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Performance evaluation of a locally developed rice dehulling machine

Dauda, Solomon Musa[1]*, Adeoye, Peter Aderemi[1], Bello, Kehinde[2], Agboola[2], Abdulfatai Adesina[2]

[1]*Department of Biological and Agricultural Engineering, Universiti Putra, 43400 UPM Serdang, Malaysia*

[2]*Department of Agricultural and Bioresources Engineering Federal University of Technology, P.M.B. 65 Minna, Nigeria*

Abstract

The performance of a locally fabricated rice milling machine at Federal University of Technology, Minna was evaluated to determine the behavior of different paddy varieties at different conditions during milling. The varieties used were: FARO52, Nerica1 and FARO55 which represent long, medium and short grain respectively commonly grown by Nigerian farmers. Ten kilogram of each variety was fed into the machine and milled at burr speed of 900 rpm. The milled rice were collected at grain outlet and examined for milled, unmilled and broken grains. From the performance test carried out, the milling efficiency, cleaning efficiency, input capacity, output capacity and average percentage of head rice yield obtained were 90.22%, 90.2%, 27.3kg/hr, 16.47kg/hr, and 44.2% respectively. Total losses, grain recovery range, capacity utilization, milling index, milling intensity, milling rate, milling recovery and co-efficient of husking were 2.5%, 97.5%, 60.3%, 53%, 0.137kg/hr, 14.8kg/hr, 48.8% and 94.8% respectively. The effectiveness of the milling machine is said to be dependent on the paddy varieties and sizes, paddy conditions, milling duration, speed of burr and operator's skill. The result of this performance evaluation can be used by future research in performance optimization of this machine and of course any rice milling machine. The results can also be used in modeling performance evaluation of any rice milling machine.

*Corresponding Author: Dauda, Solomon Musa ✉ smdauda@yahoo.com

Introduction

A rice kernel is covered by two layers, the outer layer is called the husk and the inner layer is called bran. The whole rice kernel, including these two layers, is called paddy (rough rice). Husk is not edible and bran reduces the risk luster; therefore, must be removed from the paddy. The husk is not tightly attached to the kernel and easily removed, (Gbabo *et al.*, 2009a). The process of removing the bran is called whitening and pearling. During this process, rice kernels are subjected to intensive mechanical and thermal stresses which might damage or break some of the kernels. Some parameters such as type of whitening machine, the paddy characteristics, and the environmental factors affect the rice kernel damage and breakage during the milling process (Gbabo *et al.*, 2009b). Rice kernel breakage during the milling process is affected by different parameters such as paddy harvesting conditions, paddy drying, physical properties of paddy kernels, the environmental conditions, and the type and quality of the milling system components. Many studies have been conducted in this area. Davis (1994) reported that the optimum harvest moisture content for the paddy of the Caloro variety was 20 to 24%. Dilday (1987) studied the effect of moisture content on rice breakage during the milling process. He used samples with moisture content of 12 to 16% and concluded that rice breakage decreased with increase in paddy moisture content. It was then reported that to have high quality head rice with minimal breakage, paddy must be harvested at the optimum moisture content.

Seguy and Clement (1994) found out that long and tiny rice kernels were more susceptible to breakage during milling process as compared to wide short kernels. Peuty *et al.,* (1994) reported that the paddy drying conditions affect the rice breakage during the milling process so that the rice breakage increased rapidly with decreasing moisture content of the air used to dry paddy. Autrey *et al.,* (1995) showed that the difference between the paddy temperature and the milling environment temperature decrease the performance of the rice milling system. They also found that the relative humidity of the milling environment had a significant effect on milling yield.

Rice quality is largely measured by head rice yield (HRY), which is determined in part by production practices but can also vary inexplicably from year to year and often from field to field, making it difficult for producers to predict income and for processors to minimize waste and to maintain a consistent end product (Dauda and Agidi,2005). It has been shown that high temperatures, particularly during the early reproductive stages of rice plant developments have been linked to kernel quality and chemical composition of the kernel, including decreased kernel weight, decreased kernel dimensions, and an increased number of chalky kernels, (Tashiro and Wardlaw, 1991). Moisture adsorption by low moisture content rough rice has been shown to be major cause of breakage and milling quality reduction thereby reducing the economic value of rice. Jundal and SiebenMorgen (1986) reported significant reduction due to water adsorption of rice with initial moisture contents less than 13%. Milling of paddy is the major process in paddy processing. It removes husk and outer layer of bran so as to produce acceptable white rice with minimum breakage and impurities.

Clean and good quality of paddy can give a yield of 76%. But due to several reasons it has not been possible to achieve 74% yield of rice by traditional methods and machines. Use of modern machines like rubber roll sheller along with improved method of drying, paddy separation, bran removal and graders can give higher out return. The objectives of this work are therefore to evaluate the performance of a rice milling machine on different rice varieties and different paddy conditions and to assess the impact of the milling operation on Head Rice Yield (HRY).

Materials And Method

Cleaning

Ten kilogram each of three popular rice varieties Faro 52 (WITA 4), Nerica 1 and Faro 55 which represent long, medium and short grain respectively commonly grown by Nigerian farmers were cleaned by winnowing, whereby each of the samples was thrown across the direction of natural wind in two open bowls to remove lighter materials like immature grain weed seed, straw and soil particles present in the paddy rice. And also the stones present were handpicked to ensure the readiness of the samples for the subsequent operations. The three paddy varieties were weighed using 50 kilogram capacity weighing machine (Five Goats) and put in different parboiling sacks, labeled and tied. Another 1 kilogram each of the samples was also weighed using the same machine with the readings taken from the graduated circular plate on the machine. The samples were put in another three different sacks labeled accordingly and tied for easy identification.

Soaking
An electric cylindrical boiler was filled with water and connected to the power source. The water was boiled to 75°C and then the three different samples to be parboiled were put in the boiler one variety at a time with water covering it. The rice remained in the boiler for 6 hours and later, the water was drained out, (Gbabo *et al.*, 2008).

Steaming
The Boiler was again filled with water to a level just above its bottom, and on top of the water, a wire net was placed to raise the samples above the water. The samples were then placed on the net and the boiler was closed for steam-heating, and the boiler was connected to the power source. The steaming was done for 40 minutes and the samples were taken out and allowed to temper for 3 hours (aiming at reducing the moisture content to prevent cracking while drying).

Drying
The samples were dried in an electric dryer at 73°C till when 14% moisture content was ensured when

tested in an electronic moisture content tester (steinlite). Then the samples were temper for another 8 hours (aiming at reducing breakage during milling).

Moisture content determination of grain
The key to post-production is correct turning of operations, and grain moisture content (MC).Calculating Moisture Content: Moisture Content (MC) of grains is usually determined on wet basis as:

$$MC_{wet}(\%) = \frac{Weight\ of\ moisture\ in\ wet\ grain}{Weight\ of\ wet\ grain} X\ 100$$

During dry, paddy will loose weight due to loss of moisture. Therefore

$$Final\ weight\ of\ grain = \frac{initial\ weight\ X(100 - MC_{initial})}{100 - MC_{final}}$$

Moisture weight of grain can be measured by using a drying oven or by using commercial moisture tester.

Testing the machine
The type test carried out on the milling machine to prove the conformity with the requirement of relevant standard. The tests carried out include general test, test at no load and test under load. The tests are; checking of specifications, checking of materials and visual observation and provision for adjustment (NCAM, 1990).

Test at load
Test under load was conducted to get the following data: Total losses, milling efficiency, cleaning efficiency, power consumption, input capacity and output capacity. The final sample is now analyzed for cracked and broken grains, refractions, unmilled grains, and clean grains. Analysis for cracked grains and broken grains is only made from the sample taken at the specified grain outlet. Grain losses, milling and cleaning efficiencies are equally obtained.

Determination of total losses

(i)

$$Percentage\ unmilled\ grain = \frac{quantity\ of\ unmilled\ grain\ from\ husk\ (kg)}{total\ grain\ received\ at\ grain\ outlet\ (kg)}\ X100\%$$

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$$Percentage\ of\ cracked\ and\ broken\ grain = \frac{cracked\ and\ broken\ grain\ from\ grain\ outlet\ (kg)}{total\ grain\ received\ at\ grain\ outlet\ (kg)}\ X100\%$$

(iii)

$$Percentage\ of\ blown\ grain = \frac{quantity\ of\ clean\ grain\ obtained\ at\ husk\ outlet\ (kg)}{total\ grain\ output\ (kg)}\ X100\%$$

iv)

$$Percentage\ of\ sieve\ loss = \frac{clean\ grain\ at\ sieve\ overflow + sieve\ underflow + stucked\ grain}{total\ grain\ input\ (kg)}\ X100\%$$

The major component of the sieve loss is the sieve overflow. The loss grain under the sieve was collected by spreading a nylon sack under the machine and checks the losses. The grain obtained was weighed. Both the sieve overflow and stuck grain were also weighed with readings noted and recorded. Total losses are the sum of losses obtained at (i), (ii), (iii) and (iv) above.

Determination of efficiencies

Milling efficiency: This is the ratio of total weight of grain milled to the total weight of grain fed into the machine for milling and expressed as a percentage. It is also the difference between 100% of grain, fed into the machine and the percentage of unmilled grain.

$$Milling\ efficiency\ (ME) = \frac{total\ weight\ of\ unmilled\ grain}{Total\ weight\ of\ grain\ fed\ into\ the\ machine}\ X100\%$$

$$Cleaning\ Efficiency\ (CE) = \frac{clean\ grain\ received\ at\ grain\ outlet\ (kg)}{total\ grain\ received\ at\ grain\ outlet\ (kg)}\ X100\%$$

Determination of output capacity

To determine the output capacity, the weight of milled grain received at specified grains outlet is taken and recorded.

ii)

Routine tests

Routine tests were carried out to check the requirements, which are likely to vary during iii) production or use. These are grouped into essential and optional tests. The essential routine tests are visual observations and provisions for adjustment and tests at no load. While optional routine tests are checking of specifications carried out include the determination of moisture content grain straw ratio, grain length and breadth and length of ears rice crop.

Input and output capacity

In order to evaluate the capacity of the machine cleaner, the input and output streams were carefully timed with a stop watch and rate of output calculated on the basis of the results as presented in data sheet table.

The following can be calculated based on the definition given.

$$Grain\ recovery\ range\ (GRR) = 100\% - Percentage\ total\ loss$$

$$Capacity\ Utilisation\ (CU) = \frac{output\ capacity}{input\ capacity}\ X100\%$$

$$Milling\ index\ (MI) = GRR\ x\ CU\ x\ CE\ (decimal)$$

$$Milling\ intensity\ (MIN) = \frac{power\ consumed\ by\ the\ machine}{output\ capacity}$$

One kilogram (raw and parboiled) paddy of each variety was fed into the hopper, to the rotating shaft, while the discharge outlet remained closed and it was milled for a specific time and at constant adjustment of milling knife and husk screen, different samples of the varieties at different conditions were taken and examined for whole grain (head rice) cracked and broken rice and unmilled.

Results And Discussion

From the various tests carried out on the machine, the following results presented below were obtained.

The result of test at no load

i) No any marked oscillation during operation

Presence of rattling sound due to one of the ribs touching the blade at certain adjustment.

The two-half cylinders requires an elastic material (rubber) in between their surfaces of contact

ii)   There is space left in-between the screen end and the cylinder end.

The results of test at load

The test at load carried out to mill different varieties of paddy rice at different conditions, different amount of head rice were obtained from each of the varieties at different condition after 40 seconds, and at constant milling blade adjustment. Different milling efficiencies were obtained from each of the varieties at different condition and the average of the efficiencies was obtained and presented as the machine performance efficiency. The results of the performance evaluation are presented in tables 1 and 2.

Discussion

It could be deduced that the rate of milling of the machine was efficient compared to the traditional method of milling. The average percentage of head rice yield of 44.2% was obtained which was higher considering the conditions of the paddy rice and when milled locally. The clearance between the milling blade and the ribbed rotating cylindrical shaft affects the milling efficiency of the machine, thereby little reduction in the clearance will increase the milling efficiency, because the machine will be able to mill all varieties of paddy irrespective of their sizes. The efficiency of the machine also reduces when the milling is not correctly timed. Higher milling and cleaning efficiencies than 90.22% and 90.2% respectively cannot be achieved due to the paddy escaping from hopper and mixed with the contents of the milling chamber, and the point on one of the ribs that is higher, which prevents correct blade-shaft clearance adjustment.

From Table 1, it can be seen that the parameters tested for the three rice varieties varied from one another. For instance, milling efficiency ranged from 89.31% to 91.33% for the three varieties while grain recovery range is between 96.5 to 97.7%. Cleaning efficiency varied between 88.9 and 91.2%. From table 2, output capacity varied greatly for unparboiled FARO 55 variety when compared with

values got for other varieties. These results is in line with what previous researchers recorded that milling efficiency, grain recovery range and output capacity of a rice milling machine is dependent upon the variety of rice used (Shitanda *et al.*,2008). Rice researchers have already identified many factors that affect milling quality. These factors were grouped into two major categories: engineering and varietal factors. Engineering factors include harvesting, handling, drying, storage, transport and milling operations while varietal factors include physical and mechanical properties of grains (Firouzi *et al.,* 2010). All these parameters can be varied during performance evaluation and optimization to know their optimum values that will give the machine the best performance.

Table 1. Efficiencies and losses for the machine.

Varieties of rice handled	FARO 52	NERICA 1	FARO 55
Moisture content (%)	15	14	15
Power requirement (kw)	2.25	2.25	2.25
Total losses (%)	2.8	2.5	2.7
Milling efficiency (%)	91.33	90.22	89.31
Cleaning efficiency (%)	88.9	90.2	91.2
Output capacity (kg/hr)	16.42	16.47	16.41
Input capacity (kg/hr)	26.4	27.3	27.6
Grain recovery range (%)	97.7	97.5	96.5
Capacity utilization (%)	60.8	60.3	61.2
Milling index (%)	55	53	53
Milling intensity (kW/hr)	0.227	0.225	0.228
Milling rate (kg/hr)	15.0	14.8	14.9
Milling recovery (%)	49.0	48.8	49.5
Coefficient of husking (%)	95.2	94.8	94.7

Conclusion And Recommendations

From the evaluation test, it has evidenced that the objectives of this project have been achieved because it was clearly shown that different varieties of paddy at the same condition give different output (i.e. when they are parboiled or raw paddy), and again raw paddy is tend to more breakage than parboiled rice at the same milling blade-shaft clearance, thereby the milling efficiency is low when

handling raw paddy which result in low head rice yield.

Table 2. The performance result of the machine on the milled rice.

Amount	RICE VARIETIES					
	FARO 52 (WITA 4)		NERICA 1		FARO 55	
	Parboiled	Unparboiled	Parboiled	Unparboiled	Parboiled	Unparboiled
Weight of grain received at grain outlet (kg)	0.06	0.52	0.58	0.50	0.56	0.48
Weight of the husk and mealy waste(kg)	0.38	0.45	0.40	0.47	0.42	0.49
Weight of Milled rice (kg)	0.57	0.45	0.53	0.44	0.52	0.42
Weight of broken rice in (kg)	0.12	0.37	0.21	0.28	0.17	0.30
Weight of unmilled rice (kg)	0.03	0.07	0.05	0.06	0.04	0.05
Weight of head rice (whole grain) (kg)	0.45	0.08	0.32	0.16	0.35	0.12
Weight of rice fed into the machine (kg)	1.0	1.0	1.0	1.0	1.0	1.0
Weight of husk removed (Kg)	0.32	0.30	0.30	0.34	0.32	0.39
Weight of clean rice in the husk (kg)	0.1	0.1	0.1	0.13	0.06	0.15
Milling duration in (hr)	0.011	0.011	0.011	0.011	0.011	0.011
Speed (rpm)	900	900	900	900	900	900
Input capacity in (Kg/hr)	27.3	27.3	27.3	27.3	27.3	27.3
Output capacity in kg/hr	18.2	15.73	17.55	15.50	17.3	14.55

The milling efficiency of the machine is 90.22%, the cleaning efficiency is 90.2% and total output capacity is 16.47kg/hr, all these show that the machine is good for use since it will reduce the cost of rice processing as compared to imported ones. It is recommended that the height of the machine increased so that the operator will be comfortable while operating the machine. Also, the concave husk screen should be made longer to make contact with cylinder ends to avoid leakage from the milling chamber and the two half-cylinders should be lined with rubber material in their surface contacts to prevent leakage.

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