Influence of soaking variables on rice (*Oryza sativa*) de-husking quality

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Abstract: This work studied the influence of soaking variables on rice de-husking quality. The variables considered were temperature, time and variety. Three different levels of temperatures were chosen. The three different levels of temperatures were 50ºC, 70ºC and 90ºC respectively. Two different levels of time were chosen. The time chosen were 6 and 12 hours respectively. Jemila and Sipi were the two varieties of rice used for this study. The variables to be studied were completely randomized and each combination of the experiment was replicated thrice. In all, there were 36 treatments (i.e. 3 temperatures × 2 times × 2 varieties × 3 replications). The results obtained from the experiment indicates that broken percentage decreases with increase in soaking temperature unless when the gelatinization temperature of the rice variety is exceeded while de-husking and overall de-husking efficiency increases with temperature unless when the paddy is soaked excessively. Furthermore, de-husking quality varies appreciably with soaking time, Jemila rice variety can be best soaked at a temperature of 70ºC for 12 h while Sipi is at 90ºC for 12 h.

Keywords: soaking variables, rice de-husking, rice quality, soaking time, soaking temperature

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1 Introduction

Rice is the seed of the monocot plant Oryza sativa (Asian rice) or Oryza glaberrima (African rice). It is one of the leading food crops of the world and is second only to wheat in terms of annual production for food use (Kaddus et al., 2002). Rice production originated in China, Continent of Asia. In sub-Saharan Africa, West Africa is the leading producer and consumer of rice, widely produced in Cote d'Ivoire, the Gambia, Guinea, Guinea Bissau, Liberia, Burkina Faso, Senegal and Sierra Leone (WARDA, 1996). Rice is cultivated in virtually all the agro-ecological zones in Nigeria (Akande, 2014). Abulude (2004) reported that rice is an economic crop which is used in household food security, ceremonies, nutritional diversification, income generation and employment. It is used mostly at the household level, where it is consumed as boiled or fried or ground rice with stew or soup. Rice obtained from rice kernel is also used for cake biscuits noodles.

A rice kernel is covered by two layers, the outer layer is called the husk or hull and the inner layer is the bran. The whole rice kernel, including these two layers, is called paddy (rough rice). Paddy in its raw form cannot be consumed by human beings, it needs to be suitably processed to obtain pure rice which is consumable by human.

The steps involved in rice processing includes: Pre-cleaning, de-stoning, parboiling (optional), de-husking, husk aspiration, paddy separation, whitening, polishing, length grading, weighing and bagging. De-husking (husking) refers to the process of removing the husk of paddy to obtain what is known as brown rice

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or husked rice. A combination of de-husking, whitening and polishing to obtain polished rice is referred to as milling. In other to obtain good quality de-husking (milling), parboiling is carried out.

Parboiling is an ancient method of pre-milling treatment given to paddy to improve the milling characteristics (Ramaligram and Raj, 1996). It is simply defined as the hydrothermal treatment of paddy. During this process, grain changes its physical properties as starch gelatinizes because of the heat treatment in the presence of water. Parboiled paddy provides a higher milling yield and reduces nutrient loss during milling and cooking (Rao and Juliano, 1970a). It is also done to improve the milling recovery of paddy, to salvage poor quality or spoiled paddy, and meet the demands of certain consumer preferences (Wimberly, 1983). Parboiling includes soaking, steaming and drying. The aim of soaking is to achieve quick and uniform water absorption. Steaming of paddy is carried out to achieve partial gelatinization (process by which starch granules changes to a gelatinous or jelly form, filling the voids and cementing the fissures in the grain). It is done to complete the physical and chemical changes brought about by soaking. Drying refers to the removal of moisture from agricultural products until the moisture content of the product is in equilibrium with the surrounding air. It is an essential step in the processing and preservation of paddy. Despite these various processes developed in other to improve the quality of processed rice, rice processed locally in Nigeria still has low quality.

In Nigeria today, with the present agricultural transformation agenda (ATA) of the federal government, a lot of rice has been produced in the country. This is depicted by the fact that rice area in the country has increased about 25 per cent from two million hectares in 2012-2013 to 2.5 million hectares in 2013-2014. Even at this, the importation of rice from countries like China, India, and Thailand is not on a decline (Akande, 2014). This is due to the fact that rice processed locally in Nigeria has low quality and all end users want the best quality that they can afford. A number of difficulties contributed to the low quality. For instance, different varieties of rice are grown in Nigeria. These include Sepi, Jemila which are common in Northern Nigeria (Kano), Ofada which is common in South Western Nigeria. These varieties have different shapes and sizes; moreover their physical characteristics such as strength differ from one variety to the other. For this reason, different varieties require different processing variables for best quality achievement.

One of the important processes that affect the quality of the rice produced is the soaking process. Soaking process is a complicated process involving temperature of water, time or duration of soaking and properties of the rice variety. Since quality of any processed rice is only as good as the quality of the raw materials and the control exercised during the processing, it is important to properly understand the influence of soaking variables (time, temperature and variety) on the processed rice quality (Rao and Juliano, 1970b). These vital variants are often not explored in our continuous effort towards producing quality local rice. The aim of this work is to study the influence of soaking variables on rice de-husking quality. In order to achieve this aim the specific objectives include: to study the influence of soaking temperature, soaking time and rice varieties on rice de-husking quality and to determine the significance of soaking temperatures, time and variety and the optimum combination for best de-husking quality.

2 Materials and methods

2.1 Sample preparation

Two local varieties of Paddy rice, Jamila and Sipi, were used for the experiments. These varieties are cultivated in Kura, and were chosen because they are the commonest among farmers and consumers. Moisture content of the two varieties, after purchase, was averagely 12% (w.b). Jamila variety was chosen for its longer grain size than other locally available varieties and for its good milling output that suits the consumers' preference. Sipi, on the hand, is a high yielding variety.

The following instruments were used for this study; grain moisture meter, electric weighing balance, analog weighing balance, probe thermometer, aluminum vat, warmer/thermo-flask, stop watch, pot, milling machine, jut sacks.

2.2 Experimental procedure

In order to obtain the objective of this study, the test samples were subjected to the same processes before and after the soaking process. However, during the soaking process, the different soaking variables (time, temperature and variety) were completely randomized. The study involved three variables. These variables were: temperature, time and variety.

The variables to be studied were completely randomized and each combination of the experiment was replicated thrice. In all, there were 36 treatments (3 temperatures × 2 times × 2 varieties × 3 replications). For each treatment, 5 kg weight of rice was measured out and washed thoroughly (3 times) with tap water in order to avoid discoloration, introduction of odor and contamination. The immature, unfilled grains and straw were floated off to reduce breakage during de-husking and then subjected to the following processes: soaking, steaming and drying with steaming and drying variables kept constant.

2.2.1 Soaking

Weight of water that is 1.3 times weight of paddy used (6.5 kg) was heated to 100˚C in an aluminum pot using firewood as source of energy. The water was then poured into a warmer and thermometer was used to read falling temperature of the water until it gets to required temperature +2ºC. The washed paddy was then poured into the warmer and covered rapidly and tightly for the duration of soaking.

2.2.2 Streaming

The soaked paddy was washed and poured into an aluminum vat perforated at its base and around ¼ its height from the base; the vat was then placed on an aluminum pot with 10 litres' of water and steamed for 30 minutes at maximum temperature of 90ºC. Steam was made to reach all sections of the aluminum vat by covering with jute sacks. The covering prevents the steam from escaping easily thereby creating a partial pressure over the content that aid in inward movement of molecules in each gelatinous kernel. When the paddy begins to crack open their husks and there is steam vapour arising all over the pot, it is an indication that steaming is enough.

2.2.3 Drying

The steamed paddy was then removed and conveyed to the drying area. The method employed was the natural convection shade drying method. In this method, the paddy was dried under shade and on sacks where heat generated by surrounding was the major source of moisture removal. Each treatment was laid on a thin layer with thickness of 2.5 cm and dried to a moisture content of 14% (d.b). After drying, the paddy was labeled for its combination of soaking variables (time, temperature and variety) and stored for 2 days in bags to calm internal stresses developed during processing (i.e tempering).

2.2.4 De-husking

Three kilograms (3 kg) of paddy was taken from each of the dried sample and then de-husked using a diesel de-husking machine (steel huller). The weight of grains left in the huller machine for each treatment were forced out by putting rice husk into the hopper of the machine, after which the de-husked weight was measured for evaluation of de-husking quality (IRRI, 1996).

Quality of de-husking was evaluated in accordance with the relationship obtained from International Rice Research Institute (IRRI, 2002):

$$\text{de-husking efficiency, \%} = \frac{W_h}{W_t} \times 100 \tag{1}$$

where, W_h is the weight in gram of husked/de-husked rice collected from grain outlet and W_t is the total weight in gram of paddy sample.

The percentage of broken grain was calculated using Equation (2) as given by the International Rice Research Institute (IRRI, 2002)

$$\text{\% of broken grains} = \frac{W_b}{W_t} \times 100 \tag{2}$$

where, W_b is the weight of broken rice in 100 g of the sample, g and W_t is the total weight of the collected sample (100 g).

The overall de-husking efficiency was obtained using Equation (3) as given by the International Rice Research Institute (IRRI, 2002)

$$\text{Overall de-husking efficiency (\%)} = \frac{W_w}{W_t} \times 100 \tag{3}$$

where, W_w is the weight in gram of whole grains collected from grain outlet and W_t is the weight in gram of paddy sample.

2.3 Statistical analysis

The data obtained were subjected to analysis of variance (ANOVA). Means were compared using least significant difference (LSD) where the analysis of variance (F-test) is significant at 5% and 1% level of probability. Table 1 shows the variable selected for the investigation.

Table 1 Variable selection for the investigation

VARIABLE	LEVEL	SELECTIONS		
Temperature	3	T_1	T_2	T_3
Variety	2	V_1		V_2
Time	2	t_1		t_2
Replication	3	R_1	R_2	R_3

Note: V_1 = Sipi, V_2 = Jemila, T_1=50˚C, T_2 = 70˚C, T_3 = 90˚C, t_1 = 6 hours, t_2 = 12 hours.

3 Results and discussion

3.1 Influence of investigated parameters on rice breakage

Table 2 to 4 shows the effect of each variable for given combination of other variables on rice breakage. Analysis of variance (ANOVA) was used to analyze the result obtained from the experiment, Table 5 shows the ANOVA result.

Table 2 shows the relationship between soaking temperature and rice breakage. The table shows that for a given combination of variables, breakage percentage decreases with increase in soaking temperature, but at different levels of soaking temperature for duration of 12 h for jemila, breakage percentage decreases from 6.16% at 50°C to 4.88% at 70°C and then increases to 6.13% at 90°C.

Table 2 Effect of soaking temperature on rice breakage

Soaking temperature	Constant Variables	Percentage Breakage (%)
T_1	t_1V_1	19.83
T_2		17.19
T_3		12.60
T_1	t_1V_2	20.56
T_2		17.87
T_3		13.38
T_1	t_2V_1	11.51
T_2		6.47
T_3		3.92
T_1	t_2V_2	6.16
T_2		4.88
T_3		6.13

The increase in breakage percentage is an indication that gelatinization temperature for Jemila was reached by soaking at 90°C for 12 h without having steamed and the further steaming for 30 minutes cooked the paddy leading to increase in breakage. Soaking at a temperature of 70°C for 12 h gave the least breakage for Jemila while soaking at a temperature of 90°C for 12 hours gave the least breakage for Sipi. Figure 1 shows the effect of soaking temperature on rice breakage.

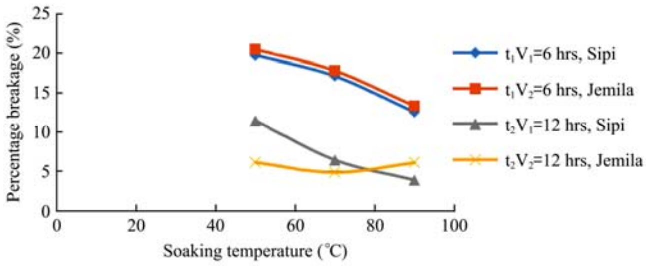

Figure 1 Effect of soaking temperature on rice breakage

Table 3 shows the relationship between soaking time and rice breakage. The table shows that for a given combination of variable, rice breakage percentage varies appreciably with soaking time. Soaking for 12 hours gave low breakage compared to soaking for 6 hours for both varieties. Figure 2 shows the effect of soaking time on rice breakage.

Table 3 Effect of soaking time on rice breakage

Soaking time	Constant Variables	Percentage Breakage (%)
t_1	T_1V_1	19.83
t_2		11.51
t_1	T_1V_2	20.56
t_2		6.16
t_1	T_2V_1	17.19
t_2		6.47
t_1	T_2V_2	17.87
t_2		4.88
t_1	T_3V_1	12.60
t_2		3.92
t_1	T_3V_2	13.38
t_2		6.13

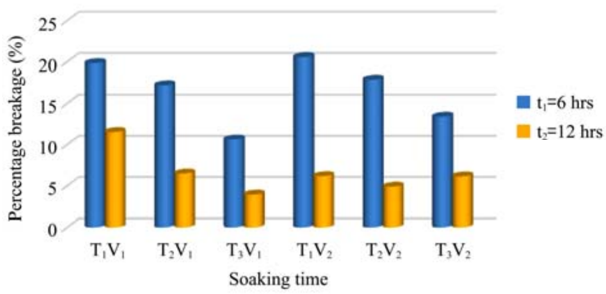

Figure 2 Effect of Soaking Time on Rice Breakage

Table 4 shows that, for a given combination of variables, the percentage breakage is nearly the same for both varieties except for when soaking at 50°C for 12 hrs and 70°C for 12 hrs where the percentage breakage of Sipi is greater than that of Jemila. Figure 3 shows the effect of variety on rice breakage.

Table 4 Effect of variety on percentage breakage

Variety	Constant Variables	Percentage Breakage (%)
V1	T1t1	19.83
V2		20.56
V1	T1t2	11.51
V2		6.16
V1	T2t1	17.19
V2		17.87
V1	T2t2	6.47
V2		4.88
V1	T3t1	12.60
V2		13.38
V1	T3t2	3.92
V2		6.13

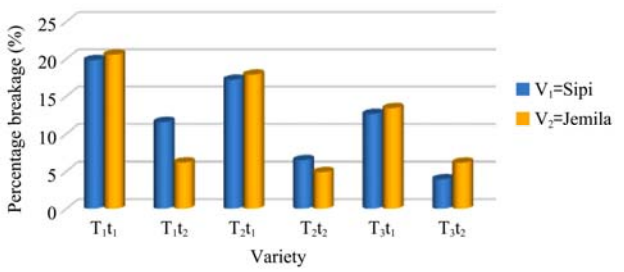

Figure 3 Effect of variety on rice breakage

Table 5 shows the contribution of some factors and their interactions on rice breakage. From the table, it can be seen that the most dominant single factor (at 1% and 5% levels) that influenced rice breakage was soaking temperature; soaking time; interaction between temperature and time, temperature and variety, time and variety; and interaction between temperature, time and variety. Other factors were not significant at 1% and 5% levels of significance.

Table 5 Analysis of variance for percentage breakage

Source	DF	Sum of squares	Mean square	F value	Tabular F-value	
					5%	1%
Replication (R)	2	4.2822889	2.1411444	3.25	3.44	5.72
Temp (T)	2	171.3345056	85.6672528	181.89**	3.44	5.72
variety (V)	1	1.8000694	1.8000694	3.82	4.30	7.95
Time (t)	1	973.5440028	973.5440028	2067.02**	4.30	7.95
T*t	2	24.7403722	12.3701861	26.26**	3.44	5.72
T*v	2	18.8130722	9.4065361	19.97**	3.44	5.72
t*v	1	11.3906250	11.3906250	24.18**	4.30	7.95
T*t*v	2	24.3240500	12.1620250	25.82**	3.44	5.72
Error	22	10.361778	0.470990			
Corrected total	35	1240.590764				

Note: ** = significant at 1% level of confidence.

3.2 Effect of investigated parameters on de-husking efficiency

Analysis of variance (ANOVA) was conducted on the data obtained for the de-husking efficiency for different combinations of variables. The result from the analysis is presented in Table 9. Table 6 shows the effect of soaking temperature on the de-husking efficiency, Table 7 shows the effect of soaking time on the de-husking efficiency, while Table 8 shows the effect of variable on the de-husking efficiency.

Table 6 shows that, de-husking efficiency increases with increase in temperature when Jemila and Sipi are soaked for 6 hrs but when soaked for 12 hrs, de-husking efficiency fluctuates with increase in temperature. It also shows that de-husking efficiency is highest when Jemila and Sipi are soaked for 12 hrs. Figure 4 is a graphical representation of the effect of soaking temperature on de-husking efficiency.

Table 6 Effect of soaking temperature on de-husking efficiency

Soaking Temperature	Constant Variables	de-husking Efficiency (%)
T_1	t_1V_1	55.58
T_2		59.98
T_3		63.80
T_1	t_1V_2	63.90
T_2		68.99
T_3		73.41
T_1	t_2V_1	87.81
T_2		90.90
T_3		88.60
T_1	t_2V_2	88.71
T_2		92.18
T_3		83.97

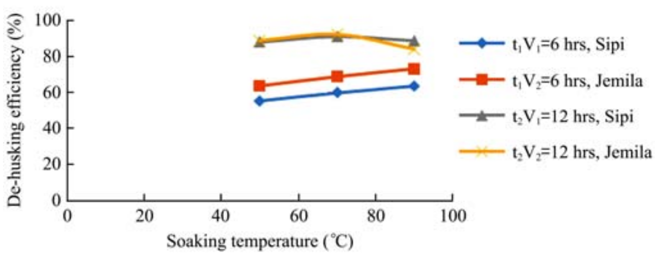

Figure 4 Effect of soaking temperature on De-Husking efficiency

Table 7 shows that for a given combination of variables, de-husking efficiency varies appreciably with increase in soaking time. Also, it shows that, soaking for 12 hours gave the highest de-husking efficiency for a given combination of factors. Figure 5 is a graphical representation of the effect of soaking time on de-husking efficiency.

Table 8 shows that for a given combination of variable, Jemila variety gave higher de-husking efficiency than Sipi variety except for soaking at 90°C for 12 hrs where Sipi gave a better result than Jemila. Figure 6 is a graphical representation of the effect of variety on de-husking efficiency.

Table 7 Effect of soaking time on de-husking efficiency

Soaking time	Constant variables	de-husking efficiency (%)
t_1	T_1V_1	55.58
t_2		87.81
t_1	T_1V_2	63.90
t_2		88.71
t_1	T_2V_1	59.98
t_2		92.18
t_1	T_2V_2	68.99
t_2		92.18
t_1	T_3V_1	63.80
t_2		88.60
t_1	T_3V_2	73.41
t_2		83.97

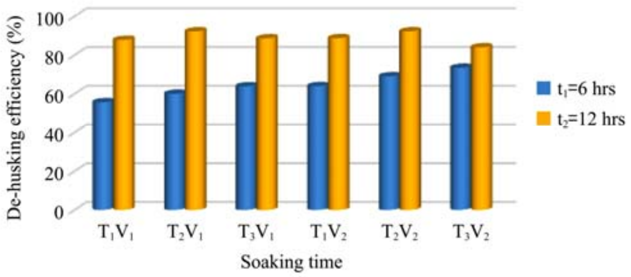

Figure 5 Effect of soaking time on De-Husking efficiency

Table 8 Effect of variety on de-husking efficiency

Variety	Constant variables	De-Husking Efficiency (%)
V1	T1t1	55.58
V2		63.90
V1	T1t2	87.81
V2		88.71
V1	T2t1	59.98
V2		68.99
V1	T2t2	92.18
V2		92.18
V1	T3t1	63.80
V2		73.41
V1	T3t2	88.60
V2		83.97

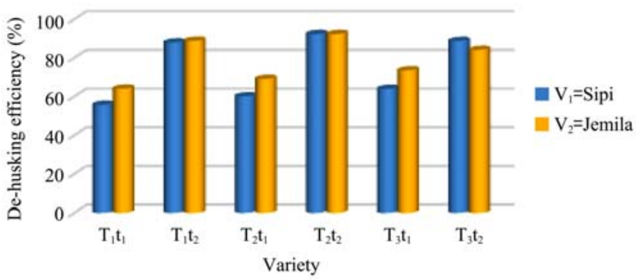

Figure 6 Effect of variety on de-husking efficiency

Table 9 shows the contribution of some factors and their interactions on de-husking efficiency. From the table, it can be seen that the most dominant single factor (at 1% and 5% levels) that influenced de-husking efficiency was soaking temperature; soaking time; interactions between temperature and time; and interaction between time and variety. Effect of variety was significant at 5% level of confidence. Interaction between temperature and variety and interaction between temperature, time and variety have shown no significant effect on rice de-husking efficiency.

Table 9 Analysis of variance table for de-husking efficiency

Source	DF	Sum of squares	Mean square	F value	Tabular F-value	
					5%	1%
Replication (R)	2	50.371817	25.185908	2.58	3.44	5.72
Temp (T)	2	149.015817	74.507908	7.62**	3.44	5.72
Time (t)	1	5164.817778	5164.817778	528.20**	4.30	7.95
variety (V)	1	70.168544	70.168544	7.18*	4.30	7.95
T*t	2	156.191106	78.095553	7.99**	3.44	5.72
T*V	2	4.748706	2.374353	0.24	3.44	5.72
t*V	1	258.888100	258.888100	26.48**	4.30	7.95
T*t*V	2	18.394350	9.197175	0.94	3.44	5.72
Error	22	215.120183	9.778190			
Corrected total	35	6087.716400				

Note: * = significant at 5% level of confidence;** = significant at 1% level of confidence.

3.3 Effect of investigated parameters on overall de-husking efficiency

The data obtained for the overall de-husking efficiency for different combinations of variables was used in running a computer program for the analysis of variance shown in Table 13. Overall de-husking efficiency is very important, as it accounts for the combined effect of percentage breakage and de-husking efficiency. Tables 10 to 12 show the effect of each variable for given combination of other variables on paddy overall de-husking efficiency.

Table 10 shows that for a given combination of variables, overall de-husking efficiency increases with increase in temperature for both Sipi and Jemila soaked for 6 h while overall de-husking efficiency fluctuates with increase in temperature for both Sipi and Jemila soaked for 12 h. Figure 7 is a graphical representation of the effect of soaking temperature on overall de-husking efficiency.

Table 11 shows that for a given combination of variables, overall de-husking efficiency increases appreciably with increase in soaking time. From the table, it can be seen that soaking for 12 h gave the highest de-husking efficiency for all combination of factors. Figure 8 is a graphical representation of the effect of soaking time on overall de-husking efficiency.

Table 10 Effect of soaking temperature on overall de-husking efficiency

Soaking temperature	Constant variables	Overall de-husking efficiency (%)
T_1		34.15
T_2	t_1V_1	43.60
T_3		51.66
T_1		44.68
T_2	t_1V_2	51.78
T_3		61.49
T_1		76.94
T_2	t_2V_1	85.69
T_3		84.91
T_1		83.37
T_2	t_2V_2	87.85
T_3		87.35

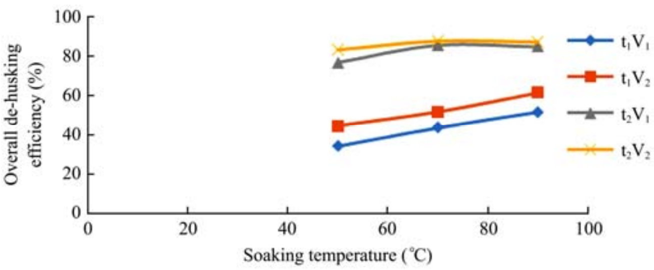

Figure 7 Effect of soaking temperature on overall de-husking efficiency

Table 11 Effect of soaking time on overall de-husking efficiency

Soaking time	Constant variables	Overall de-husking efficiency (%)
t_1	T_1V_1	34.63
t_2		43.60
t_1	T_1V_2	44.63
t_2		83.37
t_1	T_2V_1	43.60
t_2		84.79
t_1	T_2V_2	51.78
t_2		87.85
t_1	T_3V_1	51.66
t_2		84.91
t_1	T_3V_2	61.49
t_2		87.35

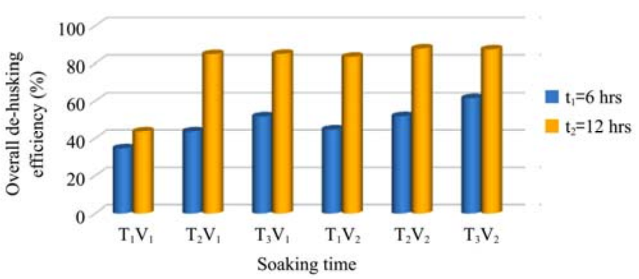

Figure 8 Effect of soaking time on overall de-husking efficienc

Table 12 shows that for a given combination of variable, Jemila variety gave the highest overall de-husking efficiency. Figure 9 is a graphical representation of the effect of variety on overall de-husking efficiency.

Table 12 Effect of variety on overall de-husking efficiency

Variety	Constant variables	Overall de-husking efficiency (%)
V1	T1t1	34.63
V2		44.63
V1	T1t2	43.60
V2		83.37
V1	T2t1	43.60
V2		51.78
V1	T2t2	84.79
V2		87.85
V1	T3t1	51.66
V2		61.49
V1	T3t2	84.91
V2		87.35

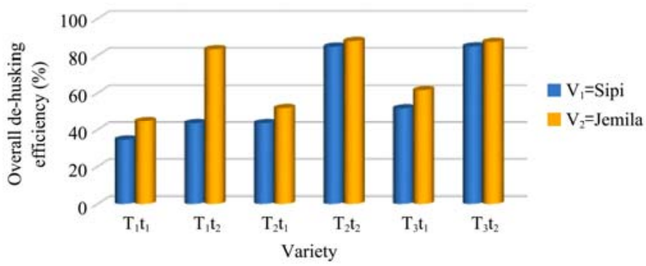

Figure 9 Effect of variety on overall de-husking efficiency

Table 13 shows the contribution of some factors and their interactions on overall de-husking efficiency. From the table, it can be seen that the most dominant single factor (at 1% and 5% levels) that influenced overall de-husking was soaking temperature; soaking time; variety; interaction between temperature and time, time and variety. Other factors and their interactions were not significant at 1% and 5% levels of significance.

Table 13 Analysis of variance for overall de-husking efficiency

Source	DF	Sum of squares	Mean square	F value	Tabular F-value	
					5%	1%
Replication (R)	2	6.94994	3.47497	1.37	3.44	5.72
Temp (T)	2	710.24057	355.12029	139.79**	3.44	5.72
Time (t)	1	11537.98223	11537.98223	4541.68 **	4.30	7.95
variety (V)	1	349.12923	349.12923	137.43**	4.30	7.95
T*t	2	176.23655	88.11827	34.69**	3.44	5.72
T*V	2	2.60542	1.30271	0.51	3.44	5.72
t*V	1	45.54000	45.54000	17.93**	4.30	7.95
T*t*V	2	15.81937	7.90969	3.11	3.44	5.72
Error	22	55.89026	2.54047			
Corrected total	35	12900.39356				

Note: ** = significant at 1% level of confidence.

4 Conclusion

Based on the results obtained from this experiment the following conclusions can be drawn.

1. Rice to be de-husked in any given locality must take cognizance of the variations in local varieties of rice. As de-husking quality is variety specific.

2. For a given combination of variables, broken percentage decreases with increase in soaking temperature unless when the combination of soaking temperature and steaming exceeds the gelatinization temperature of the rice variety. Also, broken percentage varies appreciably with soaking time for a given combination of variable.

3. For a given combination of variables, de-husking quality increases with soaking temperature when soaked for 6 h, but when soaked for 12 h, de-husking efficiency fluctuates with increase in temperature. Also, de-husking efficiency varies appreciably with time for a given combination of factors.

4. For a given combination of variables, overall de-husking efficiency increases with increase in temperature for both varieties (Sipi and Jemila) when soaked for 6 h but when soaked for 12 h, fluctuates with increase in temperature. Also, overall de-husking efficiency varies appreciably with soaking time. Sipi can best be soaked at a temperature of 90ºC for 12 h while Jemila is at a temperature of 70ºC for 12 h.

5. Soaking temperature and time has greater significant effect on de-husking quality than rice variety.

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