

DEVELOPMENT OF CLSU FERMENTED CROP REFUGE EXTRACTOR

**IDMILAO, REDENTOR JR. G.
MALANUM, RYAN ROWIE P.**

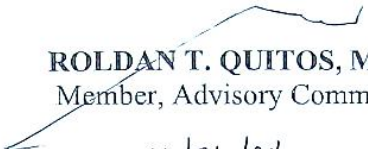
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(Major in AB Machinery and Power Engineering)**

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ACCEPTANCE SHEET

This undergraduate thesis entitled “**DEVELOPMENT OF CLSU FERMENTED CROP REFUGE EXTRACTOR**” prepared and submitted by **RYAN ROWIE P. MALANUM** and **REDENTOR G. IDMILAO JR.**, in partial fulfillment of the requirements for the degree of **BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS (AB MACHINERY AND POWER ENGINEERING)**, is hereby accepted:

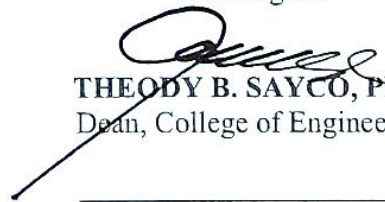

ROLDAN T. QUITOS, M. Sc.
Member, Advisory Committee
01/26/24
Date Signed


MARLON T. DELOS SANTOS, M. Sc.
Member, Advisory Committee
01/28/24
Date Signed


JOHN VINCENT A. NATE, M.Sc.
Chair, Advisory Committee
01/17/24
Date Signed

Accepted as partial fulfillment of the requirements for the degree of **BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS ENGINEERING (AB MACHINERY AND POWER ENGINEERING)**:


ELMAR M. VILLOTA, Ph. D
Head, Department of Agricultural and Biosystems Engineering

Date Signed

THEODY B. SAYCO, Ph. D
Dean, College of Engineering

Date Signed

BIOGRAPHICAL SKETCH

Ryan Rowie P. Malanum was born in San Jose City, Nueva Ecija on 8th of May, year 2001 but raised at San Isidro, Nueva Ecija. He is the only son of Mr. Willie N. Malanum and Mrs. Rosalie P. Malanum.

He is currently enrolled at Central Luzon State University located at Science City of Muñoz, Nueva Ecija taking course Bachelor of Science in Agricultural and Biosystems Engineering. He finished junior high school at Calaba National High School from academic year 2013 – 2017 and senior high school at Holy Rosary Colleges Foundation from academic year 2017 – 2019. Moreover, he completed his elementary school at Calaba Elementary School during academic years of 2006 – 2013. He was a member of school-based organization named Engineering Computer Club since 2022.

BIOGRAPHICAL SKETCH

Redentor G. Idmilao Jr. is a 22-year-old college student currently enrolled in the program; Bachelor of Science in Agriculture and Biosystems Engineering at Central Luzon State University, Science City of Munoz, Nueva Ecija.

Idmilao was born in Luna, Isabela, and residing in Diamantina, Cabatuan, Isabela. He is the son of Mr. Redentor G. Idmilao Sr. and Mrs. Aida G. Idmilao and younger brother of Maricar G. Idmilao. He finished his elementary, junior, and senior high school education at La Salette of Cabatuan, Cabatuan, Isabela. During his Grade 12 Senior high school years, Idmilao is the Buklod President, a school-wide student organization. In this service, he took part in alleviating every student's concern for quality learning. Today, Idmilao is a member and an officer of Engineering Computer Club, a college-based organization at College of Engineering, Central Luzon State University.

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ABSTRACT

MALANUM, RYAN ROWIE P., IDMILAO, REDENTOR JR. G.
Department of Agricultural and Biosystems Engineering, College of Engineering,
Central Luzon State University, Science City of Munoz, Nueva Ecija, Philippines.
FEBRUARY 2024. DEVELOPMENT OF CLSU FERMENTED SOLUTION
FROM CROP REFUGE.

Fermented Plant Juice (FPJ), a potent organic fertilizer made from young plant parts and fast-growing crops, can significantly boost agricultural productivity. Its potential is further heightened by the Philippine Republic Act 10068, encouraging the use of indigenous materials like FPJ in organic farming. However, current manual extraction methods are inefficient and limit large-scale adoption. This study addresses this challenge by developing a screw-type extractor machine for FPJ specifically from soybean and squash refuge. The machine aimed to; Increase juice recovery: Manual methods often yield low juice recovery, hindering overall fertilizer production. Reduce labor input: Manual extraction is physically demanding and time-consuming, creating bottlenecks in processing. Improve efficiency and output: A machine-based approach promises faster extraction, higher juice yield, and increased production capacity.

The extractor, constructed from readily available materials, consists of five key components: feeding hopper, extraction chamber, juice and meal outlet, transmission assembly, main frame. The screw shaft's rotational speed was the primary variable investigated during performance testing. Compared to manual methods, the extractor significantly improved juice recovery, reaching up to 84.41% at the optimal speed of 15 rpm. Extraction efficiency also exceeded the minimum PAES requirement, highlighting the machine's effectiveness. Notably, slower speeds yielded higher juice recovery at the expense of extraction rate. With an estimated payback period of 178 days under

continuous operation, the extractor offers substantial economic benefits. The daily operating cost is relatively low, and the produced fermented solution is cost-effective.

Overall, this study successfully developed a practical and efficient extractor for FPJ from crop refuge. This innovation has the potential to revolutionize organic fertilizer production, promote agricultural sustainability, and drive further advancements in this field. Future research could: explore optimized designs for different crop types and larger-scale production and investigate the effectiveness of the extracted FPJ as a fertilizer for various crops.

LITERATURE CITED

- A. (2020). Everything you need to know about pulley and belt. Student Lesson. Retrieved from: <https://studentlesson.com/belt-pulley-definiton-functions-types-parts-working/>
- Lacanilao A. (2019). Application of Soybean-based Formulations of Improved Soybean Seed Production.
- Anbu, S., & P, S. (2016, December 1). Microbially Fermented Soybean Meal as Natural Fertilizer: A Review. ResearchGate. https://www.researchgate.net/publication/319269329_Microbially_Fermented_Soybean_Meal_as_Natural_Fertilizer_A_Review
- Aviara, N. A., Lawal, A., Nyam, D. S., & Bamisaye, J. (2013, June 1). Development and performance evaluation of a multi-fruit juice extractor. Researchgate. https://www.researchgate.net/publication/260399142_DEVELOPMENT_AND_PERFORMANCE_EVALUATION_OF_A_MULTI-FRUIT_JUICE_EXTRACTOR
- Bianca. (2020, A). Nueva Ecija cooperative promotes soybean production while creating livelihood opportunities for farmers. Agriculture Monthly. <https://www.agriculture.com.ph/2020/04/20/nueva-ecija-cooperative-promotes-soybean-production-while-creating-livelihood-opportunities-for-farmers/>
- Halpern, M., Bar-Tal, A., Ofek, M., Minz, D., Müller, T., & Yermiyahu, U. (2015, January 1). The Use of Biostimulants for Enhancing Nutrient Uptake. Elsevier eBooks; Elsevier BV. <https://doi.org/10.1016/bs.agron.2014.10.001>
- Hubilla, E. K. (2020, May 14). Fermented Plant Juice (FPJ) can spur plant growth. Agriculture Monthly: <https://www.agriculture.com.ph/2020/05/14/fermented-plant-juice-fpj-can-spur-plant-growth/>
- Lacanilao, A.R. (2019). Application of Soybean-based Formulations for improved soybean seed production. College of Agriculture, Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines.
- Ladenburger, K. (2021, May 25). How Amino Acids Aid Plant Growth. MaximumYield. <https://www.maximumyield.com/how-amino-acids-aid-plant-growth/2/18124>
- Ling, F. (2002). Response of maize to foliar vs. Soil application of nitrogen–phosphorus–potassium fertilizers. <https://www.semanticscholar.org/paper/response-of-maize-to-foliar-vs.-soil-application-of-Ling-Silberbush/ae5b43b38f84ee791131dad5cdd1b90cdc5bf4fe>

- Llamelo, N. (2016). Effect of Different Bio-Fertilizers Applied as Supplemental Foliar Spray on the Growth and Yield of Corn (Zea Mays L.). <https://www.semanticscholar.org/paper/Effect-of-Different-Bio-Fertilizers-Applied-as-on-Llamelo-Bulalin/44b4d9f71130618f640e6fe80c500511e1d7550b>
- Mercado, F., Aguinaldo, T., Gavino, H., & Taylan, V. (2016). Medium-Scale Multi-Juice Extractor for Food Processing. *International Journal of Advances in Science Engineering and Technology*, <https://publications.waset.org/abstracts/49245/medium-scale-multi-juice-extractor-for-food-processing>
- Miller, S., Ikeda, D., Weinert, E., Chang, K., McGinn, K., Kelihoomalua, C., and DuPonte, M., (2013). Natural Farming: Fermented Plant Juice. 2 College of Tropical Agriculture and Human Resources, Cooperative Extension Service, Hilo, HI. Retrieved from: <https://www.ctahr.hawaii.edu/oc/freepubs/pdf/SA-7.pdf>.
- Naz, F. (2011). Studies on growth, yield and nutritional composition of different tomato cultivars in battal valley of district mansehra, khyber pakhtunkhwa, pakistan. <https://www.semanticscholar.org/paper/STUDIES-ON-GROWTH%2C-YIELD-AND-NUTRITIONAL-OF-TOMATO-Naz-Haq/96356112c2f792405b9e65003982aecd7875bd80>
- Olaniyan, A., & Obajemilhi, O. (2014, January 20). Design, Development and Test of a Small-Scale Mango Juice Extractor. ResearchGate. https://www.researchgate.net/publication/306032196_Design_Development_and_Test_of_a_Small_Scale_Mango_Juice_Extractor
- Team, C. (2023). Fixed and Variable Costs. *Corporate Finance Institute*. <https://corporatefinanceinstitute.com/resources/accounting/fixed-and-variable-costs/>
- Vinall, K. (2012). Amino acids are a nitrogen source for sugarcane. <https://www.semanticscholar.org/paper/Amino-acids-are-a-nitrogen-source-for-sugarcane.-Vinall-Schmidt/c36dca334a2e4f22d4ecfd30db0b38cb1a82c692>
- Więcek, D., & Kuric, I. (2019). Cost Estimation Methods of Machine Elements at the Design Stage in Unit and Small Lot Production Conditions. *Management Systems in Production Engineering*, 27(1), 12–17. <https://doi.org/10.1515/mspe-2019-0002>
- Xu, G. (2012). Plant nitrogen assimilation and use efficiency. <https://www.semanticscholar.org/paper/Plant-nitrogen-assimilation-and-use-efficiency.-Xu-Fan/dd9ac391f3ccedaeced616d7ea738cb98d0cb02>

- PAES, “Agricultural Machinery: Multicrop Juice Extractor – Specifications and Methods of Test”, 2008
- Tribbey, W. (2010). Numerical recipes. *ACM SIGSOFT Software Engineering Notes*, 35(6), 30–31. <https://doi.org/10.1145/1874391.187410>
- Cabral, M. (2020). Ginger (*Coix lacryma L.*) Juice Extraction using Screw-type Expression Machine.
- Eyeowa, A. D., Adesina, B., Diabana, P. D., & Tanimola, O. A. (2017). Design, fabrication and testing of a manual juice extractor for small scale applications. *Current Journal of Applied Science and Technology*, 22(5), 1–7. <https://doi.org/10.9734/cjast/2017/33360>
- Raji, N. A., Adedeji, K. A., Olaleye, J., & Adele, F. (2019). Design and fabrication of tiger nut juice extractor. *Journal of Applied Sciences and Environmental Management*, 23 Murali, V., Abhilash, P., Cs, C., Yeshwanth, N., & C, P. (2023). DESIGN AND DEVELOPMENT OF HYDRAULIC POWERED COCONUT WATER EXTRACTION MACHINE. *International Research Journal of Engineering and Technology (IRJET)*. <https://doi.org/10.31224/3022> (3), 563. <https://doi.org/10.4314/jasem.v23i3.29>
- Design and Testing of a Four-Roller Press to Extract Sugary Juice from Sweet Sorghum and Sweet Pearl Millet Biomass. (2015). *Applied Engineering in Agriculture*, 767–772. <https://doi.org/10.13031/aea.31.11143>
- Fan, Y., Zhang, J., Sun, J., Liu, H., & Sun, R. (2019). Evaluation of a novel screw press design for high-efficiency juice extraction. *International Journal of Food Engineering*, 8(1), 101.
- Publication preview page | FAO | Food and Agriculture Organization of the United Nations. (n.d.). FAODocuments. <https://www.fao.org/documents/card/en/c/8c492fec-366e-4c0d-a2b9-50cf194856f2/>