PALGO JOURNAL OF AGRICULTURE
ISSN 2476-8359
Volume 3 Issue 3,June 2016.Page 156 - 165
http://www.palgojournals.org/PJA/Index.htm
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PERFORMANCE TESTING OF THREE RICE MILLS AND THEIR EFFECT ON IMPORTANT RICE VARIETIES ADAPTED IN ETHIOPIAN RICE FIELDS

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Accepted 28 May, 2016

An experiment was conducted to evaluate the performance of three rice-milling machines. Two of the machines were imported while the third one was locally manufactured on the basis of a prototype obtained from Nigeria. Four common and popular local varieties of rice were used during the evaluation. Machine performances, in terms of total and specific throughput, machine capacity, percentage milling yield, milling recovery, whole and broken grain, and grain loss,were evaluated. In terms of mean throughput, specific throughput and machine output Jet Rice Mill (JRM) was found to be the most effective machine compared with the remaining two. However, the overall mean percentage-milling yield (MY) was highest for Rubber Roller Sheller Mill (RRSM) than the other two machines in which its mean percentage-milling yield was 4.30 and 7.20 % higher than the corresponding values for JRM and the local rice whitener (SRW), respectively. And, more generally, values of mean percent milling yield, milling recovery, milling loss and whole grain output, indicated that RRSM is the most efficient and effective machine compared with the remaining two. However, variety had significant effect on the performance of the machines. Furthermore, Milling quality of the rice varieties studied, in terms of parameters listed above, in general has shown consistent trained in that highest quality was that of the local X-Jigna variety, generally followed by Tigabe, Kokit, and Gumara in descending order. The result of this experiment has hence confirmed that under the specific test condition used, the RRSM has better overall performance among the three machines. Besides it was also observed that the local X-Jigina variety has better milling quality among the test varieties used.

Key words: Rice varieties, milling quality, rice mills

INTRODUCTION

Rice (Oryza) is one of the most important cereal crops growing in tropical regions. Globally, rice is a very important food crop consumed as healthy and staple food by more than half of the world population. It is consumed by over 4.8 billion people in 176 countries in the world(Daramola,2005;Huang, et al 2012). Compared with other cereals, rice production is regarded as the most rewarding in terms of energy production per-unit area (Ali and Talukder, 2006). Its high yield (second to maize), availability of a number of varieties adaptable to many environmental conditions, its ability to grow in swampy and marginal areas unsuitable for many cereal crops, and its high market price are some of the outstanding merits of this crop. Rice is also nutritious, and suitable to prepare different types of meals (Shakeelur, et.al, 2006). Rice was not popular crop in Ethiopia. However, there are vast areas suitable for rice production in the country and some species of wild rice has been growing naturally in *Gambela* and *Fogera* (Gashaw, 1989). Following the observations made on the wild relatives of rice variety adaptation trials were initiated in 1960s (IAR, 1980) as the result of which production levels of 36 - 85 Q ha^{-1} had been recorded from some sites of *Fogera* and *Gambela* (Gashaw, 1989). Production of rice in the country, at considerable level, began in early 1970's and the area coverage, though not consistent, has been increasing since then.

The impact of this resent rice production is more profound in Fogera area, Amhara Regional State, in which case rice continued to grow as a staple crop replacing other crops. Some rice varieties suitable to the agro-ecology had been developed and introduced to the farming community. The crop is also found to be suitable to make most of the traditional foods such as *injera, dabo, genfo*, *kinchae*, and local beverages such as *tela* and *areki.* This facilitated its adoption and dramatic economic gains with accompanying social and cultural changes are witnessed in the Region through the introduction of rice. There are different makes and models of rice milling machines introduced by private entrepreneurs in Fogera. These machines were imported mainly from China and Japan. The introduction of these machines can be regarded as an important contribution towards rice production, processing, consumption and marketing in country. Nonetheless, one should not ignore the effect of machines on the quality and quantity of processed product. Varies research undertakings indicate that milling loss could be as high as 25% of the mass of the grain out of which the machines effect will be the main one. Besides, chemical composition losses as high as 22% protein, 5% starch, 89% crude fiber, and 83% fat, could occur due to milling(Kunlun et al,2009). Despite differences in size and design, the main purpose of any rice-milling machine is to produce white and whole grains essentially free of any foreign material and contain a few broken kernels. The level of achievement of this intended product depends, among others, on the nature of rice kernels to be milled (variety) and design and adjustment of the milling machine. Natural property difference of varieties results in products of high or low quality, overall grain recovery and proportion of broken grains. Besides, as machines differ in design and operational principles, these inherent differences results in processed product differing in quality as well as quantity(Mohapatraand Satish, 2009; Saeed, et al. 2010) .Thus, Ethiopia, as a new rice producing country, should learn from others where rice has been grown as traditional crop and take the necessary measures to prevent machine related milling problems. Testing and evaluations undertaken on the performances of available machines and their qualitative and quantities effects up on milled rice grains will give this benefit. It also helps in strengthening the selection, adaption, demonstration, and dissemination of rice processing machines and improvement or development of particular design in the future. Furthermore, similar studies on the milling quality of rice varieties will assist the selection and genetic improvement programs in the country. Thus this study was conducted based on the following objectives;

i. To evaluate the performance of two imported and one locally manufactured rice milling machines using four commonly grown rice varieties;
ii. To determine some milling related properties of important rice varieties grown in Amhara region

MATERIALS AND METHODS

Location

Performance evaluation of the machines was performed at Woreta, 50 km North East of Bahir Dar, the center of the Amhara Regional state. Laboratory works other than the chemical analysis of varieties were made at Bahir Dar University food laboratory, Bahir Dar Agricultural Mechanization Research Center and at Haramaya University.

Milling machines

Three huller mills were tested;Selam made screw roller type huller (SRW), N-50 series Jet Rice Mill (JRM) and SB-10D Rubber Roll Sheller Mill (RRSM) and whitener.

- **‘Selam’ Rice Whitener SRW**

This machine is a modified version of ARCEDEM made prototype which was brought from Ibadan, Nigeria. Itis about 1100 mm in length, 730 mm wide and 1100 mm high at working condition. It is driven by rope start, oil cooled single cylinder type Gasoline Engine EY 28. The Engine rated power is 5 kW and rated speed of 4000 rpm.Its working principles are as that of a horizontal friction whitener in which paddy will first be dehusked and the resulting brown rice is whitened in only one pass (Fig. 1).

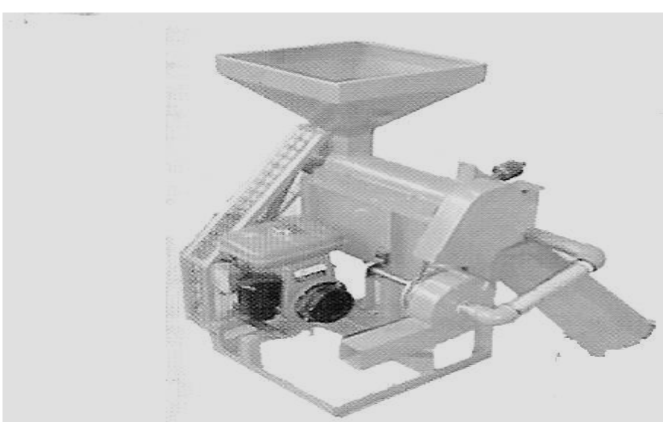

Figure 1 Selam (Vocational Training Center) made Rice Whitener (SRW)

- **Jet Rice Mill (JRM)**

Is one of the 'IINGHUA' brand 'N' series rice milling machines. It is made by SHANDONG JINGHUA Machinery (group) Co.,LTd, TANCHENG Agricultural Machinery Workers.The machine is used as combination miller, combining dehusking and whitening processes.The overall dimension of the machine is 150x404x1130 (mm^3). Electric motor Type Y 132 N-4 having 7.5 kw and 1450 RPM rated power and speed respectively, drives it. This machine is the most popular and widely used machine in the study area (Fig. 2).

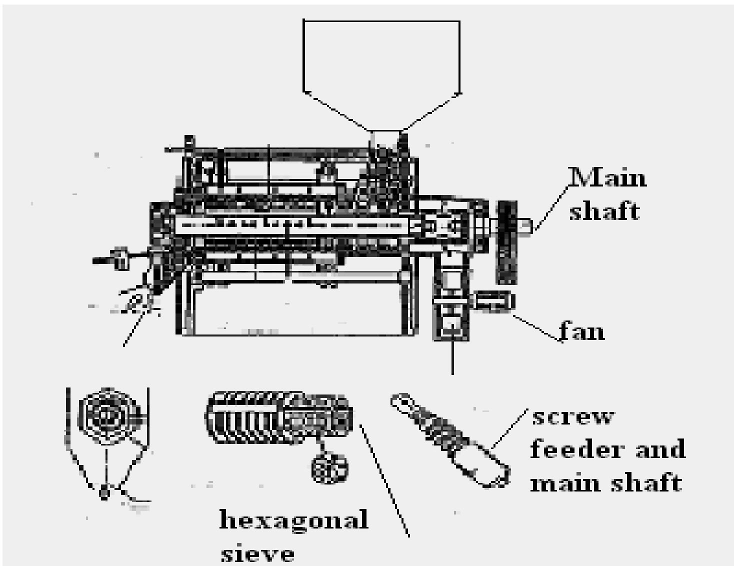

Figure 2 Exploded section view of N- 50 Series Jet Rice Mill (JRM)

- **Rubber Roll Sheller Mill (RRSM)**

The tested version was type- Model SB-10 rubber roller mill. JianguJinggu Rice Mill Company LTD produced it. The machine is consists of two rubber roller unit for dehusking of paddy, a horizontal rotor friction type milling or whitening units, and a cleaning mechanism.The machine was driven by15 HP electric motor. The overall dimension of the machine is 760×730×1235 (l×w×h) (mm) and weighs 195 kg out of the prime mover. This machine is now becoming known and some milling machine owners are using it as an alternative for JRM in the study area (Fig. 3).

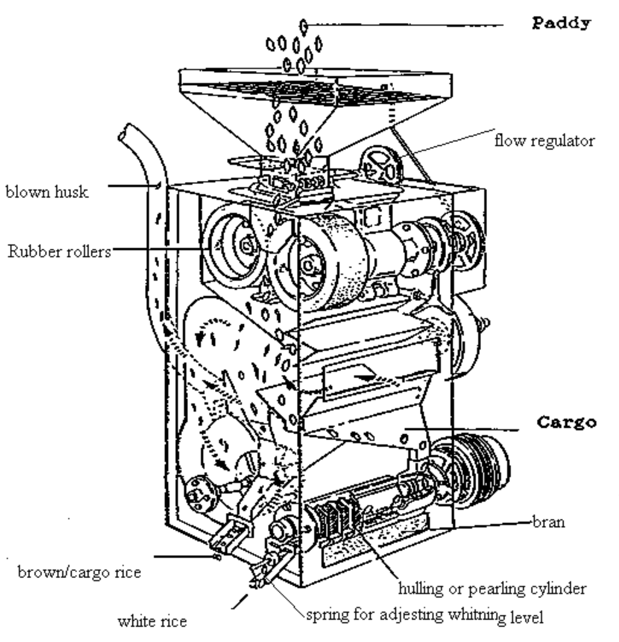

Figure 3 Internal views of Rubber Roll Sheller Mill (RRSM)

Machine adjustment

The local (SRM) machine has been optimized by some calibration trials to determine optimum settings prior to testing while the two commercial machines were set by the operators based on their customers' preference for better quality rice.

Determination of Machine Performance

To determine machine performances pre-cleaned paddy sample weighing 3 kg from raw rice were used in a given test run from each variety. Three replications were made for each test category. Time of start and completion was recorded using stopwatch. Materials from all accessible outlets were collected in labeled polyethylene bags. Samples collected from grain outlets were manually winnowed to remove impurities and bran. The clean milled rice was weighed to determine the mass of bran and impurity removed for determination of cleaning efficiency. From separated clean samples, unhusked grains were removed manually and weighed. This weight of unhusked grain was used to determine milling efficiency of each machine. The remaining mass composed of broken and whole sized kernels was clean milled rice. From these clean milled rice samples, three 100 g sub-samples were taken randomly after through mixing and progressively quartering of the bulk. Each sub- sample was sieved using 1.14 mm opening sieve to separate brewery rice. The remaining sub-samples were fractionated in to whole (unbroken), and broken grain. The weight of each fraction was determined using digital balance and the mean value of the three measurements was reported.

Study varieties

Out of the popular and economically important rice varieties, four were used in this study. They were IAC- 164 /*Gumara*/, IRAT- 209 /*Kokit*/ IREM-194 /*Tigabe*/, and the local variety called *X-Jigna*. The first three varieties were obtained from Adet Agricultural Research Centre (AARC) while sufficient amount of *X-Jigna* was bought from rice millers in Woreta town. All the varieties were of 2004/2005 production year harvests. Based on measurements made on brown rice grains and FAO standards (FAO,1970), *Gumara, Kokit*, and *Tigabe,* having mean length of6.19, 6.25, and 6.34 mm and length to width ratio of 2.32, 2.21, and 2.19 , respectively, are long and bold (LB) varieties. But *X-Jigna with* mean length of 5.39 mm and length to width ratio 1.81is medium round variety (MR).Geometrical mean diameter of *Gumara*, *Kokit*, *Tigabe*, and *X-Jigna* were 3.22, 3.21, 3.25, and 3.17 mm, and the sphericity, 0.52, 0.51, 0.51, and 0.59, respectively.

Performance indicators studied

The following evaluation parameters were used for performance assessment

- Paddy Throughput (kg/h)= $\frac{W_p \times 3600}{T_N}$ …………………………………. (1)
- Specific throughput (kg/Kw-h)= $Paddy\ throughput\,(kg\,/\,h) \big/ Rated\ power\,(kW)\ of\ drive$ ……….(2)
- Milling Capacity (Kg/h) = $\frac{W_m \times 3600}{T_N}$ ………..……………………………(3)
- Milling Yield (MY)(%) = $\left(W_m \big/ W_p \right) \times 100$ ………………………………. (4)
- Percentage whole grain (PHG) PBG = $\frac{Wh}{W_M} \times 100$ ………….……………(5)
- Thousand grain weight loss (TGWL) TGWL = $\frac{(W1 - W2)}{W1} \times 100$ …………(6)
- Percentage milling loss (PML) PML = $(100 - Milling\ Recovery - 4)$ %...... (7)

Where;
Wp – Total weight of sample paddy milled (Kg) adjusted to 14% moisture content (wb)

TN - Net time taken for milling (seconds)

Wm= Total weight of milled rice (kg)

W_B = Weight of brown rice

Wh = Weight proportion of hull from paddy infractions.

Wb = Weight proportion of whole grains

W1 = Mean 1000-grain weight of a variety at brown rice level (g)

W2 = Mean 1000-grain weight of whole milled grain (both at standard moisture content) (g)

Experimental design and analyses

To determine the performance of the machines and their effect up on the milled rice quality of four varieties, the experiment was laid out in 3X4 factorial experiment with three levels (type) of machines and four varieties in complete randomized design each replicated three times. Data was analyzed with Microsoft Excel, SPSS, and MSTAT software and statistical significant test was carried out at 0.05 and 0.01probability levels

Results and discussion

1. Throughput and Specific Throughput

Mean throughput for JRM ranged from 392.83 to 462.03 kg/h (Table1a). Under similar machine adjustment conditions, throughput was highest when milling *X-Jigna* variety while the minimum was when it was milling *Gumara*variety. Similarly RRSM showed throughput values ranging between 342.20 to 426.16 kg/h. The highest was when milling X-Jigna and the lowest during milling of *Gumara*. Regarding SRW, throughput scores ranged between 148.48 kg/h to 197.42 kg/h.

Comparing the overall mean values of machines shows that throughput of JRM was higher than that of RRSM and throughput of RRSM was higher than that of SRW. This difference could be attributed to difference in the respective power input, inherent machine design difference, machine adjustment conditions or a combination of these all.

Table 1a. Effect of variety on paddy throughput of machines

		Throughput, kg/h^{XZ}				Machine
	Machine	*Gumara*	*Kokit*	*Tigabe*	*X-Jigna*	Mean^{Y}
	JRM	392.83d	412.92de	449.23ef	462 .03f	429.23c
	RRSM	342.20c	400.63d	410.37de	426.16def	394.84b
	SRW	148.48a	184.45ab	197.42b	190.60ab	180.24a
	Variety Mean^{Y}	294.51a	332.67b	352.31b	359.59c	
LSD$_{(0.05)}$	Variety (24.76)	Interaction (42.89)				Machine (21.44)

^{X}- average of three replications
$^{Y-}$ In column/ row means followed by common letters are not significantly different at 5% level.
$^{Z-}$ In a raw or column means followed by common letters are not significantly different at 5% level
LSD- List significant difference SEm- Standard error of mean

To minimize the effect of power difference between machines, comparison was made on the bases of their throughput per kilowatt (Specific throughput). Drive power of the machines were 11.2, 15, and 5.5 kW for JRM, RRSM and SRW, respectively. Results (Table 1 b.) showed that specific throughput for JRM were 35.07, 36.87, 40.10, and 41.25 kg/kWh, for RRSM 22.81, 26.71, 27.36 and 28.41 kg/kW-h and for SRW 26.99, 33.54, 35.89, and 34.65 kg/kW-h when milling *Gumara, Kokit, Tigabe* and *X-Jigna*, respectively.

When machines are compared based on these results, a maximum throughput per kW (specific throughput) was obtained with JRM while the minimum was with that of RRSM (Table 2 b). It is also found that machines were significantly different (α=1%) in their processing rate per rated power. Here the least specific throughput of RRSM, which was significantly lower than both JRM and SRW, could be due to the presence of many power transmission units, including separate pulleys to run shelling rollers and related idlers, additional shaking mechanisms to run cleaners, large sized blower which conveys the husk out of the milling house through a long conduit, and other losses related to power transmission and accessories.

Table 1b. Specific throughputs of machines as affected by variety

	Machine	Throughput, kg/kW-h^{X}				Machine mean ^{Y}
		Gumara	*Kokit*	*Tigabe*	*X-Jigna*	
	JRM	35.07	36.87	40.10	41.25	38.32c
	RRSM	22.81	26.71	27.36	28.41	26.32a
	SRW	26.99	33.54	35.89	34.65	32.77b
	Variety Mean^{z}	28.29a	32.37b	34.45bc	34.77c	
$LSD_{0.05}$	Variety (2.24)					Machine (1.937)

^{X}- Average of three replications
$^{Y-}$ In columnmeans followed by common letters are not significantly different at 5% level.
^{Z}- In rowmeans followed by common letters are not significantly different at 5% level.
LSD- List significant difference

Machine capacity (Milled rice output)

The maximum and minimum milling capacities obtained were 336.78 and 81.22 kg/h recorded during milling of *X-Jigna* and *Gumara* varieties, using JRM and SRW, respectively. In general machine output was found to be higher for JRM than the remaining two machines. Mean output of this machine (277.43 kg/hr) was 3.74 and 143.60% higher than that of RRSM (267.42 kg/hr) and SRW (113.89 kg/hr). Besides, mean output of this machine under all varieties (except for *Gumara)* was higher than similar values for the two other machines

Table 2a.Milling output of machines as affected by variety

Machine		Milling output, kg/h^{XZ}				Machine Average^{Y}
		Gumara	*Kokit*	*Tigabe*	*X-Jigna*	
	JRM	206.67c	273.59d	292.66e	336.78g	277.43b
	RRSM	208.87c	269.49d	276.25d	315.06f	267.42b
	SRW	81.22a	119.54b	124.53b	130.28b	113.89a
	Variety Average^{Y}	165.59a	220.87b	231.15b	260.71c	
SEm	Variety (6.252)	Interaction (10.829)				Machine (5.415)

^{X}- average of three replications
$^{Y-}$ In column/row means followed by common letters are not significantly different at 5% level.
$^{Z-}$ In a raw or column means followed by common letters are not significantly different at 5% level
SEm- Standard error of mean

Both Table 2a. andANOVA table (Table 2b.) shows that statistically significant variation ($p<0.01$) exist both between the effects of machines and varieties. Besides, mean comparison results (Table 2a) shows that capacities of JRM and RRSM, having insignificant different among each other, were significantly higher than that of SRW. Considering effects of varieties alone, consistent trends were observed in output using different varieties. In all machines tested output of *Gumara* was lowest while output of *X-Jigna* was the highest. Statistical analyses also showed that mean value of output during milling of *Gumara*was lower than that of *Tigabe* and *Kokit* but no significant difference was observed between the two varieties. The results of these three varieties were significantly lower than that of *X-Jigna.*

Milling yield (MY)

From the statistical data (Table 3a.) it can be seen that maximum and minimum mean values of milling yield were 73.67 and 53.00% respectively. The maximum MY was obtained with RRSM when milling X-*Jigna* and the minimum was with JRM when milling *Gumara* varieties.

Generally, considering the mean effect of the three machines, highest milling yield (67.17%) was recorded with RRSM. The resulting mean milling yield of RRSM was 2.75% and 4.50% higher than corresponding values of JRM and SRW, respectively. In all varieties except under *Gumara*, milling yield values of SRW were slightly lower than that of JRM. Statistical evaluations reveled that there was significant difference in milling yields of the three machines (α=1%)(Table 3b.).

Table 3 a. Milling yield of machines as affected by variety

Machine		Milling yield, (%)^{XZ}				MachineMean^{Y}
		Gumara	*Kokit*	*Tigabe*	*X-Jigna*	
	JRM	53.00a	66.33d	65.33cde	73.00f	64.42b
	RRSM	61.00b	67.00d	67.00de	73.67f	67.17c
	SRW	54.67a	64.67d	63.00bc	68.33e	62.67a
	Variety Mean^{Y}	56.22a	66.00b	65.11b	71.67c	
$LSD_{0.005}$	Variety (1.83)	Interaction (3.16)				Machine (1.58)

^{X}- average of three replications
$^{Y-}$ In columnmeans followed by common letters are not significantly different at 5% level.
$^{Z-}$ In a raw or column means followed by common letters are not significantly different at 5% level
LSD- List significant difference SEm- Standard error of mean

These results indicate better milling performance of the rubber roll mill. It agrees with the results of Ahmed and Mazed, (1996). Superior yield of RRSM is due to the separation of milling and husking processes. More gentle actions of rubber rolls reduced pressure and friction in the milling chamber, and reduce breakage and over milling of grains. Lower milling yield of JRM could be due to excessive milling as manifested by higher 1000-grain weight losses. On the other hand, in spite of its lower degree of milling (lower SGWL, Table), SRW resulted in lower milling yield than the two commercial machines. This can occur due to highest grain breakage caused by the machine which will result in loss of inner grain components there by reducing the net weight of the grain and over all milled rice yield (Cruz and Khush, 2000).

Percentage whole grain (PWG)

Percentage whole grain is one of the desirable quality indicators in rice milling. From Table 4a.it can be learned that mean PWG of varieties using JRM were 42.77, 30.70, 28.33 and 50.93% for *Gumara,Kokit,Tigabe* and X-Jigna, respectively. PWG recorded using *X-Jigna*(highest) was 80.00% higher than that of *Tigabe* (the least).

Percentage whole grain obtained using RRSM was 47.40, 35.33, 29.50, and 62.17% for *Gumara*, *Kokit*, *Tigabe*, and *X-jigna,* respectively. The percentage whole grain obtained using *X-jigna* was 52.58% higher than that of *Tigabe* . PWG obtained using SRW were 31.67% for *Gumara,* 26.73% for *Kokit*, 20.63% for *Tigabe* and 36.63% for *X-Jigna.*

Percentage whole grain obtained from the four machines shows that RRSM, JRM, and SRW resulted in mean PWG of 43.60, 39.43, and 28.92%, respectively. This shows that RRSM is superior in performance and resulted in an increased PWG, which showed a percentage increment of 10.58% and 50.76% as compared with JRM and SRW, respectively (Table 4a, and 4b.).

Table 4 a. Percentage whole grain recovery as affected by machine and variety

Machine		Percentage whole grain, (%)[X]				Machine Mean [Y]
		Gumara	*Kokit*	*Tigabe*	*X-Jigna*	
	JRM	42.77	30.70	28.33	50.93	39.43b
	RRSM	47.40	35.33	29.50	62.17	43.60b
	SRW	31.67	26.73	20.63	36.63	28.92a
	*Variety*Mean [Y]	42.28b	30.92a	26.16a	49.91c	
$LSD_{0.05}$	Variety 5.31	Interaction				Machine 4.62
SEm	1.814					1.575

[X]- Average of three replications
[Y]- In column/rowmeans followed by common letters are not significantly different at 5% level.
LSD- List significant difference   SEm- Standard error of mean

Despite these percentage differences, statistical analyses made denied presence of significant difference between the mean PWG of RRSM and JRM(Table 4a and 4b.). It is also shown that PWG result of SRW was significantly lower than the other two machines. The lowest whole grain recovery figures of SRW could be related with the design problem of the machine.

Mean PWG obtained when milling *X-Jigna, Gumara, Kokit* and *Tigabe* varieties were 49.91, 42.28, 30.92, and 26.16%, respectively. Test of significance carried out at p=0.05 showed that the mean PWG for *Kokit* and *Tigabe*, were statically similar, but significantly lower than both *Gumara* and X-*Jigna*varieties while *Gumara* resulted in significantly lower PWG than *X-Jigna*.

Both the calculated mean PWG results and statistical analyses made showed the overall trend that RRSM had better performance and X-*Jigna* had superior quality than the remaining two machines and three varieties, respectively.

Its short length and higher thickness can justify the outstanding performance of *X-Jigna (*Abdure *et al.,1996)*. *Gumara* had shown good performance in terms of PWG than any other parameter discussed previously. Its relative thickness might have given better breakage resistance properties. Least performance of *Kokit*and *Tigabe* could be due to their longer and thinner dimension than the other two varieties (Sarkerand Farouk, 2003). Lowest performance of*Tigabe* can also be related to its lowest thickness and higher variability within the same grain sample composition.Besides, since head rice yield is related to the varieties crack resistance (Juliano and Duff, 1991), *Tigabe* may have lower crack resistance to end up with lower whole grain recovery.

Thousand grain weight loss

Thousand grain weights of paddy rice, brown rice and whole grains of milled rice are shown in the same table (Table 5). Since some of the grain parts were removed during milling, 1000-grain weight of whole rice grains reduced as compared with brown rice. Mean values ranged between 19.73 to 20.12 g for *Gumara*, 21.59 to 21.97 g for *Kokit*, 20.44 to 20.87 g for *Tigabe* and 23.38 to 23.43 g for *X-Jigna*.

Percentage 1000 grain weight loss when milled by JRM, RRSM, and SRW were 10.35, 9.72, and 8.60% for *Gumara* 10.45, 9.71 and 8.87% for *Kokit,* 13.65,11.82 and 12.00% for*Tigabe*, and 4.68, 4.64 and 4.48% for *X-Jigna,* respectively. This implies that JRM had caused highest weight loss than both RRSM and SRW from the same varieties. The highest and lowest weight losses of all the machines occurred on *Tigabe* and X-*Jigna* varieties, respectively.

Values of thousand-grain weight loss (percentage) were subjected to statistical analyses to see whether there existed significant difference among different varieties and machines. The result showed that there was no significant difference both among machines and varieties ($p<0.05$

Table 5 a. Thousand grain weights of paddy, brown rice and milled rice grains[a]

Grain type	1000 grain weight (gram)			
	Gumara	*Kokit*	*Tigabe*	*X-Jigna*
Paddy rice	28.97± 0.17	30.49±0.16	29.26±0.28	30.16±0.17
Brown rice	22.01±0.19	24.11±0.20	23.67±0.26	24.53±0.02
Milled rice grains; milled by				
▪ N-50 JRM	19.73 ± 0.26	21.59 ± 0.57	20.44 ± 0.06	23.38 ± 0.09
▪ SB-10D RRSM	19.87 ± 0.52	21.77 ± 0.02	20.87 ± 0.1	23.39 ± 0.21
▪ SRW	20.12 ± 0.24	21.97 ± 0.07	20.83 ± 0.06	23.43 ± 0.10

[a=] Mean±Sd of three measurements

CONCLUSION AND RECOMMENDATION

The experimental investigation made has clearly indicated that among the three machines considered in the study, Rubber Roller Sheller Mill is superior to the remaining two machines in terms mean percent milling yield, milling recovery, reduced milling loss, and whole grain output. Therefore, it is recommended that this machine be used to mill rice at village level. Nonetheless, considering the high percentage of broken grain observed during the investigation, proper adjustment of the machine and the need for skilled operator cannot be ignored. Provision of fast wearing machine components specially salvaging of rubbers on the rollers is also essential to look in to. However, variety had significant effect on the performance of the machines in terms of parameters listed above.

Selam Rice Whitener has the list performance almost in all parameters considered to be pertinent to assess a machine. This machine was made at home on the basis of a prototype obtained from Nigeria. This will definitely make the price of the machine cheaper, and amenable to local condition. Nonetheless, a detailed study on this machine is essential to improve its performance. Therefore, redesigning and evaluation is a must to proved rice grower with improved and efficient portable milling machine.

On the other hand milling quality (Millability) of the rice varieties studied, in terms of mean percent milling yield, milling recovery, milling loss, and whole grain output, was in general highest for *X-Jigna*and followed by*Tigabe, Kokit,* and*Gumara*in descending order. Thus any improvement work in rice production, processing and consumption should consider the millability of rice in depth. Selection of varieties, and demonstration and popularization of the same should consider engineering (especially milling) and chemical properties of a variety in question.

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Annex

ANOVA tables

Table 1c.ANOVA of specific throughput

Source of Variation	SS	df	MS	Fcomp.	P-value	F crit
Replication	9.977	2	4.988	0.9526^ns		3.445
Variety	240.011	3	80.024	15.282**	0.000	3.055
Machine	865.838	2	432.918	82.671**	0.000	3.445
Interaction	28.593	6	4.765	0.910^ns	0.502	2.555
Error	125.223	22	5.218			
Total	1259.648	35				

CV= 7.05% ?** Significant at 1% level ns- not significant

Table 2 b. ANOVA table of machine capacity difference

Source of Variation	SS	Df	MS	Fcomp.^b	P-value	F crit
Replication	15.437	2	7.718	0.0219*		3.445
Variety	42682.862	3	14227.621	40.44**	0.000	3.055
Machine	201651.823	2	100825.911	286.583**	0.000	3.445
Interaction	5432.295	6	905.383	2.573*	0.0483	2.555
Error	7740.058	22	351.821			
Total	246744.4	35				

CV= 8.54% b-** Significant at 1% level b-* Significant at 5% level

Table 3 b. ANOVA table of percentage milling yield

Source of Variation	SS	df	MS	Fcomp.^b	P-value	F crit
Replication	11.167	2	5.583	1.599^ns		3.445
Variety	1100.310	3	366.77	100.03**	0.000	3.055
Machine	123.500	2	61.75	16.84**	0.000	3.445
Interaction	66.940	6	11.16	3.04*	0.023	2.555
Error	76.833	22	3.492			
Total	1378.75	35				

CV=2.91%

Table 4 b. ANOVA table of percentage whole grain

Source of Variation	SS	df	MS	Fcomp.^b	P-value	F crit
Replication	60635	2	30.318	1.024^ns		3.445
Variety	3138.230	3	1046.080	35.340**	0.000	3.055
Machines	1374.250	2	687.120	23.170**	0.000	3.445
Interaction	365.700	6	60.950	2.060^ns	0.097	2.555
Error	711.820	22	29.600			
Total	5589.99	35.				

CV= 14.58% b-** Significant at 1% level ns- not significant