Characterization of UF-18 cacao pods using Arduino-based load compressor testing machine

Maricel Gamolo Dayaday[1], Renel M. Alucilja[2], Ritchell Joy T. Cuarteros[3], Jeffrey A. Lavarias[4]
[1]Department of Electronics Engineering, Faculty College of Engineering and Information Technology, University of Southern Mindanao, Kabacan, Philippines
[2]Department of Agricultural and Biosystems Engineering, Faculty College of Engineering and Information Technology, University of Southern Mindanao, Kabacan, Philippines
[3]Department of Agricultural and Biosystems Engineering, University of Southern Mindanao, Kabacan, Philippines
[4]Department of Electronics Engineering, Laboratory Aide, University of Southern Mindanao, Kabacan, Philippines

Article Info

Article history:

Received Mar 15, 2024
Revised Jun 27, 2024
Accepted Jul 14, 2024

Keywords:

Bean damage
Cacao
Mechanical
Physical
Pod-breaking

ABSTRACT

Bean damage is one of the primary concerns in the pod-breaking process. Studies for pod-breaking machines are ongoing to ensure that the products made from these machines are of good quality. The objective of the study is to determine the physical and mechanical characteristics of the UF-18 pod. The Arduino-based load compressor testing machine was designed and developed to characterize the UF-18 pod. It was found that the average geometric mean diameter, surface area, and sphericity index of 115.37 mm, 41,899.48 mm², and 0.6372, respectively, and with a variation of ±27.17, ±14538133.04, and ±0.00038 respectively. Furthermore, the cacao pod samples had an average dimension of 181.29 mm, 94.26 mm, 90.01 mm, and 17.44 mm measured for the length, equatorial diameter, intermediate diameter and external thickness, respectively. Different pod sizes and thicknesses require various forces ranging from 36.94 to 92.42 kg (362.38 N to 906.64 N) and time ranging from 6-11 seconds to be able to break the pods. Determining the physical and mechanical properties of cacao pods enables fabricators to design efficient machines, which lessens the force to break and the damage to the beans, thus producing quality beans.

Corresponding Author:

Maricel Gamolo Dayaday
Department of Electronics Engineering, Faculty College of Engineering and Information Technology
University of Southern Mindanao
Kabacan, 9407, Philippines
Email: mgdayaday@usm.edu.ph

1. INTRODUCTION

Theobroma cacao (Cacao) is considered an essential source of income for thousands of smallholder farmers and farmers' associations in East Asia. The Philippines started to grow this fruit in the 17th century. Farmers consider planting cacao as the source of their primary or secondary income; thus, it helps them to lessen the problem of poverty [1]. Criollo, Forastero, and Trinitario are the groups most cacao varieties belong to, and they only differ in their morphology, genetic, and geographical origins. The Criollo, commonly referred to as porcelana cacao, can only be found throughout the Philippines and Ecuador. The beans are the most sought-after due to their rarity and excellent quality (less bitter, more aromatic), but they are particularly susceptible to diseases and pests. The Forastero variety is renowned for its durability and versatility. It exhibits variable sensitivities to cacao pests and diseases, ranging from very susceptible to resistant. Forastero beans are notably harder than Criollo. The Trinitario belonged to the Forasteros despite having descended from a hybrid between Criollo and Forasteros. It yields high-quality beans (from Criollo parents) and possesses the resistance and vigor of the Forastero parent [2].

Cacao, a crop that thrives under the shade of forest trees [3], plays a significant role in the Philippines. Approximately 10% of its fresh fruit weight is transformed into a commercially produced product. While cocoa beans are primarily used in chocolate manufacturing, they also hold pharmaceutical and cosmetic importance [4]. This underscores the diverse applications and economic potential of the cacao industry in the country.

Globally, the Philippines ranks 72nd in exporting cocoa chocolate with a global market share of less than 0.01% [5]. Production must increase due to the increase in the demand for these products. The processes of cocoa involve pod breaking and wet bean extraction, bean fermentation, bean drying, dehulling, and winnowing of the beans, and the production of value-added products like cocoa butter, beverages, and cake [6]. The Philippines, most notably in Mindanao, is ideal for cacao growth and expansion of production. BoAS [7], the Philippines was able to produce around 4,831 metric tons of cacao in 2012, most of which came from the Davao Region, with approximately 3,763 metric tons of production. Through the efforts of the concerned agencies, both local and international, together with the private sector, initiatives were raised to revive the local cacao industry. The roadmap for cacao was developed through the initiative of the Cocoa Foundation of the Philippines (CocoaPhil), and it was highlighted in their vision that in one cropping season, it would able to produce about 100,000 tons of cacao.

The journey of cacao from farm to market involves several stages. Pods, wet beans, or dry beans are the three unprocessed forms of cacao that are sold locally or to cooperatives. Fleming *et al.* [8], the easiest way to sell cacao is in the form of pods, as wet bean extraction requires additional effort, careful, timely handling, and postharvest expenses on the side of the farmers. The pod-breaking process, which involves the separation of pods from the wet beans, is typically done manually. Ongoing studies and development for pod-breaking machines aim to ensure that the products made from these machines maintain high-quality standards.

Joshy *et al.* [6], the longitudinal loading orientation resulted in higher impact strength, bio-yield, and rupture points, compressive and rupture strengths, and modulus of stiffness and modulus of elasticity in cocoa fruits than the lateral loading orientation. In general, biological materials may break under compression load following a force-strain straight curve [9]. Impact, compressive, and shearing are the forces involved in the mechanical breaking of the cacao pod depending on the type of machine, as well as the methods and concepts that the designer and fabricator used to come up with the new designs of the machines [10]-[14].

2. THEORITICAL BACKGROUND

A compression test is where any material is being compressed or crushed through opposing forces that push the materials from opposite sides. This is being done to determine the characteristics or responses of any particular specimen while it undergoes compressive load by measuring the strain, stress, and deformation. The compression, yield, ultimate strength, elastic limit, and elastic modulus, among other parameters, could be determined by testing the specimen in compression. Knowing the concept of these different parameters and the principles associated with a specific material may determine whether the material is appropriate for specific applications or if it will break under specified stresses. Testing the compressive strength of cocoa pods provides an objective way to determine mechanical properties that permit the assessment of the minimal allowable load for the cacao pods to break without the seeds being destroyed [9].

Several studies demonstrated the usefulness of Arduino in alcohol detection, water vapor and temperature monitoring systems, and voice recognition [15]-[18]. However, only a few explore the use of Arduino to load compressor testing machines. With this study, the load compressor testing machine using Arduino was designed and fabricated. The Arduino is the heart of the machine, with the matrix keypad being a passive component that necessitates active scanning by the Arduino. Upon pressing a button on the matrix keypad, a connection is established between the row and column pins, allowing Arduino to identify the input signal and execute the corresponding code or function. The Arduino then sends a command to the motor driver, which is responsible for controlling the speed and direction of the linear actuator. The load cell is attached to the linear actuator, and as weight is applied to it, the resistance of the wires inside the load cell changes. However, due to the small magnitude of this change, the load cell amplifier is required to amplify the signal from the load cell to make it easily measurable. Finally, the amplified measurement of weight or force is transmitted to the Arduino for processing. The data that was gathered will then be displayed on a liquid crystal display (LCD) and then stored on an SD card through an SD card module. After identifying the caveats and gaps, the study seeks to identify the physical characteristics of the UF-18 cacao pod as well as the minimum and maximum load a cacao pod can bear before breaking or crushing to ensure that the beans are not damaged. This addresses the problems of low recovery of undamaged and good-quality wet beans.

3. METHOD

3.1. Sample and sampling size

In the Philippines, the best cacao variety is the Criollo. Still, since it is rare and expensive, the most commonly used variety by the farmers is the Trinitary variety, and one of these is the UF-18 since it is one of the high-yielding varieties as per the 2021 data of the Department of Agriculture, which yields an average of 895 kilograms per hectare. That same variety was used in this study and was sourced from the household multi-purpose cooperative (HMPC) farm at Antipas, North Cotabato. Cacao fruits of matured age of about 75 percent pod ripeness were gathered to determine the physical properties. Fifty cacao pod samples were randomly selected for the material properties, which are enough to represent UF-18, where in fact, only used ten (10) pod samples in the study to observe the physical and mechanical properties of the Forastero pods [19]. The properties were determined for seasoned cacao pods.

3.2. Determination of the physical properties

The physical properties determined in this study, including pod weight, size and shape, volume, and density, are crucial for the design of cacao processing machinery. These properties inform the design of critical parts, such as the hopper for loading and breaking the pods. For instance, knowing the pod thickness aids in adjusting the blade clearance to design a slicing mechanism that doesn’t damage the beans during the breaking process. This practical application of our research is particularly relevant to equipment fabricators.

3.3. Determination of size and shape

A total of fifty samples were used to determine the size and shape of the cacao pods. For each pod, the three linear dimensions were selected, length (a), equatorial diameter (b), and intermediate diameter (c). The size and shape were determined using an electronic vernier caliper with a minimum reading of 0.01 mm, ensuring precise and accurate data collection.

For the determination of the geometric mean diameters of the pod samples, the mathematical expression applied by [9], and [20]-[22] was used.

$$Gm = (axbxc)^{\frac{1}{3}} \tag{1}$$

Where:
a = length of the pod (mm)
b = equatorial diameter of the pod (mm)
c = intermediate diameter of the pod (mm)

3.4. Determination of surface area

The determination of the surface area of pod samples was computed using the given mathematical expression of [20]-[24].

$$S = \pi Gm^2 \tag{2}$$

Where:
S = surface area (mm)
Gm = geometric mean diameter (mm)
For the determination of the degree of sphericity of the pods, the applied by [20]-[23] were used.

$$Sphericity\ index = \frac{(axbxc)^{\frac{1}{3}}}{a} = \frac{Gm}{a} \tag{3}$$

Where:
a = length of the pod (mm)
b = equatorial diameter of the pod (mm)
c = intermediate diameter of the pod (mm)

3.5. Determination of weight, volume, and density

Fifty samples were used to determine the cacao pod's weight, volume, and density. The pod was weighed on the scale, hung in a rod, and then forced into the water. A digital weighing scale with a minimum reading of 1 gram was used for this purpose.

$$V = \frac{Wdw}{DW} \tag{4}$$

Where:
V = volume of water (cm³)
W_{ad} = weight of displaced water (g)
D_{aw} = weight density of water (g/cm³)

3.6. Determination of bulk density

The determination of the bulk density of the selected pod samples was calculated using the method applied by [20], [21] and [25]. In this study, a 41-liter volumetric cylinder was filled with samples of cacao pods; the samples were then weighed. The bulk density was calculated using the ratio of the weight and the volume of the cylinder.

3.7. Determination of the mechanical properties

The design for the Arduino-based load compressor testing machine for cacao pod breaking was conceptualized and fabricated prior to the determination of the UF-18 cacao pod's mechanical properties. Critical components such as the load cell, linear actuator, and Arduino for the machine were evaluated through testing. The force required and time to break the pods were determined during the testing.

The Arduino-based load compressor testing machine was designed and fabricated in this study, as shown in Figure 1. The machine comprises a 1) power source made of a 3 cell Lithium-Ion battery pack that was enclosed in a dustproof case, 2) an Arduino Uno board with 20 total inputs, and an LCD display of 20×2 characters used for the monitoring of the time and load, and a four 4) push buttons (up, down, tare, and stop) used for inputs by the researchers, 3) a platform made of galvanized steel with a dimension of 37.5 cm long and 30.5 cm wide and 3 cm thick, 4) a 1500 N (152.90 kg) load cell, 5) a holder that holds the linear actuator and the load cell, 6) frame of 59 cm high and 30.5 cm wide and 7.5 cm thick made also of galvanized steel, and 7) a linear actuator that has a speed of 5 mm/sec. The raw data from the load cell was amplified through the HX711 load cell amplifier module and then read by Arduino. Prior to the conduct of tests, the Arduino-based load compressor testing machine was calibrated, and calibration of the load cell was conducted using a known mass; as of this study, we used 100 grams, we measured the offset reading of the load cell, and adjusted the calibration factor accordingly between 0.0% to 100%. If the load cell reading is above the value of the given mass, lower the calibration factor, and inversely, if the reading is below the value of the given mass, increase the calibration factor.

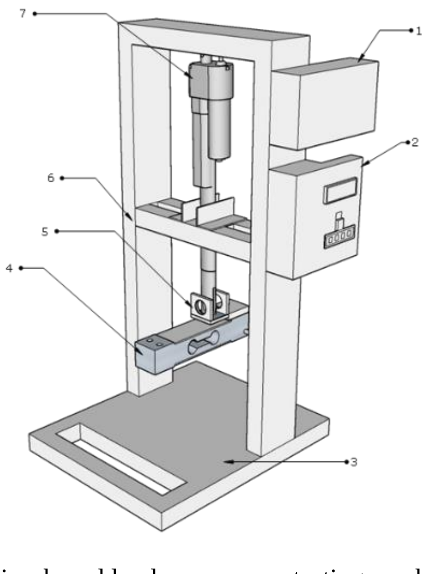

Figure 1. Isometric view of Arduino-based load compressor testing machine: 1) power source, 2) Arduino uno board, 3) platform, 4) load cell, 5) holder, 6) frame, and 7) linear actuator

3.8. Compression test

A compression test was conducted on a whole fresh cacao pod as shown in Figure 2. Fifty samples of the trinitarian variety (UF-18) were randomly selected for the test. The pods' rupture points were determined by identifying the points in the graph generated by the test. The modified Arduino-based load compressor testing machine was used with a speed of 5 mm/s.

Figure 2. Process flow of compression testing: A) positioning of pod to the compression machine, B) start of pod breaking, C) end of compression test, D) reading of result

4. RESULTS AND DISCUSSION

4.1. Physical properties

Size and shape, weight, volume, density, and bulk density; using the criteria by [21] in determining the shape and size of the fruit as shown in Figure 3, the UF-18 cacao pod has an average geometric mean diameter, surface area, and sphericity index of 115.37 mm, 41,899.48 mm², and 0.6372 respectively, and with a variation of ±27.17, ±14538133.04, and ±0.00038 respectively, as shown in Tables 1 and 2, respectively. Also, the cacao pod samples had an average dimension of 181.29 mm, 94.26 mm, and 90.01 mm measured for the length, width, and thickness, respectively. Furthermore, the average weight is 691.85 g. Using the displacement method, it had a volume of 746.19 cm³, a density of 0.93, and a bulk density of 522.68 kg/m³. Based on the study conducted by [9] on the physical properties of Trinitarian pods, the average weight was 564.6, which is lighter as compared to the result of this study, for the average geometric mean diameter [9] reported a value of 105.89 which is smaller than the trinitary pod (UF-18) used in this study.

The sphericity obtained from the study is also comparable to the result reported by [9], which is 0.67. This shows that the UF-18 pods were not perfectly sphere-shaped, thus making it difficult to roll over. Hence, when designing a pod breaker with a hopper, it would be challenging for the fabricator to determine how these pods will be aligned prior to breaking or slicing. These results on size and shape will also be useful in designing the holders/clippers for the pod breaker.

Figure 3. Pod shape and size determination using an electronic vernier caliper with a minimum reading of 0.01 mm

Table 1. Physical properties of cacao pod (UF-18)

	Pod (UF-18)			
	Length (mm)	Equatorial diameter (mm)	Intermediate diameter (mm)	External thickness (mm)
Mean	181.29	94.26	90.01	17.44
Variance	93.93	30.31	26.04	5.54

Table 2. Continue of physical properties of cacao pod (UF-18)

	Pod (UF-18)					
	Mass (g)	Volume (cc)	Density (g/cc)	Geometric mean diameter (mm)	Surface area (mm²)	Sphericity index
Mean	691.85	746.19	0.93	115.37	41899.48	0.6372
Variance	10760.57	12513.12	0.01634	27.16	14538133.04	0.00076

4.2. Mechanical properties

The force needed to break the cacao pods was evaluated using the Arduino-based load compressor testing machine, as shown in Figure 3. This study used fifty random samples of UF-18 cacao pods with a maturity of 75 percent ripeness. Different pod sizes and thicknesses have various forces ranging from 36.94 to 92.42 kg (362.38 N to 906.64 N) and time ranging from 6-11 seconds to be able to break the pods, as shown in Figure 4. In the study of [9], the result of the compression test for cocoa pods ranges from 520 N to 650 N with a rapture force of 600 N for lateral compression, which was nearly the same as the result in this study. As for the result of this study, the UF-18 had thicker pods, making them less brittle and would not produce small debris when slicing or breaking; small debris adds impurities to the beans, making them prone to fungi that cause molds to beans during the fermentation process and reduces the quality of the product.

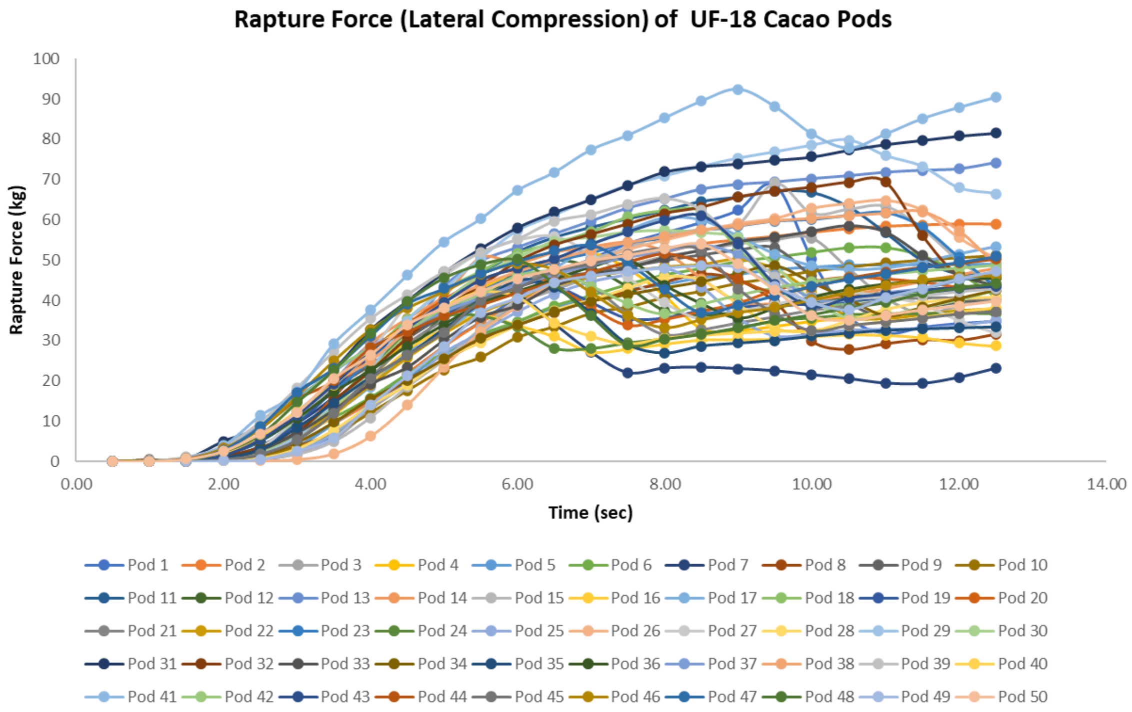

Figure 4. Different rupture points for randomly selected UF-18 cacao pods

5. CONCLUSION

The present study determined the physical and mechanical properties of UF-18 using an Arduino-based load compressor testing machine. The results show the physical and mechanical properties of UF-18, which include the dimensions (length, equatorial diameter, and intermediate diameter), average geometric mean, sphericity, and mass with the following values of 181.29 mm, 94.26 mm, 90.01 mm, 115.37 mm, 0.6372, and 691.85 g, respectively. It was also observed that a force of 362.38 N–906.64 N could break a pod within 6-11 seconds. Knowing the physical and mechanical properties of a cacao pod will help fabricators design an efficient machine that involves the use of pods such as pod breakers. Also, the determination of pod thickness helps the manufacturer decide the clearance of the blades to be placed so that it would not be able to cut the beans during the slicing process. Further, for compressive strength, it is necessary to identify the maximum and minimum rupture points of the pods to lessen the use of extra load for the pod breaking using compressors or breakers.

ACKNOWLEDGEMENTS

The authors would like to thank the Department of Science and Technology–Philippine Council for Agriculture, Aquatic, and Natural Resources Research and Development (DOST-PCAARRD) for the research funding.

REFERENCES

[1] W. C. Nabua, R. L. Aleman, A. J. B. Ardinez, and D. D. Linganay, "Cacao production in the Philippines 1990-2012," *SDSSU Multidisciplinary Research Journal*, vol. 1, no. 2, pp. 1–6, 2013.

[2] I. A. De Vera, "Cacao and Tablea Tsokolate: Spanish contribution in pangasinan agroforestry, culinary, and economy," *Journal of Natural and Allied Sciences*, vol. II No.I, pp. 49–56, 2018, [Online]. Available: www.psurj.org/jonas.

[3] A.-A. F. de Almeida and R. R. Valle, "Ecophysiology of the cacao tree," *Brazilian Journal of Plant Physiology*, vol. 19, no. 4, pp. 425–448, Dec. 2007, doi: 10.1590/S1677-04202007000400011.

[4] L. C. Vriesmann, R. D. M. C. Amboni, and C. L. D. O. Petkowicz, "Cacao pod husks (Theobroma cacao L.): composition and hot-water-soluble pectins," *Industrial Crops and Products*, vol. 34, no. 1, pp. 1173–1181, Jul. 2011, doi: 10.1016/j.indcrop.2011.04.004.

[5] "Phillipine cacao industry roadmap 2021-2025," *Department of Agriculture - Bureau of Agricultural Research*, 2022. https://www.da.gov.ph/wp-content/uploads/2023/05/Philippine-Cacao-Industry-Roadmap.pdf (accessed Apr. 13, 2024).

[6] A. Joshy, S. Geethu, K. M. Krishnendu, and C. S. Nikhil, "Development and performance evaluation of a cocoa pod breaker cum bean extractor," *Department of Post-Harvest Technology and Agricultural Processing*, 2015. http://14.139.181.140:8080/jspui/handle/123456789/250%0Ahttp://14.139.181.140:8080/jspui/bitstream/123456789/250/1/P306.pdf (accessed Apr. 13, 2024).

[7] BoAS, "Selected statistics on agriculture 2013," *Psa.gov.ph*, 2013.

[8] K. Fleming, V. E. Smith, H. C. Bittenbender, "The economics of cacao production in Kona," *Agribusiness*, no. AB-17, pp. 1–12, 2009.

[9] J. D. Fonsso, "Hertz theory application in modeling and analysis of mechanical rupture force of cocoa pod," *International Journal of Mechanical Engineering and Applications*, vol. 4, no. 5, p. 182, 2016, doi: 10.11648/j.ijmea.20160405.13.

[10] I. Audu, A. O. Oloso, and B. Umar, "Development of a concentric cylinder locust bean dehuller," *Agricultural Engineering International: the CIGR Journal of Scientific*, vol. 6, no. 3, pp. 1–11, 2004.

[11] A. Vejasit and V. M. Salokhe, "Studies on machine-crop parameters of an axial flow thresher for threshing soybean," *Agriculture Engineering International*, vol. 6, no. 1977, pp. 1–12, 2004.

[12] A. Chamsing, V. Salokhe, and G. Singh, "Design, fabrication and testing of an impact-type hand operated cocoa pod breaker," *CIGR Ejournal.*, vol. VIII, pp. 1–12, 2006.

[13] S. K. Adzimah and E. K. Asiam, "Design of a cocoa pod splitting machine," *Research Journal of Applied Sciences, Engineering and Technology*, vol. 2, no. 7, pp. 622–634, 2010.

[14] R. K. Vishwakarma, U. S. Shivhare, and S. K. Nanda, "Predicting guar seed splitting by compression between two plates using hertz theory of contact stresses," *Journal of Food Science*, vol. 77, no. 9, Sep. 2012, doi: 10.1111/j.1750-3841.2012.02861.x.

[15] H. F. Fakhruldeen, A. A. Meri, A. H. Sa'Id, A. N. Makttoof, M. A. Kadhim, and H. A. J. Al-Asady, "An Arduino-based voice-recognition elevator for special purposes," *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 31, no. 2, pp. 828–834, Aug. 2023, doi: 10.11591/ijeecs.v31.i2.pp828-834.

[16] S. A. Nordin, Z. M. Yusoff, and N. N. Mohammad, "Druken alcohol intelligent detection system IoT based Arduino controller," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 29, no. 3, pp. 1310–1317, Mar. 2023, doi: 10.11591/ijeecs.v29.i3.pp1310-1317.

[17] W. Suparta, A. Warsita, and Ircham, "A low-cost development of automatic weather station based on Arduino for monitoring precipitable water vapor," *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 24, no. 2, pp. 744–753, Nov. 2021, doi: 10.11591/ijeecs.v24.i2.pp744-753.

[18] P. W. Rusimamto, Endryansyah, L. Anifah, R. Harimurti, and Y. Anistyasari, "Implementation of arduino pro mini and ESP32 cam for temperature monitoring on automatic thermogun IoT-based," *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 23, no. 3, pp. 1366–1375, Sep. 2021, doi: 10.11591/ijeecs.v23.i3.pp1366-1375.

[19] T. A. Adekanye, E. A. Alhassan, and M. O. Iyanda, "Design, fabrication and testing of cocoa depodding machine," *Mindanao Journal of Science and Technology*, vol. 16, pp. 11–24, 2018.

[20] K. Jaiyeoba, S. O. Jekayinfa, and J. A. Olaniran, "Moisture-dependent physical properties of cocoa (Theobroma cacao) pods," *The International Journal of Organic Agriculture Research and Development*, vol. 13, pp. 40–46, 2016.

[21] F. U. Asoiro, M. Eng, and A. O. Ani, "Determination of some physical properties of african yam beans .," *The Pacific Journal of Science and Technology*, vol. 12, no. 1, pp. 374–380, 2011.

[22] E. A. Ajav and C. A. Ogunlade, "Physical properties of Ginger (Zingiber Officinale)," *Global Journal of Science Frontier Research*, vol. 14, no. 8, pp. 1–8, 2014.

[23] T. Faleye, O. A. Atere, O. N. Oladipo, and M. O. Agaja, "Determination of some physical and mechanical properties of some cowpea varieties," *African Journal of Agricultural Research*, vol. 8, no. 49, pp. 6485–6487, 2013, doi: 10.5897/ajar11.626.

[24] S. P. Sonawane, G. P. Sharma, N. J. Thakor, and R. C. Verma, "Moisture-dependent physical properties of kokum seed (Garcinia indica Choisy)," *Research in Agricultural Engineering*, vol. 60, no. 2, pp. 75–82, Jun. 2014, doi: 10.17221/59/2011-rae.

[25] C. Ogunlade, A. Alaka, N. Babajide, and S. Anjorin, "Moisture-dependent physical properties of popcorn," *Journal of Multidisciplinary Engineering Science and Technology (JMEST)*, vol. 3, pp. 3159–3199, 2016.

BIOGRAPHIES OF AUTHORS

Maricel Gamolo Dayaday is an associate professor and dean of the College of Engineering and Information Technology, University of Southern Mindanao, Kabacan, Cotabato. She is a licensed Electronics Engineer and an alumna of University of Southeastern Philippines (USeP), Davao city. She completed her Doctor of Technology Education at University of Science and Technology in Southern Philippines. Her research interest is in electronics engineering, information and communication technology and engineering education. She can be contacted at email: mgdayaday@usm.edu.ph.

Renel M. Alucilja is an associate professor and director for planning and development of the University of Southern Mindanao and a faculty member of the College of Engineering and Information Technology, University of Southern Mindanao, Kabacan, North Cotabato. He is a licensed Agricultural and Biosystems Engineer and an alumna of University of Southern Mindanao. He completed his Master of Science in Agricultural Engineering major in Farm Power and Machinery, minor in Agricultural and Bioprocess Engineering at the University of the Philippines, Los Baños, Laguna and a Ph.D. candidate in Agricultural Engineering at Central Luzon State University, Moñuz, Nueva Ecija. He can be contacted at email: rmalucilja@usm.edu.ph.

Ritchell Joy T. Cuarteros is a science research assistant under the niche center in the region: Cacao R&D program implemented in the University of Southern Mindanao, funded by the Department of Science–Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development. She is a licensed Agricultural and Biosystems Engineer and an alumna of the University of Southern Mindanao, Kabacan, North Cotabato and currently taking up her master's degree in Agricultural and Biosystems Engineering major in Natural Resource Conservation Engineering at the University of Southern Mindanao, Kabacan North Cotabato. She can be contacted at email: rjtcuarteros@usm.edu.ph.

Jeffrey A. Lavarias is a Laboratory Aide under the Niche Center in the region: Cacao R&D program implemented in the University of Southern Mindanao, funded by the Department of Science and Technology–Philippine Council for Agriculture, Aquatic, and Natural Resources Research and Development. He is a licensed Electronics Engineer and Electronics Technician and an alumna of the University of Southern Mindanao, Kabacan, North Cotabato. He can be contacted at email: lavariasjeff@gmail.com.