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Effect of moisture content on crackability of bambara groundnut using a centrifugal cracker

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Abstract. One of the most tedious operations in processing bambara groundnut is the shelling operation. However, moisture content normally affects the handling and processing of agro-materials, such as nut shelling/cracking. This study was conducted to determine the effect of moisture content on shelling efficiency of bambara groundnut using a centrifugal cracker. A 50 kg bag of bambara groundnut obtained from Damboa Local Government Area of Borno State, Nigeria, was divided into three groups. These groups were prepared for tests by soaking them in ordinary water at room temperature for different periods of 0, 60 and 90 min to obtain different levels of moisture content. Moisture content of each sample was determined by oven drying at 130°C for 6 h. The moisture content levels were found to be 5.3, 9.6, and 12.2% (d.b.) for samples A, B and C, respectively. The samples were subjected to impact energy through a centrifugal impaction device operating at an angular velocity of 1920 r.p.m., using three different types of impellers. Data obtained on the percentage of fully shelled pods and unbroken seeds, fully shelled pods with broken seeds, partially shelled pods and unshelled pods were statistically analysed. Results showed that both moisture content and impeller angulations have a significant effect on these performance indices. The most effective performance was obtained at moisture content of 5.3% (d.b.), at which the shelling efficiency, percentage of damaged seeds, percentage of partially shelled pods and percentage of unshelled pods were 96, 3.4, 0.6 and 0, 86.6, 3.6, 5.6 and 4.2, 85, 2.4, 5.4, and 7.2% for the forward facing impeller, radially positioned impeller and the backward facing impeller, respectively. The study further showed that development of a centrifugal impact bambara groundnut sheller with winnower would eliminate the tediousness of the present manual pod cracking methods.

Keywords: bambara groundnut, shelling efficiency, moisture content, centrifugal impaction device

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 (Atiku *et 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 groundnuts are widely produced in Borno, Anambara, Plateau, Taraba, Sokoto, Bauchi, Benue, Kano, Yobe, Adamawa and Gombe states.

Goli (1997) reported that bambara groundnut contains about 63% carbohydrates, 19% protein, and 6.5% oil and is consumed in different forms. In other reports by Akani *et al* (2000), Atiku (2004) and Linnemann (1988) the seed of bambara groundnut can be used for baby food, human consumption, industrial products and for animal feed. Linnemann (1990) reported that bambara groundnut flour has been used in making bread in Zambia, and Brough *et al.* (1993) noted that the milk prepared from bambara groundnut gave a preferred flavour 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 high ceremonial value.

Kay (1979) recommended that after harvesting bambara groundnut, it 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 foods.

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Despite this economic importance, no commercial production and no industrial use of the crop takes place in Nigeria. According to Akani *et 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 the dry pods. Some beat them with sticks on flat ground, others use stones to crush pods on flat ground. These methods have the disadvantage 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 obtained the maximum shelling (broken and unbroken seeds) 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%, while the percentage of partially shelled (broken and unbroken seeds) and percentage of unshelled pods were 10 and 7%, respectively.

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 and found that a centrifugal impact method can be effectively used to shell melon seeds. Odigboh (1979) developed and tested a prototype impact egusi (melon) shelling machine that gave about 96% shelling efficiency and 100% winnowing efficiency.

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 obtained cracking efficiency of 100% and winnowing efficiency of 97%. Akani *et 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 a centrifugal device to project individual bambara groundnuts at three different moisture levels against the inner surface of a cylindrical cover similar to that described by Dicken (1961), Makanjuola (1975), Odigboh (1979), and Oluwole *et al.* (2004).

MATERIALS AND METHODS

A bulk quantity of bambara groundnut pods (milk coloured) was purchased from a local farmer in Damboa, Borno state, Nigeria. The pods were cleaned and sampled for experiment using a multi-slot riffle box divider. The moisture content of the pods was varied using the method reported by Aviara *et al.* (2002), Oluwole *et al.* (2004) and Atiku *et al*. (2004). This method involved the soaking of a bulk quantity of the pods in ordinary water at room temperature for different periods of time 60 min for sample B and 90 min for sample C. Sample A was retained at the stable storage moisture content as a control sample. After soaking the pods were spread out in a thin layer to dry in natural air for about eight hours. The pods were then sealed in marked polyethylene bags and stored in that condition for a further 24 h. This enabled stable and uniform moisture content of the pods to be achieved in the bags.

The moisture content of each sample was determined using the method described by ASAE (1983), Ajibola *et al.* (1990), Oje (1993), Aviara *et al*. (2002) and Oluwole *et al.* (2004). The method involved oven drying of pod samples at 130°C with weight loss monitored on hourly basis to give an idea of the time at which the weight began to remain constant. After oven drying for about 3 h, the weight of samples was found to remain constant. After 6 h of oven drying, the pods were weighed using an electronic balance weighing to 0.001 g to determine the final weight. The moisture content was determined using the formula (Oluwole *et al.*, 2004):

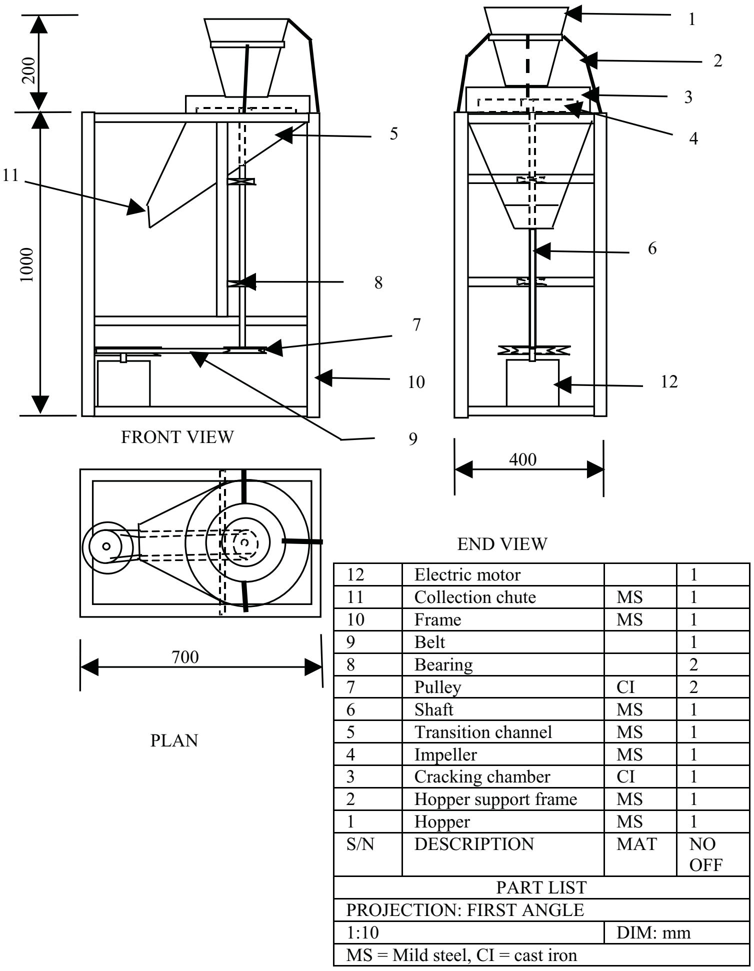
$$M_C = [(W_i - W_f)/W_f]\,100 \text{ (d.b.)}, \qquad (1)$$

where: M_C – moisture content (%), W_i – initial mass of pods (g), W_f – final mass of pods (g), (d.b.) – dry basis.

This was replicated three times for each sample and the average values were determined.

A photograph of the impaction device is presented in Fig. 1. Figure 2 shows the orthographic drawing of the impaction device and the device, which is similar in principle to Odigboh's impact egusi Sheller, consists of a feed hopper, pod shelling unit and power unit. The conical shaped hopper is mounted on a tool frame and held in place by a hopper support frame. The base is connected directly to the shelling unit. The shelling unit consists of a 410 mm diameter by 150 mm height cylindrical shell, made from 5 mm steel sheet, whose inner surface serves as a cracking surface, and

Fig. 1. Centrifugal impaction machine.



12	Electric motor		1
11	Collection chute	MS	1
10	Frame	MS	1
9	Belt		1
8	Bearing		2
7	Pulley	CI	2
6	Shaft	MS	1
5	Transition channel	MS	1
4	Impeller	MS	1
3	Cracking chamber	CI	1
2	Hopper support frame	MS	1
1	Hopper	MS	1
S/N	DESCRIPTION	MAT	NO OFF

PART LIST
PROJECTION: FIRST ANGLE
1:10 DIM: mm
MS = Mild steel, CI = cast iron

Fig. 2. Orthographic drawing and parts list of the centrifugal impaction device.

an impeller made of 25 by 50 mm rectangular steel pipe similar to that described by Dickens (1961) shown in Fig. 3. Figure 4 shows the impeller mounted in operational position. The cylindrical shell is covered with a transparent plastic cover, 400 mm in diameter of 4 mm thick, with a concentric opening (80 mm diameter) at the centre (pods inlet). The impeller is concentrically positioned within the cylindrical shell and horizontally mounted on a vertical shaft to give a clearance that is greater than the size of the seed with cracking surface. This impeller is driven by the vertical shaft powered by a 0.5 Hp, 1920 r.p.m. electric motor through a belt and pulley system.

To carry out the performance tests, 100 pods were randomly selected and weighed. These pods were poured into the hopper while the pods flow control was completely closed. The main power supply 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. These pods were carefully collected after going through the impeller, and the number of pods fully shelled without broken seeds (N_1), number of broken seeds (N_2), number of partially shelled pods (N_3) and number of unshelled pods (N_4) were determined and recorded.

Each of these tests was replicated five times for each of the evaluated impellers and the performance of the cracker was evaluated on the basis of the following indices (Oluwole *et al.*, 2004):

– shelling efficiency,

$$\eta_s = (N_1 / N_T)100, \tag{2}$$

– percentage of broken seeds,

$$\eta_b = (N_2 / N_T)100, \tag{3}$$

– percentage of partially shelled pods,

$$\eta_p = (N_3 / N_T)100, \tag{4}$$

– percentage of on shelled pods,

$$\eta_u = (N_4 / N_T)100. \tag{5}$$

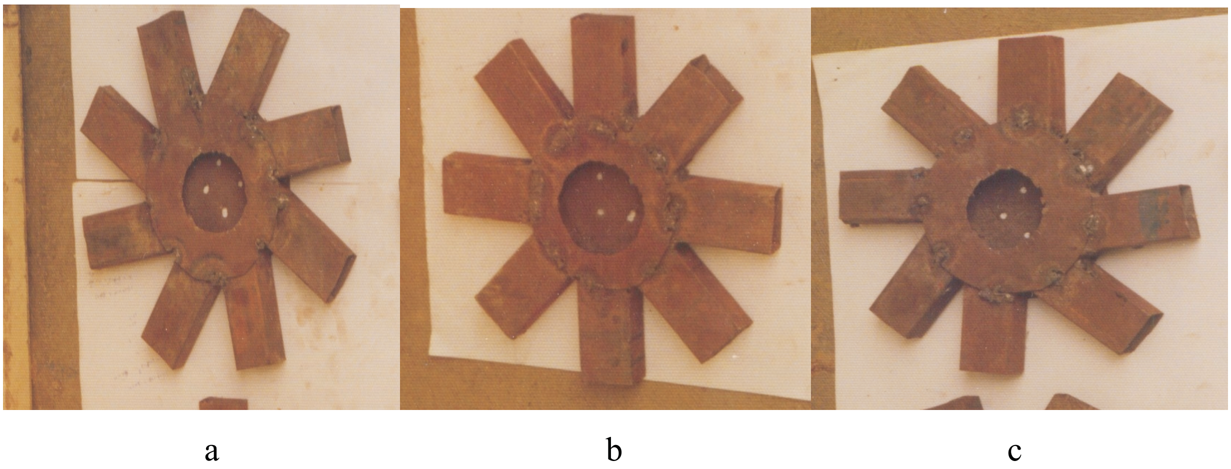


Fig. 3. Impeller: a – forward facing, b – radially positioned, c – backward facing.

Fig. 4. Impeller mounted in operational position.

These results were statistically analysed using t-test to evaluate the effect of moisture content on the performance indices of the cracker.

RESULTS AND DISCUSSION

The initial moisture content of the pod was found to be 5.3% (d.b.). The two other moisture levels obtained after conditioning the pods were 9.6 and 12.2% (d.b.), respectively. The investigations were carried out at the above moisture levels to determine the effect of moisture content on the shelling efficiency of bambara groundnut.

The results of the performance test analyses are presented in Tables 1, 2, 3 and 4. Table 1 shows that moisture content, impeller vane angulations and interaction between moisture content and impeller vane angulations significantly affect the shelling efficiency, percentage of broken seeds, percentage of partially shelled pods and percentage of unshelled pods at 5% level of significance.

Table 2 shows the results of applying the Duncan Multiple Range Test (DMRT) to the means of moisture content on the performance indicators. It can be seen from Table 2 that shelling efficiency (η_s) and percentage of broken seeds (η_b) decreased with increase in moisture content, while the percentage of partially shelled pods (η_p) and percentage of unshelled pods (η_u) increased with increase in moisture content. This is because at low moisture level bambara groundnut pods are brittle, which makes them susceptible to mechanical damage (Atiku *et al.,* 2004).

Table 3 shows the results of applying DMRT to the means of impeller vane angulations on the performance indicators. It can be seen from this table that the forward facing impeller gave the highest average shelling efficiency (78.60%), followed by the radially positioned impeller (71.60%) and the backward facing impeller (69.27%), respectively. Similar findings were reported by Odigboh (1979) and Oluwole *et al.,* (2004) in the performance evaluation of an egusi (melon) shelling machine and performance evaluation of a sheanut cracker, respectively.

The result of applying DMRT to the means of interaction between moisture content and impeller vane angulations is presented in Table 4. These results show that interaction between moisture content and impeller vane angulations statistically affected all the performance indicators at 5% level of significance. The forward facing impeller gave the best shelling efficiency at all three investigated moisture contents, with the highest of 96% at moisture content of 5.3% (d.b.). However, the percentages of broken seeds, partially shelled pods and unshelled pods were 3.4, 0.6 and 0%, respectively, at this moisture content. The backward facing impeller gave the lowest shelling efficiency at all

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

Source of variation	Shelling efficiency (η_s)	Percentage		
		breakage (η_b)	partially shelled pods (η_p)	unshelled pods (η_u)
Main effects:				
Moisture content (M)	1559.94*	16.23*	80.97*	477.37*
Angulation (A)	162.35*	3.33*	3.34*	65.90*
Two-factor interaction:				
M x A	10.22*	16.42*	4.12*	2.46*

*Denotes statistically significant difference at 5% level.

Table 2. Effect of moisture content on performance indicators

Moisture content (%) (d.b.)	Shelling efficiency (η_s)	Percentage		
		breakage (η_b)	partially shelled pods (η_p)	unshelled pods (η_u)
5.3	89.20^a	3.13^a	3.87^c	3.80^c
9.6	70.93^b	2.20^b	8.53^b	18.33^b
12.2	59.33^c	0.87^c	13.07^a	26.73^a

Values in the same vertical column with the same superscript letters are not significant.

Table 3. Effect of impeller vane angulations on performance indicators

Slot angulation	Shelling efficiency (η_s)	Percentage		
		breakage shelled pods (η_b)	partially pods (η_p)	unshelled (η_u)
F	78.60^a	2.33	7.40^b	11.67^c
R	71.60^b	2.27	8.93^a	17.00^b
B	69.27^c	1.60	9.13^a	20.20^a

Explanations as in Table 2. F – forward facing impeller, R – radially positioned impeller, B – backward facing impeller.

Table 4. Effect of interaction between moisture content and slot angulation on performance indicators

Moisture content x impeller angulation	Shelling efficiency (η_s)	Percentage		
		breakage (η_b)	partially shelled pods (η_p)	unshelled pods (η_u)
M_1 F	96.0^a	3.4^a	0.6^e	0.0^h
M_1 R	86.6^b	3.6^a	5.6^d	4.2^g
M_1 B	85.0^c	2.4^b	5.4^d	7.2^f
M_2 F	77.8^d	2.4^b	7.8^c	12.0^e
M_2 R	69.0^c	2.4^b	9.4^b	19.2^d
M_2 B	66.0^f	1.8^{bc}	8.4^{bc}	23.8^c
M_3 F	62.0^g	1.2^c	13.8^a	23.0^c
M_3 R	59.2^h	0.8^c	12.4^a	27.6^b
M_3 B	56.8^i	0.6^c	13.0^a	29.6^a

Explanations as in Table 2.

three investigated moisture contents, with the least of 56.8% at moisture content of 12.2% (d.b.). However, higher percentages of unshelled pods (29.6%) and of partially shelled pods (13%) and the least percentage of seeds breakage (0.6%) were recorded at this moisture content.

CONCLUSIONS

1. Moisture content of bambara groundnut statistically affected the performance indicators at 5% level of significance.

2. Impeller vane angulations significantly affected the performance indicators at 5% level of significance

3. Shelling efficiency and percentage of broken seeds decreased with increase of moisture content.

4. Percentages of partially shelled pods and unshelled pods increased with increase of moisture content.

5. The forward facing impeller gave the best shelling efficiency, followed by the radially positioned impeller and the backward facing impeller, respectively.

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