

Impact of Moisture content, number slots and Impeller angulation on performance efficiency of a Bambara Groundnut Sheller

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ABSTRACT

A centrifugal Bambara groundnut sheller was designed, constructed and evaluated. The sheller consists of a feed hopper with a flow rate control device, shelling unit, separating unit and power system. Nine different impellers were used for the investigation at three different pod moisture contents. Results of the performance tests were examined using a 3 x 3 x 3 factorial design with moisture content, impellers lot angulations, and number of impeller slots as variables. Results showed that moisture content, impeller slot angulations, number of impeller slots and interaction between these variables statistically affected the performance indicators (shelling efficiency, percentage of breakage, percentage of partially shelled pods, percentage of unshelled pods and winnowing efficiency) at the significance level of 5%. The forward facing impeller with eight slots gave the best performance of 96% shelling efficiency, 3.4% breakage, 0.6% partially shelled pods. No unshelled pods were recorded, and winnowing efficiency of 97.3% was recorded at an average feed rate of 215.8 kg h

Keywords: Bambara groundnut, centrifugal impeller, pods, winnowing

I. INTRODUCTION:

Bambara groundnut (*Vigna subterranean* L. Verdc) is an indigenous African crop grown across the continent from Senegal to Kenya and from the Sahara to South Africa (Atikuet al., 2004). Bambara groundnut is the third most important grain after groundnut and cowpea (Ezeaku, 1994). In separate reports by Ezue (1977) and Atiku (2000), it was noted that in Nigeria bambara groundnut is widely produced in Borno, Anambra, Plateau, Taraba,

Sokoto, Bauchi, Benue, Kano, Yobe, Adamawa and Gombe states.

Goli (1997) reported that bambara groundnut contains about 63% carbohydrate, 19% protein, and 6.5% oil and is consumed in different forms. Other reports by Akaniet al. (2000), Atikuet al. (2004) and Linnemann (1988), stated that the seed of bambara groundnut can be used for baby food, human consumption, industrial products and Animal feed. Linnemann (1990) reported that bambara groundnut flour has been used in making bread in Zambia, and Broughtet al. (1993) noted that the milk prepared from bambara groundnut gave a flavour preferred to that of milks from cowpea, pigeon pea and soybean. According to Atiku (2000) the fresh bambara groundnut seed is cooked before eating. It is used as main food, snacks, relish and medicine, and has a high ceremonial value. Kay (1979) recommended that after harvesting, bambara groundnut is dried in the sun to about 8 to 12% moisture content (w.b.). The dried seed could be taken as snacks after roasting or milled to flour for other food.

Despite these economic importance's, no commercial production and no industrial use of the crop take place in Nigeria. According to Akaniet al. (2000) research is concentrated only on the agronomic aspect, while the processing aspects have been neglected. The pod of Bambara groundnut is very hard and the cracking methods are still traditional. These cracking methods vary from locality to locality depending on the quantity produced. Some communities use mortar and pestle to crush dry pods. Some beat them with sticks on flat ground; others use stones to crush the pods on flat ground. These methods have the disadvantages of damaging the seeds, and are slow and tiresome.

Atiku et al. (2004) evaluated the performance of a bambara groundnut sheller working on the principle of rollers and pneumatically separating the shells from the seeds. They got the maximum shelling and winnowing efficiencies of 80% and 79.5%, respectively, at pod moisture content of 5% (w.b.) and feed rate of 93.6 kg h⁻¹. The percentage of damaged seed was about 20%, the percentage of partially shelled (broken and unbroken seeds) and percentage of unshelled pods were 10 and 7%, respectively, while the machine loss accounted for 3%.

Adigun and Oje (1993) reported that nuts whose shells/pods cannot be easily broken by the roller cracker are commonly cracked using a centrifugal cracker. Makanjuola (1975) evaluated some centrifugal impaction devices for shelling melon (egusi) seeds (*Citrullus vulgaris*) and found that a centrifugal impact method is a good technique for shelling melon seeds. He evaluated three types of impellers (A, B and C) with four slots, eight slots, and two parallel plates, respectively. He concluded that impeller type A was the most effective of all the three types tested. Odigboh (1979) developed and tested a prototype impact melon (*Citrullus vulgaris*) shelling machine that gave about 96% shelling efficiency and 100% winnowing efficiency. He also evaluated three types of impellers at different vane angulations with four vanes each. Impeller type A had radially positioned vanes, type B vanes positioned at 45° to the radius, while type C vanes at 90° to the radius of the circle. He concluded that impeller type B gave the best combination of higher shelling and low percentage of damage.

Oluwole et al. (2004) developed and tested a sheanut cracker working on the principle of impaction and pneumatically separating the shells

from the kernel. They got cracking efficiency of 100% and winnowing efficiency of 97%. They evaluated three types of impeller, similar to those of Odigboh (1979) but with slight differences in the vane angulations. Impeller type A had radially positioned vanes; type B and type C had their vanes positioned at 45° and 30° to the radius respectively. They concluded that the radially positioned vanes impeller gave 100% effective cracking efficiency. Akaniet al. (2000) determined the optimum impact energy for shelling bambara groundnut at pod moisture content range of 5-8% (w.b.) and found that the impact energy ranged from 0.24 to 0.59 J.

This paper presents the results of applying nine types of impeller (three with radially positioned slots, three with forward facing slots and three with backward facing slots) to project individual bambara groundnuts at three moisture levels against the inner surface of a cylindrical cover cracking surface.

DESCRIPTION OF THE IMPACT SHELLER

The machine, similar in principle to Odigboh's impact melon (*Citrullus vulgaris*) sheller (Fig. 1), consists of a feed hopper, pod shelling unit, separation unit and power unit. Figure 2 shows the assembly details of the machine. The conical shaped hopper is mounted on the tool frame and is held in place by a hopper support frame. The base is connected directly to the shelling unit. A nut flow control device is located between the hopper and the shelling chamber. The shelling unit consists of a 410mm diameter by 150mm height cylindrical shell made from 5mm steel sheet, whose inner surface serves as the cracking surface, and an impeller of 370mm diameter made of 25 by 50mm



Figure 1

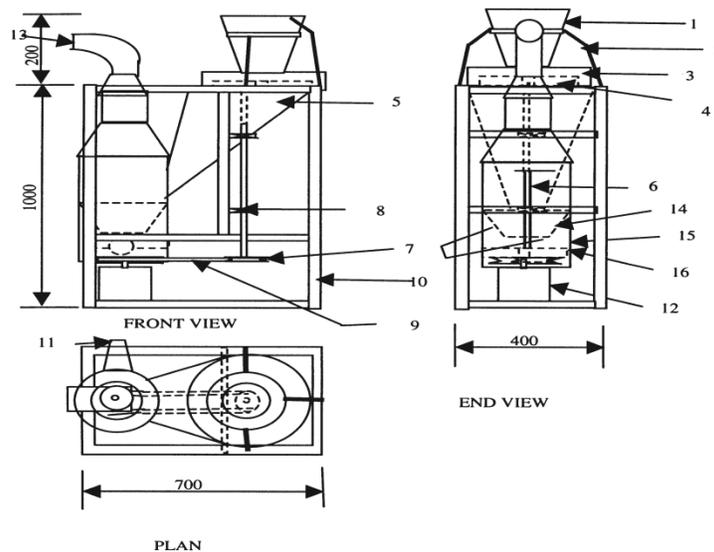


Figure 2

Fig. 2 Centrifugal impaction device: 1 – hopper, 2 – hopper support frame, 3 – cracking chamber, 4 – impeller, 5 – transition channel, 6 – shaft, 7 – pulley, 8 – bearing, 9 – belt, 10 – frame, 11 – seed collection chute, 12 – electric motor, 13 – chaff-outlet, 14 – inner funnel, 15 – separation compartment, 16 – axial fan. Rectangular steel pipe similar to that described by Dicken (1961) as shown in Fig. 3. These impellers were divided into three groups: A – impeller slots positioned at 4 to the tangent at the slots outlet (forward facing) represented with subscript F; B – radially positioned impeller slots (at 90 to tangent at the slots outlet) represented with subscript R; and C – impeller slots

positioned at 135 to the tangent at the slots outlet (backward facing)

PRINCIPLE OF OPERATION

To operate the device, the nut flow control device is closed completely. The hopper is then filled with a known number and mass of nuts. The main switch is then switched on to actuate the electric motor which runs the impeller in the cracking chamber. As the impeller reaches its operating speed, the nut flow control device is opened to allow nuts to flow into the impeller eye. The incoming nuts slide and roll on the inner surface of the rectangular pipe, the centrifugal force developed as a result of the rotation of impeller throws the nuts against the

cracking surface and causes the nuts to crack. These seeds and the shelled pods flow down through the clearance between the impeller and the cylindrical shell and fall on an inclined transition channel that leads to the separating compartment. Here the shells, which are lower in density than the seeds, are lifted up by the air stream from the axial fan and blown out through the shells outlet. The denser seeds fall through the air stream into the inner wire mesh funnel to the seed collection chute. Figure 4 shows the impeller mounted in the operational position.

PERFORMANCE TESTS

To carry out the performance tests, nine types of impellers were evaluated. Each of these impellers were used to shell bambara groundnut at three different moisture levels in the range of 5.3-12.2% (d.b.). Some quantity of bambara groundnut pods (N_T) were randomly selected and weighed. These pods were poured into the hopper while the pods flow control was completely closed. The main control switch was switched on; as the impeller attained the operating speed, the pod flow control was opened to allow the pods to flow into the eye of the impeller at an average feed rate of 215.8 kg/h. These pods were carefully collected after going through the impeller, and the number of pods fully

shelled without broken seeds (N_1), number of pods fully shelled with broken seeds (N_2), number of pods partially shelled (N_3) and number of unshelled pods (N_4) were determined at the end of each run. The quantities of shells winnowed out (M_{SW}) and of those collected with the seeds (M_{UW}) were determined and recorded.

Each of these tests were replicated five times at each of the moisture level and for each of the evaluated impellers. The performance was evaluated based on the following indices (Oluwole et al, 2007b): shelling efficiency,

$$s(N_1 / N_T)100, \quad (1)$$

Percentage of broken seeds,

$$b(N_2 / N_T)100, \quad (2)$$

Percentage of partially shelled pods,

$$p(N_3 / N_T)100, \quad (3)$$

Percentage of unshelled pods,

$$u(N_4 / N_T)100, \quad (4)$$

Winnowing efficiency,

$$w(M_{SW} / M_{TS})100, \quad (5)$$

Where: N_T – number of pods fed into the impeller;

$M_{TS} = M_{SW} + M_{UW}$.

These results were statistically analysed using factorial design.

Table 1: F-ratio for the results of the performance tests

Source of variation	Shelling efficiency (s)	Breakage (b),	partially shelled pod (p)	unshelled pods (u)	Winnowing efficiency (w)
Main effects					
Moisture content (M)	1181.73*	69.55*	157.64*	50.90*	1189.11*
Number of slots (f)	564.37*	13.01*	77.93*	20.22*	21.74*
Impeller angulation (S)	148.86*	7.98*	3.43*	11.32*	203.05*
2-way Interaction effect					
M × f	8.12*	0.814	9.06*	0.76	0.99
M × S	5.21*	0.869	10.64*	0.09	8.34*
S × f	2.37	0.61	1.32	0.28	0.85
3-way Interaction effect					
M × f × S	0.88	0.49	1.34	0.16	0.55

Result of the performance

II. RESULTS AND DISCUSSION

Tables 1 and 2 show the results of the performance tests analyses. Table 1 shows that moisture content (M), number of impeller slots (f) and impeller slot angulations (S) significantly affect

the shelling efficiency (s), percentage of broken seeds (b), percentage of partially shelled pods (p), percentage of unshelled pods (u) and winnowing efficiency (w) at the significance level of 5%. The interaction between moisture content and number of

impellers lots(Mxf) has a significant effect on the shelling efficiency and the percentage of partially shelled pods at the significance level of 5%, while the interaction between moisture content and impeller slots angulations (MxS) significantly affects the shelling efficiency, the percentage of partially shelled pods and the winnowing efficiency at the significance level of 5%.

Table 2 shows that the forward facing impeller consistently gave the best performance. Similar findings were reported by Oluwole et al. (2004) and Oluwole et al. (2007a) in performance evaluation of a sheanut cracker and effect of moisture content on crack ability of bambara groundnut using a centrifugal cracker, respectively. Table 2 also reveals that the impellers with eight slots consistently gave the best performance. Similar findings were reported by Oluwole et al. (2007b) in an evaluation of some centrifugal impaction devices for shelling bambara groundnut.

At all the moisture contents employed and for each of the impeller groups the shelling efficiency, percentage of broken seeds and the winnowing efficiency increased with increase in number of impeller slots, while the percentage of partially shelled pods and the percentage of unshelled pods decreased with increase in the number of impeller slots. This is because the higher the number of impeller slots the higher the number of pods that will emerge from the impeller and hit the cracking surface. The forward facing impeller with eight slots gave the best shelling efficiency of 96, 77.8 and 62% at moisture contents of 5.3, 9.6 and 12.2% (d.b.), respectively, which is similar to the results of Odigboh (1979) in evaluation of an melon (*Citrullus vulgaris*) shelling machine. Also the forward facing impellers gave the best winnowing efficiency because the broken shells produced by these impellers are relatively small compared to those produced by the radially positioned slots and the backward facing impellers.

Moisture content of 5.3% (d.b.) gave shelling and winnowing efficiencies of 96 and 87.3%, respectively, for the forward facing impeller with eight slots, 86.6 and 85.3%, respectively, for the radial impeller with eight slots, and 85 and 83.7%, respectively, for the backward facing impeller with eight slots. This is because at low moisture level bambara groundnut pods are brittle, which makes them susceptible to mechanical damage (Oluwole et al. (2007a) and Atiku et al. (2004)).

III. CONCLUSIONS

The moisture content of bambara groundnut affected the machine performance at the significance level of 5%. The machine gave the best performance at moisture content of 5.3% (d.b.). The number of impeller slots affected the machine performance at the significance level of 5% with the eight slot impellers giving the best performance. While the impeller slots angulations also affected the performance of the machine at the significance level of 5%, the best performance was recorded with the forward facing impellers.

RECOMMENDATIONS

It is recommended that the separating unit be improved upon to increase the winnowing efficiency of the machine.

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Table 2: Performance indices of bambara groundnut sheller

Impeller types*	Shelling efficiency	Breakage(b),	partially shelled pod (p)	unshelled pods u	Winnowing efficiency w
Moisture content – 5.3% (d.b.)					
SF8	96	3.4	3.4	0	87.3
SF4	83.4	8.6	5.6	8.6	82.4
SF2	74.6	3.6	11.4	14	80.9
SR8	86.6	2.2	5.4	4.2	85.3
SR4	74.4	2.4	12.4	17.2	79.3
SR2	64.8	2	4.4	21.6	79.1
SB8	85	0.6	2.8	7.2	83.7
SB4	73.2	2.8	5.2	19.6	78.3
SB2	63.6	2	2.8	22	77.6
Moisture content – 9.6% (d.b.)					
SF8	77.8	2.4	7.8	12	79.1
SF4	67.4	2	11	19.6	72.8
SF2	60.3	2.4	9.8	19.8	70
SR8	69	1	11.8	19.2	75.9
SR4	60.2	1..8	8.4	27	67.3
SR2	51.4	0.6	12.8	32.4	67.9
SB8	66	0.6	17.4	23.8	71.1
SB4	61.2	0.8	15.4	25.4	70.6
SB2	51	1.2	12.8	31	65.7
Moisture content – 12.2% (d.b.)					
SF8	62	0.6	17.4	23	66
SF4	55.4	1.2	13.8	28.6	61.1
SF2	49.4	0.4	15.6	33	57.7
SR8	59.2	0.4	17.2	27.6	64.1
SR4	52.6	0.8	12.4	34.6	57.7
SR2	42	0.6	12.2	43.3	57.2
SB8	56.8	0.2	14.4	29.6	50.3
SB4	52.2	0.6	13	34.2	60.3
SB2	40.4	0.4	13.2	45.8	57.6

Result of the performance indices