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Full Length Research Paper

Effects of Operative Processing Conditions on the Performance of Cowpea Dehuller Using Selected Cowpea Varieties

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Abstract
The study evaluates the performance of a modified cowpea dehuller using two varieties of cowpea namely, IAR 48 and IAR60/62. Two important parameters namely speed of the machine and soaking time of the cowpea were selected at various levels and varied for the purpose of achieving their optimum values. The levels of these factors are; machine speed: 150, 200, 250, 300 and 350rpm and soaking time: 2, 4, 6, 8 and 10mins. Also, the performance evaluation parameters measured were dehulling efficiency, cleaning efficiency, feed rate and output capacity. Empirical results show that both soaking time and machine speed have significant effect on all the performance evaluation parameters of the machine. Optimum dehulling efficiency of 96.0147% and 83.1513% was observed at a speed of 150rpm for IAR 48 and IAR60/62 varieties respectively. Six minutes soaking time was found to be appropriate to achieve the dehulling efficiency. The Cleaning efficiency of the machine increases when the machine speed was increase from 150rpm through 350rpm. This trend was consistent for feed rate and output capacity. Optimum machine speed and soaking time for all the three parameters were 350rpm and 10 minutes soaking time respectively. The cleaning efficiency of the machine was 73.46% and 73.23% respectively for IAR60/62 and IAR 48. The feeding rate was 256.79kg/hr and 254.11kg/hr for IAR60/62 and IAR 48 respectively while the output capacity was18.25kg/batch and 18.30kg/batch the two varieties respectively.

Key words: *Cleaning, Dehulling, Efficiency, Feed, IAR60/62, IAR 48, Machine, Varieties*

Introduction
Cowpea (*Vigna unguiculata* or *Vigna sinensisunguiculata*) is one of the most highly proteineous African crop that feeds people, their livestock and the next crop. In the Americas, it is also known as "black-eyed peas" and the plant itself can be dried and stored until needed as fodder for livestock.

In Nigeria as well as most West African countries, cowpea is 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, eaten as moin – moin which is steamed – cook of wet – milled cowpea mixed with cooking ingredients and it is also used in preparing a popular cowpea stew called gbegiri (Babatunde, 1995). In recent time cowpea seeds are now processed into packaged cowpea flour for further preparation into any form of food products. Dehulling of cowpea seeds plays a major role in the processing of cowpea seeds.

Akinjayeju and Ajayi (2011) and Kurien, et al., (1972) defined dehulling as the removal of the seed coat (hull) which results in the separation of the cotyledon. There are two major methods of dehulling; wet dehulling and combined dehulling (i.e. dry and wet) method

In the rural sector, the decortications process is still a part of the housewife's work in food preparation. In the case of black gram, green gram and cowpeas, where the hull is firmly attached to the cotyledons, water soaking is used to facilitate hull removal. The hulls absorb moisture and swell, thereby facilitating dehulling by gentle rubbing of the seed by hand or pounding inside a mortal. The hulls are easily separated from cotyledons by floatation. At this stage, the cotyledons are wet and must be used immediately or dry and store for further processing into food products such as moin-moin, bean cake, etc.

In the recent years, According to Olowonibi, (1999) and Kolade, (2003), both manually operated and motorized dehulling machines have been developed by institutions like National Centre for Agricultural Mechanization, (NCAM), Ilorin and Department of Agricultural Engineering, University of Ilorin.

It has been observed that when cowpea seed is over soaked in water, the dehulling becomes difficult. Also, according to Sefa-Dedeh et al. (1978) and Sefa-Dedeh and Stanley (1979), Cowpea seeds with smooth seed coat texture tend to absorb less water than seeds with wrinkled seed coat. Also, Babatunde, (1995) and Reichert, et al. (1979) evaluated dehulling machines and discovered that operating speed of dehuller and soaking time of cowpea seeds affect the performances of the dehullers. The main objective of this work therefore is to investigate the effects of cowpea soaking time and machine operating speed on the performance of the cowpea dehulling machine using two varieties of cowpea seeds.

Materials and Methods

Experimental Procedure

The effects of operative processing conditions on the performance of the cowpea dehulling machine as shown in figure 1 was investigated, such conditions considered are the soaking time which determined the moisture content of the soaked cowpea seeds, the Operating speed of screw conveyor which also determined the operating speed of the agitator and the locally available cowpea variety. The treatment combinations in the design layout for the experiment are 4 x 5^2 factorial design experiments.

Experiment to study the effects of operative processing conditions on the performance of the modified cowpea dehuller was carried out at National Centre for Agricultural Mechanization, (NCAM), Ilorin, Kwara State, Nigeria, where the modified cowpea dehulling machine was developed.

Figure 1: Pictorial View of the Cowpea Dehulling Machine

The experiment took the procedure illustrated thus; the motorized cowpea dehuller was tested using a 2hp electric motor at various operating speeds of 150rpm, 200rpm, 250rpm, 300rpm and 350rpm. The two commonly available cowpea varieties (IAR 48 and IAR60/62) were used for the experiment. The selected cowpea varieties were weighted out in three replication of 1kg each. The weighted quantities of cowpea were soaked for specified time of 2mins, 4mins, 6mins, 8mins and 10mins. The moisture contents at each soaking time were then measured.

The soaked and weighed cowpea seeds were fed into the dehuller at the various speeds of dehulling operation.The time taken to feed each weighed quantity of the cowpea at various speeds, weight of the dehulled seeds, and weight of the undehulled seed, weight of chaffs inside both chaff collector and separating chamber were recorded.

Performance Indices

The equations expressed below followed the format of Standard test code for groundnut sheller, NIS (1997) and Babatunde, (1995).

i. **Feed Rate; F_R (kg/hr): -** This is the quantity of soaked cowpea seeds that is fed into the dehulling chamber from the hopper per unit time. It determined the rate at which the soaked cowpea seeds are fed into the auger from the hopper. It is expressed as;

$$F_R = \frac{W_1}{T_1} \text{ (kg/hr)} \qquad (1)$$

Where,
W_1 (kg) = Total weight of soaked seeds fed into the machine.
T_1 (hr) = Time of feeding

ii. **Dehulling efficiency; D_E (%): -** This indicates the quantity of soaked cowpea seeds that is being dehulled by the machine and it is expressed in percentage. This shows how efficient the machine is dehulling the sample. It is expressed as:

$$D_E = \frac{W_3}{W_2} x100 (\%) \quad (2)$$

Where,
W_2 (kg) = W_3 + W_4
W_3 (kg) = Weight of dehulled cowpea seeds.
W_4 (kg) = Weight of undehulled cowpea seeds.

iii. **Cleaning Efficiency; C_E (%):-** This indicates the quantity of hull (chaff) that is being removed from the dehulled seeds inside the separating chamber, it is expressed in percentage. It determines how efficient the machine is able to remove hull from the cotyledon. It is expressed as:

$$C_E = \frac{W_6}{W_5} x100 (\%) \quad (3)$$

Where,
W_5 = W_6 + W_7
W_6 (Kg) = Weight of chaff inside chaff collector.
W_7 (Kg) = Weight of chaff remaining inside the cleaning chamber after operation.

iv. **Output capacity O_c (kg/hr):-** This is the quantity of soaked cowpea seeds that cleaned dehulled per batch per unit time. It can be expressed as:

$$O_C = \frac{W_1}{T_2} \text{ (kg/hr)} \quad (4)$$

Where,
T_2 (hr) = Time of operation.
W_1 is as earlier defined

Statistical analysis of results obtained was carried out at the National Centre for Agricultural Mechanization (NCAM) Statistics department, using the Statistical Package for Social science (SPSS).

Results and Discussion

***Dehulling Efficiency*: -** The result of the Analysis of variance for dehulling efficiency is as presented in Table 1. From Table 1, it can be inferred that the process conditions (speed of auger and soaking time) and the interaction between the two had significant effect on dehulling efficiency 1% level of significance. Hence, the hypothesis of equal of mean treatment effect is rejected. This implies that at least one of the mean treatment effect is significantly different from the others

To determine the differences in the mean treatment effect of operating speed on oil yield, New Duncan's Multiple Range Test (DMRT) was conducted (Table 2). The result of the comparison among the five levels of speed revealed that dehulling efficiency reduces with increase in operating speed for IAR 60/62 and IAR 48 varieties and that the mean differences observed for each level of speed is significantly different from each other. The maximum dehulling efficiency of 96.0147% observed at 150rpm while a minimum dehulling efficiency of 80.2907% was observed at 300rpm.

This is in contrast with findings of Babatunde, 1995 which showed that dehulling efficiency of a manually operated cowpea dehuller increases with increase in operating speeds, although Babatunde, 1995 worked at a low speed levels of 60rpm, 80rpm and 100rpm, however, Reichert, et al. (1979) reported that dehulling of cowpea seeds at lower speed is more efficient than dehulling at higher speed. The lowest dehulling efficiency mean value at speed level 350rpm might be attributed to the fact that the residence time of the soaked cowpea seeds inside the dehulling chamber were shorten by the high conveying speed, hence there is no enough time for the seeds to rub against each other and wall of the dehulling chamber. While at speed level 150rpm comparable to the maximum speed of 100rpm chosen by Babatunde, 1995, there was enough time for the seeds to rub against each other and the wall of dehulling chamber before they were being conveyed out.

It was observed that there was an increase in dehulling efficiency of the dehuller from 2mins soaking time to 6mins soaking time, but at level 8mins soaking time, the dehulling efficiency of the dehuller IAR60/62 began to decrease. IAR 60/62 which had the initial moisture content 11.0%mc (wb) had its highest mean value of dehulling efficiency at soaking time level 6mins, while its least mean value of dehulling efficiency was at soaking time level10mins. All the levels of soaking time were significantly different from each other at $P \leq 0.01$. This implies that they both had different effect on the dehulling efficiency of the dehuller. From the experiment

Also, Table 2 showed that there was an increase in dehulling efficiency of the dehullerfrom soaking time 2mins to soaking time 6mins, but at 8mins soaking time the dehulliing efficiency of dehuller started decreasing.IAR48 which had initial moisture content of 10.3%mc (wb) had it highest mean value of dehulling efficiency at soaking time level 6mins, and the least mean value of dehulling efficiency was observed at soaking time level10mins, although, soaking time levels 4mins and 8mins were not significantly different at P≤ 0.01, which means that they had similar effect on the dehulling efficiency of the dehuller. IAR48 variety with highest mean value of dehulling efficiency might have a weaker adhesive force between the hull and the cotyledon making it to detach easily from each other. According to Sefa-Dedeh et al. (1978) and Sefa-Dedeh and Stanley (1979), Cowpea seeds varieties differ from each other in term of seed coat texture.The seed coat texture could be an important selection index when processing cowpea seeds into flour, especially for ease of soaking and dehulling operations. Hence the difference in the response of the two selected cowpea seeds varieties during the experiment might be as a result of their different characteristics.

Table1: Effect of Speed and Soaking Time on Dehulling Efficiency of Cowpea Seeds

variety	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
1	Speed (A)	3723.856	4	930.964	1.148E4	0.001*
	Soaking Time (B)	303.555	4	75.889	935.988	0.001*
	A x B	24.945	16	1.559	19.229	0.001*
	Error	4.054	50	0.081		
	Total	428629.710	75			
2	Speed (A)	2688.973	4	672.243	7.321E3	0.001*
	Soaking Time (B)	298.739	4	74.685	813.298	0.001*
	A x B	26.836	16	1.677	18.265	0.001*
	Error	4.591	50	0.092		
	Total	584583.230	75			

*Significant at p≤0.01, Variety 1= IAR60/62, Variety 2 = IAR48,

Table 2: Mean Dehulling Efficiency for Cowpea using New Duncan multiple Range Test

	Variety	
Operating speed	IAR 60/62	IAR 48
350	63.0967^a	80.2907^a
300	72.7207^b	82.5633^b
250	76.4827^c	88.3267^c
200	80.7460^d	93.0940^d
150	83.1513^e	96.0147^e
Soaking time		
10	72.4360^a	85.6480^a
2	73.7367^b	86.1727^b
8	75.5387^c	88.5933^c
4	76.2427^d	88.6727^c
6	78.2433^e	91.2027^d

Mean with the same alphabet are not significantly different from each other.

Cleaning Efficiency

This determines how efficiently the machine is able to separate hull from the cotyledon during dehulling operation of the soaked cowpea seeds. The result of the analysis of variance for cleaning efficiency in Table 3 showed significant effect in the magnitudes of cleaning efficiency at all speeds of operationand the soaking time for the two varieties of cowpea seeds tested at P≤ 0.01.

From table 3, it is observed that the speed of operation for the agitator had significant effect on cleaning efficiency of the machine for two the varieties of cowpea seeds tested P≤ 0.01.

The Using New Duncan Multiple Range Test (NDMRT) in Table 4 revealed that the speed of operation of the machine for the two varieties of cowpea seeds at level 150rpm had the least cleaning efficiency mean value followed by 200rpm. The mean value of cleaning efficiency increases as the speeds of operation increases and that the highest cleaning efficiency mean value was obtained at speed level 350rpm. This is in line with the findings of Babatunde, 1995 which showed higher values of cleaning efficiency of the manually operated cowpea dehuller at the higher speeds of operation.

This could mean that the agitators beat the water inside the separating chamber faster, causing a turbulent action on the water, and keeping the light hull afloat while the cotyledons that were heavier than water sinks down to the bottom plate. While at speed level 150rpm, however, the agitator gently beats the water inside separating chamber and the turbulent action caused is not strong enough to keep the hull afloat, hence, it sinks down with the cotyledon. The Table4 showed that all levels of speed of the agitator were significantly different at P≤ 0.05. This means that they do not have similar effect on the cleaning efficiency of the dehuller.

The New Duncan Multiple Range Test also showed the difference in the levels of the cleaning efficiency of the dehuller. Table 4,showed very slight significant differencesfor IAR 60/62 variety and non significant differences for IAR48. The highest Cleaning efficiency of 73.46% was at 8mins soaking time, and this was not statistically different from what was observed at 6mins and 2min respectively, while soaking time level 10mins had the least value of cleaning efficiency, and this was statistically the same with cleaning efficiency at 4mins. Cleaning efficiency for IAR48 was statistically the same irrespective of soaking time.

Table 3: Effect of Speed and Soaking Time on Cleaning Efficiency of Cowpea Seeds

variety	Source	Sum of Squares	df	Mean Square	F	Sig.
1	Speed (A)	12898.056	4	3224.514	2.191E3	0.001*
	Soaking Time (B)	27.139	4	6.785	4.611	0.003*
	A x B	99.809	16	6.238	4.239	0.001*
	Error	73.575	50	1.471		
	Total	411153.164	75			
2	Speed (A)	11676.033	4	2919.008	2.588E3	0.001*
	Soaking Time (B)	15.221	4	3.805	3.373	0.16ns
	A x B	45.679	16	2.855	2.531	0.006*
	Error	56.402	50	1.128		
	Total	408373.310	75			

*Significant at p≤0.01; ns Significant at p≤0.01 Variety 1 = IAR60/62, Variety 2 = IAR48.

Table 4: Mean Cleaning Efficiency for Cowpea using New Duncan multiple Range Test

	Variety	
Operating speed	IAR 60/62	IAR 48
150	52.4053[a]	52.9220[a]
200	65.8000[b]	66.6013[b]
250	73.5100[c]	73.8233[c]
300	82.3067[d]	80.6280[d]
350	90.2373[e]	89.6093[e]
Soaking time		
10	71.9833[a]	72.1107[a]
4	72.2780[a]	72.2547[a]
2	73.2113[b]	72.9107[a]
6	73.3227[b]	73.0707[a]
8	73.4640[b]	73.2373[a]

Mean with the same alphabet are not significantly different from each other.

Feed Rate: - Feed Rate is the rate at which the soaked cowpea seeds are fed into the auger from the hopper. The effect of soaking time and speed on each variety of cowpea under study is as shown in Table 5.The analysis showed that the speed of operation, soaking time for each variety of cowpea seed as well as the interactions between them were significant at P≤ 0.01.This showed that the operation/process conditions and their interactions had effect on the feed rate.

Using the New Duncan Multiple Range Test (NDMRT), the levels of the speed of operation were the significant differences lies were investigated. Table 6 shows that feed rate increases as the operating speed of the machine increase from 150rpm through 350rpm for both varieties of cowpea seed. Different levels of operating speed recorded were significantly different from each other in terms of their feed rate at 1% level of significance. The highest feed rate mean value at speed level 350rpm was as a result of the fact that the auger was conveying the soaked cowpea seeds faster, leading to faster intake of soaked cowpea seeds from the hopper into the dehulling chamber at very short time. While at speed level 150rpm, the soaked cowpea seeds were gradually take into dehulling chamber from the hopper, hence taken a longer time to feed into the dehulling chamber. It can therefore be inferred that for high feed rate, high operating speed to should be considered.

Soaking time was also seen to have a similar effect on the feed rate of the dehulling machine being evaluated. Different levels of soaking time show significantly different feed rates. Higher soaking time also mean higher feed rate.

Table 5: Effect of Speed and Soaking Time on Feed Rate of Cowpea Seeds

variety	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
1	Speed (A)	226416.343	4	56604.086	3.156E3	0.001*
	Soaking Time (B)	2282.938	4	570.734	31.817	0.001*
	A x B	1139.098	16	71.194	3.969	0.001*
	Error	896.892	50	17.938		
	Total	2882652.109	75			
2	Speed (A)	223074.034	4	55768.509	8.018E3	0.001*
	Soaking Time (B)	2239.067	4	559.767	80.483	0.001*
	A x B	582.748	16	36.422	5.237	0.001*
	Error	347.754	50	6.955		
	Total	2861901.210	75			

*Significant at $p \leq 0.01$; Variety 1 = IAR60/62, Variety 2 = IAR48,

Table 6: Mean Feed Rate for Cowpea using New Duncan multiple Range Test

	Variety	
Operating speed	IAR 60/62	IAR 48
150	104.40[a]	103.01[a]
200	149.52[b]	149.09[b]
250	199.55[c]	204.44[c]
300	229.93[d]	226.67[d]
350	256.79[e]	254.11[e]
Soaking time		
2	1.8127[a]	1.8050[a]
4	1.8226[a]	1.8441[b]
6	1.8898[b]	1.8741[c]
8	1.9233[c]	1.8797[c]
10	1.9536[c]	1.9702[d]

Mean with the same alphabet are not significantly different from each other.

***Output Capacity*: -** This is determined by measuring the quantity of soaked cowpea seeds that can be dehulled per hour. The analysis of variance test for output capacity as a result of speed of operation of the dehuller and soaking time on each variety of cowpea seeds presented on Table 7 showed significant effect for speed of operation and soaking time for both variety of cowpea. The interaction between the two factors also found to be significant at 1% level of significance. This shows that the process conditions and their interactions had effect on the output capacity of the machine.

Table 8 shows significant differences for output capacity for the various level of speed. Higher output capacity was relatively associated with higher speedthough not statistically significant. There was no significant difference in output capacity between speed 150 rpm, 200rpm and 250rmp for IAR60/62. Also 300rpm and 350rpm recorded relatively same output capacity for IAR60/62.
IAR48 variety show relatively the same mean output capacity for all speed levels except 350rpm. At this speed level, the mean output capacity was significantly different from all other lower levels of speed considered.

Table 8 also investigate the mean output capacity along the different levels of soaking time. Higher values of mean output capacity were observed at higher soaking time for both varieties of cowpea. The highest output capacities of 19.5960 and 19.7353 for IAR 60/62 and IAR 48 respectively were recorded at level 10mins which is the highest soaking time experimented. Soaking time level 2mins had the least mean value of output capacity. This mean that cowpea seeds soaked for 10mins had taken in more moisture thereby increasing its weight. Hence the weightier cowpea becomes easier to dehull thereby recording higher output capacity at this the longer soaking time.

Table 7: Effect of Speed and Soaking Time on Output Capacity of Cowpea Seeds

Variety	Source	Sum of Squares	Df	Mean Square	F	Sig.
1	Speed (A)	1.093	4	0.273	3.459	0.014**
	Soaking Time (B)	82.972	4	20.743	262.582	0.000*
	A x B	4.544	16	0.284	3.595	0.001*
	Error	3.950	50	0.079		
	Total	24699.884	75			
2	Speed (A)	0.332	4	0.083	2.906	0.031**
	Soaking Time (B)	92.235	4	23.059	806.856	0.001*
	A x B	0.685	16	0.043	1.499	0.138ns
	Error	1.429	50	0.029		
	Total	25023.660	75			

*Significant at p≤0.01, ns not significant, Variety 1 = IAR60/62, Variety 2 = IAR48

Table 8: Mean Output Capacity for Cowpea using New Duncan multiple Range Test

	Variety	
Operating speed	IAR 60/62	IAR 48
150	17.9873[a]	18.1287[a]
200	17.9973[a]	18.1773[b]
250	18.0680[a]	18.2733[b]
300	18.2553[b]	18.2773[b]
350	18.2593[b]	18.3007[b]
Soaking time		
2	16.5013[a]	16.6587[a]
4	17.5167[b]	17.4020[b]
6	18.2373[c]	18.2793[c]
8	18.7160[d]	19.0820[d]
10	19.5960[e]	19.7353[e]

Mean with the same alphabet are not significantly different from each other.

Conclusion

The study evaluates the performance of a modified cowpea dehuller using two varieties of cowpea (IAR 48 and IAR60/62). In evaluating the cowpea dehuller, the parameters investigated were dehulling efficiency, cleaning efficiency, feed rate and output capacity. Empirical results showed that dehulling efficiency reduces with increase in speed. An optimum dehulling efficiency of 96.0147% and 83.1513% was observed at a speed of 150rpm for IAR 48 and IAR60/62 varieties respectively. Also optimum soaking time of six (6) minutes was appropriate for good cleaning efficiency of the machine under study. The cleaning efficiency of the cowpea dehuller is proportional to the operating speed. This implies that the cleaning efficiency increases as the speed increases. Therefore for higher separating of the hull from the seed, higher speed (say 350rpm) will be needed. The results also suggest that the speed increases for both varieties of cowpea under study. Optimum soaking time of 8 minutes for both varieties of cowpea gave rise to cleaning efficiency of 73.46% and 73.23% respectively for IAR60/62 and IAR 48. Similarly, Feed rate also increase when the speed of machine was increase 150rpm through 350rpm suggesting a proportionate relationship. This means that for higher feed rate, higher speed should be considered. Also higher soaking time mean higher feed rate as far as this machine was concern and as far as the two varieties of cowpea under study was also concerned. Finally, the output capacity of the machine was also seen to be affected by the appropriately manipulating the speed of the machine and soaking time of the cowpea. The output capacity resulting from speed 300rpm and 350rpm are relatively the same on the average for the two varieties of cowpea understudy. As regard soaking time, however higher output capacity were obtained at 10 minutes soaking time for both varieties of cowpea. Generally speaking, both soaking time and speed of the machine were seen to be proportional to output capacity.

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