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Performance Evaluation of the Cowpea Wet De-Hulling Machine

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Abstract

The performance evaluation of the cowpea de-hulling machine was done using a factorial experiment in a completely randomize design involving speed, soaking time and cowpea variety each at 3, 3, and 2 levels respectively. These were replicated three times. LSD was used to further analyze the significant means. The results showed that the speed, soaking time and cowpea variety had significant effect on de-hulling efficiency and output capacity for the developed de-huller while only soaking time and speed had significant effect on mechanical damage. The developed de-huller performs the best at 120 rpm speed, 11 mins soaking time, and with Dan-barere variety. Based on these variables, the performance indices obtained were 90.75%, 74.27 kg/hr. and 0.39% for de-hulling efficiency, output capacity and mechanical damage respectively.

Keywords: De-hulling; Soaking; Cowpea; Dan-barere, Dan-sokoto

Introduction

Cowpea (*Vigna unguiculata* or *Vigna sinensis nunguiculata*) is a popular leguminous crop in Africa which is known as "black-eyed peas" in America. In Nigeria, it is known as 'beans'. Kano State is one of the largest cowpea producing areas in Nigeria, cultivating about 4,050 ha which yields above 1,000 kg/ha compared with the national average of 212 kg/ha. Common varieties include SAMPEA 10, SAMPEA 8, and Oloka [1]. Cowpea is one of the most highly proteineous African crop that feeds people, their livestock and the next crop. The nutritional value of cowpea is in the composition of its grain. Cowpea grains are rich in amino acids, lysine and tryptophan making it better than cereal and root and tuber based diets of many coastal and forest communities [2]. In Nigeria and some other West African countries, cowpea grains are eaten in various forms; as porridge along with fried or boiled yam or plantain, as bean cake called akara or kosei among Yoruba and Hausa respectively, as moin-moin which is steamed – cook of wet – milled cowpea mixed with cooking ingredients, and cowpea stew called gbegiri in Yoruba language [3].

De-hulling can be defined as the removal of seed coat (hull) from the seed, resulting in the separation of the cotyledons from the hulls [4]. In the rural sector, the wet method of de-hulling process is still part of the house wife's manual work in food preparation. Water soaking is used to facilitate hull removal. The cowpea seeds absorb moisture and swell, thereby facilitating de-hulling process. If thoroughly soaked, the seed coats can be removed by hand. If not, the aid of a grinding stone or a mortar is needed to roughly bruise the skins with a stirring action (not pounding).

Material and Methods

Experimental procedure

The performance evaluation of the cowpea wet de-hulling machine as shown in Figure 1 was carried out, such conditions considered are the 3 levels of machine operating speeds, 3 levels of soaking time, and 2 varieties of cowpea. The effect of these conditions was investigated on the de-hulling efficiency, output capacity and mechanical damage of the machine.

Experiment to study was carried out at Nigerian Stored Products Research Institute, (NSPRI), Kano, Kano State, Nigeria, where the cowpea wet de-hulling machine was developed.

Performance indices

The performance indices that were used include; De-hulling efficiency (%) and Output capacity (kg/hr).

De-hulling efficiency - D_E (%): This shows how efficiently the machine is de-hulling the sample. It was expressed as given by Olotu et al. as:

$$D_E = \frac{W_1}{W_1 + W_2} \times 100 \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (1)$$

Where, W_1 = Weight of de-hulled cowpea seed (kg).

W_2 = Weight of un-dehulled cowpea seed (kg)

Output capacity - O_c (kg/hr): This is the total quantity of cowpea

Figure 1: Evaluation of cowpea wet de-hulling machine.

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seeds collected at the machine outlet per batch per unit time. It was expressed as given by Olotu et al. as:

$$O_C = \frac{W}{T} \text{ (kg/hr)} \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where W = Total weight of de-hulled cowpea, unde-hulled cowpea and hulls collected at the outlet of the machine (kg).

T = Time taken to dehul the cowpea seed (hr).

Experimental index

The factors that were considered in the evaluation of the constructed de-hulling machine were Operating speed (**S**), Soaking time (F) and Cowpea variety (V).

Operating speed (S): The operating speed of the machine is the speed of the shaft carrying the de-hulling component. Olotu et al. reported optimum de-hulling speed for cowpea as 150 rpm. Based on this value, the constructed de-hulling machine was evaluated with following operating speeds: S_1 = 120 rpm, S_2 = 150 rpm and S_3 = 180 rpm.

Soaking time (T): The soaking time is the time required for the cowpea seeds to absorb moisture through soaking. Babatunde and Olotu et al. [5] reported 7 and 6 mins respectively as optimum soaking time before cowpea de-hulling. Based on these values, the constructed de-hulling machine was evaluated with following soaking times: T_1 = 5 mins, T_2 = 8 mins, and T_3 = 11 mins.

Cowpea varieties (V): Danbarere and Dansokoto varieties of cowpea which can be of smaller and bigger sizes are widely used in Kano (Dakata/Yankaba) area by most bean cake sellers. Based on this, smaller sizes of the two varieties [Danbarere (V_1) and Dansokoto (V_2)] were selected.

Results and Discussion

Effect of evaluated factors on de-hulling efficiency of the ecto de-hulling machine

The results of the analysis of variance are as shown in Table 1. The results show that there is no significant difference at 1% probability level between the means of the replicate, meaning that the experimental error is minimum. The results also show that the speed of operation (S), soaking time (T) and cowpea varieties (V) as well as their interactions were all significant at 1% probability level. That means all the evaluated factors and their interactions had effect on the de-hulling efficiency of the machine.

Effect of speed of operation on the de-hulling efficiency

The effect of operating speed on the de-hulling efficiency was further analysed using Least Significant Difference (LSD) test and the results of the analysis are as shown in Table 2. The results show that the mean de-hulling efficiency for 120 rpm operating speed is higher and significantly different from those of 150 rpm and 180 rpm. The mean for 150 rpm operating speed is also different and higher than that of 180 rpm operating speed. That is, the de-hulling efficiency decreases as operating speed increases. This can be explained by the fact that the lower the operating speed, the longer the residence time for the soaked cowpea seeds to rub against one another and wall of the de-hulling chamber which results to detachment of hulls before discharge. This result is in agreement with Reichert et al. [6] who reported that de-hulling of cowpea seeds at lower speed is more efficient than de-hulling at higher speed. Similarly, Olotu et al. also reported that the higher the speed of operation, the lower the de-hulling efficiency. Mean de-hulling efficiencies of 90.58%, 87.46% and 86.04% were achieved for 120 rpm, 150 rpm and 180 rpm operating speed, respectively.

Effect of soaking time on de-hulling efficiency

The results of further analysis of the effect of soaking time on the de-hulling efficiency using Least Significant Difference (LSD) test are as shown in Table 2. The results show that the mean de-hulling efficiency for 5 mins soaking time is lower and different from those of 8 mins and 11 mins. The mean for 8 mins is also different and lower than that of 11 mins soaking time. That is, the de-hulling efficiency increases as soaking time increases. This can be attributed to the fact that the longer the soaking, the more the water is absorbed and the weaker the adhesive force between the hulls and cotyledons of the cowpea seeds. The results are in agreement with Olowonibi [7] who reported that the longer the soaking period of cowpea, the higher the de-hulling efficiency. Mean de-hulling efficiencies of 86.77%, 87.11% and 90.20% were achieved for 5 mins, 8 mins and 11 mins soaking time respectively.

Effect of cowpea varieties on de-hulling efficiency

The results of further analysis of the effect of cowpea variety on the de-hulling efficiency using Least Significant Difference (LSD) test are as shown in Table 2. The results show that the mean de-hulling efficiency for Dan-barere is significantly different and higher than that of Dan-sokoto. That is, the de-hulling efficiency differs for different variety of cowpea. This can be attributed to the fact that cowpea seed as a biological material grouped into different varieties and each variety is known with specific characteristics. Dan-barere with higher de-hulling efficiency might have weaker adhesive force between its hulls and cotyledons than that of Dan-sokoto which makes it easily detachable. This result is in agreement with Olotu et al. who reported that variety of cowpea can be an important factor that can affect de-hulling efficiency. Mean de-hulling efficiencies of 89.25% and 86.70% were achieved for Dan-barere and Dan-sokoto cowpea variety, respectively.

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	F (Value)	5%	1%
Rep	2	0.0022333	0.001116	0.00 NS	3.29	5.31
V	1	88.283107	88.28310	58.99**	3.29	5.31
T	2	118.2420247	59.121012	39.51**	3.29	5.31
S	2	186.859668	93.429834	62.43**	4.14	7.48
V × T	2	0148224	73.007411	48.79**	3.29	5.31
V × S	2	63.5730113	31.786505	21.24**	3.29	5.31
T × S	4	344.665088	86.166272	57.58**	2.66	3.94
V × T × S	4	154.969745	38.742436	25.89**	2.66	3.94
Error	34	50.880231	1.496477	--	--	--
Total	53	1153.489933	--	--	--	--
**Highly Significant; NS: Not Significant						

Table 1: Analysis of variance showing effect of variables and their interaction on de-hulling efficiency (DE).

S (rpm)	DE (%)	LSD	T (mins)	DE (%)	LSD	V	DE (%)	LSD
120	90.58	a	5	86.77	c	Dan-barere	89.25	a
150	87.46	b	8	87.11	b	Dan-sokoto	86.70	b
180	86.04	c	11	90.20	a	--	--	--
S.E = 1.342	--	--	S.E = 1.092	--	--	S.E. = 1.278	--	--

Table 2: LSD test for effect of speed (S), soaking time (T) and cowpea variety (V) on de-hulling efficiency. (DE).

The interaction effect of cowpea variety and operating speed on de-hulling efficiency

The results for the interaction effect of the cowpea variety and operating speed on de-hulling efficiency are as presented in Table 3. The results show that operating speed of the machine interacting with cowpea variety is a major factor affecting the de-hulling efficiency. The de-hulling efficiency for 120 rpm operating speed interacting with Dan-barere and Dan-sokoto cowpea variety respectively was high compared with that of 150 rpm operating speed and considerably high when compared with that of 180 rpm operating speed. It can also be seen from the table that for the same Dan-barere cowpea variety, the mean de-hulling efficiency decreases as the operating speed increases. Similarly, for the same Dan-sokoto cowpea variety, the mean de-hulling efficiency also decreases as operating speed increases. Highest de-hulling efficiency was obtained from interaction of Dan-barere and 120 rpm while lowest de-hulling efficiency was obtained from interaction of Dan-sokoto and 180 rpm.

The interaction effect of cowpea variety and soaking time on de-hulling efficiency

The results for the interaction effect of the cowpea variety and soaking time on de-hulling efficiency are as presented in Table 4. In these results, no definite pattern was established. However, the mean for Dan-sokoto variety and 11 mins is the highest and different from other means. There is no significant difference in mean de-hulling efficiency for Dan-barere /8 mins and Dan-barere/11 mins. There is also no difference in Dan-barere/ 5 mins soaking time and Dan-sokoto / 5 mins. The mean de-hulling efficiency for Dan-sokoto/ 8 mins is the lowest and differs significantly from other means.

The interaction effect soaking time and operating speed on de-hulling efficiency

The results for the interaction effect of the soaking time and operating speed on de-hulling efficiency is as presented in Table 5. From the results, the effect of operating speed is more pronounced when compared with that of the soaking time. In these results, no definite pattern was established. However, on average the mean for 11 mins soaking time and 120 rpm is the highest and different from other means. There is no significant difference in mean de-hulling efficiency for 5 mins/150 rpm interaction, 8 mins/120 rpm interaction and 11 mins/180 rpm interaction. There is also no difference in 5 mins/120 rpm interaction, 11 mins/150 rpm interaction and 8 mins/180 rpm interaction. Consequently, mean de-hulling efficiency for 5 mins and 180 rpm operating speed is the lowest and significantly differs from other means.

The interaction effect of cowpea variety, soaking time and speed of operation on de-hulling efficiency

The results for the interaction effect of the cowpea variety, soaking time and operating speed on de-hulling efficiency are as presented in Table 6. In these results, no definite pattern was established. However, it can be seen from the table that there is no significant difference in mean de-hulling efficiency for Dan-sokoto /11 mins/180 rpm interaction, Dan-sokoto /11 mins/120 rpm interaction, Dan-barere/5 mins/150 rpm interaction, Dan-barere/8 mins/120 rpm interaction, Dan-barere/11 mins/120 rpm interaction, Dan-sokoto/5 mins/150 rpm interaction and Dan-barere/8 mins/180 rpm interaction. There is also no difference in mean for Dan-sokoto/8 mins/120 rpm interaction, Dan-sokoto/5 mins/120 rpm interaction, Dan-barere/11 mins/180 rpm interaction, Dan-barere/5 mins/120 rpm interaction, Dan-barere/11 mins/180 rpm interaction, Dan-barere/8 mins/150 rpm interaction, Dan-sokote/11 mins/150 rpm interaction, Dan-barere/5 mins/180 rpm interaction and Dan-sokoto/8 mins/180 rpm interaction. However, the first set listed above have significantly different and higher means for de-hulling efficiency the later set mentioned. Mean for Dan-sokoto/8 mins/120 rpm interaction is statistically at par with that of Dan-sokoto/5 mins/180 rpm interaction but lower than the second set mentioned above.

Treatment	Mean DE	LSD
V_1S_1	90.33	a
V_2S_1	90.83	a
V_1S_2	89.26	b
V_2S_2	88.28	c
V_1S_3	85.65	d
V_2S_3	83.24	e
S.E = 1.201	--	--

Means with the same letter are not significantly different.

Table 3: LSD test for interaction effect of variety (v) and operating speed (s) on de-hulling efficiency (DE).

Treatment	Mean DE	LSD
V_2T_3	91.34	a
V_1T_2	89.60	b
V_1T_3	89.25	b
V_1T_1	88.92	bc
V_2T_1	85.30	c
V_2T_2	83.94	d
S.E = 1.153	--	--

Means with the same letter are not significantly different.
Note: V_1= Danbarere; V_2= Dansoko; T_1= 5 mins; T_2= 8 mins; T_3 =11 mins.

Table 4: LSD test for interaction effect of variety (v) and soaking time (t) on de-hulling efficiency (DE).

Treatment	Mean DE	LSD
T_3S_1	92.04	a
T_1S_2	90.95	b
T_2S_1	90.37	b
T_3S_3	90.29	b
T_1S_1	89.33	c
T_3S_2	88.27	cd
T_2S_3	86.79	d
T_2S_2	83.15	e
T_1S_3	81.04	f
S.E = 1.242	--	--

Means with the same letter are not significantly different.
Note: S_1= 120 rpm; S_2= 150 rpm; S_3= 180 rpm; T_1= 5 mins; T_2 = 8 mins; T_3 = 11 mins.

Table 5: LSD test for interaction effect of operating speed (s) and soaking time (t) on de-hulling efficiency (DE).

Effect of evaluated factors on output capacity of the de-hulling machine

The results for experimental evaluation of the effect of operating speed, cowpea varieties and soaking time on output capacity of the developed machine using completely randomized design are as presented. The results of the analysis of variance are as shown in Table 7. The results show that there is no significant difference at 1% probability level between the means of the replicate, meaning that the experimental error is minimum. The results also show that the speed of operation (S), soaking time (T) and cowpea varieties (V) as well as their

Treatment	Mean DE	LSD
$V_2T_3S_3$	94.46	a
$V_2T_3S_1$	93.27	a
$V_1T_1S_2$	91.15	a
$V_1T_2S_1$	91.12	a
$V_1T_3S_1$	90.81	a
$V_2T_1S_2$	90.75	a
$V_1T_2S_3$	90.12	a
$V_2T_2S_1$	89.61	b
$V_2T_1S_1$	89.60	b
$V_1T_3S_2$	89.08	b
$V_1T_1S_1$	89.06	b
$V_1T_3S_3$	88.21	b
$V_1T_2S_2$	87.56	b
$V_2T_3S_2$	87.46	b
$V_1T_1S_3$	86.53	b
$V_2T_2S_3$	83.45	b
$V_2T_2S_2$	78.74	c
$V_2T_1S_3$	75.54	c
S.E. = 1.115	--	--
Means with the same letter are not significantly different.		

Table 6: LSD test for interaction effect of cowpea variety, soaking time, and operating speed on de-hulling efficiency (DE).

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	F (Value)	5%	1%
Rep	2	0.00378	0.00189	0.00NS	3.29	5.31
V	1	1192.05932	1192.0593	2237.47**	3.29	5.31
T	2	44.29943	22.14971	41.57**	3.29	5.31
S	2	35245.0505	17622.525	33077.1**	4.14	7.48
V × T	2	1254.99940	627.49970	1177.80**	3.29	5.31
V × S	2	1220.33632	610.16816	1145.27**	3.29	5.31
T × S	4	308.81013	77.20253	144.91**	2.66	3.94
V × T × S	4	1058.87298	264.71824	496.87**	2.66	3.94
Error	34	18.11423	0.53277	--	--	--
Total	53	40342.5461	--	--	--	--
**Highly Significant; NS: Not Significant.						

Table 7: Analysis of variance showing effect of variables and their interaction on output capacity (OC).

interactions were all significant at 1% probability level. That means all the evaluated factors and their interactions had effect on output capacity of the machine.

Effect of speed of operation on the output capacity

The effect of operating speed on the output capacity was further analysed using Least Significant Difference (LSD) test and the results of the analysis are as shown in Table 8. The results of the LSD show that the mean output capacity for 120 rpm operating speed is lower and significantly different from those of 150 and 180 rpm. The mean for 150 rpm operating speed is also different and lower than that of 180 rpm operating speed. That is, the output capacity increases as operating speed increases. This can be attributed to the fact that since the number of turns of conveying auger per unit time increases at higher speed, then the quantity of soaked cowpea being conveyed per unit time is expected to increase as well. This result is in agreement with Olotu et al. and Babatunde who reported that increase in operating speed increases the output capacity of the de-huller. Mean output capacity of 49.83 kg/hr, 68.33 kg/hr and 110.84 kg/hr were achieved for 120 rpm, 150 rpm and 180 rpm operating speed respectively.

Effect of soaking time on output capacity

The results of further analysis of the effect of cowpea variety on the output capacity using Least Significant Difference (LSD) test are as shown in Table 4. The results of the LSD show that the mean output capacity for 5 mins soaking time is significantly higher and different from those of 8 mins and 11 mins. The mean output capacity for 8 mins is also significantly different and higher than that of 11 mins soaking time. That is, the output capacity decreases as soaking time increases. This can be attributed to the fact that the longer the cowpea seed is soaked the more the moisture absorbed which increases its weight and size. This might reduce the quantity of soaked cowpea seeds handled by the machine per unit time. The results are in agreement with Olowonibi who reported that the longer the soaking period of cowpea, the lower the machine output capacity. Mean output capacity of 77.08 kg/hr, 76.53 kg/hr and 75.38 Kg/hr were achieved for 5 mins, 8 mins and 11 mins soaking time respectively.

Effect of cowpea varieties on output capacity

The results of further analysis of the effect of cowpea variety on the output capacity using Least Significant Difference (LSD) test are as shown in Table 4. The results of the LSD show that the mean output capacity for Dan-barere is significantly different and lower than that of Dan-sokoto. That is, the output capacity differs for different variety of cowpea. This can be attributed to the fact that cowpea seed as a biological material grouped into different varieties and each variety is known with specific characteristic part of which is the way different variety flows when it is being conveyed within a conveyor system. This result is in agreement with Olotu et al. who reported that cowpea varieties affect output capacity of de-hulling machine. Mean de-hulling efficiency of 71.81 kg/hr and 81.20 kg/hr were achieved for Dan-barere and Dan-sokoto cowpea variety respectively.

The interaction effect of cowpea variety and operating speed on output capacity

The results for the interaction effect of the cowpea variety and operating speed on output capacity are as presented in Table 9. The results show that operating speed of the machine is a major factor affecting the output capacity. The output capacity for 180 rpm operating speed interacting with Dan-barere and Dan-sokoto cowpea variety respectively was high compared with that of 150 rpm operating speed and considerably high when compared with that 120 rpm speed. It can also be seen from the table that for the same Dan-barere cowpea variety, the mean output capacity increase as the operating speed increases. Similarly, for the same Dan-sokoto cowpea variety, the mean output capacity also increases as operating speed increases.

The interaction effect of cowpea variety and soaking time on output capacity

The results for the interaction effect of the cowpea variety and

S(rpm)	DE (%)	LSD	T (mins)	DE (%)	LSD	V	DE (%)	LSD
120	49.83	c	5	77.08	a	Dan-barere	71.81	b
150	68.33	b	8	76.53	b	Dan-sokoto	81.20	a
180	110.8	a	11	75.38	c	--	--	--
S.E = 18.62	--	--	S.E = 0.38	--	--	S.E. = 4.70	--	--
Means with the same letter are not significantly different.								

Table 8: LSD test for effect of speed (s), soaking time (t) and variety (v) on output capacity (OC).

Treatment	Mean OC	LSD
V_2S_3	124.67	a
V_1S_3	99.77	b
V_2S_2	72.67	c
V_1S_2	63.98	d
V_2S_1	51.09	e
V_1S_1	48.56	f
S.E = 1.201	--	--
Means with the same letters are not significantly different.		
Note: V_1= Danbarere; V_2 = Dansoko; S_1 = 120 rpm; T_2 = 150 rpm; T_3 = 180 rpm.		

Table 9: LSD test for interaction effect of variety (v) and speed (s) on output capacity (OC).

soaking time on output capacity are as presented in Table 10. In these results, no definite pattern was established. However, the mean for Dan-sokoto variety and 8 mins interaction is the highest and statistically at par with that of Dan-sokoto variety and 5 mins interaction. There is no significant difference in mean output capacity for Dan-barere /11 mins interaction, Dan-sokoto/11 mins interaction and Dan-barere / 5 mins interaction. Consequently, mean output capacity for Dan-barere and 8 mins interaction is the lowest and differs from other means.

The interaction effect soaking time and operating speed on output capacity

The results for the interaction effect of the soaking time and operating speed on output capacity is as presented in Table 11. From the results, the effect of operating speed is more pronounced when compared with that of the soaking time. In these results, no definite pattern was established. However, the mean for 5 mins interaction and 180 rpm interaction is the highest and different from other means. The mean output capacity for 11 mins and 120 rpm operating speed is the lowest and differs from other means.

Cowpea variety, soaking time and speed of operation interaction effect on output capacity

The results for the interaction effect of the cowpea variety, soaking time and operating speed on output capacity are as presented in Table 12. It can be seen from the results that the difference in mean output capacity for Dan-sokoto /11 mins/150 rpm interaction, Dan-sokoto /11 mins/120 rpm interaction, Dan-barere/8 mins/120 rpm interaction, Dan-sokoto/5 mins/150 rpm interaction and Dan-barere/5 mins/120 rpm interaction are statistically at par. Also difference in mean for Dan-barere/11 mins/150 rpm interaction and Dan-sokoto/8 mins/150 rpm interaction, Dan-barere/5 mins/150 rpm interaction and Dan-barere/8 mins/150 rpm interaction are statistically the same. Mean values of output capacity for the first list of interactions was significantly higher than those for the later list of interactions. Mean for Dan-sokoto/5 mins/120 rpm interaction is statistically at par with Dan-sokoto/8 mins/120 rpm operating speed but lower than the previous set of interactions.

Effect of evaluated factors on mechanical damage of the de-hulling machine

The results for experimental evaluation of the effect of operating speed, cowpea varieties and soaking time on mechanical damage of the developed machine using completely randomized design are as presented. The results of the analysis of variance are as shown in Table 13. The results show that there is no significant difference at 1% probability level between the means of the replicate, meaning that the experimental error is minimum. The results also show that the speed of operation (S) and soaking time (T) significantly affected mechanical damage of seed 1% probability level while varieties as well as all variables interactions have no significant effect on mechanical damage of seed at 1% probability level. That means, only operating speed and soaking time had effect on the mechanical damage of the machine while varieties and interaction of all the evaluated factors had no effect on mechanical damage.

Effect of soaking time on mechanical damage

The results of further analysis of the effect of soaking time on

Treatment	Mean OC	LSD
V_2T_2	85.10	a
V_2T_1	82.79	a
V_1T_3	78.72	b
V_2T_3	75.03	b
V_1T_1	70.27	b
V_1T_2	65.67	c
S.E = 1.201	--	--
Means with the same letter are not significantly different.		

Table 10: LSD test for interaction effect of variety (v) and soaking time (t) on output capacity (OC).

Treatment	Mean OC	LSD
T_2S_3	113.18	a
T_1S_3	111.10	b
T_3S_3	108.24	c
T_3S_2	73.68	d
T_1S_2	68.47	e
T_2S_2	62.84	f
T_2S_1	50.14	g
T_1S_1	50.03	g
T_3S_1	49.31	h
S.E = 1.242	--	--
Means with the same letter are not significantly different.		

Table 11: LSD Test for interaction effect of operating speed (s) and soaking time (t) on output capacity (OC).

Treatment	Mean OC	LSD
$V_2T_2S_3$	137.53	a
$V_2T_1S_3$	121.11	a
$V_2T_3S_3$	110.72	a
$V_1T_3S_3$	107.00	a
$V_1T_1S_3$	101.01	a
$V_1T_2S_3$	100.82	a
$V_2T_3S_2$	78.61	b
$V_2T_3S_1$	74.65	b
$V_1T_2S_1$	74.64	b
$V_2T_1S_2$	74.27	b
$V_1T_1S_1$	74.06	b
$V_1T_3S_2$	68.74	c
$V_2T_2S_2$	65.13	c
$V_1T_1S_2$	62.66	c
$V_1T_2S_2$	60.55	c
$V_2T_1S_1$	52.99	d
$V_2T_2S_1$	52.64	d
$V_1T_3S_1$	50.98	d
S.E. = 1.115	--	--
Means with the same letter are not significantly different.		

Table 12: LSD test for interaction of effect cowpea variety, soaking time and operating speed on output capacity (OC).

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	F (Value)	5%	1%
Rep	2	0.011	0.003	0.001NS	3.29	5.31
V	1	0.007	0.007	1.384NS	3.29	5.31
T	2	1.301	0.650	56.245**	3.29	5.31
S	2	0.018	0.009	7.869**	4.14	7.48
V × T	2	0.015	0.007	0.586NS	3.29	5.31
V × S	2	0.017	0.008	2.186NS	3.29	5.31
T × S	4	0.008	0.002	0.142NS	2.66	3.94
V × T × S	4	0.022	0.022	1.449NS	2.66	3.94
Error	34	0.054	0.532	--	--	--
Total	53	1.453	--	--	--	--
**Highly Significant; NS: Not Significant.						

Table 13: Analysis of variance showing effect of variables and their interaction on mechanical damage (M_d).

S(rpm)	Mean M_d (%)	LSD	T (mins)	Mean M_d (%)	LSD
120	0.706	c	5	0.55	c
150	0.711	b	8	0.69	b
180	0.747	a	11	0.93	a
S.E. = 0.002		--	S.E. = 0.057		--
Means with the same letter are not significantly different.					

Table 14: LSD test for effect of speed (s) and soaking time (t) on mechanical damage (M_d).

the mechanical damage using Least Significant Difference (LSD) test are as shown in Table 14. The results of the LSD show that the mean value of mechanical damage for 5 mins soaking time is significantly lower and different from those of 8 and 11 mins. The mean mechanical damage for 8 mins is also significantly different and lower than that of 11 mins soaking time. That is, the mechanical damage increases as soaking time increases. This can be attributed to the fact that the longer the cowpea seed is soaked the more the moisture absorbed and the softer the cotyledons become. This might increase the quantity cowpea seeds being deformed during the de-hulling process. The results are in agreement with Olowonibi, who reported that the longer the soaking period of cowpea, the higher the de-hulling efficiency but the more the percentage of mechanical damage. Mean mechanical damage of 0.55%, 0.69% and 0.93% were achieved for 5 mins, 8 mins and 11 mins soaking time respectively.

Effect of operating speed on mechanical damage

The results of further analysis of the effect of operating speed on the mechanical damage using Least Significant Difference (LSD) test are as shown in Table 14. The results of the LSD show that the mean mechanical damage for 120 rpm operating speed is significantly lower and different from those of 150 rpm and 180 rpm. The mean mechanical damage for 150 rpm is also significantly different and lower than that of 180 rpm soaking time. That is, the mechanical damage increases as operating speed increases. This can be attributed to the fact that the higher the speed of operation the more the impact effects on cowpea cotyledons. This might increase the quantity cowpea seeds being deformed during the de-hulling process. Mean mechanical damage of 0.706%, 0.711% and 0.747% were achieved for 120 rpm, 150 rpm and 180 rpm operating speed respectively (Table 13).

Recommendations

The de-hulling machine should also be evaluated on other legume seeds such as soybean and locust bean seeds so as to make it multi-crop de-hulling machine and increase its potential.

Conclusion

Cowpea de-hulling machine had been evaluated. From the evaluation of the machine, de-hulling efficiency, output capacity and mechanical damage were in the range of 86.04% to 90.58%, 49.31 kg/hr to 137.53 kg/hr and 0.23% to 0.93% respectively. The best de-hulling efficiency, output capacity and mechanical damage were obtained at 120 rpm operating speed, 8 mins soaking time, and with dan-barere cowpea variety. Based on this, the average de-hulling efficiency, output capacity and mechanical damage of the machine were 90.79%, 74.27 kg/hr. and 0.39%.

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