.

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References

Abobatta, W. (2018). Impact of hydrogel polymer in agricultural sector. *Advances in Agriculture and Environmental Science, I*(2), 59-64. doi:10.30881/aaeoa.00011

Atmaja, A., Hakim, A., Wibowo, A., & Pramata, L. (2021). Communication systems of smart agriculture based on Wireless Sensor Networks in IoT. *Journal of Robotics and Control, 2*(4), 297-301.

Bai, X., Zhang, L., He, C., & Zhu, Y. (2020). Estimating Regional Soil Moisture Distribution Based. *Remote Sensing*, 1-20. doi:10.3390/rs12152414

Bairwa, D. D., Prajapat, B. S., & Kadam, S. S. (2020). Hydrogel : The Best Option for Saving Irrigation Water. *Vigyan Varta, I*(8), 63-66.

Costa, L., Nunes, L., & Ampatzidis, Y. (2020). A new visible band index (vNDVI) for estimating NDVI values on RGB. *Computers and Electronics in Agriculture*, 1-13. doi:https://doi.org/10.1016/j.compag.2020.105334

Fernández, R. D., Jarama, F. R., Gallo, F. M., & Intriago, D. A. (2016). Hydrogel for improving water use efficiency of. *Rev. FCA UNCUYO*, 1-8.

Hwe, T. T. (2016). Penerapan System Development Life Cycle Berbasis Perilaku Bagi Sistem Informasi Akuntansi Pada PT. "X". *Calyptra: Jurnal Ilmiah Mahasiswa Universitas Surabaya*, 5(2), 1002-1020.

Ikhwana, N., & Hapsari, D. R. (2019). Wawasan Tani Drone Application for Agriculture in Simpang Lima, Sungai Besar, Selangor. *Journal of Community Innovation Center*, *1*(1), 99-104.

Jin, H., Köppl, C. J., Fischer, B. M., Rojas-Conejo, J., Johnson, M. S., Morillas, L., Garcia, M. (2021). Drone-based Hyperspectral and Thermal Imagery for Quantifying Upland Rice Growth and Water Use Efficiency After Biochar Application. *Preprints*, 1-19.

Kraetzig, N. M. (2020, September 1). *5 Things To Know About NDVI (Normalized Difference Vegetation Index)*. Retrieved from up42: https://up42.com/blog/tech/5-things-to-know-about-ndvi

Kristanto, A. A., Harjoseputro, Y., & Samodra, J. E. (2020). Implementing Golang and New Simple Queue on a REST API-Based Third Party Sandbox System.. *Jurnal RESTI (Rekayasa Sistem dan Teknologi Informasi), 4*(4), 745-750.

Li, S., & Chen, G. (2020). Agricultural waste-derived superabsorbent hydrogels : Preparation, performance, and socioeconomic impacts. *Journal of Cleaner Production*, 1-10. doi:https://doi.org/10.1016/j.jclepro.2019.119669

McMurtrey, M. (2013). A Case Study Of The Application Of The Systems Development Life Cycle (SDLC) In 21st Century Health Care: Something Old, Something New?. *Journal of the Southern Association for Information System*, 1(1), 14-25.

Mustaquim, M., & Nyström, T. (2015). A System Development Life Cycle for Persuasive Design for Sustainability. Persuasive Technology: 10th International Conference, PERSUASIVE 2015, Chicago, IL, USA, June 3-5, 2015, Proceedings (pp. 217-228).

NASA. (2020, August 30). *Measuring Vegetation (NDVI & EVI)*. Retrieved from earth observatory: https://earthobservatory.nasa.gov/features/MeasuringVegetation/measuring_vegetation_2.php

Neethu, T. M., Dubey, P. K., & Kaswala, A. R. (2018). Prospects and Applications of Hydrogel Technology in Agriculture. *International Journal of Current Microbiology and Applied Sciences, 7*(5), 3155-3162. doi:https://doi.org/10.20546/ijcmas.2018.705.369

Pillai, R., & Sivathanu, B. (2020). Adoption of internet of things (IoT) in the agriculture industry deploying the BRT framework. *Benchmarking: An International Journal, 27*(4), 1341-1368. doi:https://doi.org/10.1108/BIJ-08-2019-0361

Ping, H., Wang, J., Ma, Z., & Du, Y. (2018). Mini-review of application of IoT technology in monitoring agricultural. *Int J Agric & Biol Eng, 11*(5), 35-45.

Purwandoko, P. B., Seminar, K. B., Sutrisno, & Sugiyanta. (2019). Development of a Smart Traceability System for the Rice Agroindustry Supply Chain in Indonesia. *Information*, 1-16. doi:10.3390/info10100288

Purwania, I. B., Kumara, I. N., & Sudarma, M. (2020). Application of IoT-Based System for Monitoring Energy Consumption. *International Journal of Engineering and Emerging Technology, 5*(2), 81-93.

Raeva, P. L., Sedina, J., & Dlesk, A. (2019). Monitoring of crop fields using multispectral and thermal imagery from UAV. *EUROPEAN JOURNAL OF REMOTE SENSING, 52*(S1), 192-201.

Wahab, I., Hall, O., & Jirström, M. (2018). Remote Sensing of Yields: Application of UAV Imagery-Derived NDVI for Estimating Maize Vigor and Yields in Complex Farming Systems in Sub-Saharan Africa. *Drone, 2*(28), 1-16. doi:doi:10.3390/drones2030028

Yudhana, A., & Wardani, M. (2017). Design of Pesticide Sprayers for Quadcopter-Based Rice Farming. *Jurnal Ilmu Teknik Elektro Komputer dan Informatika (JITEKI), 3*(2), 132-140.

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