DESIGN, FABRICATION AND PERFORMANCE EVALUATION OF A CYLINDRICAL BATCH-TYPE PADDY (*Oryza Sativa*) DRYER

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ACCEPTANCE SHEET

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LITERATURE CITED

Adesoji, M.O. & Omotara, A.A (2014).Conceptual design of a charcoal fired dryer. Proceedings International Conference of Agricultural Engineering. Zurich, 06-10.07.2014

Adzimah, K.S & Seckley, E. (2009). Improvement on the design of a cabinet grain dryer. *American Journal of Engineering and Applied Sciences* 2 (1): 217- 228, 2009.

Appiah, F., Guisse, R., & Dartey, P.K.A. (2011). Postharvest losses of rice from harvesting to milling in ghana. *Journal Stored Products and Postharvest Research*, Vol. 2 (4), 64-71. Retrieved from https://academicjournals.org/journal/JSPPR/article-full-textpdf/4FA055C8791.pdf

Ashfaq S., Ahmad M., Munir A., Wajid A (2015). Design development and performance evaluation of a small-scale solar assisted paddy dryer on farm processing. *Mehran University Research Journal of Engineering and Technology* 06 (09). doi:10.4172/2157-7110.100048.

Bautista, G. (2018). The flat bed paddy dryer. A potential rice postharvest game-changer. Retrieved from https://www.agriculture.com.ph/2018/07/05/the-flat-bed-paddy-dryer-a-potential rice-postharvest-game-changer/

Bautista, E. & Javier, E. (2008). Rice production practices. *Philippine Institution for development Studies. Retrieved* from https://dirp3.pids.gov.ph/ris/rps/pidsrp0802.pdf

Billiris, M. (2013). Measuring the energy required to dry rice in commercial rice dryer. *Theses and Dissertations.726.* Retrieved from https://scholarworks.uark.edu/cgi/viewcontent.cgi?article=1725&context=etd

Chupungco, A., Dumayas, E., & Mullen, J. (2008). Two-stage grain drying in the Philippines. Impact Assessment Series Report No. 59, 50pp. Retrieved from https://www.aciar.gov.au/sites/default/files/legacy/node /10108/IAS59.pdfde

Padua, D. (n.d). Postharvest handling in Asia. *International Rice Research Institute, Philippines*. Retrieved from https://www.fftc.org.tw/htmlarea_file/library/20110715231853 /eb465a.pdf

Djaeni, M., Asiah, N., Suherman, S., Sutanto, A., & Nurhasanah, A. (2015). Energy efficient dryer with rice husk fuel for agricultural drying. *Journal of Renewable Energy Development* 4(1), 20-24. https://doi.org/10.14710/ijred.4.1.20-24

Earle, R.L., & Earle, M.D. (1983). Unit operations in food processing. Retrieved from https://nzifst.org.nz/resources/unitoperations/index.html.

FAO (1994). Mechanical dryers. Retrieved from https://www.fao.org/3/t1838e/T1838E0w.htm#Mechanical%20dryers

Field, H. L., & J. B. Solie. (2000). Equipment Efficiency and Capacity. *Introduction to Agricultural Engineering Technology. Pp 118-128.*

Hemhirun, S. & Bunyawanichakul, P. (2020). The use of temperature and relative humidity sensors to estimate the final moisture content of drying process. *International Journal of Engineering Research and Technology* 9(05), 926-932. http://dx.doi.org/10.17577/IJERTV9IS050645

Histifarina, D., Rachman, A. & Purnamasari, N. (2019). In-store drying application on shallot postharvest handling.IOP Conf. Series: *Earth and Environmental Science* 230 (2019) 012034. doi:10.1088/1755-1315/230/1/012034

Hung, N.V., Tuan, T.V., Meas, P., Tado, C.J., Kyaw, M.A. & Gummert, M. (2018). Best practices for paddy drying: Case studies in Vietnam, Cambodia, Philippines, and Myanmar. *Plant Production Science 22* (1), Pp 107 118. doi.org/10.1080/1343943X.2018.1543547

Ila'ava, V. (2015). Handbook on rice postharvest techniques. Retrieved from https://www.jica.go.jp/png/english/activities/c8h0vm00008t2xqjatt/activity10_04.pdf

Islam, S. & Ahiduzzaman, Md. (2012). Green electricity from rice husk: A model for Bangladesh. Retrieved from https://www.intechopen.com/chapters/44239

IRRI (2008). PADDY DRYING. Postharvest Unit, CESD. Retrieved http://www.knowledgebank.irri.org/images/docs/training-manual paddy drying.pdf

IRRI (n.d). Harvesting. Rice Knowledge Bank. Retrieved from http://www.knowledgebank.irri.org/images/docs/training-manual harvesting.pdf

Field drying and stacking. Rice Knowledge Bank. Retrieved from http://www.knowledgebank.irri.org/stepbystepproduction/postharvest/drying/traditional-drying-systems/field-drying-and-stacking

Drying. Rice Knowledge Bank. Retrieved from http://www.knowledgebank.irri.org/stepbystepproduction/postharvest/drying#mechanical-drying-systems

Kader, A.A. (2013). Postharvets technology of horticultural crops-an overview from farm to fork. Ethiop .J. Appl. Sci.Technol. (Special Issue No.1): 1- 8 (2013). Retrieved from https://ucanr.edu/sites/Postharvest_Technology_Center_/files/231724.pdf

Kerr, W. (2019). Food drying and evaporation processing operation-chapter 14. *Handbook of Farm, Dairy and Food Machinery Engineering (Third Edition).* Pages 353-387.https://doi.org/10.1016/B978-0-12- 814803-7.00014-2

Kiaya, V. (2014). Postharvest losses and strategies to reduce them. *Action Contre la Faim International.* Retrieved from https://www.actioncontrelafaim.org/wpcontent/uploads /2018/01/technical_paper_ phl .pdf

Klomklao, P., Kuntinugunetanon, S. & Wongkokua, W. (2017). Moisture content measurement in paddy. *Journal of Physics Conference Series.* 901 (1):012068 doi :10.1088/1742-6596/901/1/012068

Mishra, A., Jha, S.K., Bhandari, G.R., Khatri, S., Shrestha, S. & Ojha, P. (2020). Performance evaluation of solar bubble dryer. *International Journal Of Scientific and Research Publication, Vol.* 10, Issue1. doi: 10.29322/IJSRP.10.01.2020.p9764

Mistry, B. (2016). Properties and industrial applications of rice husk. *International Journal of Engineering Sciences and Computing 6* (10), pp. 2677-2679. Retrieved from https://ijesc.org/upload/d6218bb4bd34bb4dcd7e9ed4666a4cdf.Properties%20and %20Industrial%20Applications%20of%20Rice%20Husk.pdf

Phetmanyseng, X., Khamtai V., Senthong P., Jaquie M., & Shu F. (2019). Rice milling quality as affected by drying method and harvesting time during ripening in wet and dry seasons. *Plant Production Science*, 22:1, 98-106. doi:10.1080/1343943X.2018.1544463

Philippine agricultural engineering standards.2000. PAES 201:2000. Agricultural Machinery: Heated-Air Mechanical Grain Dryer – Specifications

Philippine agricultural engineering standards. 2000. PAES 202:2000. Agricultural Machinery: Heated-Air Mechanical Grain Dryer – Methods of Test

PHilMech, 2018. PHilMech set to commercialize Fluidized Bed Dryer. Retrieved from https://www.philmech.gov.ph/?page=story_full_view&action=story_fullview&re cordID=NEPHI2018090002&recordCategory=News

Ricepedia (2012). Philippines. Retrieved from https://ricepedia.org/philippines

Rwubatse, B., Akubor, P.I. & Mugabo, E. (2014).Traditional drying techniques for fruit and vegetables losses alleviation in Sub-Africa. *Journal Environmental Science, Toxicology and Food Technology*. Vol. 8, Issue 9. Pp. 52-56. doi:10.9790/2402-08945256

Saba, S.S. & Ibrahim, H.I. (2018). Postharvets loss in rice: causes, stages, estimates and policy implications. *Agricultural Research and Technology Open Access Journal* 15(4). doi:10.19080/ARTOAJ.2018.15.555964

Sanchez, A., Lipan, L., Cano-Lamadrid, M., Kharaghani, A., Masztalerz, K., Barrachina, A. & Figiel, A. (2020). Comparison of traditional drying techniques and its effect on quality of fruits, vegetables and aromatic herbs. *Foods* 9(1261). doi:10.3390/foods9091261

Sikarwar, V. S., Zhao, M., Clough, P., Yao, J., Zhong, X., Memon, M.Z., Shah, N., Anthony, E. & Fennell, P.(2016). An overview of advances in biomass gasification. *Energy and Environmental Science* 9(10):2927-3304. doi: 10.1039/C6EE00935B

Statista (2021). Leading Countries based on the production of milled rice in 2019/2020(in million metric tons). Retrieved from https://www.statista.com/statistics/255945/top-countries-of-destination-for-usrice-exports-2011/

Sweeney, M. & McCouch, S.(2007). The complex history of the domestication of rice.*Annals of Botany*, Vol. 100, Issue 5, pp. 951-957. https://doi.org/10.1093/aob/mcm128

Tado, C.J., Ona, D., Abon, J.E., Gagelonia, E., Nghi, N.T., & Vhin, L.Q. (2015). Development and promotion of the reversible airflow flat dryer in the Philippines. *Annals of Tropical Research* 37(1):97-109. doi:10.32945/atr3717.2015

Zafar, S. (2021). Rice husk as energy source. Retrieved from https://www.bioenergyconsult.com/tag/rice-husk-as-energy-source/