

**DESIGN, FABRICATION, AND PERFORMANCE EVALUATION OF  
MECHANICAL RICE STRAW CHOPPER CON MIXER**

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An Undergraduate Thesis Submitted to the Faculty of the Department of Agricultural and  
Biosystems Engineering, College of Engineering, Central Luzon State University,  
Science City of Muñoz, Nueva Ecija, Philippines  
in Partial Fulfillment of the Requirements  
for the Degree of

**BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS  
ENGINEERING  
(AB Machinery and Power Engineering)**

**JULY 2024**

**ACCEPTANCE SHEET**

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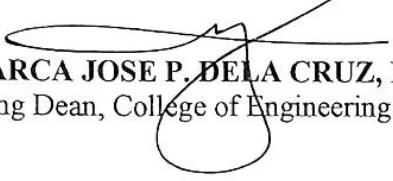
  
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## BIOGRAPHICAL SKETCH

Christine Neil C. Mariano, born on April 19, 2001, in Cabanatuan City, Nueva Ecija, is the youngest child of Mr. Noel Mariano and Mrs. Nelia Mariano. Her parents are originally from Ilagan City, Isabela, and Ozamiz City, Misamis Occidental. Growing up in a military-disciplined environment, Christine inherited the values of dedication and hard work, witnessing the rigors of military training firsthand.

Neil began her educational journey at BC Achiever's Integrated Inc., where she built a strong academic foundation. She then attended St. Louis Anne Montessori High School and Colleges for her junior high school years, distinguishing herself as the Corps Commander of Citizenship Army Training and earning the title of Most Valuable Player in girls' basketball. Christine's versatility extended beyond the basketball court, as she won championships in badminton, darts, chess, and table tennis. Her leadership abilities were recognized with a prestigious leadership award.

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Neil is currently pursuing a Bachelor of Science in Agricultural and Biosystems Engineering at Central Luzon State University. Her passion for sustainable agriculture and technological innovation drives her academic endeavors, blending her rural upbringing with a desire to advance agricultural practices and contribute to the development of sustainable solutions in the field.

## ACKNOWLEDGEMENT

Embarking on this academic odyssey has been both challenging and rewarding. Reaching this milestone compels the researcher to express profound gratitude to those who have played instrumental roles in shaping this journey. The foundation of this thesis has been their unwavering support, guidance, and encouragement.

The researcher is indebted to her parents, Mr. Noel Mariano and Mrs. Nelia Mariano, for their unending encouragement and sacrifices. Their belief in her abilities has been the driving force behind her academic pursuits, instilling in her the values of resilience and determination.

A special space in the tapestry of gratitude is reserved for Shaina Gem P. Cardenio. Her unwavering support, understanding, and love have illuminated the path of this thesis journey. Shaina has been a rock, providing encouragement during moments of self-doubt and celebrating every small triumph. Her family, Mr. Eduardo Magno and Mrs. Grace Padiernos, have graciously welcomed the researcher into their home and hearts. Shaina Gem P. Cardenio, to whom the researcher expresses profound thanks for being the anchor that steadied her through this academic voyage.

In pursuing this academic endeavor, the researcher is humbled and grateful for the unwavering support of her sisters, Noreen M. Respicio, Nonielou C. Mariano, and Leonailen C. Mariano. Their moral and financial support has been a lifeline, easing the burdens that often accompany higher education. The bond shared extends beyond familial ties; it is a source of strength that has propelled the researcher toward completing this thesis. To Leonailen C. Mariano and Noreen M. Respicio, the researcher is profoundly thankful for their belief in her abilities and their generosity.

The researcher extends her deepest gratitude to her thesis adviser, Engr. Novalyn G. Delos Santos, whose invaluable suggestions and dedicated efforts were instrumental in refining this study. Profound gratitude is also extended to Engr. Eliza E. Camaso for her unwavering support, motivation, and consistent guidance; and to Engr. Ruel G. Peneyra for his exceptional contributions and remarkable inputs, which significantly enhanced the quality of this research.

Gratitude is expressed to God for being the partner and guiding light throughout the researcher's college journey, providing comfort in challenges and clarity in uncertainty. To her family, friends, and mentors, the researcher extends thanks for their invaluable support and wisdom. As she transitions to the next chapter, she carries the lessons learned and divine guidance that have shaped her collegiate experience.

This thesis is the culmination of the collective efforts of many, and the researcher is humbled by the contributions of each individual who played a part, no matter how small, in bringing this work to fruition.

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## ABSTRACT

**MARIANO, CHRISTINE NEIL C.** College of Engineering, Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines, **July 2024**, **DESIGN, FABRICATION AND PERFORMANCE EVALUATION OF MECHANICAL RICE STRAW CHOPPER CON MIXER**

Adviser: NOVALYN G. DELOS SANTOS, M.Sc

The mushroom industry in the Philippines is experiencing growth due to the recognized nutritional and medicinal benefits of mushrooms. However, the manual preparation of mushroom growing substrate poses challenges in terms of labor intensity and costs. To address this, a study was undertaken to design and assess the performance of a mechanical rice straw chopper with a mixer tailored for the local mushroom industry.

The study aimed to mechanize the labor-intensive process of mushroom substrate production by designing and fabricating a rice straw chopper con mixer. The development process was detailed, involving the design and fabrication of the machine to address existing challenges. Performance metrics such as chopping and mixing efficiency, along with output capacity, were assessed using ANOVA and mean comparisons by LSD.

The study successfully addressed key operational challenges and achieved its objectives. It was determined that the machine operates at a maximum output of 283.67 kg/hr with an efficiency of 94.54%. A comparative analysis of manual versus mechanized methods revealed significant reductions in labor costs and an increase in substrate production when using the machine. Economic viability was affirmed through a comprehensive cost analysis.

Keywords: Mushroom industry; substrate preparation; rice straw chopper; mechanization

## LITERATURE CITED

- Aliero, A. A. (2016). *An introduction to mushroom production in Nigeria*. Usmanu Danfodiyo University Sokoto.
- Abdula, R. (2018). *Rice-based mushroom manual*. Philippine Rice Research Institute (PhilRice), Maligaya, Science City of Muñoz 3119 Nueva Ecija, Philippines. ISBN: 978-621-8022-36-2.
- Abrishamkesh, S., Gorji, M., Asadi, H., Bagheri, G. H., & Purbabae, A. A. (2021). Effects of rice husk biochar application on the properties of alkaline soil and lentil growth. *Plant, Soil and Environment*, 61(10), 475-482. <https://doi.org/10.17221/203/2021-PSE>
- Abdurrahman, A. (2020). Utilization of agricultural waste for the cultivation of edible fungi in Indonesia. *IOP Conference Series: Earth and Environmental Science*, 460(1), 012041. <https://doi.org/10.1088/1755-1315/460/1/012041>
- Adejumo, I. O., & Adebiyi, O. A. (2020). Agricultural solid wastes: Causes, effects, and effective management. In N. Singh, R. K. Sharma, & B. B. Pant (Eds.), *Strategies of sustainable solid waste management* (pp. 1-19). IntechOpen. <https://doi.org/10.5772/intechopen.93601>
- Alam, S. M., & Raza, M. S. (2001). Importance of mushrooms. *Industry and Economy*, NIA, Tandojam, Pakistan.
- Arthur, A. (1992). Energy requirement for size reduction of agricultural and woody residues using tub grinders. *Journal of Agricultural Engineering Research*.
- Balan, V. (n.d.). IoT based smart automated mushroom production system. USDA National Institute of Food and Agriculture. <https://portal.nifa.usda.gov/web/crisprojectpages/1026673-iot-based-smart-automated-mushroom-production-system.html>
- Cabatbat, A. J. T. (2021). An act declaring Guimba, Nueva Ecija as the rice capital of the Philippines (House Bill No. 10719). House of Representatives. [https://hrep-website.s3.ap-southeast-1.amazonaws.com/legisdocs/basic\\_18/HB10719.pdf](https://hrep-website.s3.ap-southeast-1.amazonaws.com/legisdocs/basic_18/HB10719.pdf)
- Corales, R. G., Sajor, J. T., Corales, A. M., Rivera, J. M., & Catalon, A. F. (2018). *Rice-based mushroom production manual*. Philippine Rice Research Institute. <https://www.pinoyrice.com/wp-content/uploads/rice-based-mushroom-production-manual.pdf>

- Chang, S.-T. (1999a). Global impact of edible and medicinal mushrooms on human welfare in the 21st century: Non-green revolution. *International Journal of Medicinal Mushrooms*, 1, 1-7. <https://doi.org/10.1615/IntJMedMushr.v1.i1.10>
- Chang, S.-T. (1999b). World production of cultivated edible and medicinal mushrooms in 1997 with emphasis on *Lentinus edodes* (Berk.) Sing. in China. *International Journal of Medicinal Mushrooms*, 1, 291-300. <https://doi.org/10.1615/IntJMedMushr.v1.i4.20>
- Chen, M. Z., Xu, G. F., Wei, M. J., Li, X. W., Wei, Y. Z., Diao, P. S., et al. (2023). Optimizing rotary chopper design for agricultural efficiency. *16*(3), 67.
- Chattopadhyay, S., & Pandey, S. (1999). Flail-type forage harvesters: Technology and energy aspects. *Journal of Agricultural Engineering Research*, 72(2), 123-133.
- Ebrahimi, M., Yaraghi, A., Ein-Mozaffari, F., & Lohi, A. (2018). The effect of impeller configurations on particle mixing in an agitated paddle mixer. *Powder Technology*, 332, 158–170.
- Farashah, H. R., Tabatabaeifar, S. A., Rajabipour, A., & Sefeedpari, P. (2013). Energy efficiency analysis of white button mushroom producers in Alburz Province of Iran: A data envelopment analysis approach. *Open Journal of Energy Efficiency*, 2, 65-74. <https://doi.org/10.4236/ojee.2013.22010>
- Göbel, F., Golshan, S., Norouzi, H. R., Zarghami, R., & Mostoufi, N. (2018). *Simulation of granular mixing in a static mixer by the discrete element method*. Retrieved November 26, 2022, from <https://www.cemf.ir/pdfs/publications/simulation-of-granular-mixing-in-a-static-mixer-by-the-discrete-element-method.pdf>
- Ismail, M., Yassene, Ali, & Afify, M. (2011). Mechanical properties of rice straw fiber-reinforced polymer composites. *Fibers and Polymers*, 12(5), 648-656. <https://doi.org/10.1007/s12221-011-0648-5>
- Jenike, A. W. (1961). *Gravity flow of bulk solids* (Master's thesis). University of Utah. <https://collections.lib.utah.edu/details?id=709033>
- Lu, X., Dai, B., & Yang, S. (2022). Investigating solid transportation and mixing performance in vertical mixers: A discrete element method approach. *Indian Engineering Chemistry Research*, 16.
- Marczuk, A., Misztal, W., Savinykh, P., Turubanov, N., Isupov, A., & Zyryanov, D. (2019). Improving efficiency of horizontal ribbon mixer by optimizing its constructional and operational parameters. *Eksploatacja i Niezawodność –*

*Maintenance and Reliability*, 21(2), 220–225.  
<http://dx.doi.org/10.17531/ein.2019.2.5>

- Mehos, M., & Morgan, S. (2016, January 1). Hopper design principles. *Chemical Engineering*. January 11, 2023, from <https://www.chemengonline.com/hopper-design-principles/>
- Niazi, A. R., & Ghafoor, A. (2021). Different ways to exploit mushrooms: A review. *All Life*, 14 (1), 450-460. <https://doi.org/10.1080/26895293.2021.1919570>
- Oh, J. H. O. (1996, June 1). Physical properties of rice hull and straw for handling facilities. *Korea Science*. Retrieved May 24, 2023, from <https://koreascience.kr/article/CFKO199611919846762.pdf>
- Philippine Agricultural Engineering Standards (PAES) 301:2000. Engineering materials – V-belts and pulleys for agricultural machines – Specifications and applications.
- Philippine Agricultural Engineering Standards (PAES) 303:2000. Engineering materials – Roller chains and sprockets for agricultural machines – Specifications and applications.
- Philippine Agricultural Engineering Standard (PAES) 304:2000. Engineering materials – Keys and keyways for agricultural machines – Specifications and applications.
- Philippine Agricultural Engineering Standard (PAES) 305:2000. Engineering materials – Shafts for agricultural machines – Specifications and applications.
- Philippine Agricultural Engineering Standard (PAES) 309:2000. Engineering materials – Anti-friction bearings for agricultural machines – Specifications and applications.
- Philippine Agricultural Engineering Standard (PAES) 310:2000. Engineering materials – Journal bearings for agricultural machines – Specifications and applications.
- Rambey, R., Handayani, D., & Oktavia, Y. (2020). Growth and productivity of oyster mushrooms (*Pleurotus ostreatus*) on media rice straw mixed with sawdust. *IOP Conference Series: Earth and Environmental Science*, 454, 012082. <https://doi.org/10.1088/1755-1315/454/1/012082>
- Ryhenan. (2017). Evaluation of the concrete mixer. [https://www.academia.edu/99568889/327\\_Enhancement\\_of\\_properties\\_of\\_concrete\\_with\\_phase\\_changing\\_materials\\_a\\_state\\_of\\_the\\_art\\_review](https://www.academia.edu/99568889/327_Enhancement_of_properties_of_concrete_with_phase_changing_materials_a_state_of_the_art_review)

Sidayao, J., Launio, C. C., Manalili, R., & Beltran, J. (2014). Exploratory study on the cost of collecting and transporting rice straw for power generation plant: Case of Nueva Ecija, Philippines. ResearchGate. [https://www.researchgate.net/figure/fig3\\_309127423](https://www.researchgate.net/figure/fig3_309127423)

Suraweera, R. W. P. H., Kahandage, P. D., Kosgollagedara, E. J., & Dissanayake, D. M. D. (2020). A review of mechanization and automation of mushroom cultivation. *Journal of Agriculture and Environmental Sciences*, 9 (2), 135-148. <https://www.researchgate.net/publication/348621134>

#### A\_Review\_of\_Mechanization\_and\_Automation\_of\_Mushroom\_Cultivation

Tian, F., Xia, K., Wang, J., et al. (2021). Design and experiment of self-propelled straw forage crop harvester. *Advances in Mechanical Engineering*, 13 (7). <https://doi.org/10.1177/16878140211024455>

Tseng, M. C., & Luong, J. H. (1981). Mushroom cultivation: Technology for commercial production. In J. G. Horsfall Jr. & A. E. Dimond (Eds.), *CRC handbook of microbiology* (pp. 307-320). CRC Press.

United Nations. (n.d.). Philippines population growth rate 1950-2022 [Graph]. World Population Prospects. Retrieved November 22, 2022, from <https://population.un.org/wpp/graphs/probabilistic/pop/tot/608>

World Export Company Limited. (n.d.). Sawdust and its role in mushroom cultivation. <https://worldexport.com.vn/sawdust-and-its-role-in-mushroom-cultivation>

Womac, A. R. (2007). Operational factors affecting the performance of tub grinder. *Journal of Agricultural Engineering Research*, 7-10.

Zastempowski, M., & Bochat, A. (2019). Analysis of the cutting moments for the selected chopper's cutting drums constructions. *MATEC Web of Conferences*, 287, 01024. <https://doi.org/10.1051/mateconf/201928701024>