Philippine Center for Postharvest Development and Mechanization
TECHNICAL BULLETIN
Vol. 7 No. 1 | ISSN 2243-8483 | 2018

DEVELOPMENT OF VILLAGE-LEVEL RICE MILL WITH IMPELLER HULLER

Michael A. Gragasin, Ph.D., Jayvee P. Illustrisimo
and Romualdo C. Martinez, Ph.D.

ISSN: 2243-8483

Cover photos by: Dr. Michael A. Gragasin

DEVELOPMENT OF VILLAGE-LEVEL RICE MILL WITH IMPELLER HULLER

Michael A. Gragasin, Ph.D., Jayvee P. Illustrisimo
and Romualdo C. Martinez, Ph.D.

Department of Agriculture
PHILIPPINE CENTER FOR POSTHARVEST DEVELOPMENT AND MECHANIZATION
CLSU Compound, Science City of Muñoz, Nueva Ecija, 2018

TABLE OF CONTENTS

ABSTRACT

Rice mills play a vital role in the rice self-sufficiency program of the Philippine government as these could affect the supply of rice in the market. The purpose of this research was to develop a new type of village-level rice mill that could be used to address the huge deficit of appropriate rice mill in the upland and remote areas. Test trials revealed that the coefficient of hulling, coefficient of wholeness and hulling efficiency of the impeller huller of the newly developed rice mill were 0.990, 0.877 and 86.8%, respectively.

Likewise, it is capable of efficiently milling palay with moisture content of 10-18 % without significantly affecting the milling recovery and hulling efficiency of brown rice. Its unique and innovative design has successfully made it compact yet powerful with milling capacity of 250-300 kg/hr and capable of producing both brown rice and white rice, a distinct feature not possible for traditional village-level compact rice mills.

Cost of milling was estimated at Php 0.87/kg with internal rate of return of 82.5%. The developed rice mill technology can be used by farmers' cooperatives and local entrepreneurs that are interested to engage in custom-milling or rice trading business, thus providing additional business opportunities in the rural areas.

INTRODUCTION

The low level of agricultural mechanization is highly evident on the limited rice mills in the upland and remote areas in the Philippines (BPRE, 2007). Such problem is partly caused by the high investment costs of the rice mill and the shed for the machine. A study conducted by PHilMech in 2013 revealed that the total rice mill deficit in the country was 7,906 units of 1.5 mt/hr capacity (PHilMech, 2013; Bingabing, et al. 2013).

With such huge deficit, old *kiskisan* rice mill with under-runner disk huller continue to operate in the country. However, *kiskisan* could only provide a milling recovery of 50 – 55 % as compared to modern rice mills of 63 – 67 % (IRRI, 2012). The prevalent use of inefficient rice mills like *kiskisan* could limit the available supply of rice in the country due to its low milling recovery of 50 - 57 % as compared to rubber-roll type rice mills of 60 – 67 %. As such, farmers are expected to get a lesser output of 12 % for using a *kiskisan* rice mill.

Majority of existing rice mills operating in the Philippines require three-phase electrical lines (if not converted into engine-driven rice mill) that are not commonly available in the barrio or rural areas. As such, the locations of these rice mills are situated along the national highway where three-phase electrical lines are available. Hence, huge deficit of rice mill is highly evident in the upland and remote areas.

Moreover, most of the rice mills operating in the country are rubber-roll type. Based on the International Rice Research Institute (IRRI), however, this type of rice mill requires higher investment and operating cost, higher power requirement, and regular replacement of rubber rolls (IRRI, 2012). Likewise, studies conducted in Japan revealed that rubber-roll type rice mills could perform better with short grain varieties (Japonica) than long grain varieties (Indica) with milling recoveries of 70 - 75 % and 60 - 67 %, respectively, and with head rice yield of only 56 - 61 % for long grain as compared to 63 - 68 % for short grain (MAFF, 1995). This can be traced to the difference of the physical characteristics of long and short grain rice varieties. Short or Japonica rice varieties have relatively round-shape with firm texture that is rarely deformed, unlike long grains that can be easily broken (MAFF, 1995). Rubber-roll type huller imparts shearing force coming from peripheral velocity difference between two rubber-rolls with different speed and direction (Aveyire, 2008). Such milling mechanism is highly favorable for short grain varieties.

Because of the growing demand for brown rice, rice mill for brown rice is highly needed nowadays (Pabuayon, et al. 2011). However, the widely used village level compact rubber roll rice mill is not capable of producing brown rice while modern rice mills can mill brown rice but they are not available for custom milling, since these are highly dedicated to the business milling operations of the rice mill owners while some modern rice mills require minimum of 100 bags of 50 kilogram before accepting milling for brown rice.

In the early 1980s, a new type of hulling mechanism for rice mill has been developed in Japan using impeller huller, but not yet been used for large scale commercial milling (Aveyire, 2008). The impeller huller removes the hull of palay by rotating it with impeller blades that accelerates radially through centrifugal force and dehulls palay with the aid of frictional force and impact force when palay passes through the blades and the liner surface of the impeller housing (Aveyire, 2008). Results of various studies revealed that the physical characteristics of long grain are appropriate for impeller-type huller (Shitanda, et al. 2001). The husked ratio performance of rubber-roll huller is highly dependent on the size and shape of palay unlike the impeller huller with almost the same performance (maximum husking energy efficiency) for both long and short grain samples. Rubber-roll type huller has higher system cracked ratio compared to impeller huller for both short and long palay samples due to the existence of shearing force when palay passes through two rubber-rolls operating at different speeds that tends to stretch the grain between the rolls.

Rice mills for the farmers and for small business milling operation is highly needed in the country particularly in the remote and upland areas. Total volume of palay retained by farmers for home consumption was estimated at 22 % of the total volume of rice production. Given this production volume, the total estimated rice mill deficit in the upland and remote areas in the country is about 2,000 units of 300 kg/hr capacity. Therefore, the development of a new type of village-level compact rice mill that is appropriate for upland and remote areas is imperative to address the rice mill deficit in the upland and remote areas of the country.

OBJECTIVES

General:

This project aimed to develop a technically feasible and economically viable village-level impeller-type rice mill.

Specific:

The project aimed to:

1. Establish different technical parameters that may lead to the design of new type of village-level rice mill.
2. Design the different components of the new impeller rice mill technology;
3. Determine the technical performance of the new impeller rice mill technology; and,
4. Determine the financial viability of using the developed impeller rice mill technology.

METHODOLOGY

Identifying the customer segment

In the eventual introduction of a new type and design of rice mill in the country, the initial question was, what are the basic features of this new impeller rice mill technology that can address specific problems of farmers in the upland and remote areas that warrant its desirability in the market. To address this issue, the conduct of one-on-one interview/consultation with farmers, rice traders, millers, and even policy makers involved in the rice mechanization program of the Department of Agriculture was undertaken. All the inputs gathered have served as basis in the design and development of the different features of the new rice mill technology.

Design of major components of the rice mill

Basic design parameters that affect the hulling efficiency of the rice mill that includes the speed and type of materials used in the impeller blades, the clearance between the tip of the blade and the impeller lining, and other parameters were thoroughly analyzed using laboratory prototype model. Likewise, the principle of operation of the impeller huller was studied based on available published technical papers, and some of these were validated through a laboratory setup.

Note that in the absence of high speed camera, it is impossible to determine the velocity of palay as it rotates with the impeller blades as it is thrown, impacts and slides at the lining of the impeller. Given this limitation, the optimum centrifugal force and frictional force that will yield the highest hulling efficiency and milling recovery using different materials of impeller blades and impeller lining cannot be computed.

In lieu of this, series of laboratory test trials were conducted to establish the optimum revolution, the material used and desired shape of the impeller blades that will yield the highest hulling efficiency and recovery. The same procedures were undertaken in designing the aspirator, whitener and de-stoner of the rice mill using available published papers and books including existing design of the different components of traditional rice mill.

Fabrication of the prototype unit

The concept of the new design was drawn through CAD software featuring the detailed parts and components of the impeller rice mill machine. The laboratory setup of the impeller huller, the aspirator, whitener and de-stoner were all fabricated and tested at the PHilMech fabrication shop to determine their performance. Debugging and modifications were conducted until the desired performances of each component were achieved.

The upscale model of the final design of the different parts and components of the new impeller-rice mill were again drawn through CAD software. The CAD drawings have served as reference in the fabrication of the final prototype unit and to clearly visualize the final design of the impeller rice mill as one machine in three dimensional perspectives. The fabrication of the different parts and components of the impeller rice mill were all undertaken at the fabrication shop of PHilMech.

Performance testing

The standard laboratory method of test for a rice mill (PAES 207:2000) was strictly followed during the laboratory and field trials to establish the technical performance of the developed rice mill such as the input capacity, output capacity, milling capacity, milling recovery, coefficient of hulling, coefficient of wholeness, percent head rice, percent broken rice and percent brewers (PAES. 2001). Per PAES 207:200, the formula in getting the milling capacity, milling recovery and hulling efficiency, are as follows:

$$\text{Milling capacity (kg/hr)} = \frac{\text{Weight of clean paddy (kg)}}{\text{Total operating time (h)}}$$

$$\text{Milling recovery (\%)} = \frac{\text{Wt. of milled rice (kg)}}{\text{Wt. of clean paddy (kg)}} \times 100$$

$$\text{Hulling recovery (\%)} = \frac{\text{Wt. hulled paddy (kg)}}{\text{Wt. of clean paddy (kg)}} \times 100$$

$$\text{Coefficient of hulling } 1 - = \frac{\text{Wt.of uhulled paddy (kg)}}{\text{Wt.of clean paddy (kg)}}$$

$$\text{Coefficient of wholeness } 1 - = \frac{\text{Wt.of whole brown rice (kg)}}{\text{Wt.of total hulled samples (kg)}}$$

$$\text{Percent head rice (\%)} = \frac{\text{Weight of head rice (g)}}{\text{Weight of milled rice (g)}} \times 100$$

Hulling efficiency (%)= Coeff.of hulling x Coeff. of wholeness x 100

The performance of the developed impeller huller was also compared with the performance of the rubber-roll huller of a single-pass compact rice mill currently installed at PHilMech.

The results of series of test trials have served as bases in modifying the initial design to further improve the performance of the rice mill, safety, ease of operation, and most importantly, the financial viability of the developed rice mill technology. The final prototype unit was also pilot tested in Catalanacan Multi-Purpose Cooperative in Catalanacan, Science City of Munoz, Nueva Ecija, Philippines for two months.

Financial analysis

Based on the actual technical performance of the rice mill, the milling cost or simply the total cost of producing one kilogram output was estimated. As such, it is expected that the computed milling cost shall be less than the average or minimum prevailing milling fee in the country to realize economic benefits of operating the technology.

To determine further the financial soundness of the developed rice mill technology, the Internal Rate of Return (IRR) was estimated (Hartman, 2004). In more specific terms, the IRR on a project is the rate of return at which the project Net Present Value (NPV) equals zero. At this point, the NPV of costs (negative cash flows) of the investment equals the NVP of the benefits (positive cash flows) of the investment on the developed technology. This can be shown by the following equality:

$$I_0 + \frac{I_1}{(1+r)^1} + \frac{I_2}{(1+r)^2} + \cdots . + \frac{I_m}{(1+r)^m} = \frac{B_1}{(1+r)^1} + \frac{B_2}{(1+r)^2} + \cdots . + \frac{B_m}{(1+r)^m}$$

$$\sum_{n=0}^{m} \frac{I_n}{(1+r)^n} = \sum_{n=1}^{m} \frac{B_n}{(1+r)^n}$$

where; I0 is the initial investment costs in the year 0 (the first year during which the project is constructed) and I1 ~ Im are the additional investment costs for maintenance and operating costs during the entire project life period from year 1 (the second year) to year m. B1 ~ Bm are the annual net incomes for the entire operation period (the entire project life period) from year 1 (the second year) to year m. By solving the above equality, the value of r or commonly known as the Internal Rate of Return (IRR) is obtained.

Experimental design and statistical analysis

The data gathered were consolidated and analyzed using Analysis of Variance (ANOVA) to determine the differences among group means on the different designs and components of the developed rice mill technology. Each test trials had two repetitions while the collection of samples for laboratory analysis had two replicates. Statistical analysis was performed using Statgraphics Plus, a statistic package software that performs and explains basic and advanced statistical functions.

RESULTS AND DISCUSSION

Design aspect

Based on individual interviews with key players of the rice milling industry (farmer-rice producers, rice traders, millers and policy makers), it was suggested that the envisioned rice mill technology should have a smaller capacity of about 250 - 350 kg/hr than the current single-pass, two stage compact rice mill with milling capacity of 450 - 500 kg/hr. A smaller capacity was highly recommended so that this will not compete but rather complement with existing traditional rubber-roll compact rice mills. A smaller capacity rice mill was highly recommended by the stakeholders to suit the level of operation of farmer's cooperative in the upland and remote areas including the rice mill requirement of small grains businessmen for their rice trading or custom milling business operations.

As such, the following features of the new rice mill technology were fully considered in the overall design: (1) the utilization of single-phase electric motor so that this can be easily installed in the villages or remote areas with no rice mill currently operating in their locality; (2) a compact design but with capacity of 300 - 400 kg/hr to reduce working space and minimize additional investment of the shed for the rice mill; and, (3) all parts and components of the rice mill should be locally readily available.

Technology breakthroughs

Development of new type of huller

A new type of huller was successfully developed using impeller huller as illustrated in Figure 1. It dehulls rough rice as it slides to the rotating blades, and as it is thrown and slides to the impeller lining. Rough rice is rotated by the blades, moved in radial direction by centrifugal force, and received vertical and frictional forces from the blade surface. Based on technical reports, 20 - 50% of rough rice are dehulled as it slides at the impeller blades through the application of frictional force (MAFF, 1995), though such data cannot be confirmed due to the absence of high speed camera in the laboratory. From the rotating impeller blades, rough rice is then thrown and slides to the lining of the impeller for further dehulling given the application of impact force and frictional force, respectively. Therefore, when rough rice slides at the surface of the blades and at the lining of the impeller, it receives shearing stress due to friction and inertial forces causing the separation of rice hull with the brown rice. In addition, rough rice also receives impact force when collides with the lining of the impeller causing the separation of the rice hull with the brown rice.

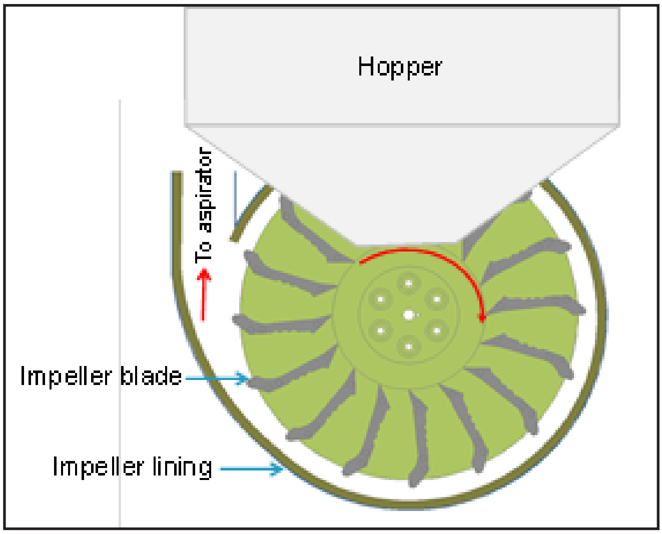

Figure 1. Cross-section of the impeller huller,2015

The performance of the developed impeller huller was compared with the rubber-roll huller of Satake single-pass, two stage compact rice mill that is currently installed at PHilMech using newly harvested Rc216 rice variety is shown in Table-1. Test results revealed that the coefficient of hulling of the impeller huller is significantly higher with 0.98 as compared with rubber-roll huller of 0.88 and as such, the coefficient of wholeness of rubber-roll is significantly higher than the impeller.

However, in terms of hulling efficiency that accounts both the degree of hulling and wholeness of the brown rice, there is no significant difference between the rubber-roll and impeller huller. The milling capacity of the impeller huller is 337 kg/hr is within the desired capacity and expectedly lower than the single pass rubber-roll compact rice mill of 540 kg/hr.

Table 1. Technical performance of the developed compact impeller huller with existing rubber-roll type huller, 2015

PARAMETERS	RUBBER-ROLL	IMPELLER
Coeff. of hulling	0.88a	0.98b
Coeff. of wholeness	0.85a	0.76b
Hulling efficiency (%)	74.61a	74.41a
Hulling recovery (%)	78.98a	78.00a
Milling capacity (kg/h)	535.90a	337.25b

Note: Means across rows having the same super script are not significantly different at 5% level.

The performance of the impeller huller was also tested using different types of material, the Acrylonitrile butadiene styrene or "ABS" as mentioned by (Shitanda, et al., 2001) and Polylactide or "PLA" as alternate plastic material for the fabrication of impeller blades. The material of the blade can directly affect the frictional force as the palay slides to the impeller blades during dehulling operation and, as such, the hulling efficiency of the rice mill.

The ABS is a durable thermoplastic, resistant to weather and some chemicals, popular for vacuum formed components and a rigid plastic with rubber like characteristics, that provides good impact resistance and heat resistance between -20 and 80 oC (Szeteiova, 2010). The results revealed that the hulling efficiency of ABS is higher by 14 - 15 % than the PLA material as shown in Figure 2, though it provides the same characteristics that a decrease in the revolution of the accelerating impeller blades would increase the hulling efficiency of the impeller huller.

However, the laboratory trials have not established the optimum revolution of the impeller blades that could provide the highest hulling efficiency given a type of materials used in the impeller blades. The result of the laboratory trials, however, confirmed the findings of Shitanda for the utilization of ABS plastic for the impeller blades (Shitanda, et al., 2001) given its high coefficient of friction that yields higher hulling efficiency than PLA (MAFF, 1995).

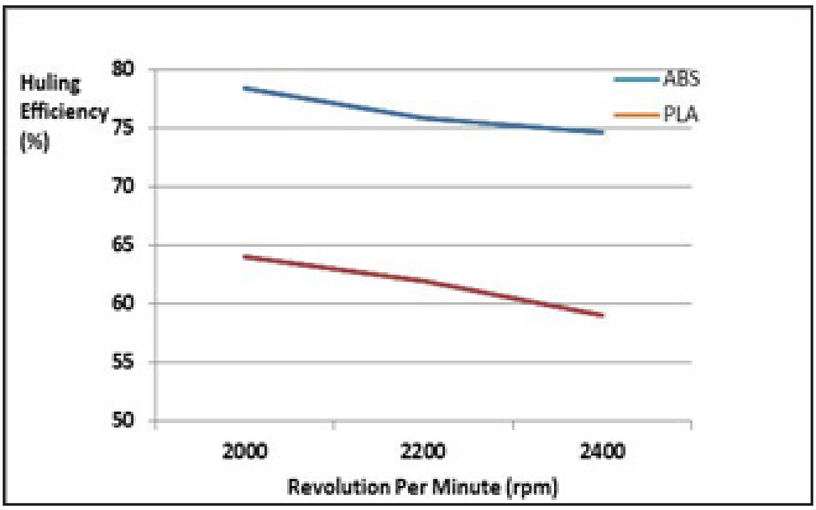

Figure 2. Hulling efficiency at different types of material of impeller blades, 2015

Multi-functional rice mill

The rice mill was also designed to produce not only white rice but also brown rice by using the whitener as second stage of hulling. Results of laboratory test trials revealed that the impeller huller is capable of producing 'coefficient of hulling' of as high as 0.99, by setting the rotation of the impeller blades to 2,400 rpm. The 'coefficient of hulling' measures the ability of the machine to remove rice hulls (PAES, 2001). However, it was observed that a higher 'coefficient of hulling' could provide a higher percent of 'broken grains' given a higher impeller force applied to the rough rice as it impact to the impeller lining. As such, the rotation of the impeller blades is set to 2,000 rpm to reduce the impeller force to get a coefficient of hulling of 0.90 - 0.94 thereby achieving higher coefficient of wholeness of 0.85 – 0.91.

Given the high coefficient of hulling of the impeller huller, the whitener of the rice mill was successfully designed in the production of brown rice to eliminate the utilization of a paddy separator. In here, the whitener was also designed to complete the second stage of hulling without removing the bran of hulled rough rice. The theory here is that the inter-fold lock of lemma and palea of the unhulled rice was already loosened by the time rough rice had passed the impeller huller, and therefore, requires only a small amount of force to complete the removal of hull from the brown rice.

In line with this, the whitener was designed for two major functions: (1) to remove the bran of the brown rice for the production of white rice; and (2) to serve as second stage huller for the complete removal of hull for the production of brown rice. Note that based on laboratory test trials, rubber-roll-type hullers could provide only a coefficient of hulling of 0.85 and as such, the utilization of the new design of whitener for such purpose is not possible.

New design of aspirator

Another critical component of the rice mill is the aspirator that separates rice hulls with brown rice and unhulled rice. With the initial amount of airflow coming from the impeller huller, the utilization of traditional design of aspirator is no longer applicable, thus, necessitating the development of a new design that is compatible with the impeller huller. The aspirator was carefully designed to provide the desired quality of milled rice and at the same time, minimize quantitative losses (Figure 3). The application of excessive airflow in the aspirator could throw not only rice hulls but includes brown rice to the cyclone, resulting to high incidence of quantitative losses. On the other hand, the application of less airflow to the aspirator than the required could mix rice hulls with the brown rice, resulting to the high mixture of unhulled rice with milled rice.

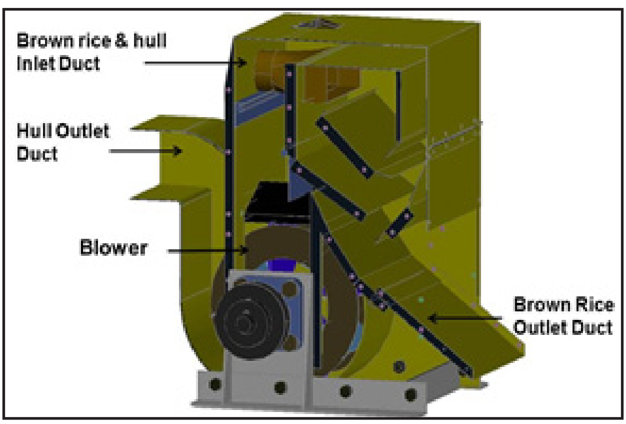

Figure 3. Aspirator of the rice mill, 2015

Accessibility of the hopper by the operator

During laboratory test trials, it was observed that the brown rice and rice hulls can be thrown upward by the impeller blades towards the aspirator. Given the impeller force from the impeller blades, the huller of the machine can be placed below the aspirator to reduce the height of the rice mill. In configuring the design of the new rice mill, therefore, the huller is placed at the bottom of the machine (Figure 4), and not at the top of the rice mill beneath the hopper as traditionally designed, so that the input hopper can now be placed within the reach of the operator. The new position of the hopper can eliminate the installation of elevator or a ladder for the second floor of the shed of the rice mill, thus, significantly reducing the cost of the rice mill and the shed of the machine.

Figure 4. Difference in location of hopper of traditional rice mill (left) as compared with the developed technology (right), 2015

Technical features of the developed rice mill technology

The new impeller rice mill was designed with the following components as shown in Figure 6, namely: (1) impeller huller, (2) aspirator, (3) whitener; and (4) destoner and grader. Likewise, the rice mill technology is also equipped with the following primary components: (1) a blower that is incorporated at the aspirator; (2) blower to suck bran from the whitener ; (3) input hopper that serves as storage bins for rough rice or rough rice before flowing gravitationally to the impeller huller; (4) two 5-hp electric motors that serve as the prime-movers of the major components of the rice mill; (5) cyclone to control dust pollution; and, (6) control panel that contains the “on” and “off” push bottom switches of the impeller huller, whitener, blower, aspirator, and destoner including the installation of emergency switch and contactors for ease of operation and to ensure the safety of the operator as well as to protect the electric motors from breaking down.

The major and primary components of the rice mill are lodged in a mainframe with a leveler installed at the bottom of the main frame of the rice mill unit. As emphasized in the previous section, the final design of the impeller rice mill was a product of series of laboratory trials and “trial and error” method to achieve the desired performance of the rice mill.

Capability to mill over dried and under dried rough rice

Laboratory trials were conducted to test the performance of the impeller huller using Rc 222 rice variety at different moisture contents (Table 2). It was observed that paddy samples with moisture content of 20 %, 16 %, 14 % and 10 % could yield hulling efficiency of 72.1 %, 74.0 %, 74.9 %, and 75.3 % and hulling recovery of 79.0 %, 76.0 %, 79.9 % and 77.5 %, respectively.

Table 2. Performance of the impeller huller at different moisture content of rough rice, 2015

PARAMETERS	20	18	16	14	12	10
Coeff. of hulling	0.93[a]	0.94[ab]	0.96[bcd]	0.96[abc]	0.98[cd]	0.98[d]
Coeff. of wholeness	0.77[a]	0.78[a]	0.77[a]	0.75[a]	0.77[a]	0.76[a]
Hulling efficiency	72.1[ab]	73.5[b]	74.0[ab]	71.9[a]	75.5[ab]	75.3[ab]
Hulling recovery	79.0[a]	77.0[a]	76.5[a]	79.9[a]	78.6[a]	77.5[a]

Note: Means across rows having the same super script are not significantly different at 5% level.

The results of test trial revealed that the impeller huller is capable of milling palay with moisture contents of 10-20 % without significantly affecting hulling recovery of brown rice. Such distinct feature of the impeller huller technology will fully address the problem of farmers in over drying or under drying their palay with moisture content of 12-16% as they heavily rely on sun drying and without any moisture meter at hand. Traditional rice mills like rubber-roll type require rough rice to be dried at 14% to get higher milling recovery and hulling efficiency (MAFF, 1995).

Installation of destoner to the already compact rice mill

After the short pilot-testing, the project collaborator suggested the installation of a destoner and mini-grader in the new rice mill technology given the fact that farmers are drying their produce in the highway, wherein the accumulation of tiny stones during drying cannot be avoided. As such, a new destoner was designed and developed with the inclusion of mini-grader to separate brewers with milled rice. The design of the destoner (Figure 5) was made small but still matched the capacity of the rice mill so that it can be incorporated to the current dimension of the already compact small rice mill.

Figure 5. Design of de-stoner and mini-grader of the developed rice mill, 2015

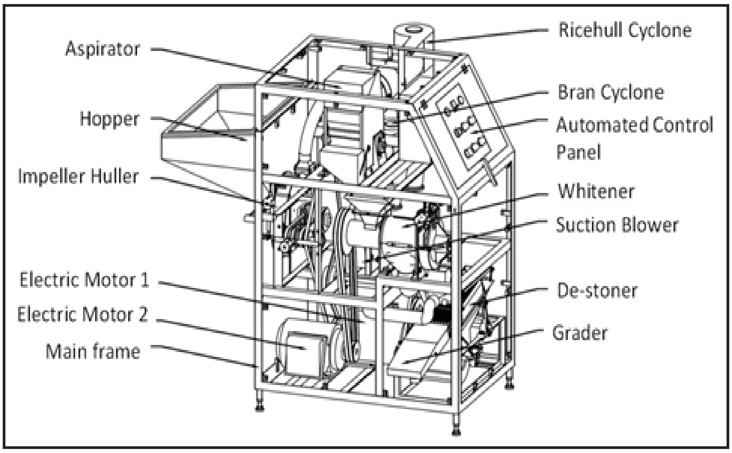

Figure 6. Different parts of the developed rice mill, 2015

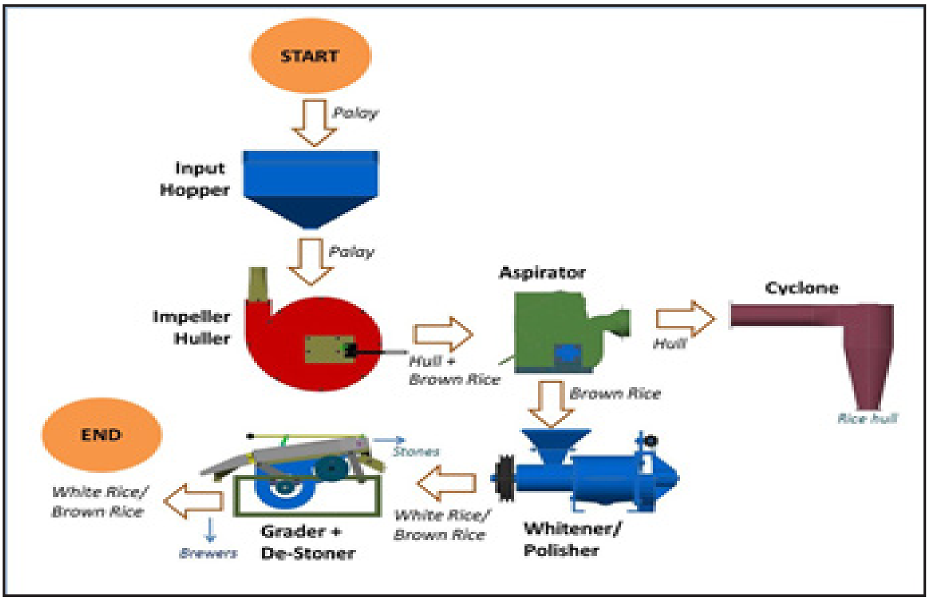

Figure 7. Process flow of the compact impeller rice mill, 2015

The connection of each component of the impeller mill for brown rice and white rice can be more explained with the process flow as shown in Figure 7. As designed, rough rice is fed to the feeding hopper 1 and when the feed shutter is opened, rough rice flows directly to the impeller huller. The volume of rough rice that enters to the impeller huller is controlled by an inlet control mechanism. The rice hull is detached and separate from the brown rice through the impeller huller and the aspirator, respectively. From the aspirator, rice hull goes directly to the rice hull cyclone. Brown rice then proceeds to the whitener to remove the bran from the endosperm. The milled rice then automatically fell to the de-stoner to remove tiny stones. Brewers then will be separated from milled rice once the milled rice passes through the mini-grader. Brown rice can be produced by adjusting the shaft speed of the impeller huller through the transmission assembly and by loosening the discharge valve of the whitener. The entire operation is centralized by an automated control panel disposed conveniently by the operator.

The developed new type of rice mill (Figure 8) is compact yet powerful with milling capacity of 250 - 300 kg/hr and milling recovery of 62 - 65 % for white rice and 75 - 78 % for brown rice with potential head rice recovery of 63.9 - 64.2 % for white rice and 75.4 - 91.1 % for brown rice.

The distinct technical features of the technology with traditional rice mill are shown in Table 3. The impeller design has successfully reduces the investment cost and space requirement of the traditional rice mill, and hence become affordable to private small-scale grain business and to the farmer's cooperative as well. Most importantly, it can mill rice paddy with moisture content of 10 - 18% and capable of producing both white rice and brown rice, a distinct features not available to the current rice mill technology. It was ensured during the design that all parts and components of the rice mill are locally available in the market. The connection of the rice mill using household or single-phase electrical lines was fully considered to ensure its easy installation in the countryside. Majority of traditional rice mills requires three-phase electrical line that is not commonly available in the countryside.

Figure 8. Actual picture of the prototype unit,2015

Table 3. Technical features of the impeller rice mill as compared with traditional rice mill, 2015

FEATURES	NEW IMPELLER RICE MILL	TRADITONAL RICE MILL
Hulling mechanism	Impeller	Rubber-roll
Cost of rice mill with shed (Php)	320,000	600,000
Milling recovery (%)	62-65	62-65
Milling capacity (kg/hr)	250-300	450-500
Production of white rice	/	/
Production of brown rice	/	X
Can mill paddy at 10- 18% m.c.	/	X
Reduces Investment for the shed	/	X
Smaller space (60% less)	/	X
Connectivity to single-phase electrical supply	/	X

Table 4. Annual operating cost per kg output of the rice mill, 2015

PARTICULARS	COST	REMARKS
Fixed cost per year (Php/yr)	37,500	
Depreciation cost	22,500	(Investment cost – Salvage value) /Lifespan of 12 yrs
Repairs and maintenance	15,000	5% of Investment cost
Variable cost per year (Php/yr)	119,479	
Electricity cost	80,979	Php14/kW x 6.26 kW/h x 924 h/yr
Labor cost	38,500	1 operator x Php 250/day x 154 d/yr
Total cost per year (Php/yr)	156,979	Fixed cost + Variable cost
Cost of milling per kg output (P/kg)	0.87	Total cost per yr/Total annual cap.
Profit (P/kg)	0.88	Milling fee – Cost of milling
Payback period (Yr)	1.89	Investment cost/(Profit x Total capacity)
Internal rate of return (%)	82.5	Refer to item III.3.2.e , page 6

Note: Assumptions used in the computation:
Input Capacity - 300 kg/hr; Annual total capacity – 180,180 kg; Investment cost: rice mill- Php 300,000, shed- Php 50,000; Salvage value – 10 % of investment cost; Power requirement - 6.26 kW/h; Total time of operation per yr – 924 h at 7 mos x 22 days x 6 hr.

Cost of milling and financial viability of the developed technology

Based on the technical performance of the developed rice mill technology, the financial viability of the rice mill machine was analyzed. The results of the estimation (Table-4) revealed that the total cost of milling per kilogram output is estimated at Php 0.87 which is far below the existing milling fee of Php 1.75 - 2.25 per kg of milled rice. If the rice mill shall be used for custom milling business, the estimated profit is about Php 0.88 per kg even charging a minimum milling fee of Php 1.75/kg of milled rice. This is equivalent to total projected annual net income of Php 158,558 for a total annual capacity of the rice mill of 180,180 kg. From this, the estimated payback period is 1.89 years with internal rate of return of 82.5 %.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the laboratory and field trials, the technical features of the newly developed rice mill technology, are as follows:

- Ultra: milling capacity of 250 - 300 kg/hr and capable of producing both white rice and brown rice, and can mill 10 - 18 % moisture content for the production of brown rice which the traditional rice mill is not capable of doing.
- Compact: 60 % reduction in the space requirement of current rice mill technology;
- Efficient: Milling recovery of 62-65% for white rice and 72-78% for brown rice, while the cost of milling is Php 0.87 per kg of milled rice which is far below the prevailing milling fee of Php 1.75 - 2.50/kg; and
- Simple setup: Compatible with single-phase electrical lines and working space of 16 m^2.

Given its capability to produce brown rice that can yield higher milling recovery than white rice, which can be translated to additional rice supply in the country, the developed technology could contribute in achieving food self-sufficiency in the country.

The newly developed rice mill technology is highly favorable for villages with no existing rice mill installed in their areas as this can be easily connected to household or single-phase electrical line. The technology can also be used by brown rice producers and organic rice suppliers.

The developed rice mill technology can be used by farmer cooperative and local entrepreneurs that are interested to engage in custom-milling or rice trading business in the locality. As such, the new rice mill technology could provide additional business opportunities in the locality other than limited to owning a tricycle or a jeep for transport services or operating a small *sari-sari* store, the common businesses in the rural areas.

REFERENCES

Aveyire J., K.A. Dzisi, A. Bart-Plange, 2008. Adaptation of Impeller Type Husker for Long Grain Rice. Agricultural Mechanization in Asia, Africa and Latin America. Volume 39, No. 1.

Bingabing R.L., R.R. Paz, A.E. Badua, M.A. Gragasin, 2015. Mechanization in Rice Farming ed: S.J. Banta, “Department of Agriculture Rice Mechanization Roadmap: On Farm and Postharvest Mechanization Program (2011-2016)”, College, Laguna, Philippines: Asia Rice Foundation.

Bureau of Postharvest Research and Extension BPRE, 2007. “Postharvest Database and Master Planning”. Unpublished Report. ScienceCity of Munoz, Nueva Ecija, Philippines: BPRE

International Rice Research Institute, 2012. “IRRI Rice Knowledge Bank: Milling and processing”. Available on line: http://knowledgebank.irri.org./step-by-step-production/ postharvest/milling. Accessed on 9 August 2012.

International Rice Research Institute, 2012. “Rice Milling Manual”. Manila, Philippines. Available online: http://www.knowledgebank. irri.org Accessed on 9 August 2012.

J.C. Hartman and I.C. Schafrick, 2004. “The Relevant Internal Rate of Return”, The Engineering Economist, vol. 49, no. 2, pp. 139–158.

K. Szeteiova, 2010. “Automotive Materials Plastics in Automotive Markets Today”, Faculty of Material Science and Technology, Trnava, Slovak Republic: Slovak University of Technology.

Ministry of Agriculture, Forestry and Fisheries MAFF, 1995. “Rice Postharvest Technology”. Chapter VIII: Rice Milling and Processing, pp. 325-416. Japan: The Food Agency, Ministry of Agriculture, Forestry and Fisheries.

Pabuayon, I. and J. Quilloy. 2011. Brown Rice Market Chain and Marketing Practices, Luzon, Philippines. Philippine Agricultural Scientist. Vol. 94, No. 1, pp. 54-65

Philippine Agricultural Engineering Standard Method of Test for Rice Mill. 207:2000 Agricultural Machinery Testing and Evaluation Center, University of the Philippines at Los Banos, Laguna, Philippines, 2001

Philippine Agricultural Engineering Standard Rice Mill Specifications. 206:2000. Agricultural Machinery Testing and Evaluation Center, University of the Philippines at Los Banos, Laguna, Philippines, 2001

Philippine Center for Postharvest Development and Mechanization (PHilMech), 2013. “Establishment of GIS-based Decision Support System for Postharvest Development and Mechanization”. Science City of Munoz, Nueva Ecija, Philippines

Shitanda, D., Y. Nishiyama, S. Koide, 2001. Performance Analysis of an Impeller Husker Considering the Physical and Mechanical Properties of Paddy Rice. Journal of Agricultural Engineering Research, Vol. 79, pp. 195-203.

ACKNOWLEDGMENT

The authors gratefully acknowledge the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD), Department of Science and Technology (DOST) for funding this research project.

NOTES

About PHilMech

The Philippine Center for Postharvest Development and Mechanization, known then as the National Postharvest Institute for Research and Extension (NAPHIRE), was created on May 24,1978 through Presidential Decree 1380 to spearhead the development of the country's postharvest industry.

As a subsidiary of the National Grains Authority in 1980, the agency's powers and functions were expanded in line with the conversion of NGA to the National Food Authority.

In 1986, PHilMech moved to its new home at the Central Luzon State University compound in Muñoz, Nueva Ecija.

The agency was transformed from a government corporation into a regular agency through Executive Order 494 in 1992. It was renamed the Bureau of Postharvest Research and Extension (BPRE).

For years now, PHilMech is engaged in both postharvest research, development and extension activities. It has so far developed, extended and commercialized its research and development outputs to various stakeholders in the industry.

With Republic Act 8435 or Agriculture and Fishery Modernization Act (AFMA) of 1997, PHilMech takes the lead in providing more postharvest interventions to empower the agriculture, fishery and livestock sectors.

Pursuant to Executive Order 366 or the government's rationalization program in November 2009, BPRE became the Philippine Center for Postharvest Development and Mechanization (PHilMech) with twin mandates of postharvest development and mechanization.

For more information, please contact:

Executive Director
Philippine Center for Postharvest
Development and Mechanization
CLSU Compound, Science City
of Muñoz, Nueva Ecija
Tel. Nos.: (044) 456-0213; 0290; 0282; 0287
Fax No.: (044) 456-0110
Website: www.philmech.gov.ph

PHilMech Liaison Office
3rd Floor, ATI Building
Elliptical Road, Diliman, Quezon City
Tel. Nos.: (02) 927-4019; 4029
Fax No.: (02) 926-8159