ADAPTABILITY OF VIETNAMESE REVERSIBLE AIRFLOW FLATBED DRYER IN THE PHILIPPINES

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ABSTRACT. *A fixed flatbed rice dryer model that operates based on the principle of airflow-reversal drying was introduced in the Philippines through a collaborative project between the Nong-Lam University, Ho Chi Minh City, Vietnam (**NLU**) and the Philippine Rice Research Institute (**PhilRice**), Philippines. The dryer can be an alternative solution for rice drying in the Philippines, especially during the rainy season. The study was conducted to evaluate the performance of the reversible airflow flatbed dryer under Philippine conditions, and compare it with the existing conventional flatbed dryer (also called as PhilRice-UAF (or Maligaya) flatbed dryer which was a result of the collaboration between NLU and PhilRice in 1994). The performance evaluation was conducted in three drying batches of newly harvested rice seeds. In the technical aspect, the comparison of means (using two-tail t-Test) for respective parameters in the two dryers revealed that the reversible airflow flatbed dryer was not significantly different from the existing conventional flatbed dryer; this implies that the SRA dryer could be promoted on large scale production, given that the drying cost of PhP0.74* is lower than the prevailing mechanical drying cost of PhP1.13 per kg of dried paddy in the Philippines.*

Key words: flatbed dryer, reversible airflow, rice seed drying

INTRODUCTION

The problem facing rice production in Southeast Asian countries is high postharvest losses. According to reports cited by the Food and Agriculture Organization (FAO) and the International Rice Research Institute (IRRI), rice postharvest losses are from 10% up to 37% of total harvested production. Among the stages of rice postharvest operations (cutting, collecting and piling, threshing, hauling, drying, storing, and processing [milling]), the drying is one of the most important stages because it affects almost all other stages, and the loss due to drying stage is still at the rather high level.

Farmers often use sun-drying to dry their crops, but during rainy season, the weather is erratic, the drying of crops using the solar energy cannot be done, and with the lack of mechanical dryers, losses increase since grains deteriorate, discolor, germinate; and hence, quality and quantity of dried grains reduced.

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*: PhP: Philippine Peso (US$1 ~ PhP45)

Drying of paddy on pavements, canvases, mats/nets or sun-drying is still very popular in the Philippines, although there are many different dryer models that have been already introduced in the country. Advantages of the sun-drying method are as follows: utilizing natural energy sources; does not need to purchase machine; suited to small-scale production; and utilizing unskilled labor. However, sun-drying method cannot be done during rainy or cloudy weather condition as well as at night; besides, under this method, it is difficult to control the drying temperature. Moreover, in sun-drying, qualitative and quantitative losses of rice grains occur because of birds, rodents, mixing with grits, and other factors.

Conventional Flatbed Dryer (CFD) could partly remedy these losses of sun-drying method, but there are still existing restrictions, e.g. occupying much land space, requiring manual labor to turn the paddy layers in the drying process in order to overcome the downside of non-uniformity of final grain moisture content.

The reversible airflow dryer (code named “SRA dryer” in Vietnam, of which “S” is drying in Vietnamese, “RA” is abbreviation for Reversible Airflow, and the number following “SRA” indicates the capacity in tons per batch; e.g. the SRA-8 dryer means the reversible airflow flatbed dryer with capacity of 8 tons per batch) is also fixed flatbed-batch type, but as experienced in Vietnam, it has some advantages compared with the conventional flatbed dryer, namely: 1) With same capacity, the drying bed area was smaller; 2) No labor was needed for turning the grain mass during drying operation but the final moisture content of grain mass was still uniform; 3) The SRA dryers could be used to dry not only rice but also other materials with very high initial moisture content, e.g. corn, coffee fruit, sliced cassava, longan, etc., and 4) The investment and drying cost were not higher compared to a flatbed dryer with same capacity (Hien et al., 2003). Therefore, the SRA dryer can be an alternative solution for rice drying in the Philippines, especially during the rainy season.

Objectives of the study were to evaluate the drying performance of the Vietnamese reversible airflow flatbed dryer (the SRA-8 dryer) under Philippine conditions and compare it with an existing conventional flatbed dryer (the CFD-6); concurrently estimate the cost of drying of both dryers, thence judge adaptability of the SRA dryer in the Philippines.

The study was conducted at the PhilRice Central Experiment Station, Maligaya, Science City of Muñoz, Nueva Ecija 3119, Philippines from October 2010 to July 2011. The performance test was conducted in October 2010, that was during the rainy harvest season.

REVIEW OF LITERATURE

Flatbed dryer for grains is an old technology, originally introduced in the Philippines by the University of the Philippines at Los Baños in the 1970s and the International Rice Research Institute (IRRI). These designs use kerosene as fuel. In the flatbed dryers, grain is laid out on a perforated screen, and dried by forcing heated air from below. A fan that provides the drying air is usually a simple axial flow fan. A furnace provides drying heat. Generally, the drying floor is flat although dryers with inclined sections (to facilitate unloading) or vibrating sections (to facilitate stirring) exist as well. The height of the layer is usually 25-40 cm. An air temperature of 40-45ºC is normally used with a heater capable of raising the air temperature 10-15º C above ambient. An air velocity of 0.15-0.25 m/s is required and typical fan power requirements are 1.5-2.5 kW/ton of paddy. The efficiency of these dryers as well as the head rice recovery is improved by mixing grain mass in the drying process (IRRI, 2008).

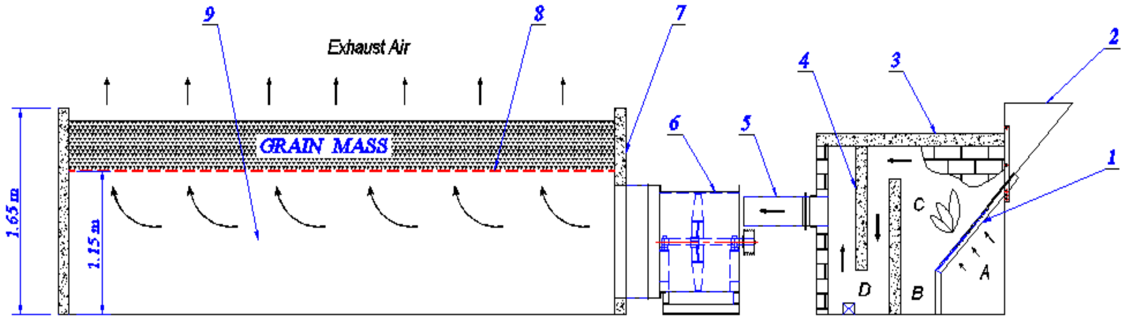

Figure 1. Schematic diagram of the CFD used in the research: (1) Inclined-step grate, (2) Feeding hopper, (3) Top cover, (4) Baffle, (5) Furnace outlet, (6) Dryer fan, (7) Drying bin, (8) Perforated floor, (9) Air plenum chamber

A- Primary air; B- Ash pit; C- Combustion chamber; D- Ash trapping chamber

In Vietnam, the flatbed dryer has been scaled up by the University of Agriculture and Forestry (UAF) in Ho-Chi-Minh City, with the first 8-ton/batch dryer installed in 1983. In Vietnamese flatbed dryers, the UAF modified and later improved rice husk furnace from an IRRI design. Today, rice hull-fired flatbed dryers are now widely adopted in the Mekong Delta of Vietnam. Vietnamese flatbed dryers were introduced in the Philippines in 1994 through a collaboration between the UAF (it is called NLU nowadays) and PhilRice. As a result of that collaboration, the 6-ton flatbed dryer model was developed. This dryer model became popular among rice growers and cooperatives in the Philippines, owing to its ease of operation and maintenance. Feedback raised by users of the flatbed dryer include non-uniformity of the drying front, especially at high drying temperatures. Mixing is therefore recommended to remedy this problem. However, this activity is laborious. Recently, the Department of Agriculture included the distribution of this type of dryer to clusters of farmers (irrigators' associations; cooperatives) as a component of the government's rice self-sufficiency program. Before the government intervention, the number of 6-ton flatbed dryers in the country was estimated at more than 200 units. To date, the number of operational flatbed dryers now number around 800 units (Tado and Bautista, 2008).

Reversible-airflow drying is not a new concept. These types of dryer have been developed in Taiwan and in the United States of America. In the Philippines, reversible-air dryers were built by a manufacturer in Leyte since the early 1990s'. In the Taiwanese and Philippine designs, the air is blown at the center, thus increases the bed height level, making more difficult for manual loading. The American vertical-bed only fits granular drying materials like grains, thus could not accept other high moisture and sticky materials (Hien et al., 2003). In Vietnam, research on the reversible dryer began in 1999 at Nong-Lam University (NLU, formerly the University of Agriculture and Forestry) with a laboratory model for basic information about drying characteristics of various crops with reversible airflow. Finally, the dryer was scaled up to different models of 2; 4; 6; 8; 10; and 12 tons per batch. To date, more than 700 units of these dryers have successfully introduced and installed in several provinces of Vietnam (Hien, 2008, cited by Tado and Bautista, 2008).

Operating Principle of the SRA dryers. Drying material is loaded into the drying bin with a depth of 50 to 60 cm on a screen floor. Heated air is produced by the furnace and sucked by the dryer fan. The drying air blown into the drying bin is a mixture of the hot air from the furnace and ambient air. The drying air temperatures of 42 to 45°C and 40 to 43°C are used for drying milling grains and seed grains, respectively. During the drying operation, rice husk is fed into the furnace and ash is discharged manually. The drying process involves two periods (Fig. 2): *1) Upward drying period: grain mass dried from bottom to top layer, the exhaust air exits on top of grain mass; and 2) Downward drying period: the grain mass dried from top to bottom layer, the drying air carry moisture evaporating from material comes out at windows installed on the wall of side-air duct*. The drying process is stopped when the grain mass attained a desired final MC.

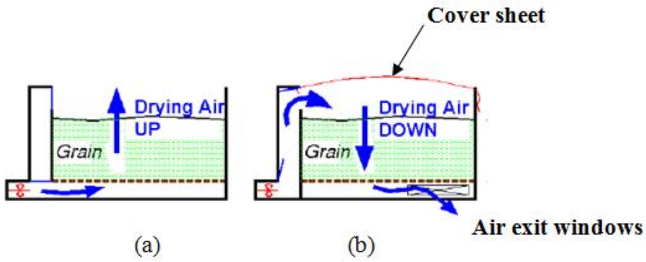

Figure 2. Principle of operation of the SRA dryers

MATERIALS AND METHODS

Machines used in the study were an SRA-8 dryer (nominal capacity is 8 tonnes/batch, but it can dry from 7-9 tonnes) which was fabricated and constructed in the Philippines by PhilRice Team assisted by Vietnamese engineers, and an existing CFD-6 (6 tons/batch); both were installed at the PhilRice compound.

THE REVERSIBLE AIRFLOW FLATBED DRYER (the SRA-8 dryer)

Figure 3. The SRA-8 dryer (8 tons/batch) used in the study

The dryer (Fig. 3) has the following main components:

- a rice husk-fed furnace with cylindrical combustion chamber which traps ash and sparks more thoroughly compared to existing box-shaped furnaces.
- a two-stage axial-tube blower with 10 blades on each stage, diameter of 900 mm, and has an airflow straightener in the middle, drawn by an 18-22 HP diesel engine. The blower was designed to overcome higher pressure due to higher grain mass depth of up to 0.7 m, compared with 0.25 to 0.35 m layer in conventional flatbed dryers. Air volume is around 8 m^3/s at 40-mmH_2O static pressure.
- a plenum system including two parts: a plenum chamber located on the side (side-air duct), which is consisting of two sub-plenum chambers inside, i.e. upper and lower

plenum chambers. Depending on upward or downward drying operation, one of two sub-plenum chambers is connected to the air-reversal chamber; and another one is right below the perforated screen as upward drying, this will be a space between top of grain mass and the cover sheet as downward drying.

- a drying bin is constructed in stationary form (hollow blocks and concrete). The flooring has a wooden frame with nylon net on top.
- a shed is in steel-type and open-type.

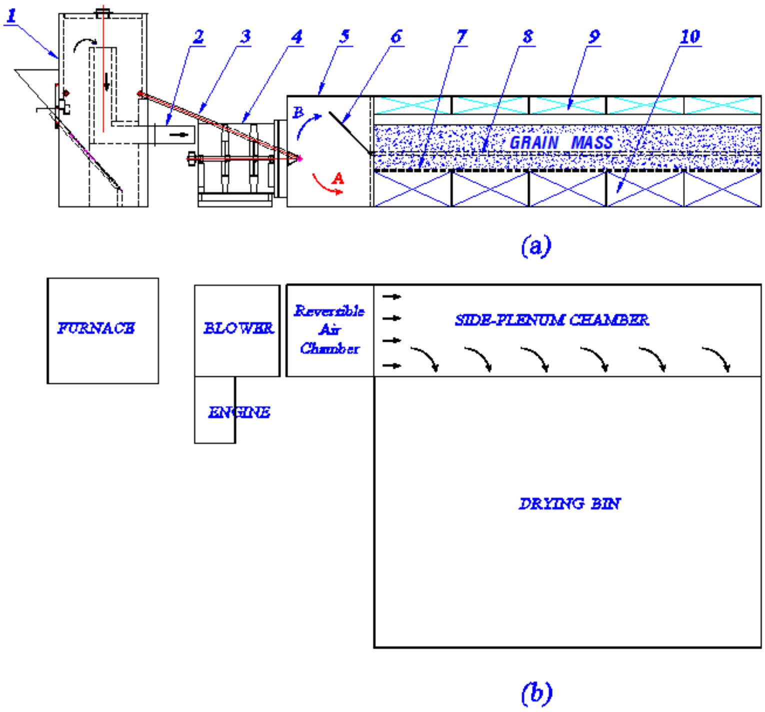

Figure 4. Schematic diagram of the SRA-8 dryer: (a) front view, and (b) layout plan; (1) Furnace, (2) Furnace outlet, (3) Secondary air pipes, (4) Blower, (5) Reversible air chamber, (6) Reversible plate, (7) Screen floor, (8) Middle slap, (9) Upper air inlets (B connected), (10) Lower air inlets (A connected)

(A) Upward drying (1st drying period)
(B) Downward drying (2nd drying period)

THE CONVENTIONAL FLATBED DRYER (CFD-6)

Figure 5. The CFD-6 (6 tons/batch) used in the study

The CFD-6 (Fig. 5) consists of the following components: a rice husk-fed furnace in box-shaped type, a single-stage axial-tube fan drawn by a 12.5-HP diesel engine, a drying bin with a plenum chamber right beneath, and a shed. Components of fan and furnace are located in the middle of drying bin widthwise.

PERFORMANCE EVALUATION OF THE DRYERS

For comparing the performance of the dryers (*the comparative analysis was carried out only on some comparable parameters of the drying performance of two dryers, namely: moisture content gradient, moisture reduction rate, drying efficiency, drying system efficiency, and quality of dried grains)*, each dryer was a treatment; three replications (or 03 drying batches) were done. Long grain varieties that were newly harvested, threshed, and intended for seed purposes were used as samples. In each drying batch, the performance test of the two dryers was done simultaneously. The two dryers were tested based on the Philippine Agricultural Engineering Standard (PAES) 202:2000. The germination and milling tests were carried out by PhilRice analysts at respective laboratories. The experiment was conducted and relied on a statistical tool of two-tail t-Test for making decisions on the treatment means.

RESULTS AND DISCUSSION

Through intermediate computations, the data of the performance of the two dryers are shown in Table 1. The drying curves and the linear regressions (blue lines) in the two dryers derived from collected data in the range from 24-25% down to 12-13% are shown in Fig. 6 and Fig. 7 for the SRA-8 dryer and the CFD-6, respectively. The drying time was almost equivalent, it was from 11 to 12 hours per batch. In fact, the regression is only handy, it does not reflect essence of drying process since there are many factors affecting this process. Comparisons of respective parameters using t-Test revealed that the SRA-8 dryer performance was not significantly different from the CFD-6.

Table 1. Parameters of drying and quality of dried grains observed in the SRA-8 dryer and the CFD-6

PARTICULARS	SRA-8 DRYER	CFD-6
Mean Moisture Reduction Rate, %/hr	0.88	1.05
Mean Drying Rate, kg/hr	76.8	62.3
Mean MC Gradient, %	1.0	1.9
Mean Heat Utilization, kJ/kg water removed	5 986	5 776
Drying Efficiency, %	44.0	46.3
Drying System Efficiency, %	39.2	42.1
Milling Recovery, %	69.5	69.7
Head Rice Recovery, %	60.3	60.2
Broken Rice Percentage, %	9.2	9.4
Germination Rate, %	91.5	79.9

In drying process, non-uniformity of MC of a grain mass is unavoidable. For fixed flatbed dryers, grains at lower layers are always dried faster than upper parts. When a grain mass is more non-uniform in moisture content, there will be a higher ratio of broken rice when milling. That is because once a rice milling system is being adjusted in accordance with some level of moisture content to get a maximum head rice yield, then it will not be appropriate with other levels of MC (Hien et al., 2000). The results also showed that the mean *MC gradient of samples dried at the SRA-8 dryer was less than that of the CFD-6, 1.0% versus 1.9%, this is one of advantages of air-reversal drying*. The result of milling analysis did not manifest any differences on head rice recovery, this is because the drying temperature for rice seeds (i.e. lower than 43^{o}C) was applied during drying operation, and all samples for milling tests were re-dried in the shade to attain the final MC of 13% (this MC level is standardized for milling tests). Therefore, the head rice yields of paddy dried at the two dryers were high and almost similar.

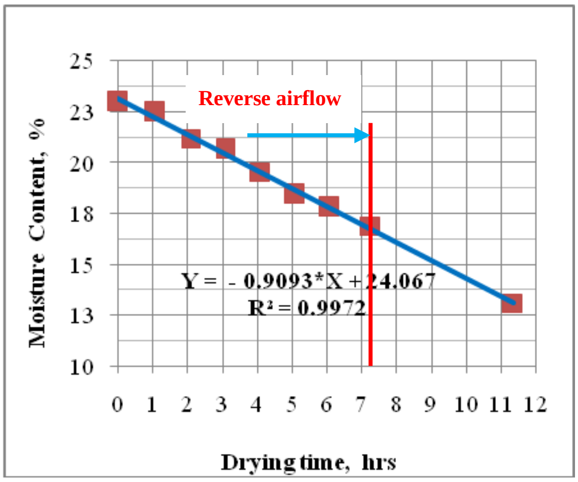

Figure 6. Drying curve in the SRA-8 dryer

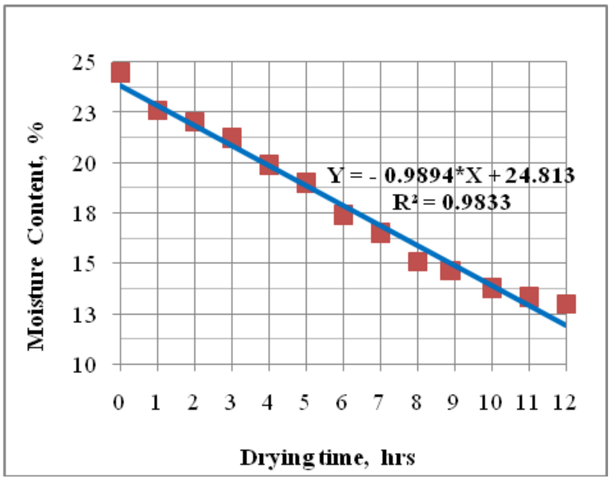

Figure 7. Drying curve in the CFD-6

Extracted from Table 1, factors of drying efficiency and drying system efficiency observed in both dryers were rather low (less than 50%), these happened perhaps because of experimental samples with low initial MC (only 23-25%) used, leakage of drying air, loss of heat through the drying bins' walls, etc. Besides, a superficial velocity of 13-16 m/min. applied in SRA dryer (while it was around 9-11 m/min. in the CFD) might have influenced its drying process and resulted in the slightly lower efficiencies of the SRA-8 dryer.

Because the authors wanted to receive a complete set of data of drying performance, milling analyses were also taken. The drying temperature in the range of 40-43^{o}C during drying operation in both dryers applied since the samples would be used for seed purposes, high milling recovery, high head rice recovery, and low broken rice percentage attained were unsurprising.

Regarding to Germination rate, germination is a measure of the capability of a grain kernel of producing a normal seedling. It is the most important parameter of rice seed. Based on the analytical result in the laboratory conducted by the National Seed Quality Control Services, a high mean germination rate of 91.5% was attained in seeds dried at SRA-8 dryer that meets Philippine Standards for germination rate of 85% and above, while the mean germination rate observed in the CFD was only 79.9%. However, the statistical analysis with the t-Test showed no significant difference between the two treatments. Thus we can only state the confidence interval (at 5% significance level) of the SRA-8 dryer is at between 84.8% and 98.3%, which meets the required standards.

ECONOMIC ANALYSIS OF USING THE DRYERS

For estimating the cost of drying, the maximum drying capacities of the two dryers were used to compute related parameters, where: maximum capacity of SRA-8 dryer is 9 metric tons, and it is 6 tonnes for CFD-6. Estimate the drying cost needs assumptions as well as data of actual drying batches. Therefore, the following assumptions were relied on actual conditions at the PhilRice Central Experiment Station and data of a typical drying batch (e.g. purchase price, fuel consumption, labor costs).

Table 2. Assumptions and data for economic analysis

PARTICULARS	SRA-8 DRYER*	CFD-6**	SRA-8 DRYER #L
Dryer investment cost (IC), PhP	915,000	490,000	823,500
Estimated useful life, yrs	5.0	5.0	5.0
Interest Rate, %/year	16	16	16
Repair and Maintenance, PhP (10%*IC)	91,500	49,000	82,350
Tax and Insurance, PhP (3%*IC)	27,450	14,700	24,705
Drying time per batch, hrs	12.0	11.0	12.0
Holding capacity, kg/batch	9,000	6,000	9,000
Number of batches per year, batches	120	120	120
Rice husk Consumption Rate, kg/hr	45	33	45
Rice husk Cost, PhP/kg	0.90	0.90	0.90
Diesel fuel Consumption Rate, liters/hr	1.6	1.1	1.6
Diesel fuel Cost, PhP/liter	34	34	34
Labor cost for Operator, PhP/hr	37.5	37.5	37.5
Labor cost for Loading, PhP/tonne	100.0	100.0	100.0
Labor cost for Unloading, PhP/tonne	100.0	100.0	100.0

- ***Notes***:

- (*) & (**) : the SRA-8 dryer and the CFD are consisting of a concrete drying bin, a blower, a rice husk-fed furnace, a diesel engine, and a steel-type and open-type shed.
- SRA-8 DRYER #L: Purchase price of the dryer is lowered by 10% = PhP823,500.

As mentioned early, the SRA-8 dryer used in this study is the first unit installed in the Philippines from the collaborative program, it is under a researching project and constructed for the PhilRice (constructions of drying bin and the shed are straight contracts, taxes, etc.), the foregoing are making the cost of the machine high. In case, an investor constructs the SRA-8 dryer by himself (excluding the furnace, the blower, and the diesel engine), meaning he buys materials and hires labors to construct the drying bin and the shed, the initial investment cost of the dryer lowered by 10% (see 4th column, Table 2) is entirely possible.

For a rice dryer that could operate about 120 batches per year, presently this is hard to do in the Philippines where there are commonly two harvest seasons per year, at which each harvest season is lasting for a maximum of 30 days, it is more practicable to regions where farmers may plant 3 rice crops annually. However, if investors are rice-mill owners or seed companies, based on what was happening in the past in Vietnam, this is feasible in near future, notably the Philippine government wants to be a self-sufficient country on rice by 2013.

With an annual use of 120 batches (see Table 3), the drying costs were acceptable, at which PhP0.74/kg of dried paddy was pegged for the SRA-8 dryer and PhP0.68/kg for CFD-6, versus the prevailing mechanical drying cost of PhP1.13/kg (*in the Philippines, the custom rate of mechanical drying services is PhP1.0 per kg of wet paddy, thence it can be inferred that the rate is equivalent to PhP1.13 per kg of dried paddy*). Although the drying cost of the SRA-8 dryer is 8% higher than the CFD's, the annual net income generated from the SRA dryer is more (about PhP87,093 per year) due to its higher drying capacity. Payback period was 2.4 years and 1.7 years for the SRA-8 dryer and the CFD-6, respectively. Break-even points shown in Fig. 8 were 53.0 batches/yr for the SRA-8 dryer, and 42.5 batches/yr for the CFD. The SRA-8 had an internal rate of return of 33.1%; meaning if the interest rate is less than 33.1% (it is normally 12-20 %/yr), the investment is profitable. Similarly, for the CFD-6, it was 54.4%.

Table 3. Results of economic analysis of using the dryers

PARTICULARS	SRA-8 DRYER	CFD-6	SRA-8 DRYER #L
Drying cost, PhP/kg	0.735	0.681	0.706
Payback Period, yrs	2.4	1.7	2.0
Internal Rate of Return, %	33.1	54.4	41.4
Break-even point, batches/yr	53.0	42.5	48.0
Annual net income at 120 batches/yr	378,200	291,100	406,500

In the case that the purchase price of the SRA-8 dryer is lowered by 10%, i.e. its price now is PhP823,500, the drying cost of PhP0.706 per kg is obtained, which is also closer to the drying cost of PhP0.68 per kg at the CFD-6 in spite of significant difference on the initial investment cost between the two dryers; based on that, the payback period is 2.0 years, and the break-even point is 48.0 batches/yr. Furthermore, annual net income generated is more, around PhP115,000 per year. The 10% lowered price is possible with medium-scale production (and not single-unit fabrication in the study), and would make the SRA-8 dryer more practicably to be accepted in the country.

CONCLUSIONS

Results of comparison of the two dryers' performance revealed that there was no significant difference between compared respective parameters. Regarding to the most important factor when drying rice seeds, i.e. germination rate, it was 91.5% for the samples dried at the SRA dryer, which meets Philippine Standards for germination rate of 85% and above, while it was only 79.9% at the CFD, which is lower based on the required standard (Of course, the germination rate is influenced not only by dryers but also by other agronomic factors, e.g. variety, maturity, harvest time, farming condition, harvest method, etc.); and based on the statistical analysis, this factor was not also significantly different. In the operation aspect, the reversible airflow flatbed dryer also indicated some advantages compared with the conventional flatbed dryer, e.g. loading of paddy into the drying bin was more convenient since the height of screen floor was much lowered, maintaining regularly the drying temperature was easier, no labor was needed for turning the grain mass, etc.

The SRA-8 dryer is costly compared to the CFD-6, so its cost of drying was also a little higher. The drying costs of PhP0.74 and PhP0.68 per kilogram of dried paddy estimated in the SRA-8 dryer and the CFD-6 respectively were applicable under Philippine condition due to the price of materials and the operating cost of dryer were getting higher nowadays. These costs of drying are equivalent to about 4.1% of paddy value for the SRA-8 dryer, and 3.8% of paddy value for the CFD-6; supposed that the prevailing price of dried rice seed is PhP18.0/kg (*selling price to traders*). Anyway, a lower investment cost will make the SRA dryer to be another option which is more attractive for Filipino farmers. And the more important thing is that the SRA dryer with higher capacities can contribute to resolve the lack of mechanical dryers and to reduce postharvest losses in the Philippines.

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