Comparative Analysis of the Technical Performance of Selected Rice Mills in Bida, Niger State

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***Abstract* —This study was carried out to compare the technical performance of some selected rice milling machines in Bida, in terms of the milling capacity, milling recovery, head rice recovery and broken grains. The rice milling machines used for the study were the NCRI-Nigeria developed steel friction mill with aspirator, a local steel friction mill without aspirator and a Chinese-TORA rubber roller mill. Three rice varieties (an improved cultivar and two local cultivar): Faro44, Babanyagi and Ndawodzufagi (long, medium and short grain types respectively) were parboiled under the same conditions and used for the test. The test was replicated three times for accuracy. It was observed that the Chinese-rubber roll mill performed better compared to the other mills. The Chinese-rubber roll mill had the highest percentage milling recovery of 68.33% - 69.73%, percentage head rice of 62.06% - 68.4% and minimal percentage of broken grains compared to the friction mills. The NCRI-Nigeria mill had a percentage milling recovery of 63.37% - 67.07% and percentage head rice recovery of 53.63% - 58.23%. The Local mill had a percentage milling recovery of 59.07% – 62.40% and percentage head rice recovery of 51.10% - 55.23%. However, the rubber roll mill had the least average milling capacity compared to the other mills.**

Keywords – Rice, Milling machine, Milling capacity, Milling Recovery, Head rice, Broken grains.

I. INTRODUCTION

A rice kernel is covered by two layers. The outer layer is calledthe husk or hull and the inner layer is called bran. The whole kernel, including these two layers is called paddy or rough rice (Afzalina et al., 2002).Husk is not edible and bran reduces the rice luster; therefore, they are removed from the paddy. The weight of hull is 18 – 22 % of the total weight of paddy grain. The endosperm weighs about 70 – 72%, whereas 4 – 6% bran is removed during polishing. Rice, unlike most other cereals, is consumed as a whole grain. Therefore, quality characteristics and general appearance of a given rice variety is of utmost importance (Diack et al., 2010, Danbaba et al., 2013).

Milling of paddy is a crucial step in post-production of rice. The basic objective of a rice milling system is to remove the husk and the bran layers, and produce an edible, white rice kernel that is sufficiently milled and free of impurities(Rickman J.F. and GummertM., 2004).Depending on the requirements of the customer, the milled rice should have minimum broken kernels.

Rice is milled by removing the husk to obtain 'brown rice' and gently polishing off the bran to obtain a whole milled grain. It involves hulling and polishing, that is,the application of load to the kernels in order to remove the bran and germ (Lu and Siebenmorgen, 1995). Hulling involves the removal of husk from the Paddy with minimum damage to the grain and separating the husk from the Paddy to produce brown rice. Polishing on the other hand refer to the process of removing the 'Subaleurone' layer after whitening to give the rice grains a shiny appearance(Diack et al., 2010).The degree to bran layer is removed is known as the milling degree. The rice miller assesses the quality of milled rice upon the total recovery and the proportion of broken and head rice on milling.

The performance of a rice mill in terms of milled rice recovery and quality does not only depend on the type or condition of the equipment and the skill of the operator, but it largely depends on the quality of rough rice to be converted into milled rice.The milling behavior of rice varieties has been considered to be one of the most important components of quality (Karim et al., 2011). Biswas et al., (1992) reported that recovery from modern varieties range from 69 to 73% and any result less than 67% is not economically acceptable (Dipti et al., 2003).

Rice milling equipment has developed over the years from the primitive method of pounding the paddy in a wooden mortar with pestle, followed by winnowing to the use of conventional and modern rice milling machines.Shwetha et al. (2011) showed that poor capacity utilization of rice milling units' results in poor performance, therefore modernization of rice mills with the adoption of improved technology is a necessity.Therefore, thestudy was carried out to compare the technical performance of selected rice mills in Bida local government area, based on yields and quality of rice milled and to ascertain the need for the modernization of rice milling machines in Bida.

A. Description Of Rice Milling Machines

i. NCRI-NigeriaDeveloped Rice Mill:

The National Cereals Research Institute's (NCRI) rice mill is a single-pass, friction type rice milling machine made up of a frustum hopper, milling chamber, husk aspirator, spout and power unit. The milling chamber is comprised of a milling cylinder that is enclosed within a half cylindrical casing on the top and sets of screen at the lower side. Power to the milling cylinder and husk aspiration units are supplied by a 15hp electric motor through pulleys and belts.The dried rough rice is put into the machine through the hopper while the shutter is closed. The machine is then put on for 2-3 minutes before releasing the shutter slowly for the rice to be dehusked in the first pass. Proper dehusking is ensured by adjusting the pressure device at the spout. The dehusked rice is then polished in a second pass using the same procedure. An aspirator siphons the husk out of the machine while a blower incorporated at the spout separates lighter impurities and bran from the polished rice.

Fig. 1 NCRI Developed Rice Mill

ii. Local steel friction type mill without Aspiration Unit

The mill is also a single-pass rice milling machine that converts rough rice into milled rice through a fast-running horizontal, cast-steel cylinder provided with hard steel obstructions in the milling chamber. The lower half of the cylinder working chamber is provided with a hard steel screen with perforations. An adjustable steel blade, positioned at the lower half of the machine and parallel to the cast-steel cylinder introduces the necessary resistance and friction. It is powered by a 30hp electric motor through pulleys and belts. Unlike the NCRI developed rice mill, it doesn't have the aspiration and blower units.

Rough rice enters the milling chamber of the machine through a hopper. At the point of entry, the cast steel cylinder has inclined hard steel obstructions, partly to function as a horizontal feeder but mainly to introduce obstructive forces through friction, resulting in dehulling of rough rice. The dehulled rice comes out of the collection outlet with the hull; it is therefore passed through the milling chamber 3-5 times before obtaining a clean polished rice grain.

Fig. 2Local steel friction mill without Aspiration Unit

iii. TORA-ChineseRubber Roll Huller with Aspiration Unit

This mill is made up of two rubber rollers of different diameters: 130mm and 145mm, operating at different speeds to remove the husk from the paddy. One roller has a fixed position and the other is adjustable to meet the desired clearance. The adjustable roller rotates slightly slower than the fixed roller. It has an aspirator at the base of the machine to separate the hulls from the brown rice. The correct clearance is dependent on the varietal characteristics and the width and length of paddy.

Fig. 3 Rubber Rolls Huller with Aspirator Unit

II. MATERIALS AND METHODS

Three rice varieties weighing 10kg each were used: two local cultivars: Ndawodzufagi, Babanyagi (short and medium grain types respectively) and an improved cultivar: Faro 44 (long-grain type). The analysis was done with parboiled paddy. The paddy samples were winnowed to remove thrash, soaked at 70^0c for 8 hours and steamed for 40 minutes. The samples were dried to a moisture content of between 13%. The moisture content of the paddy was taken with a resistance type moisture meter (IRRI moisture meter).

The paddy samples were then milled with the milling machines. Before milling each of the samples, a trial run was carried out with the same lot of paddy that was to be put through the mill. This allowed setting of units, filling of empty spaces, flushing of previous lots of rice, approximating the adjustment of the clearances of the hullers and ascertaining that the mill was in a fit condition to carry out the test. After the trial run, the weighed sample of paddy was passed once in the Chinese rubber roll mill, twice in the NCRI-Nigeria developed mill and three to four times in the local mill for dehusking and polishing of the paddy samples. Three replications were done for each experiment, that is, for each grain type. The times taken to dehusk and polish each sample were recorded. Also the records of the mill products for each replication were taken.(Tables 1, 2 and 3)

After weighing and sorting, the following parameters of the milling process were calculated using the following equations:

$$Milling\ \ Capacity\ (kg/hr) = \frac{weight\ of\ \ paddy\ sample}{milling\ \ time}$$

$$Milling\ \ \text{Recovery}(\%) = \frac{weight\ of\ \ milled\ \ rice}{weight\ of\ \ paddy\ sample} \times 100$$

$$Head\ \ Rice\ \ \text{Recovery}(\%) = \frac{weight\ of\ \ milled\ \ head\ \ rice}{weight\ of\ \ milled\ \ rice} \times 100$$

$$Percentage\ \ Broken(\%) = \frac{weight\ of\ \ broken\ milled\ \ rice}{weight\ of\ \ milled\ \ rice} \times 100$$

III. RESULTS AND DISCUSSION

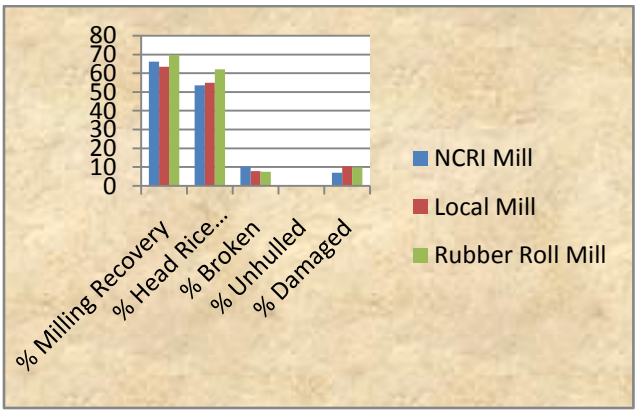

Fig. 4 Comparison of the rice mills using Faro44 (long grain variety)

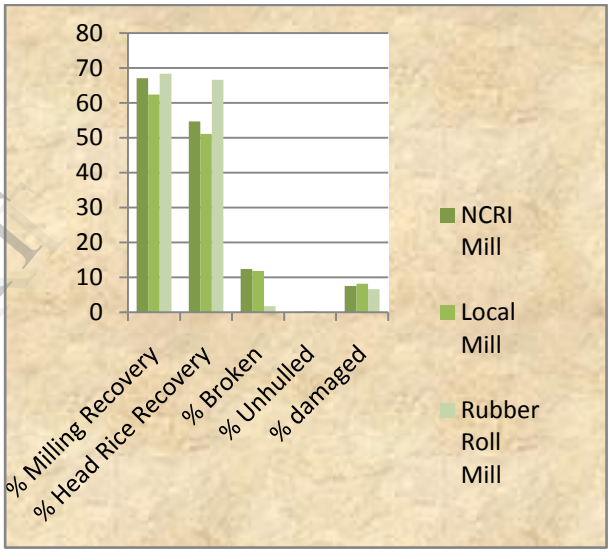

Fig. 5 Comparison of the rice mills usingNdawodzufagi (short grain variety)

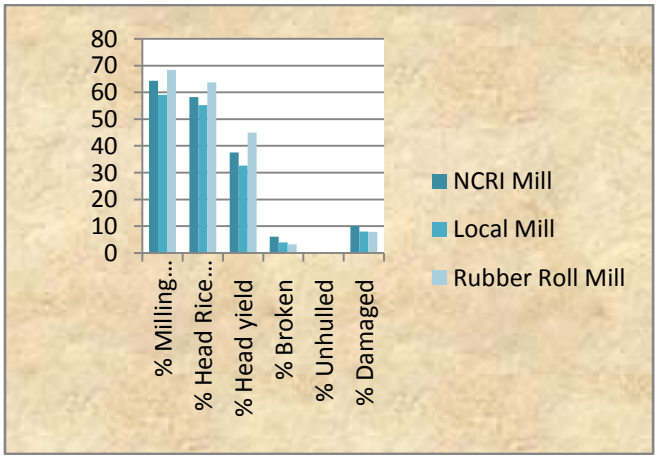

Fig. 6 Comparison of the rice mills using Babanyagi(short grain variety)

Local MillChinese Rubber Roll

NCRI-Nigeria Milled Rice

Fig. 7 Milled rice from the milling machines

A. *Milling Capacity*

For the grain types used in the test, the Chinese-rubber roll mill had an averagemilling capacity of 99.97kg/hr., which is the least of the rice mills used in the test. The NCRI-Nigeria developed mill had an average of 114.07kg/hr., and the local mill had an average of 211.7kg/hr. However, the local mill was powered by an electric motor with 30hp rating, while the others used a 15hp electric motor. It can therefore be inferred that the higher the power of the electric motor, the higher the milling capacity.

B. *Percentage Milling Recovery*

The milling recovery is significantly influenced by the milling degree (the extent of polishing the rice kernel). The milling recovery is higher with the Chinese-rubber roll type compared with the friction type rice milling machine.The Chinese-rubber roll mill had the highest percentage grainrecovery of 68.33% - 69.73%; this still falls in the recovery range reported by Biswas et al., (1992).That is, 69% to 73%,compared to the NCRI-Nigeria mill, which had percentage milling recovery of 63.37% - 67.07% and the local mill, which had a percentage milling recovery of59.07% – 62.40%.

C. Percentage Head Rice Recovery

Head rice recovery is the proportion of whole grains in the milled rice. From the testresults,the Chinese-TORA rubber roll milling machine had the highest percentage of whole grains of 62.06% - 68.4%. The NCRI-Nigeria milling machine had a percentage head rice recovery of 53.63% - 58.23% and the local milling machine had a percentage head rice recovery of 51.10% - 55.23%. The values were lesser with the steel friction mills because with increased pressure, milling degree increased which polished the rice more and hence the broken grains increased as more friction is inserted between the rice and the shaft. The rice head yield which is based on the milling recovery also decreased with increasing milling degree.

D. Percentage Broken

The local milling machine had the highest percentage of broken grains compared to the other milling machines; this can be attributed to the higher capacity of the electric motor and the vibration of the machine during milling. Also the broken grains increased as friction is increased between the rice and the shaft. Hence, the rubber roll milling machine had the least percentage broken grains.

IV. CONCLUSION

The study showed that the rubber roll mill, which is a modern type of rice mill, has the highest performance in terms of grain recovery, head yield and least broken grain followed by the NCRI developed milling machine which has an aspiration unit and the local steel friction mill without an aspiration unit. The rubber roll mill is expensive and may not be affordable for the small and medium scale rice millers in Bida. The NCRI developed milling machine has an aspiration unit that ensures cleaner rice output, recovers more than the local milling machine with lower broken rice.

Table 1: Comparison of the rice millsusing a Faro 44 (long grain) variety

NCRI-Nigeria mill				Local mill				Chinese -rubber roll mill			
	Rep 1	Rep 2	Rep 3	Avg	Rep 1	Rep 2	Rep3	Avg	Rep 1	Rep 2	Rep3	Avg
Weight of paddy sample (kg)	10.00	10.00	10.00		10.00	10.00	10.00		10.00	10.00	10.00	10.00
Milling time (s)	6.26	5.63	5.38	5.75	3.14	2.52	3.05	2.90	6.17	6.15	6.22	6.18
Total milled rice (kg)	7.38	5.98	6.48	6.61	5.59	6.04	6.34	5.99	7.18	6.86	6.88	6.97
Head rice (kg)	5.71	4.89	5.49	5.36	4.82	5.28	5.49	5.19	6.00	6.39	6.23	6.20
Broken grains (kg)	1.32	0.81	0.94	1.02	0.77	0.76	0.85	0.79	1.17	0.46	0.65	0.76
Unhulled grains (kg)	0.02	0.03	0.03	0.03	0.02	0.02	0.04	0.02	0.01	0.01	0.02	0.01
Damaged grains (kg)	0.09	1.27	0.76	0.70	1.20	1.10	0.8	1.03	0.70	1.40	0.86	0.98
Percentage milling recovery (%)	73.80	59.80	64.80	66.13	55.90	60.40	63.40	59.90	71.80	68.60	68.80	69.73
Percentage head rice recovery (%)	57.10	48.90	54.90	53.63	48.20	52.80	54.90	51.96	60.00	63.90	62.30	62.06
Percentage head yield (%)	42.14	29.24	35.57	35.65	26.94	31.89	34.81	31.21	43.08	43.80	42.90	43.26
Percentage broken (%)	7.70	7.60	8.50	7.93	13.0	8.10	9.40	10.23	11.70	4.60	6.50	7.60
Percentage unhulled (%)	0.20	0.30	0.30	0.26	0.20	0.20	0.40	0.26	0.10	0.09	0.15	0.11
Percentage damaged (%)	0.90	12.70	7.60	7.06	12.00	11.00	8.00	10.33	7.00	14.0	8.60	9.86
Average milling capacities kg/hr	105.2				206.8				97.06			

Table 2: Comparison of the rice mills using Babanyagi (medium grain variety)

NCRI-Nigeria mill					Local mill				Chinese -rubber roll mill			
	Rep 1	Rep 2	Rep 3	Avg	Rep 1	Rep 2	Rep3	Avg	Rep 1	Rep 2	Rep3	Avg
Weight of paddy sample (kg)	10.00	10.00	10.00		10.00	10.00	10.00		10.00	10.00	10.00	10.00
Milling time (s)	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Total milled rice (kg)	5.52	5.36	5.44	5.44	3.25	3.13	3.48	3.29	6.02	5.42	5.12	5.52
Head rice (kg)	6.65	7.09	6.38	6.71	6.20	5.90	6.62	6.24	6.85	6.83	6.82	6.83
Broken grains (kg)	5.56	5.92	4.93	5.47	5.07	5.02	5.24	5.11	6.72	6.66	6.61	6.66
Unhulled grains (kg)	1.09	1.17	1.45	1.24	1.30	0.88	1.38	1.19	0.13	0.17	0.21	0.17
Damaged grains (kg)	0.01	0.01	0.02	0.01	0.01	0.01	0.06	0.03	0.00	0.00	0.00	0.00
Percentage milling recovery (%)	0.64	0.78	0.82	0.75	0.90	1.00	0.58	0.83	0.62	0.55	0.82	0.66
Percentage head rice recovery (%)	66.50	70.90	63.80	67.07	62.00	59.00	66.20	62.40	68.50	68.30	68.20	68.33
Percentage head yield (%)	55.60	59.20	49.30	54.70	50.70	50.20	52.40	51.10	67.20	66.60	66.10	66.63
Percentage broken (%)	36.97	41.97	31.45	36.80	31.43	29.62	34.69	31.91	46.03	45.49	45.08	45.53
Percentage unhulled (%)	13.00	8.80	13.80	11.87	10.90	11.70	14.50	11.87	1.30	1.70	2.10	1.70
Percentage damaged (%)	0.10	0.07	0.20	0.12	0.09	0.07	0.60	0.25	0.00	0.00	0.00	0.00
Average milling capacities kg/hr	110.20				182.56				108.69			

Table 3: Comparison of the rice mills using Ndawodzufagi (short grain variety)

NCRI-Nigeria mill					Local mill				Chinese -rubber roll mill			
	Rep 1	Rep 2	Rep 3	Avg	Rep 1	Rep 2	Rep3	Avg	Rep 1	Rep 2	Rep3	Avg
Weight of paddy sample (kg)	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Milling time (s)	4.50	4.34	5.37	4.74	2.30	2.53	2.51	2.45	6.36	6.37	6.39	6.37
Total milled rice (kg)	6.68	6.28	6.35	6.44	5.98	5.78	5.96	5.91	6.55	6.95	7.02	6.84
Head rice (kg)	6.06	5.65	5.76	5.82	5.61	5.45	5.51	5.52	6.18	6.41	6.54	6.38
Broken grains (kg)	0.62	0.62	0.61	0.62	0.37	0.38	0.45	0.40	0.28	0.34	0.35	0.32
Unhulled grains (kg)	0.02	0.02	0.01	0.02	0.03	0.02	0.02	0.02	0.003	0.003	0.003	0.003
Damaged grains (kg)	0.83	1.15	1.04	1.01	0.70	0.70	1.00	0.80	0.81	0.72	0.84	0.79
Percentage milling recovery (%)	66.80	62.80	63.5	64.37	59.80	57.80	59.60	59.07	65.5	69.50	70.20	68.4
Percentage head rice recovery (%)	60.60	56.50	57.60	58.23	56.10	54.50	55.10	55.23	61.80	64.10	65.4	63.8
Percentage head yield (%)	40.48	35.48	36.58	37.51	33.56	31.50	32.84	32.63	44.55	44.55	45.91	44.97
Percentage broken (%)	3.70	3.80	4.50	4.00	6.20	6.20	6.10	6.17	2.80	3.40	3.50	3.20
Percentage unhulled (%)	0.20	0.20	0.10	0.17	0.30	0.20	0.20	0.23	0.03	0.03	0.03	0.03
Percentage damaged (%)	7.00	7.00	10.00	8.00	8.30	11.40	10.40	10.07	8.10	7.20	8.40	7.90
Average milling capacities kg/hr	126.80				245.90				94.16			

Note: (Rep → Replication)
(Avg. → Average)

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