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Technical performance of developed appropriate technologies: Its utilization as an approach for sustainable Philippine agricultural mechanization

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Abstract The study related to the technical performance of the different appropriate technologies developed in Iloilo City, Philippines to introduce the agriculture sector machinery and equipment access and solutions towards sustainable agricultural mechanization operations. The utilization of agricultural equipment is cited as an important tool to promote agricultural modernization through the use of technologies, preserving the environmental and cultural components and incorporating socio-economic considerations in order to attain the sustainable development of both the food and the agriculture sectors. The six selected technological development are subdivided into three mechanization categories, namely: Crop Management Technologies, Size Reduction Technologies, and By-Product Utilization Technologies. They were all subjected to actual operating performance evaluation at a minimum of three test runs and the results were compared in terms of the minimum requirements set by the Philippine National Standards or Philippine Agricultural Engineering Standards (PNS/PAES). Results revealed that the important operating parameters such as operating efficiency of the technologies developed starting from postharvest (77% - 80%), to size reduction (92% - 99.67%) and by-product utilization (8.4% - 13.1%) were computed to be within the Philippine National Standards or Philippine Agricultural Engineering Standards. These outcomes indicated the promising technical potentials when they are introduced in communities to the users.

Keywords: Agricultural machineries, Agricultural machine evaluation, Farm mechanization, Sustainable development goals, Technology utilization

Introduction

The United Nation's Food and Agriculture Organization (FAO) mentions

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that sustainable agricultural mechanization indicates enhanced farming operations which covers the utilization of technologies from the use of basic and simple manual tools to elevating on the application of motorized and automated machineries and equipment. The availability of these tools and machines in farm operations helps the agriculture sector lessen its burdens in facing the challenges created by the scarcity of human labor especially when many start to harvest almost at the same time, a very common scenario during the peak seasons. With sustained mechanization of agricultural operations, productivity is enhanced while the timeliness of scheduled farm activities is guaranteed leading to the efficient utilization of resources. In addition, a timely operation due to agricultural mechanization also boosts the market access of the products, hence creating an economic vibrancy on the part of producers and minimizes the likelihood of abandoning their landholdings intended mostly for agricultural production (FAO, 2019; Ma *et al.*, 2021).

The use of machineries and equipment in the agriculture sector is cited as necessary in promoting modernization and its promising application in the 20th century and even to the present times has been recorded to be increasing due to many breakthroughs in production processes (James, 2021). In the Philippines, government policies and regulations on agriculture and related-sectors are inclined towards making sure that self-sufficiency is attained in terms of securing availability of food supply by properly adopting and utilizing the technologies introduced in order to enhance the productivity of lands, crops and human labor (Amongo and Larona, 2015).

In addition, agricultural mechanization considers different aspects from operation, from production to harvest by integrating the use of technologies, preserving the environmental and cultural components and incorporating socio-economic considerations in order to sustain the growing development of both the food and agriculture sectors (Li *et al.,* 2019; FAO, 2019). Sustainable agricultural mechanization also integrates the use of different forms of power sources into appropriate machineries and equipment for agricultural production and the value adding of other agri-products (Sims and Kienzie, 2017). In line with this, the member states of the United Nations adopted in 2015 the Sustainable Development Goals' call for action to universally end poverty, protect our planet Earth and ensure that in the year 2030 all people in the world will enjoy peace and prosperity. The integration of the seventeen (17) Sustainable Development Goals or SDGs means recognizing that the actions created or made in the area will have correspondingly affected the outcomes in the others, emphasizing development to significantly balance socio-economic and environmental sustainability (https://www.undp.org/content/undp/en/home/sustainable developmentgoals.html). With the essential connection between man and its environment for food and agriculture, tapping the two latter sectors is the key to helping attain the multiple Global Goals of the United Nations. Aligned to this is one of the five key principles, which is to increase productivity, employment opportunities and value adding to food systems. When we help increase the productivity of the people, we are also providing them opportunities to transform their sources of livelihood. However, many of our small-holding farmers are struggling to have access or to be linked with services and resources such as affordable input materials and agri-related technologies. Creating the conditions for inclusive rural and agricultural transformation would mean investments that would provide them greater access especially to technologies and modern tools to generate energy (FAO, 2018). With access to available appropriate technologies, the small players in the agriculture sector will have opportunities to choose to invest in technologies that are deemed necessary in enhancing their productivity.

In the Philippine Agricultural and Fisheries Mechanization Law (Republic Act 10601), mechanization is defined as “Development, adoption, assembly, manufacture and application of appropriate, location specific and cost-effective agricultural and fisheries machinery using human, animal, mechanical, electrical, renewable and other nonconventional sources of energy for agricultural production and postharvest/postproduction operations consistent with agronomic conditions and for efficient and economic farm and fishery management towards modernization of agriculture and fisheries” .

With sustainable agricultural mechanization, the modernization and transformation of agriculture and related sectors may be achieved, thereby contributing especially to the following SDGs: 1-no poverty, 2-zero hunger, 7-affordable and clean energy, and 9-industry, innovation and infrastructure (https://www.officialgazette.gov.ph/2013/06/05/republic-act-no-10601/; FAO, 2018).

Central Philippine University’s Appropriate Technology Center or the CPU Approtech was established in 2000 with the purpose of developing and introducing machineries appropriate to the specific needs of its stakeholders especially the agriculture sector in order to enhance operation and production. It has developed cutting-edge technologies focusing on production and post-harvest activities and now it is integrating the utilization of biomass wastes not just as resources but as potential machinery and equipment for sustainable operations. This study focused only on the technical performance of the six developed appropriate technologies providing access and solutions for sustainable agricultural mechanization. They were evaluated for their technical operating performance.

Materials and methods

Study area and technologies developed

The technologies developed are subdivided into three mechanization categories, namely: Crop Management Technologies, Size Reduction Technologies, and By-Product Utilization Technologies.

Crop management technologies

The mechanical dryer is a flatbed-type wherein the fixed volume of rough rice or paddy grains is placed inside the shallow horizontal grain holding bin for drying until the desired moisture, which is about 14%, is attained. It is composed of the following major parts: furnace, air duct, blower, drying chamber and plenum chamber (Figure 1).

The abaca decorticating (or deco) machine, shown in Figure 2, is powered by a 6.5 Hp gasoline engine. Major parts of the machine include an input chute, a decorticating drum cover, an output chute and a prime mover in the form of a gasoline engine. Inside the decorticating cover includes a decorticating chamber, decorticating blades, decorticating drum and a scraper block.

Figure 1. Installed paddy dryer on-site

Figure 2. Actual field testing of the abaca deco machine

Size reduction technologies

Size reduction technologies are designed to reduce the particle size of materials such as biomass wastes for composting and root crops like cassava *(Manihut esculenta)* for further post-production processing.

The stationary type biomass shredder is a technology for reducing the form of the materials as a result of the impact due to cutting and beating actions of the blades and hammers against the materials. The machine basically consists of a feed hopper, shredding cylinder, discharge chute, feed tube, support frame and prime mover in the form of an electric motor (Figure 3).

The developed cassava chipper is powered and connected via v-belt pulleys by a 2 Hp single-phase capacitor start driven electric motor. It is composed of the following major parts: feeding hopper, push handle, cutter blades, blowers, cylinder cutterhead and motor and transmission assembly (Figure 4).

Figure 3. Biomass shredder

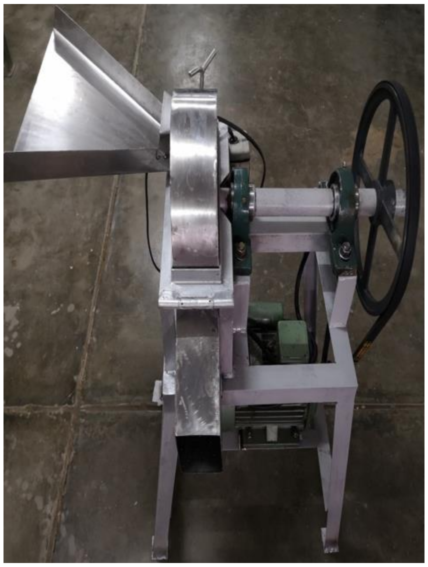

Figure 4. Cassava chipper

Size reduction technologies

These cooking technologies were designed in order to utilize abandoned biomass waste resources such as rice husks into fuel. Rice husk, which is the outermost rough covering of the paddy grain (palea and lemma) consisting of the empty glumes, floral glumes, and awn, is a generated waste product during rice milling operation and it is about 20 to 25% of paddy’s weight (Philippine National Standards/Philippine Agricultural Engineering Standards [PNS/PAES], 2015; Jenkins, 1989).

The side-in stove consists of an inverted conical grate with holes on its periphery serving as the fuel hopper, a conical plate cover, a cylindrical flue duct that directs the flame vertically towards the pot holder, a pipe centrally located in the grate for the entry of secondary air, an ash discharge lever maneuvered sideways for downward fuel movement and a pan to collect the burned fuel used (Figure 5).

The batch-type fixed cylinder stove is consist of the following major parts: burner, fuel reactor and fan. This single burner stove operates on gasification process where limited air is supplied by a 16-watt 3 in. diameter axial-type fan attached to a 220 volt alternative current (AC) line.

Figure 5. Side-in stove

Figure 6. Gasifier stove

Performance evaluation of the technologies developed

Technical evaluation of the technological development started with preliminary testing. During this phase, adjustments were made such as the materials utilized and operating speeds for the rotating cylinders including the flow of air to be supplied to the system. When the proper operating performance has been attained, the technologies were subjected to actual operating evaluation at a minimum of three test runs. All the materials utilized for testing the technologies were obtained within Iloilo except for the paddy dryer and abaca deco machine.

Also, aside from the paddy dryer and the abaca deco machine, all the technologies presented in this study were evaluated inside the facilities of Appropriate Technology Center which is located inside the 24 ha campus of CPU following the different recommended Philippine standards for testing. The paddy dryer's operating performance and the materials used for testing were evaluated and obtained, respectively, on-site to the location of the adaptor of the technology which is in San Jose in the Province of Antique, Philippines. For the abaca equipment, performance evaluations were conducted in two areas in the vicinity of Sta. Ana - San Joaquin Agrarian Reform Cooperative Office located in Pandan, Antique and in Aparicio, Ibajay, Aklan in the Philippines. The abaca samples used were obtained from Sta. Ana, Pandan in Antique and also from Ibajay, Aklan.

Results

Machine operation and performance

Crop management technologies

In operating this technology, the heated air needed by the batch-type drying chamber is supplied by the attached furnace that is fueled by rice husks. The 70 cm diameter axial fan connected to a 3 Hp capacitor-start powered electric motor is located behind the furnace and is responsible in transferring the heat through convection process where the hot air is forced to go inside the plenum chamber. The plenum chamber serves as a vacuum-like component of the dryer where the developed air pressure is responsible in uniformly distributing the heated air from the furnace to move horizontally and vertically in the grain mass. The combustion of the fuel inside the furnace, in turn, is further enhanced using a 2.5 in. electric blower.

The paddy dryer with attached furnace fueled by rice husks was designed to be flatbed-type that has a grain holding capacity of 75 sacks per loading. It has a computed operating capacity of 3,000 kg per day for a maximum drying time of 18 hours. The technology was computed to remove moisture at a drying rate of 0.67% per hour.

The abaca decorticating machine is a through-flow hold-on type technology that operates by feeding the leaf sheaths manually into the input chute. The abaca leaf sheath used in each operation was cut into half along its length and was fed faced down into the decorticating chamber for effective extraction. Once inside the decorticating chamber the fibers are beaten and scraped by the decorticating blades. The first half of the leaf sheath was the first to be fed while tightly gripping the other half. The fibers are extracted through the impact force produced by the high speed decorticating blades and the waste residues are scraped off through theresistance provided by the scraper block. The leaf sheath was then pulled out and the other half was then fed into the decorticating chamber. The waste materials or residues scraped were discharged at the output chute. The extracted fiber was then collected, hanged and sundried.

For the abaca deco machine, its technical operating performance tests revealed a fiber recovery rate of 3.68%. The abaca samples used during testing were of ideal harvesting age (between 18 to 24 months or during the emergence of a flagleaf), indicating that good quality stalks will yield to high fiber recovery rate and good quality fibers as well. This can be said because the machine was also tested using younger abaca samples and it generated a fiber recovery of only 1.66%. The extraction efficiency is the ability of the decorticating machine to produce clean abaca fibers. Higher extraction efficiency means better performance of the decorticating machine because of lesser extraction losses. Performance test of the abaca decorticating machine resulted to an extracting efficiencyof 80.30%. The fuel consumption rate (FCR) is important in determining the usability and profitability obtained by using a technology. In this machine, the FCR refers to the amount of fuel consumed by the 6.5 Hp gasoline engine for the duration of the operation per test at a rate of 0.73 li of gasoline per hour. The general grade of the fiber produced was AD-1 based on the fiber color which ranged from white to ivory white. This fiber grade was obtained from middle and inner leaf sheaths of the abaca stalk (Hisu-an, 2020; Philippine Fiber Industry Development Authority [PhilFIDA], 2016).

The results of the technical performance of the paddy dryer and that of the abaca decomachine are detailed in Table 1.

Table 1. Summary of results of the technical performance of the crop management technologies developed

Parameters	**Technologies**	
	Paddy dryer	Abaca deco machine
Operating Capacity, kg per day	3,000	63.36
Drying Rate, % per hr	0.67	-
Drying/Extracting Efficiency, %	77	80.30
Fiber Recovery Rate, %	-	3.68
Fuel Consumption Rate:		
Rice husk @ kg per hr	30	-
Gasoline @ li per hr	-	0.73

Size reduction technologies

When this shredder technology is operated, the blades and shaft assembly rotate with respect to the horizontal axis, operating in an axial flow manner where the biomass enters the shredding cylinder through the feed hopper and are discharged on the other end. The continuous type machine, in terms of feeding, is connected via v-belt pulleys to a 1.5 Hp capacitor-start driven electric motor.

Results revealed that the 400 kg per day capacity biomass shredder can reduce the materials to an average size of 5 to 30 mm. Its shredding efficiency, which pertains to the ratio of the weight of the input biomass materials less the unshredded materials against the total weight of the input materials to the biomass shredder, was computed to be 92%. The use of a 1.5 Hp electric motor in driving the shredder could generate an electric energy consumption rate of 0.22 kW-hr.

The cassava chipper operates in a through-flow manner where the peeled cassava tubers are fed perpendicularly at the feeding hopper to the direction of the rotating cylinder. The machine is equipped with two cutting blades fixed to a rotating cylinder. This cylinder is rotated through the movement of the electric motor and cutting or slicing of cassava is made possible by the shearing action of the cutting blades against the end periphery of the feeding hopper. A scraper, bolted at the end of the two blades is then responsible in discharging the chipped materials out of the chute for collection. The use of a 2 Hp electric motor for the cassava chipper could consume 0.20 kW-hr of electric energy. Both results for the biomass shredder and cassava chipper are presented in Table 2.

Table 2. Summary of results of the technical performance of the size reduction technologies developed

Parameters	**Technologies**	
	Biomass shredder	Cassava chipper
Operating Capacity, kg per day	400	564.24
Average Size of Material Produced:		
Size of materials, mm	5 – 30	-
Thickness of chips, mm	-	2 – 4.5
Shredding/Chipping Efficiency, %	92	99.67
Electric Energy Consumption Rate, kW-hr	0.22	0.20

Size reduction technologies

For the stove technologies, both has an operating capacity of 12 to 14 kg per day. This parameter refers to the amount of rice husk utilized by the side-in and gasifier stoves for a whole day cooking operation (breakfast, lunch and dinner preparations).

The technology is called side-in stove because of the placement of the steam box that cuts through the side of the cylindrical cover through the flue duct. With the side injection of the steam, an improved cleaner flame is produced during the combustion of rice husk fuel. Once these biomass fuels are placed in the hopper, burning pieces of paper are loaded to the cylindrical flue duct. Combustion is maintained by gradual removal of burned fuel using the discharge lever while intermittently replacing the fuel at the hopper. Combustion, likewise, is sustained by the supply of primary and secondary airs (Romallosa, 2008).

In operating the single-burner gasifier stove, the biomass fuel in the form of rice husks is loaded first in the double-wall reactor. Then burning pieces of paper are placed at the top of the filled reactor whilst turning the axial-type fan ON. Once the burning of fuel is sustained, the burner is placed on the top. At the combustion zone, the burned rice husk fuels slowly moves on a downward direction while that of the supplied air is upward. As the burning of fuel moves downward, the combusted rice husks are converted into carbonized form inside the reactor still. The carbon element present in the fuel then reacts with the introduced air coming from the axial fan and then mixes with other converted combustible gases. These combustible gases would then come out of the stove's reactor through the holes of the burner. Once lighted by a match, the gases are turned into a luminous flame enhanced by the mixture of secondary air which comes out of the holes found on the upper side of the gasifier close to the burner. After each operation, char is discharged by tipping over the stove.

The side-in stove which operates on a direct combustion principle has a thermal efficiency of 8.4%. That of the gasifier stove, operating on a gasification method has a 13.1% thermal efficiency. Thermal efficiencies of the stove technologies were computed using the water boiling test method. The computed results are presented in Table 3.

Table 3. Summary of results of the technical performance of the by-product utilization technologies developed

Parameters	**Technologies**	
	Side-in stove	Gasifier stove
Process of Combustion	Direct combustion	Gasification
Operating Capacity, kg per day	14	12
Thermal Efficiency, %	8.4	13.1
Fuel Consumption Rate, kg per hr	1.74	1.5

Discussion

The paddy dryer technology was computed to remove moisture at a drying rate of 0.67% per hour. The performance of this technology is numerically lower when compared to PAES which is 0.80% per hour for the batch-type design (PAES 201, 2015). Nevertheless, the 77% drying efficiency of the paddy dryer is above the PAES minimum requirement which is 75% (PAES 201, 2015). The 77% drying efficiency was also higher when compared with other studies which observed the effect of temperature of paddy drying with and without the use zeolite giving an average efficiency of 35.19% to 57.85% (Djaeni *et al.,* 2019) and 40.27% to 71.07% efficiency of the drying process under experimental conditions (Wang *et al.,* 2022). Drying efficiency means the ratio between the total heat utilized to release the moisture in the material and the amount of heat introduced to the drying air expressed in percent. This indicates acceptable operating performance for the dryer developed.

The computed fiber recovery rate of 3.68% for the abaca deco machine was analyzed to be numerically higher compared to that of the PAES standard set at 3.34% for decorticating machines (PNS/PAES 229, 2005). Higher extraction efficiency means better performance of the decorticating machine because of lesser extraction losses and the results indicated that the computed extracting efficiency of the machine at 80.30% is equal to the stripping efficiency of spindle stripper at 80% (PNS/PAES 254, 2011).

The 92% shredding efficiency of the developed biomass shredder was computed to be above the recommended PAES efficiency which is at 90% (PNS/PAES 244:2010) and was also higher when compared with another study which focused on shredding biomass materials like coconut leaves, areca leaves and paddy straw (Ganesh *et al.,* 2017). This indicated a promising technical potential from this small and compact biomass shredder which was developed.

The 99.67% operating efficiency for the cassava chipper shows a promising performance as well for the developed technology since it has a higher efficiency when levelled to other motor-driven designs developed which has a computed value of 78.19% (Daniel *et al.,* 2017) and 86.7% (Awulu and Harmoniz, 2015).

Biomass resources are considered as one example of renewable energy. Biomass when properly tapped through appropriate technologies, is capable of providing the needed demands for both heat and electricity most effective in the combined form of heat and power. International commitments to minimize environmental damage from the indiscriminate burning of biomass is also attained when they are properly utilized as a cooking fuel such as the two technologies developed in this part of the Philippines. Comparing it to the thermal efficiency of biomass stoves ranging from 5 to 40% (Phusrimuang and Wongwuttanasatian, 2016; Rasoulkhani *et al.,* 2018), the side-in and the gasifier stoves performed within the range of other biomass stoves developed in other countries. A more efficient stove will use less fuel to provide the same amount of heat, indicating thermal efficiency for these technologies developed. The use of liquified petroleum gas (LPG), charcoal andwood are minimized when using these cooking technologies.

The important technical parameters such as operating efficiency of the technologies developed starting from crop management to size reduction and by-product utilization were computed to be within or even above the values set by the Philippine National Standards or the Philippine Agricultural Engineering Standards. These results indicated technical potentials for the machines especially when they are introduced in communities to the users.

The availability of these agricultural machineries that are within the Philippine government standards also means that the agriculture sector is provided with technology access that would enhance their mechanization programs and efforts. Their farm operations become manageable and the productivity and timeliness of activities are improved and sustained on a technological perspective. Improved productivity through mechanized operation becomes a key to transforming livelihood sources of many people.

When these efficient technologies are introduced in the area, labor scarcity may also be addressed, a reality in the Philippine agriculture sector where less and less workers are interested in manual labor. This means agricultural operations and production continues, providing us security and sustainability in foods supply. With sustained agricultural mechanization, Sustainable Development Goals on 1-reducing poverty, 2-zero hunger, 7-availability of affordable and clean energy, and 9-presence of industry, innovation and infrastructure may be achieved.

The promising technical performance of the developed technologies based on their operating efficiencies may be regarded as an important contributor to modernize and sustain the Philippine government's efforts on agricultural mechanization specifically intended for crop management, product size reduction and by-production utilization of prime agricultural commodities like rice, abaca and cassava.

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References

Amongo, R. M. C. and Larona, M. V. (2015). CSAM policy brief. Agricultural mechanization policies in the Philippines. Retrieved from http://un-csam.org/publications/policy-brief-issue-no5-march-2015-agricultural-mechanization-policies-philippines.

Awulu, J. O. and Harmoniz, J. (2015). Development of cassava chipping machine. Federal University of Agriculture, Makurdi. Retrieved from https://www.researchgate.net/publication/323116759.

Daniel, I., Terngu, Y. and Terfa, G. (2017). Design, construction of a motorized tuber chipping machine. Retrieved from https://www.researchgate.net/publication/318109233_Design_Construction_and_Testing_of_a_Motorized_Tuber_Chipping_Machine.

Djaeni, M., Irfandy, F. and Utari, F. D. (2019). Drying rate and efficiency energy analysis of paddy drying using dehumidification with zeolite. Journal of Physics Conference Series, 1295:012049.

Food and Agriculture Organization (2018). Sustainable agricultural mechanization. Retrieved from http://www.fao.org/sustainable-agricultural-mechanization/overview/what-is-sustainable-mechanization/en/.

Food and Agriculture Organization (2019). Transforming food and agriculture to achieve SDGs. Retrieved from http://www.fao.org/3/I9900EN/i9900en.pdf.

Ganesh, U. L., Rampur, V. V. and Banagar, A. R. (2017). Design and fabrication of organic portable shredder machine. International Journal of Engineering Research & Technology, 6(08).

Hisu-an, L. M. (2020). Design Modification, Fabrication and Performance Evaluation of the Newtech Pulp Inc.'s First Generation Manually-Fed Abaca (*Musa textilis*) Decorticating Machine (Bachelor's Thesis). Central Philippine University, Jaro, Iloilo City, Philippines.

James, H. S. Jr. (ed). (2021). Handbook on the human impact of agriculture. https://doi.org/10.4337/9781839101748

Jenkins, B. M. (1989). Physical properties of biomass. New York: Gordon and Breach.

Li, W., Wei, X., Zhu, R. and Guo, K. (2019). Study on factors affecting the agricultural mechanization level in China based on structural equation modelling. Sustainability, 11(51).

Ma, W., Zhu, Z. and Zhou, X. (2021). Agricultural mechanization and cropland abandonment in rural China. Applied Economics Letters. Retrieved from https://doi.org/10.1080/13504851.2021.1875113

Philippine Agricultural Engineering Standards. (2000). PAES 201:2000. Philippine agricultural engineering standard for agricultural machinery – Heated-air mechanical grain dryer – Specifications.

Philippine Fiber Industry Development Authority (PhilFIDA) (2016). PNS/BAFS 180:2016 ICS. Philippine National Standard for abaca fiber grading and classification – hand-stripped and spindle/machine-stripped. Quezon City, Philippines: Department of Agriculture.

Philippine National Standard / Philippine Agricultural Engineering Standard (2005). PNS/PAES 229:2005. Philippine national standard for agricultural machinery – Fiberdecorticator – Methods of test.

Philippine National Standard / Philippine Agricultural Engineering Standard (2010). PNS/PAES 244:2010. Philippine national standard for agricultural machinery – Biomass shredder specifications.

Philippine National Standard / Philippine Agricultural Engineering Standard (2011).PNS/PAES 254:2011. Philippine national standard for agricultural machinery – Abaca stripper – specifications.

Philippine National Standard / Philippine Agricultural Engineering Standard (2015). PNS/PAES 264:2015. Philippine national standard for agricultural machinery – Rice husk fed heating system – Specifications.

Philippines (2013). Republic Act No. 10601 – Agricultural and Fisheries Mechanization (AFMech) Law. https://www.officialgazette.gov.ph/2013/06/05/republic-act-no-10601.

Phusrimuang, J. and Wongwuttanasatian, T. (2016). Improvements on thermal efficiency of a biomass stove for a steaming process in Thailand. Applied Thermal Engineering, 98:196-202.

Rasoulkhani, M., Ebrahimi-Nik, M., Abbaspour-Fard, M. H., and Rohani, A. (2018). Comparative evaluation of the performance of an improved biomass cook stove and the traditional stoves of Iran. Sustainable Environment Research, 28(6).

Romallosa, A. R. D. (2008). Evaluation of the different rice hull gasifier stoves developed at CPU Approtech Center. Patubas – Multidisciplinary Research Journal, 4:15-31. ISSN 1908-515X.

Sims, B. and Kienze, J. (2017). Sustainable agricultural mechanization for smallholders: What is it and how can we implement it?. Agriculture, 7(6) 50. Retrieved from https://doi.org/10.3390/agriculture7060050.

Wang, G., Wu, W., Fu, D., Xu, W., Xu, Y., Zhang, Y. (2022). Energy and exergy analyses of rice drying in a novel electric stationary bed grain-drying aystem with internalcirculation of the drying medium. Foods, 11(101).

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