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An Investigation of the Drying Methods and their Effects on Milling Quality of Rice in Guyana.

Narita Singh[1], Dharamdeo Singh[2*] and Roland C.G. Daynauth[3]

*[1]Head of Post-harvest/Value--added Department, Rice Research Station, Guyana Rice Development Board, [2]Lecturer, Faculty of Agriculture and Forestry, University of Guyana, [3]Lecturer, Faculty of Natural Sciences, University of Guyana. *Corresponding author: Dharamdeo Singh, singhdharamdeo@yahoo.com*

Abstract

Rice is the largest agricultural crop produced in Guyana. There are various post-harvest operations for rice, which include: threshing, cleaning, drying, milling, storage, transportation and marketing. Post-harvest losses can occur during any one of these operations. Drying reduces the moisture content (MC) of the grains for milling and storage. It is one of the most critical factors that contribute to both qualitative and quantitative losses; these include: yellowing or discolouration caused by mold development and heat build-up from respiration, and reduced head rice recovery. Despite the importance of this operation to losses, no work has been done on the various drying systems in Guyana. This study seeks to investigate the drying methods used in Guyana's rice growing regions and determine the effects of these methods on the milling qualities of rice.

All operable mills were selected in Regions 2, 3, 4, 5, and 6. A survey was carried out using a questionnaire during the harvesting period and 1000g of paddy samples were collected in replicates from each mill after drying was completed. The average percentage of fissure kernels and the milling yield was determined in the laboratory.

Two drying methods were used in Guyana: sun drying and mechanical drying. There were various types of mechanical dryers; the column dryer (44.4%) was the most popular among millers. Prior to drying, only 37% of the millers group their paddy according to moisture content (MC); however, during the drying, 81.5% monitored MC. The final MC of the grains significantly affected the percentage of fissure kernels and the overall milling yield (P=0.001). There were no significant differences in the average fissure kernel percentage and milling yield of samples collected from the sun and mechanical drying methods (P=0.598 and P=0.185); however, sun drying was affected by several parameters such as the thickness of the paddy on the drying floor, final moisture content, weather and labour availability.

***Keywords**: sun drying, mechanical drying, moisture content, fissure kernels, milling yield*

Introduction

Rice (*Oryza sativa L*) is classified as a cereal grain and is the third highest cereal produced worldwide after maize and wheat (International Rice Research Institute 2013). In Guyana, rice cultivation began in the eighteenth century when it was first introduced by the Dutch. Since its introduction, rice cultivation has improved and increased tremendously over the last few decades. In addition to meeting local consumption demands, the rice industry is a major source of income for many stakeholders.

Guyana's rice production includes several post-harvest operations i.e. harvesting, cleaning, drying, milling, storage and marketing. Post-harvest losses can occur during any of the different stages in the postharvest operations. These losses may be either quantitative, qualitative and in some cases both.

There has been limited post-harvest research in Guyana, as it relates to the various methods utilized for drying rough rice, and their effects on milling qualities. United Nations of the Food and Agriculture Organization (FAO) states that drying attributed 1-5% of post-harvest losses, due inadequate drying facilities and unsuitable drying conditions. A proper comprehension of the various drying methods and their effects on milling qualities is critical to reduce fissuring and achieve maximum head rice recovery.

Drying reduces the grains moisture content for milling and storage. Rough rice is usually harvested at grain moisture of 22% wet basis (wb) and dried to the final moisture of 12-14%. Any delay in the drying process of freshly harvested grains results in qualitative and quantitative and losses, these include: yellowing or discolouration caused by mold development and heat build-up from respiration; and reduced head rice recovery caused by improper drying conditions.

Drying of Rough Rice (paddy)

Drying is the primary method of grains preservation. Rice grains are hygroscopic; they absorb and release moisture as a result of the relative humidity (RH) and temperature of the surrounding environment. At harvest, grains contain an average of 18-22% moisture content (wet basis), however; moisture of grains can be as high as 30% especially when harvesting is done during the rainy season.

According to the International Rice Research Institute (IRRI), the drying process of rough rice involves: moisture removal and tempering (IRRI 2013). Moisture is found on the surface and interior of the grain. Once exposed to heated air, moisture present on the outer surface of the grain evaporates readily while; internal moisture evaporates at a slower rate since the moisture present will first move to the surface of the kernel before evaporating. Drying of grains is temporarily stopped allowing the moisture within the grain and among the grains, to reach a state of equilibrium. This process of stopping intermittently is called tempering. Tempering ensures grain quality maintenance since it allows for the redistribution of internal moisture in the grain.

Drying methods of Rough Rice (paddy)

There are various methods used for drying rough rice which utilizes different technologies with varying complexity. These methods are divided into two groups: sun and mechanical drying. Sun drying often refers to as traditional drying, utilizes natural sunlight (solar energy) for drying paddy. It does not require fossil fuel for the production of heat energy (heated air), however; sun drying requires a longer period for drying (usually 3- 4 days). Sun drying uses pavements (concrete) or specifically constructed areas for drying rough rice which is usually spread in a thin layer (2-4 cm). These activities attract high operational cost since it is labour- intensive. (Djaeni *et al.* 2013). In addition, sun drying depends on favourable climatic conditions, since drying cannot be conducted when it is raining. Other limitations include temperature control, fungal growth if drying is delayed for prolong periods and damage that may be caused by birds, insects and other animals.

Mechanical dryers expose grains to heated and/or ambient air which lowers the moisture content of the grains to that which is suitable for milling and storage. Mechanical drying reduces operational time; contamination, operational costs, and dependency on the climatic conditions (Djaeni *et al.,* 2013). There are various types of mechanical dryers that are used worldwide and in Guyana; these include: flat/incline bed dryers, re-circulating batch and columnar dryer (continuous flow).

This study focuses on investigating the drying methods utilized by millers in the rice growing regions of Guyana (Regions: 2, 3, 4, 5, and 6) with the aim to determine their effect on the milling quality of rice.

Methodology

Location of Study

This study was conducted in Guyana's rice producing Regions (Regions 2, 3, 4, 5, and 6). Operable mills within these Regions were selected to facilitate the research.

Data and Sample Collection Procedures

A questionnaire was developed to collect information on the various practices involved in the drying of rough rice. During the harvesting season, there were only 27 operable mills in the various rice growing regions. Interviews were done at all operable mills which use the different drying method(s). The drying methods were evaluated and documented. Upon completing the drying and tempering process, three (3) samples of 1000 grams (g) were weighted using a digital scale and collected for each method(s) of drying.

Determination of Moisture content

The Moisture content of all samples was determined using a Kett portable moisture meter. Samples were labeled, sealed and transported to the Guyana Rice Development Board (GRDB) central laboratory for milling analysis.

Fissured kernel determination

One hundred (100) rough rice grains were randomly selected from each sample collected. Each grain was manually dehulled to avoid mechanical damages to the kernel. Using a magnifying glass, brown rice kernels were inspected and fissured line(s) were enumerated as outlined by Hashemi *et al.* (Hashemi *et al*., 2008). The percentage of fissured kernels was calculated using the formula below:

$$Fissured\ \% = 100\ [\ (No.of\ fissured\ kernels)/(No.of\ grains(= 100))]$$

Milling Analysis

Milling analysis was executed in accordance with the GYS 211: Rice Specification, sampling, tests and analysis. (Guyana Rice Development Board 2017, 97). Each collected sample was mixed thoroughly using a Boerner divider, after which 200g of rough rice (paddy) was weighed using a digital scale and dehulled using a laboratory huller (Leroy, MTH- 35) to obtain brown rice which was polished for sixteen (16) seconds, using a laboratory mill (Taka Yama O5), to achieve an average whiteness of 37- 38 degrees. Whiteness was determined using the Kett whiteness meter. Milled rice (recovery) was weighed using a digital scale and recorded. One hundred (100) polished whole grains were randomly selected and measured using a calliper and enumerated to determine the average grain length, which was used to differentiate between the whole (grains that are 75 % intact) and broken grains.

Whole grains were separated from broken grains manually. Grains were weighed and head rice recovery (HRR) was calculated. Head rice recovery was determined using the following formula:

$$Head\ rice\ recovery\ = 100\ [\ (Weight\ of\ the\ Head\ rice)/(Weight\ of\ the\ Paddy\ Sample)]$$

Data Analysis

All statistical analyses, including the means, standard deviation, and graphs were conducted using the SPSS Statistics Base 16.0 program. One-way analysis of variance tests were performed to detect the statistical differences ($P \leq 0.05$) of the paddy samples collected from the various drying systems. The LSD test was used to perform multiple comparisons ($P \leq 0.05$). A regression analysis was done to determine the effects of final moisture content and thickness of paddy on the drying floor for paddy that were sun-dried.

Results and discussions

After harvesting, farmers sell their paddy to different mills, buying centers and in some cases toll millers (farmers or traders) across Guyana. Here the drying process that is essential for milling and safe storage commences. While sun drying is traditionally used for drying, mechanical dryers are becoming very popular. For this research, a total of 27 drying systems were surveyed in Regions 2, 3, 4, 5, and 6 (figure 1).

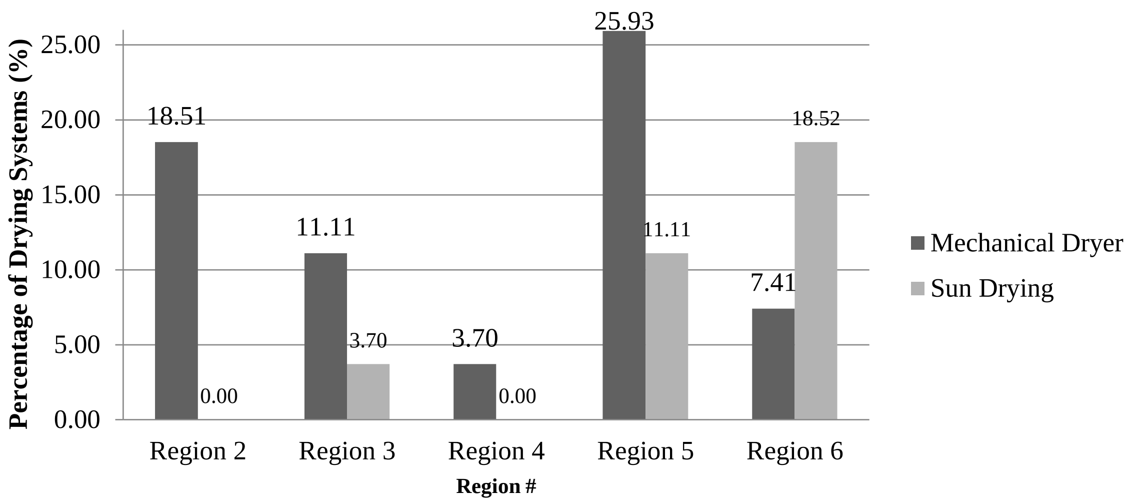


Figure 1: Drying systems surveyed across the rice growing Regions

Ten (10) of the drying systems monitored (37%) were found in Region 5 while only 3.7% were in Region 4. From the total, mechanical drying system accounted for 66.7% (18) while 33.3% (9) were sun dryers (Figure 1).

Years of Operation for both Sun and Mechanical Dryer

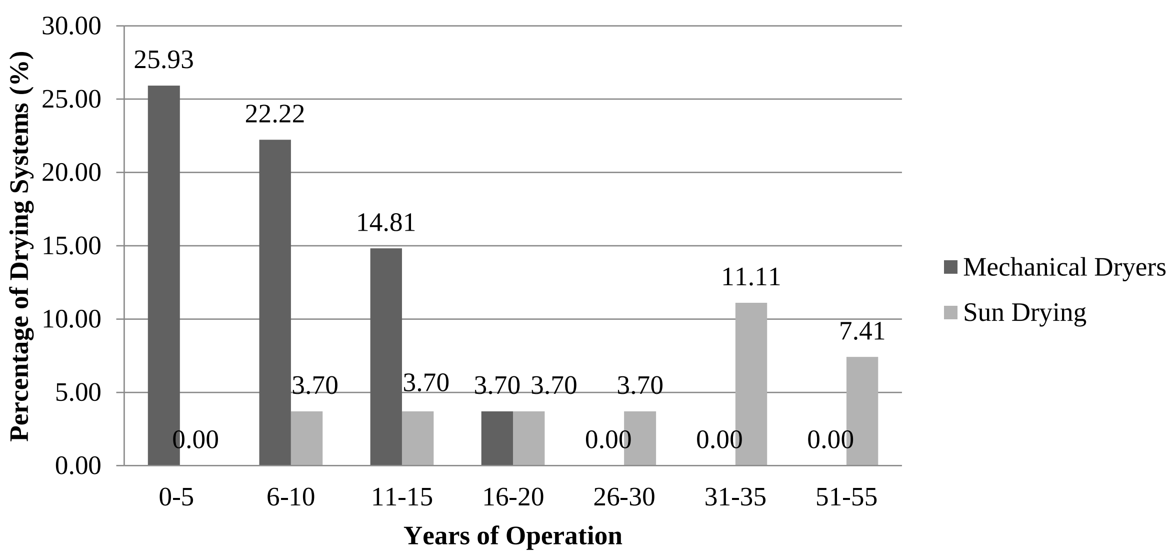


Figure 2: Years of operation for sun and mechanical dryers

The types of dryers or drying systems used at the mills surveyed have been in operation for periods ranging from less than one year to as long as 55 years. The majority of the dryers

(59.2%) surveyed have been in operation for less than 10 years. Only sun drying systems (22.2%) have been in operation for 26 to 55 years.

Before Drying

The majority of mills (63%) stated that they group paddy according to the moisture content when drying and 66.7% (18) mills stated that the paddy is usually cleaned prior to drying (Figure 3).

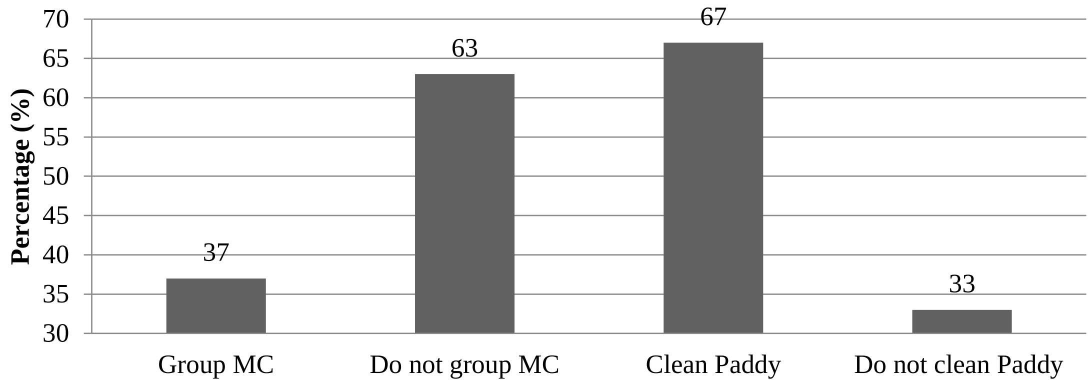


Figure 3: Percentage of mills that group moisture content and clean paddy before drying

Drying Process

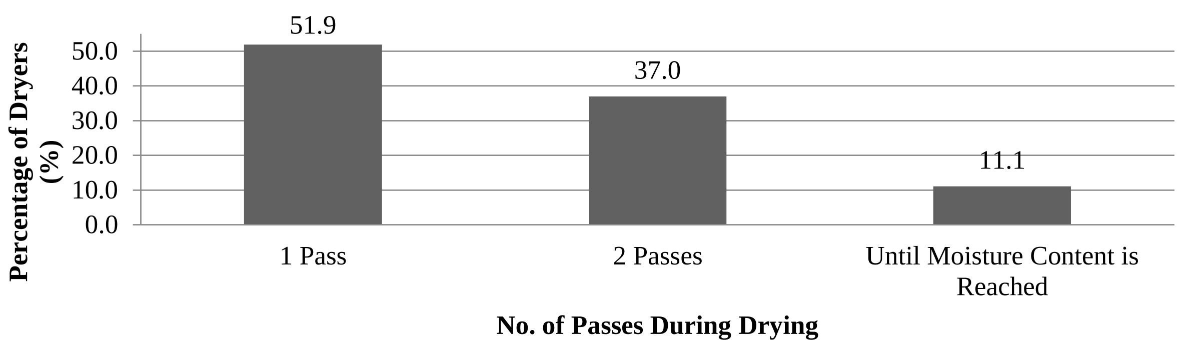


Figure 4: Number of passes during drying

Figure 4 show that most mills (51.9%) pass/dry the paddy once in the drying system when drying, while 11.1% (3) dry until the moisture content is reached.

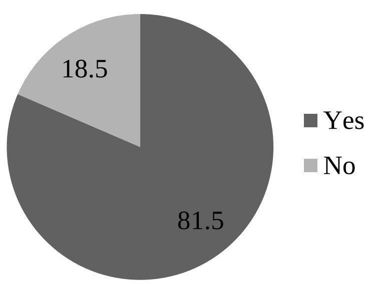
Tempering of Grains

Table 1: Tempering of grains during drying

Tempering	Frequency % (Number)
Tempering for 24 hours then moving paddy to next dryer	3.7 (1)
Tempering for 8 hours then move paddy to next dryer	3.7 (1)
Tempered after drying	85.2 (23)
Tempering for 6 hours then move paddy to next dryer	3.7 (1)
Tempered for 10-14 hours then move paddy to next dryer	3.7 (1)
Total	100.0 (27)

Twenty-three (23) mills (85.2%) temper grains after drying is completed while four (14.8%) temper grains for varying hours in the first dryer then move the grains to the next dryer for further drying.

Monitoring of Moisture Content during Drying



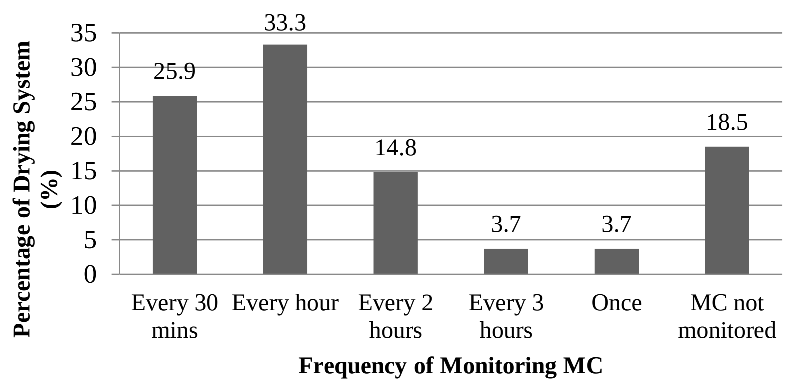


Figure 5: Monitoring of MC during drying

Figure 6: How often is MC monitored during drying

Figure 5 shows that 81.5% (22) of the drying system surveyed stated that moisture content (MC) was monitored while 18.5% (5) do not monitor MC. According to Figure 6, more than half of the millers monitor MC every 30 minutes (25.9%) or every hour (33.3%) when paddy is drying. All millers who monitor MC stated that their moisture meters were calibrated before every crop. For millers that do not monitor MC, the moisture was determined by biting the grain. Final moisture content of grains for the various drying systems varied, with a range of 11.0-14.0%.

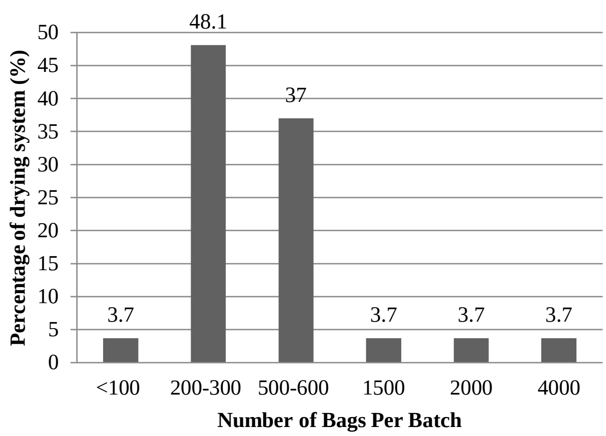
Moisture Content after Drying (Final MC)

Table 2: Final Moisture Content of Grains

Final Moisture Content (%)	Fissure Kernels (%)	Milling Yield (%)
10-11.5	12.67 ± 3.72 a	52.06 ± 2.54 a
11.6-12.5	3.97 ± 4.70 b	57.39 ± 3.91 b
12.6-13.5	3.54 ± 3.75 b	57.14 ± 2.59 b
13.6-14.5	11.88 ± 6.51 a	52.20 ± 5.55 a
≥14.6	25.00 ± 5.00 c	39.72 ± 8.28 c
Total	7.53 ± 7.38	54.73 ± 5.91
P - Value	0.001	0.001

Table 2 shows that the final moisture content after drying significantly affects the fissure kernels (P=0.001) and milling yield (P =0.001). Grains with final MC ranging from 11.6-13.5 recorded the lowest percentage of fissure kernels and the highest milling yield.

Drying Capacity



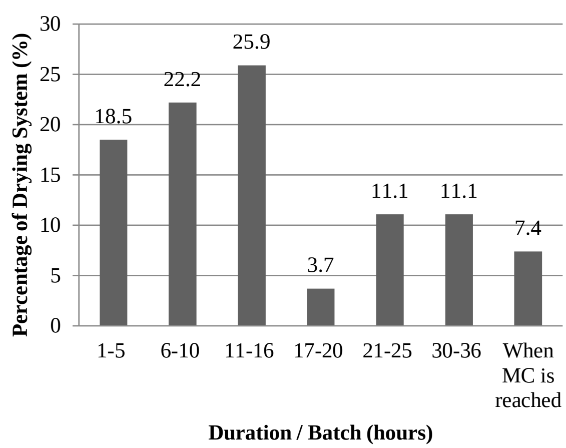


Figure 7: Number of bags per batch

Figure 8: Duration of drying 1 batch of grains

The number of bags that can be dried per batch for each drying system surveyed, varied, with 48.1% (13) having the capacity to dry 200-300 bags per batch (Figure 7). Duration of drying one batch of paddy also differed with the various drying systems. Eleven of the mills (40.7%) took between 1-10 hours to dry one batch of paddy while two mills (7.4%) stated that drying is complete when the desired MC is achieved.

Number of persons required for drying operations

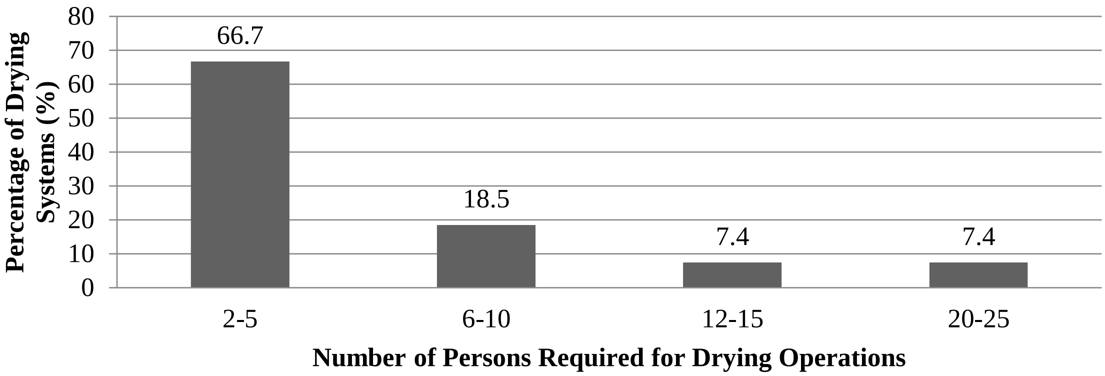


Figure 9: Number of persons required for drying operations

Figure 9 shows that 66.7% of drying systems surveyed required 2-5 workers for their operation.
Drying systems that utilize the sun (33.3%) required more labour for their operation and stated that they required from 6-25 workers while mechanical dryers require approximately 2-5 persons.

Factors Affecting Drying

Table 3: Factors affecting drying

Factors	**Percent of Drying Systems**
Mechanical	66.7 (18)
Weather	25.9 (7)
Weather and Labour Availability	7.4 (2)
Total	100.0 (27)

As expected mills using mechanical dryers only listed mechanical issues as factors affecting their drying system (Table 3). Sun drying on the other hand, was affected by both weather conditions and the availability of labour.

Types of Mechanical Dryers

Based on the survey, it was observed that there are three (3) different types of mechanical dryers utilized namely: column/continuous flow, fluidized flatbed, and inclined bed dryer. In some cases millers/mills use a combination of two mechanical dyers, for example: Fluidized flatbed+ inclined bed dryer or the column + inclined bed dryer.

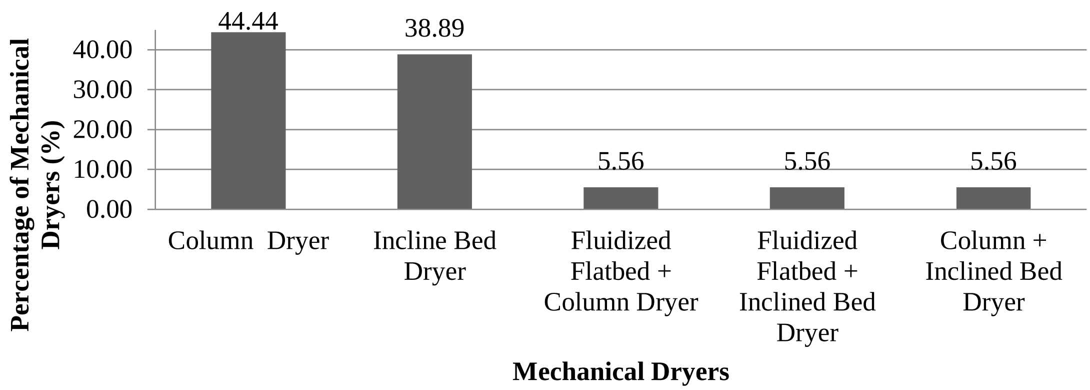


Figure 10: Types of mechanical dryers

The most popular mechanical dryer sampled was the column dryer which accounted for 44.4% (8) (Figure 10). These dryers were imported (55.6%), locally made (38.9%) or a combination of both (5.56%). Column dryers were imported and installed with attached appendages such as grain cleaner and the cyclonic biomass furnace. The brands for the column dryers include Kepler Weber and Superbrix brand. These brands dry grains in a continuous flow, assuring homogeneous and high volume of drying. All inclined bed dryers were locally constructed.

A mechanical dryer consists of three main components; namely: furnace, fan and a drying bin/chamber, which are made up of additional accessories. The furnace, also called the heating system, is used for pre-heating the drying air (International Rice Research Institute, 2008). Mills utilizing mechanical dryers in all the Regions are equipped with rice hull furnaces. Rice hulls are readily available and free and are used as the primary source of fuel.

Sun Drying

Sun drying, also known as traditional drying is widely used in many countries to reduce moisture content in paddy by spreading grains on a concrete surface in the sun. Solar radiation from the sun, as well as the ambient air, heat up the grains, thereby increasing evaporation of moisture from the grains. (International Rice Research Institute, 2013). Sun drying entails a smaller investment than mechanical drying and is environmentally safer, as it uses the sun as a heat source (IRRI 2010).

Nine of the mills (33.33%) surveyed utilized sun drying systems. These mills stated that paddy is dried at various hours during the day; with some mills starting as early as 07:00 hours and finishing as late as 16:00 hours.

Thickness of paddy during the drying process

The IRRI recommended that the ideal thickness paddy should be spread is 2-4 cm and should not exceed 5 cm (IRRI 2010). Thin layers will heat up quicker and result in lower head rice recovery; while too thick layer will cause dry grains to be on top and wet grains at the bottom creating in a moisture gradient (IRRI 2013).

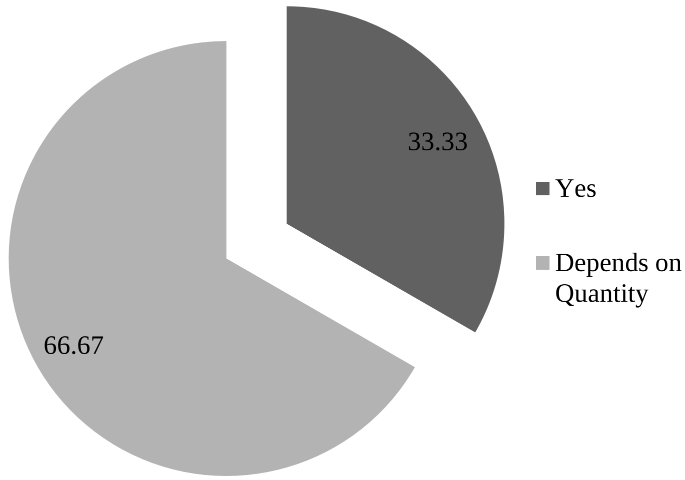


Figure 11: Is the thickness of the paddy the same during sun drying

Six of the millers utilizing the sun to dry paddy (66.7%) stated that the thickness of the paddy on the drying floor depends on the quantity of grains while 33.3% (3) stated that thickness is the same regardless of quantity (Figure 11). The majority (55.6%) of the mills stated that paddy is spread to a thickness of 5-6 cm when drying.

Table 4: The effect of thickness of paddy on drying floor on the percentage of fissure kernels and *milling yield*

Thickness (cm)	**Average Fissure Kernels (%)**	**Average Milling Yield (%)**
3-4 cm	0.83 ± 2.04 a	61.07 ± 0.94 a
5-6 cm	6.67 ± 6.73 b	54.74 ± 4.41 b
≥7 cm	19.17 ± 10.21 c	42.78 ± 9.97 c
Total	8.15 ± 9.32	53.49 ± 8.39
P-Value	0.001	0.001

The thickness of paddy on the drying floor significantly affected the percentage of fissure kernels (P=0.001) and the milling yield (P=0.001) of the samples (table 4). Paddy spread to a thickness of 3-4 cm recorded the lowest fissure kernels and the highest milling yield.

How often is Paddy Stirred

Table 5: Frequency of stirring paddy on the drying floor

Frequency	Percentage of Mills (%)
Once	33.33 (3)
Every 30 Mins	33.33 (3)
Every 45 Mins	11.1 (1)
Every Hour	11.1 (1)
Every 2 hour	11.1 (1)
Total	(100) 9

According to IRRI, paddy that is sun dried should be turned or mixed every 30 minutes or at least on an hourly basis (IRRI 2013). Turning the grains will allow for more uniform moisture content. Table 5 shows that paddy on the drying floor is stirred at various times during drying; with 33.3% of the mills only stirring once. Other mills mixed grains as frequently as every 30 minutes (33.3%), 45 minutes (11.1%), every hour (11.1%) and every 2 hours (11.1%).

Table 6: Regression model for predicting milling yield for sun-dried paddy using thickness and final moisture content

	b	SE b	Standardized b	p-value	Tolerance	VIF
Constant	115.15	14.13		0.001		
Thickness (cm)	-3.14	1.26	-0.49	0.04*	0.90	1.11
Final MC (%)	-3.41	1.11	-0.60	0.02*	0.90	1.11

Dependent Variable: Milling Yield $R^2 = 0.79$, * $p < 0.05$

The model explained 79% ($R^2 = 0.79$) of the variance and was a significant predictor of the milling yield of paddy that is sun-dried, F(2,6)=11.18, p=0.009 (table 6). Multicollinearity among independent variable was indicated by the tolerance, which should be > 0.1 and the variance inflation factor (VIF), which should be: VIF < 10. The table below shows that the tolerance and VIF were within the required range for all variables and so we can say that there was no multicollinearity. Both thickness of the paddy on the drying floor (p=0.04) and final MC (p=0.02) contributed significantly to the model. Based on the beta values, the milling yield for paddy sun-dried decreased by 3.14% for every centimeter (cm) increase in thickness. Milling yield also decreased by 3.41% for every percent (%) increase of final moisture content of paddy on the drying floor.

The final predictive model is:

Milling yield of paddy sun-dried = 115.15 -3.14*thickness -3.41*final MC

Milling Analyses

Fissure Kernel Enumeration and Milling Yield

Grains that were sun dried recorded a higher average percentage of fissure kernels than grains that were dried using the mechanical dryers (7.22 ± 6.27 as compared to 8.15 ± 9.32); however, there were no significant difference (P=0.598). The milling yield of samples collected from the mechanical dryers was higher but not significantly different from samples collected from the sun drying systems (55.34 ± 4.12 as compared to 53.39 ± 8.39) (P=0.185).

Milling Analyses of Mechanical Dryers

Table 7: Fissure kernel enumeration and milling yield of mechanical dryers

Mechanical Dryer Type	Fissure Kernels (%)	Milling Yield (%)
Column Dryer	7.29 ± 4.89 a	55.91 ± 2.98 a
Inclined Bed Dryer	5.95 ± 7.00 a	55.53 ± 4.33 a
Fluidized Flatbed + Column Dryer	18.33 ± 2.89 b	46.89 ± 1.99 b
Fluidized Flatbed + Inclined Dryer	10.00 ± 0.00 a	53.14 ± 1.68 a
Column + Inclined Bed Dryer	1.67 ± 2.89 a	60.17 ± 0.86 c
Total	7.22 ± 6.27	55.34 ± 4.12
P-Value	0.006	0.001

There were significant differences in the average percentage of fissure kernels and the average milling yield of samples collected from the various mechanical dryers (P=0.006 and P=0.001 respectively) (table 7). Samples from the fluidized flatbed and column dryer recorded the highest percentage of fissure kernels and the lowest milling yield (18.33 ± 2.89% and 46.89 ±1.99% respectively).

Conclusion

A total of 27 dryers were surveyed; nine of which utilized sun drying. There were no significant differences in the average milling yield when comparing samples collected from the two drying systems (sun drying versus mechanical drying). However, it was noted that the thickness of the grains during sun drying and the type of mechanical dryers were important in achieving good milling quality. Final moisture of dried grains also affected milling yield; grains with too high and too low final moisture content recorded low milling yield and high percentage of fissure kernels.

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