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# Design and development of a compact and highly efficient small-scale rice mill machine: A case study

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## Abstract

Small-scale farming with different varieties of rice is common in the rural areas in Thailand. This can complicate the milling process and affect the production yield. In addition, a high logistic cost to the commercial mill is another barrier. To cope with the problems and to support self-reliance, a compact and highly efficient small-scale rice mill machine has been developed and evaluated at Ban Samkha village in Thailand. This user-friendly machine with low maintenance was suitable for rice milling in the rural areas. It consisted of five main units: a double-layer oscillating sieve cleaner, a rubber-roller husker and aspirator, a compartment-type paddy separator, two horizontal friction-type rice whiteners, and oscillating grading sieves. The design offered unique aspects as follows: 1) a compact and efficient small-scale rice mill with multi stages comparable to a large commercial mill, 2) a new design of a rubber-roller husker and aspirator to increase the husking efficiency and product yield, 3) a new and compact design of the friction-type whitener to increase the whitening efficiency. It ran on single-phase motors with a capacity of 200 kg paddy/hr. The average milling recovery was remarkable about 65% when applied with various varieties of local Thai rice. The production yield was 50-70% of brown head rice and 50-60% of white head rice. At least 25 machines have been used by Thai farmers nationwide. The design and development of this machine as well as lessons learned from the actual usage in the community level were discussed in the paper.

***Keywords***: *agricultural machinery, machine design, rice mill machine, rural development, sufficiency economy, technology transfer, Thailand*

## 1. Introduction

Rice is usually composed of approximately 20% rice husk, 11% bran layers, and 69% starchy endosperm. By-products of rice milling are husk, germ, bran layers, and fine broken kernels. Head rice is milled rice with length greater than three quarters of the average length of the whole kernel, while broken grains have smaller size varied from small chips with less than 1.4 mm to large broken kernels with 50-75% of the whole kernel size. It was reported that the maximum milling recovery, *i.e.* milled rice including broken kernels, was 69-70% depending on rice varieties. While 65% milling recovery with 55% head rice was possible for commercial milling, only 55% or lower milling recovery with 30% head rice was the output from some village-type rice mills (Dhankhar, 2014). However, according to the Thai Standard for small rice mill, 64% milling recovery with 40% head rice is required to pass the standard (Thai Industrial Standards Institute, 1989).

After harvesting, Thai farmers especially in the rural areas often keep some paddy for their own consumption. Normally, milling of 50-500 kg paddy each time can be expected from a household. Small-scale farming with many different varieties of rice is common for Thai farmers particularly in the rural areas. In addition, a long distance between a rice farm and a commercial mill has often caused a high logistic cost for the farmers. An efficient small-scale rice mill machine is clearly needed to help Thai farmers cope with the problems, and to follow the philosophy of sufficiency economy bestowed by His Majesty the King Rama IX which supports self-reliance and sustainable development (Wibulswasdi, Piboolsravut, & Pootrakool, 2010;

Mongsawad, 2010). In Thailand, small-scale rice mill machines have been commercialized for many years. However, these machines mostly used the under-runner husker and the abrasive whitener which have quite low efficiency regarding the quality of milled rice and yield, especially not suitable for production of brown rice or premium products. Therefore, National Metal and Materials Technology Center (MTEC, 2018) under National Science and Technology Development Agency (NSTDA, 2019) has designed and developed a small-scale rice mill machine with multi-stages and high efficiency comparable to a large commercial mill and suitable for rice milling in the rural areas. Then, MTEC collaborated with Agricultural Technology and Innovation Management Institute (AGRITEC, 2019), NSTDA, transferring this technology to communities in Thailand.

Ban Samkha (Thailand Digital Tourism Center, 2020), a small village in Lampang province located in the Northern part of Thailand, was selected for the technology transfer in this study. The village is located 45 km away from the down town and surrounded with mountains. There are 159 households covering the area of 2,560 hectares. The rice farming area of Ban Samkha Rice Mill Community Enterprise are 48 hectare producing 180 tons of paddy/year. Because the farmers rely on rain water for rice farming, only one crop per year can be grown. Small-scale farming with many different varieties of rice is common here. Each variety of rice usually has different physical properties such as kernel size, color, hardness, and texture. This can complicate the milling process and affect the production yield. Therefore, a highly efficient and adjustable small-scale rice mill machine is necessary for the community.

Ban Samkha village has pursued the philosophy of sufficiency economy bestowed by His Majesty the King Rama IX and showed an outstanding performance. To support the village with appropriate technology, NSTDA has transferred rice milling technology to Ban Samkha rice mill community enterprise. The machine as shown schematically in Figure 1 with a flow chart of the rice milling process shown in Figure 2 was delivered to the community. It has been developed to the third generation and was the final invention of the research team. Currently, this model is still in use by the members of Ban Samkha community. The design and development of the machine as well as lessons learned from the actual usage in the community level were discussed in the paper.

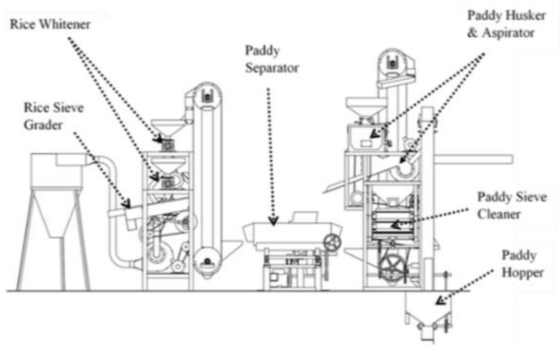


**Figure 1** Design of the small-scale rice mill machine in this study

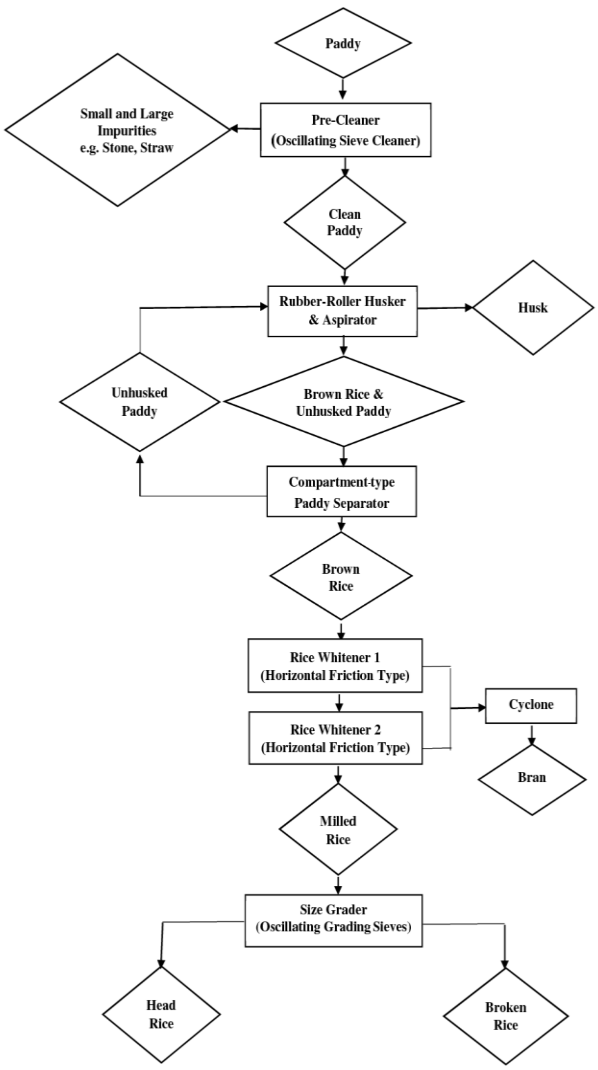


**Figure 2** Flow chart of the rice milling process

## 2. Objectives

The objectives of this study were 1) to design and develop a compact and highly efficient small-scale rice mill machine, and 2) to transfer the technology to Ban Samkha village in Thailand.

## 3. Materials and methods

### 3.1 Design and development of the small-scale rice mill machine

This semi-automatic rice mill machine was designed and developed as a multi-stage mill running on single-phase (1 Φ, 220 V. AC.) motors of 8-10 Hp (6-7.5 kW) in total. It had a capacity of 200 kg paddy/hr and could produce both brown and white rice. It was designed to have low maintenance and work on simple, continuous, and adjustable processes suitable for rice milling in the rural areas. This compact mill as seen in Figure 1 consisted of five main units: a double-layer oscillating sieve cleaner, a polyurethane rubber-roller husker and aspirator, a compartment-type paddy separator, two horizontal friction-type rice whiteners, and oscillating grading sieves. This model also had an underground paddy hopper to ease the transfer of paddy to the hopper. This multi-stage machine possessed features and a configuration comparable to a modern commercial mill (Tangpinijkul, 2010), but it had a more compact size. Dimensions of the machine are shown in Table 1.

**Table 1** Unit dimensions of the small-scale rice mill machine in this study

| No. | Details | Dimensions (m) |
|---|---|---|
| The whole rice mill machine | | 2.5 x 5.0 x 3.0 |
| 1 | A double-layer oscillating sieve cleaner and a polyurethane rubber-roller husker and aspirator | 0.7 x 1.5 x 3.0 |
| 2 | A compartment-type paddy separator | 1.2 x 1.6 x 1.2 |
| 3 | A horizontal friction-type rice whitener | 1.3 x 1.5 x 2.5 |
| 4 | Oscillating grading sieves | 0.9 x 2.2 x 3.0 |

### 3.2 Principles of the five main units

#### *3.2.1 Double-layer oscillating sieve cleaner*

The pre-cleaning process is crucial to protect the milling machine from unusual damage and to improve the quality of the milled rice. This pre-cleaner separates the paddy from the impurities such as stones, straw, weed seeds, dirt, and dust by using their different physical characteristics especially size, specific gravity, weight, and length (Chakraverty & Singh, 2016). In this case, impurities are removed by sieving, aspiration, and gravity separation.

#### *3.2.2 Rubber-roller husker and aspirator*

This stage is to remove the husk layer from the paddy with minimum broken grains. The rubber-roller husker is the most efficient husking machine to remove the husk (Dhankhar, 2014). Good quality of brown rice with minimum broken grains could be expected from this type of husker. Compression provided by two rubber rollers rotating at different speeds and in opposite directions creates frictions between the paddy and the surface of the rubber rollers. The husk is stripped off by the shearing action. The mixture of brown rice, husk, and bran is then separated in the aspirator section using an airstream (Satake, 2003).

#### *3.2.3 Compartment-type paddy separator*

This unit aims to separate the unhusked paddy from the brown rice before it goes to the bran removal process. The paddy separator works by using different characteristics of the paddy and the brown rice which are specific gravity, size, and coefficient of friction. The specific gravity of the paddy is lower than that of the brown rice, but its size is bigger in all dimensions. The main part of this unit is the oscillating compartment in one or more decks. One deck may have up to 10 compartments. More compartments result in more separation capacity (Tangpinijkul, 2010).

#### *3.2.4 Horizontal friction-type rice whitener*

The horizontal friction-type rice whitener is used to peel off bran layer from the husked rice by the friction force between rice grains and by the high pressure resulted from a rotating ribbed steel roll (Chakraverty & Singh, 2016). An airstream is applied into the hollow shaft to remove the bran and cool down the grains to reduce breakage (Tangpinijkul, 2010).

#### *3.2.5 Oscillating Grading Sieves*

This grading unit is to separate the white head rice from the broken kernels by an oscillating single screen bed. The head rice is filtered by the sieves while the brokens that smaller than the perforations pass through the screen. When the brown rice is the final product, it can be used for separating the broken brown rice from the mixture of the whole kernels and the head brown rice.

3.3 Field application at Ban Samkha rice mill community enterprise

In this study, four varieties of local Thai rice (Rice Department, Thailand, 2016; Rice Family Thailand, 2017) *i.e.* Hom-Nin or Black rice, Hom-Daeng rice, Thai Jasmine or Khao Dawk Mali 105, and Kor-Khor 6 or RD 6 (Glutinous rice) as shown in Figure 3 with 11-13% moisture content were selected for testing. They were considered as common types of rice grown by Thai farmers. Each variety has different physical properties such as kernel size, color, texture, and hardness. These four types could be representatives of other local Thai rice.

(a) (b) (c) (d)

**Figure 3** Four Thai rice varieties (a) Hom-Nin (b) Hom-Daeng (c) Thai Jasmine (d) Kor-Khor 6

Each batch of the husking and whitening efficiency tests used approximately 30 kg of the rice samples and tested for at least 3 times for each rice variety. Then the data were averaged for the final results. However, only Thai Jasmine and Kor-Khor 6 were used for the whitening efficiency test due to the fact that the other two rice varieties are generally served as brown rice.

After the field test, the machine was placed in the community for the routine operation. The usual operational period was 1-2 times/week after the harvesting season. Two operators were trained to operate the machine. Business model for rice mill management was also given to the enterprise management team. User technical manual was provided as well to ease the routine operation and maintenance. Follow up visits for the evaluation of the machine performance were also carried out using intensive interviews.

## 4. Results and discussion

Design and development of the five main units of the rice mill machine, performance follow up and comparison, as well as lessons learned were described as follows. However, only the two main units *i.e.* the rubber-roller husker and the whitener were reported in details.

4.1 Double-layer oscillating sieve cleaner

This cleaner consisted of double-layer sieves oscillating with a frequency of 160-180 double strokes per minute. The screen size of each layer is 40 cm x 80 cm. Large-sized impurities such as dirt and rice straw were removed from the paddy by the upper oscillating sieve with 2.5 mm openings. The second layer with 1.7 mm openings then filtered the paddy from small contaminants *e.g.* dust and undeveloped grains. An aspirator with 0.5 Hp motor was used to remove light impurities.

4.2 Rubber-roller husker and aspirator

As shown in Figure 4, it was designed to have two polyurethane rubber rollers with the same diameter of 150 mm and 100 mm width. One roller was fixed, whereas the other was adjustable to a suitable clearance for optimum de-husking. The two rollers moved towards each other in the opposite direction at different speeds to remove husk from the paddy. The husking capacity was 200 kg paddy/hr. Unique designs in this model to increase the husking efficiency and product yield were as follows: 1) Adding the huller side cover as shown in Figure 4 to control paddy flow and prevent side overflowing of paddy; 2) Adding deceleration plates (in Figure 5) to increase the falling distance and slowdown the rice flow for more effective of chaff extraction by an air suction blower, and 3) Adding a buffer stop as shown in Figure 5 to prevent suction of brown rice to the chaff extractor.

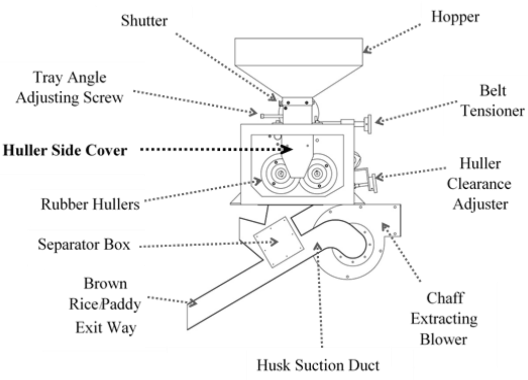


**Figure 4** Rubber-roller husker and aspirator

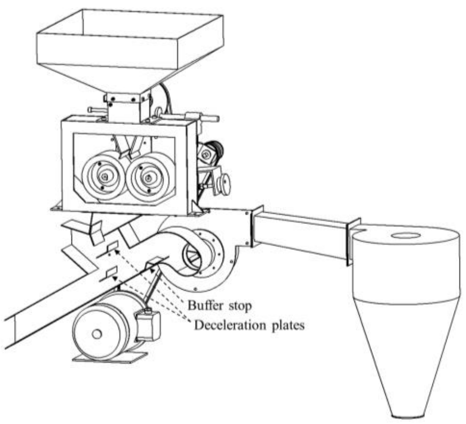


**Figure 5** New design in the husk suction duct

At the base of the husker, an aspirator was located to separate the husk from the brown rice. Diagram of the rubber-roller husker with details of the motor power and shaft speeds used is shown in Figure 6.

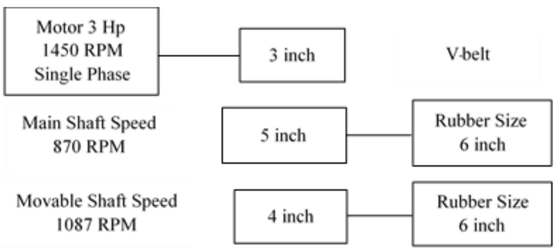


**Figure 6** Diagram of the rubber-roller husker

The 3 Hp motor in Figure 6 was selected based on the following calculations. Refer to the previous research (Chaitep, Ungsiyakull, & Watanawanyoo, 2008), Shear resistance of a rice grain (for Thai Jasmine in a parallel grain position) with respect to shear angle or feed angle of two rollers of 90 degrees was calculated as shown in (1), (2), and (3), as follows:

$$F_1 = -0.0227\theta^2 + 2.0807\theta \qquad (1)$$

($F_1$ = Shear resistance of brown rice,
$\theta$ = Shear angle)

$$F_1 = -0.0227\theta^2 + 2.0807\theta$$
$$= -0.0227(90)^2 + 2.0807(90) = 3.393 \text{ N}$$

$$F_2 = -0.0282\theta^2 + 2.641\theta \qquad (2)$$

($F_2$ = Shear resistance of paddy, $\theta$ = Shear angle)

$$F_2 = -0.0282\theta^2 + 2.641\theta$$
$$= -0.0282(90)^2 + 2.641(90) = 9.27 \text{ N}$$

$$F_{max} = F_2 - F_1 \qquad (3)$$

($F_{max}$ = Maximum shear for one grain, $F_2$ = Shear resistance of paddy, $F_1$ = Shear resistance of brown rice)

$$F_{max} = 9.27 - 3.393 = 5.877 \text{ N}$$

Based on the weight of Thai Jasmine paddy with 2.77 g for 100 grains and 2.5 mm width (Chourwong, Iaprasert, & Meehom, 2017), maximum rice grains passed through a 100 mm roller equaled to 40 grains. Therefore, maximum shear for de-husking 40 grains equaled to 235.08 N. When this maximum shear was timed with the radius of the 6-inch rubber, the result was the required torque for the roller shaft which equaled to 17.91 Nm. Then, required motor torque calculation was performed using equation (4).

$$T_{motor} = T_{load}/(i \times \eta_g) \qquad (4)$$

($T_{motor}$ = Motor torque, $T_{load}$ = Load torque, i = transmission ratio, $\eta_g$ = transmission efficiency)

$$T_{motor} = 17.91/(1.6 \times 0.9)$$
$$= 12.44 \text{ Nm}$$

Then, motor power was calculated using equation (5).

$$P = 2\pi NT/60000 \qquad (5)$$

(P = Power (kW), N = Speed of shaft (rpm), T = Torque (Nm))

$$P = 2 \times 3.14 \times 1450 \times 12.44 /60000$$
$$= 1.89 \text{ kW}/0.746 = 2.53 \text{ Hp}$$

As a result, the motor power of 3 Hp was selected for this rubber-roller husker.

Husking efficiency as well as percentage of head rice and broken rice were examined as in equations (6)-(8) (Das, Saha, & Alam, 2016).

Three rice varieties as seen in Figure 3 (Hom-Nin, Hom-Daeng, and Thai Jasmine) were used for the test. However, the equation (7) in this case was actually adapted to the Percentage of the whole kernels plus head rice due to the weight used in the calculation was the mixture of the whole kernels and the brown head rice.

$$\text{Husking Efficiency (\%)} = \frac{\text{Weight of Milled Rice}}{\text{Weight of Paddy}} \times 100 \qquad (6)$$

$$\text{Head Rice (\%)} = \frac{\text{Weight of Head Rice}}{\text{Weight of Paddy}} \times 100 \qquad (7)$$

$$\text{Broken Rice (\%)} = \frac{\text{Weight of Broken Rice}}{\text{Weight of Paddy}} \times 100 \qquad (8)$$

Table 2 shows the results of the husking efficiency test (for a single pass) with the clearance or distance between two rollers setting at 1, 0.5, and 0.2 mm. The smaller clearance clearly provided better husking efficiency. The optimum clearance setting for these rice varieties was 0.2 mm producing 66-78% of the brown whole kernels plus head rice with 18-29% of unhusked paddy. However, the hardness of the rubber was also crucial affecting the husking efficiency and the quality of brown rice. Therefore, the adjustment of clearance could be varied from this study.

**Table 2** Husking efficiency test for three Thai rice varieties at 11-13% moisture content

| Thai Rice Varieties | Clearance or distance between two rubber rollers | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 mm. | | | 0.5 mm. | | | 0.2 mm. | | |
| | Brown rice | | Paddy | Brown rice | | Paddy | Brown rice | | Paddy |
| | Whole + Head rice (%) | Broken kernels (%) | Unhusked kernels (%) | Whole + Head rice (%) | Broken kernels (%) | Unhusked kernels (%) | Whole + Head rice (%) | Broken kernels (%) | Unhusked kernels (%) |
| Hom-Nin | 26 | 3 | 71 | 41 | 3 | 56 | 78 | 4 | 18 |
| Hom-Daeng | 22 | 5 | 73 | 36 | 6 | 58 | 68 | 6 | 26 |
| Thai Jasmine | 16 | 3 | 81 | 33 | 4 | 63 | 66 | 5 | 29 |

4.3 Compartment-type paddy separator

After the husking process, brown rice and unhusked paddy were separated by the next unit called a 20-compartment-type paddy separator. It consisted of two decks with 10 stainless-steel compartments for each deck. Its capacity for separation was 140-160 kg brown rice/hr with oscillating frequency of 90-105 double strokes per minute. Inverter motor was used to ease the frequency adjustment of this paddy separator. Brown rice was separated from the unhusked grains and moved to a bucket elevator ready for a whitening process.

4.4 Horizontal friction-type rice whitener

Schematic drawing of this whitener is shown in Figure 7, and a photograph of whitening unit with fresh air inlet holes is shown in Figure 8. Horizontal friction type was used in this rice whitening unit to enable a more compact design especially when connecting the units in series as described later (Figure 9), and to avoid stone-residue from the abrasive-type one. Furthermore, a steel-ribbed shaft designed to rotate inside a hexagonal metal-screen cylinder had a longer life time than the whitening part in the abrasive type whitener. Bran layer was removed from the rice kernel by the frictional forces caused by individual rice grains and between the grains and the metal screen surface. A blower in this friction type whitener sucked the outside air into the air inlet holes to cool the grain and moved bran from the metal screen to the bran cyclone. This new design by placing the air inlet holes on the top of the hexagonal cylinder as shown in Figure 8 has navigated air flow through the whitening part directly and significantly reduced temperature of grains and the metal surface. This change resulted in the increase of whitening efficiency and better quality of the white rice with less broken grains.

Pressure adjustment was another important factor in this whitening process. Optimum pressure setting should provide the best product yield. Low pressure caused insufficient whitening, whereas high pressure increased the number of broken grains. Generally, the Amp-meter was used in the friction-type whitener to measure electricity load for the motor in the whitening unit and to indicate the pressure used in the process. The adjustment of pressure could be achieved by adjusting the flow rate of grain outlet which controlled by the outlet valve.

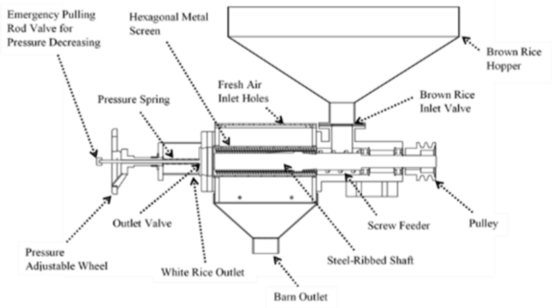


**Figure 7** Horizontal friction-type rice whitener

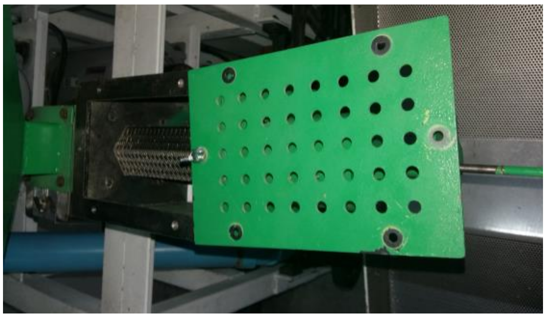

**Figure 8** Whitening unit showing fresh air inlet holes in green part

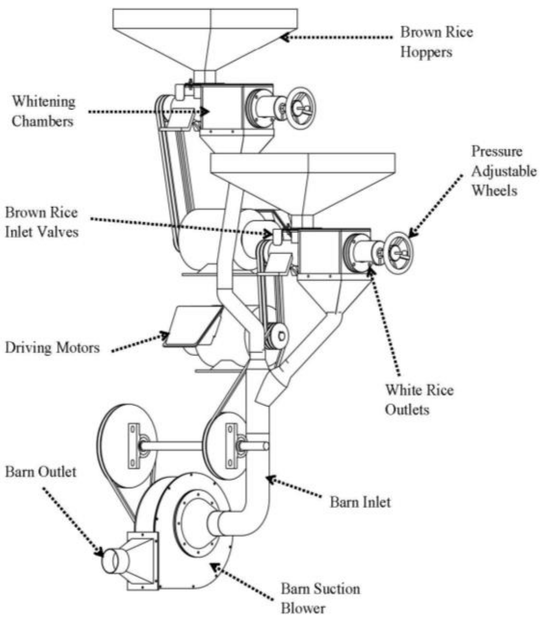


**Figure 9** Two horizontal friction-type rice whiteners connected in series

For a large production, connecting two or more horizontal whiteners in stacking arrangement was usually done in a modern commercial mill to reduce the number of broken grains and the grain temperature during the whitening process (Tangpinijkul, 2010). However, this type of arrangement requires more space and enlarge the machine size. Therefore, the new arrangement was designed in this study as shown in Figure 9, created a more compact design of our machine suitable for the community level. It also reduced the cost of conveying parts as well as increased the whitening efficiency.

To calculate the motor power for the whitener, torque must be calculated first as in equation (9) using properties of medium grain brown rice (Narasimhan & Vijayakumar, 2016; Mohapatra, 2004a & 2004b).

$$M_c = 4\pi 2\mu_c M_g \omega^2 R^3 t \qquad (9)$$

($M_c$ = Torque in Nm, $\mu_c$ = Dynamic coefficient of friction of rice grains, $M_g$ = Bulk mass of grain (kg), $\omega$ = Angular velocity of shaft (rad $s^{-1}$), R = Shaft radius (m), t = Whitening time (s))

$$M_c = 4\text{x}3.14\text{x}2\text{x}0.5\text{x}0.3\text{x}\ (151.84)^2\text{x}\ (0.02)^3\text{x}10$$
$$= 6.95 \text{ Nm}$$

Power requirement for whitening was then calculated as in equation (5)

$$P = 2\pi NT/60000 \qquad (5)$$

(P = Power (kW), N = Speed of shaft (rpm), T = Torque (Nm))

$$P = (2\text{x}3.14\text{x}1450\text{x}6.95)/60000$$
$$= 1.05 \text{ kW or } 1.41 \text{ Hp}$$

As a result, the motor power of 2-3 Hp was selected for this whitening unit. Particularly, the 3Hp motor could overcome an overfeeding problem of the users.

Whitening efficiency of this whitening unit was assessed at 1450 RPM using two Thai rice varieties *i.e.* Thai Jasmine, and Kor-Khor 6 or RD 6 (Glutinous rice). The results listed in Table 3 showing the whitening efficiency of the white head rice in the range of 50-55% (by weight) were satisfactory.

**Table 3** Whitening efficiency test at 1450 rpm (or 151.84 rad $s^{-1}$) shaft speed

| Thai Rice Varieties | Paddy (% by weight) | White Head Rice (%) | White Broken Kernels (%) | Bran (%) |
|---|---|---|---|---|
| Thai Jasmine | 100 | 49.95 | 10.22 | 8.49 |
| Kor-Khor 6 (RD 6) | 100 | 55.10 | 11.76 | 11.64 |

4.5 Oscillating Grading Sieves

Oscillating single screen bed was used to separate white head rice and broken kernels from the whitening unit. The head rice was filtered by the sieves with 2.5 mm openings and oscillated to the outlet, whereas the broken grains passed through the screen and moved to the collected reservoir. Oscillating frequency used for this stage was 160-180 double strokes per minute.

4.6 Machine performance follow up and comparison

The 5-week production data recorded by the mill operator at Ban Samkha village were reported in Table 4. The data indicated that our machine could mill various local rice varieties having 13-14% moisture content with a high average milling recovery of 65%. When comparing to the Thai Standard for small rice mill and the previous report (Dhankhar, 2014), the production yield and quality of milled rice from this study were remarkable with 50-70% of brown head rice, 50-60% of white head rice, and 2-21% of broken grains. For a relatively high percentage of broken grains for Thanyasirin glutinous rice sample at 21% might be caused by quality of paddy or skill of the operator during clearance adjustment of the roller husker. This could happen especially for a small load of sample.

Direct comparison of our machine with commercial ones in the market could not be made due to the fact that there is no machine with the same specification and no sufficient technical data for similar machines in the market. Therefore, intensive interviews with the mill operators and stakeholders at Ban Samkha who used our machine and another abrasive-type rice mill in the village were performed to check satisfactory of users towards our machine. The results indicated that they were more satisfied with our machine than the other one. Strong features of our machine were high quality of rice and production yield, low maintenance, simple and adjustable processes suitable for milling various varieties of local rice in the village. Generally, milled rice from our machine contained more whole kernels and less broken grains, while that of the other machine often contained over-polished head rice with stone-residue from the abrasive and more broken rice. As a result, the villagers preferred to use our machine to mill rice for their own consumption or for sale as a premium product. The other machine was commonly used for mass production and for sale to suppliers.

**Table 4** Production data from the mill operator at Ban Samkha village

| Period | Local Rice Varieties | Paddy (Kg) | Kg of Brown Rice (%) | Kg of White Head Rice (%) | Kg of Broken grains (%) |
|---|---|---|---|---|---|
| Week 1 | Black glutinous rice | 28 | 18.2 (65) | - | (N/A) |
| | Thanyasirin glutinous rice | 28 | 14 (50) | - | 6 (21) |
| | Hom Lanna | 86.5 | 49 (57) | - | 6 (7) |
| Week 2 | Hom Lanna | 398.4 | 251.4 (63) | - | 27 (7) |
| | Hompupan white glutinous rice | 26 | - | 13 (50) | (N/A) |
| | Snake-fang white glutinous rice | 27 | - | 14.2 (53) | (N/A) |
| Week 3 | Thanyasirin glutinous rice | 54.4 | - | 29.8 (55) | 5 (9) |
| | Hom Lanna | 234.5 | 160 (68) | - | 5 (2) |
| | Red glutinous rice | 30 | - | 18 (60) | 5 (17) |
| Week 4 | Thanyasirin glutinous rice | 82 | 57 (70) | 49 (60) | 4.6 (6) |
| Week 5 | Hom Lanna | 94 | 63 (67) | - | (N/A) |
| | White glutinous rice | 28 | - | 15 (54) | 3.8 (14) |
| | Jasmine rice | 55 | - | 29 (53) | 3.8 (7) |

4.7 Lesson learned

After the success at Ban Samkha village, at least 25 machines have been used by Thai farmers nationwide: 3 in the Northern, 16 in the North Eastern, 5 in the Central, and 1 in the Southern parts of Thailand. Furthermore, one machine has been donated to the Republic of Guinea.

For successful introduction of this small-scale rice mill machine to the community level and for sustainable development in the long run, other factors besides the quality of the machine and the paddy should be considered. These can directly affect the production yield, quality of milled rice, and the milling business. Examples include as follows:

- Primary Good Manufacturing Practice (GMP) compliance. The users are generally unaware of Primary GMP although it is required in a packed rice business.
- Development of good accounting system and management, which are crucial for successful long-term operation of the machine. Data collections and analyses are critical for evaluating the machine performance and the milling business. This information is also useful for setting up a management strategy for optimum utilization of the machine.
- Human resource development. Skill and expertise of the mill operator are critical, especially for the community level. Usually, only 1-2 operators are assigned for the machine and mostly work as part-time employees. Therefore, after a hands-on training, other alternative teaching materials such as a practical user manual, a video clip demonstrating best practice for the rice mill operation as shown in Figure 10 (AGRITEC Channel, 2017), and a brief-instruction chart presented in Figure 11 are important and recommended to be prepared for the users.

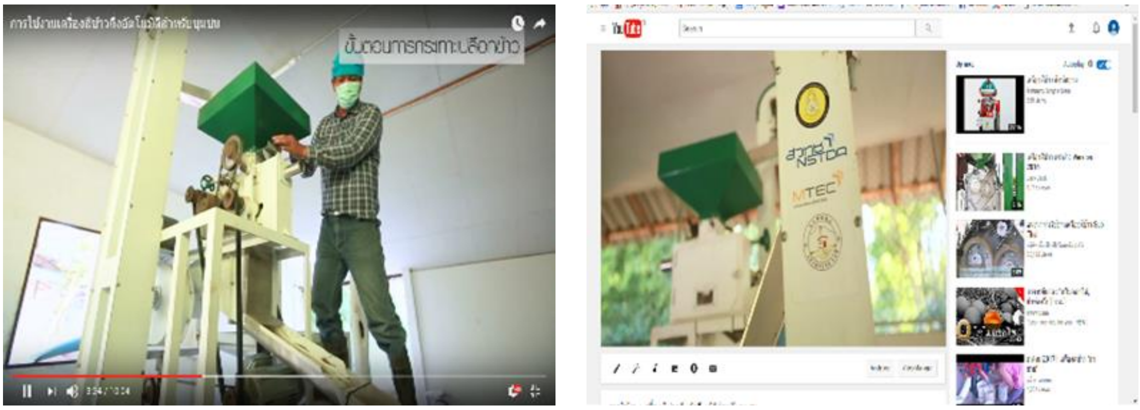


**Figure 10** Video clip demonstrating best practice of the rice mill operation at Ban Samkha rice mill community enterprise


**Figure 11** Brief-instruction chart of the small-scale rice mill at Ban Samkha village

## 5. Conclusion

A compact and highly efficient small-scale rice mill machine was designed and developed in this study. This semi-automatic machine ran on single-phase motors of 8-10 Hp in total with a capacity of 200 kg paddy/hr. It could produce both brown and white rice. This model consisted of five main units: a double-layer oscillating sieve cleaner, a polyurethane rubber-roller husker and aspirator, a compartment-type paddy separator, two horizontal friction-type rice whiteners, and oscillating grading sieves. It also had an underground paddy hopper to ease the transfer of paddy to the hopper. The design offered unique aspects as follows: 1) a compact and efficient small-scale rice mill with multi stages from cleaning of paddy to producing of graded brown- and white-rice; 2) a new design of a rubber-roller husker and aspirator by adding the huller side cover, the deceleration plates, and a buffer stop to increase the husking efficiency and the production yield, and 3) a new and compact design of the friction-type whitener to increase the whitening efficiency by placing the air inlet holes on the top of the hexagonal cylinder to navigate air flow through the whitening part directly and by connecting the whiteners in series for a large production. The design was simple, continuous, and adjustable, suitable for rice milling in the rural areas. Easy maintenance was also its feature. Most parts could be changed or fixed by local operators using replacements simply found in the communities. When comparing to the Thai Standard for small rice mill and the previous report (Dhankhar, 2014), the milling recovery and the production yield were remarkable. The average milling recovery for various varieties of local Thai rice having 13-14% moisture content was about 65%, while the production yield was 50-70% of brown head rice and 50-60% of white head rice. Lastly, for successful introduction of this small-scale rice mill machine to the community level, additional factors such as GMP compliance, good accounting system and management, and human resource development should also be considered and provided to the community to ensure the sustainable development.

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