Effect of Moisture Content and Impact Energy on the Crackability of Sheanut

F. A. Oluwole[1]; N.A Aviara[2*] and M. A. Haque[2]
[1]Department of Mechanical Engineering, University of Maiduguri
Maiduguri, Nigeria
[2] Department of Agricultural and Environmental Resources Engineering
University of Maiduguri, Maiduguri, Nigeria

*corresponding author's e-mail:nddyaviara@yahoo.com

ABSTRACT

The difficulties inherent in the cracking of sheanuts to obtain clean kernels have caused it to pose a bottleneck to sheanut processing. The elimination of this bottleneck requires the development of effective and appropriate technology equipment for the cracking of the nut. Moisture content normally affects the handling and processing of agro materials and energy is normally expended in carrying out such operations as the cracking of nuts. Therefore, this study was conducted to determine the effect of moisture content and impact of energy on the crackability of the sheanut. A 100 kg bag of sheanuts obtained from Minchika in Minchika Local Government Area of Adamawa State, Nigeria was divided into four portions and conditioned at room temperature for different time durations to obtain different levels of moisture content. The moisture contents obtained were determined by oven drying the samples at 130^{0}C for 6 hours, and found to be 6.2, 13.0, 22.7 and 27.9 %(dry basis).

Samples of nut at each moisture level were subjected to impact tests on the longitudinal orientation using a specially constructed impact test apparatus. The energy level employed ranged from 0.13J – 0.65J. Data obtained on the quantity of fully cracked and unbroken, fully cracked but broken and uncracked nuts were subjected to statistical analysis.

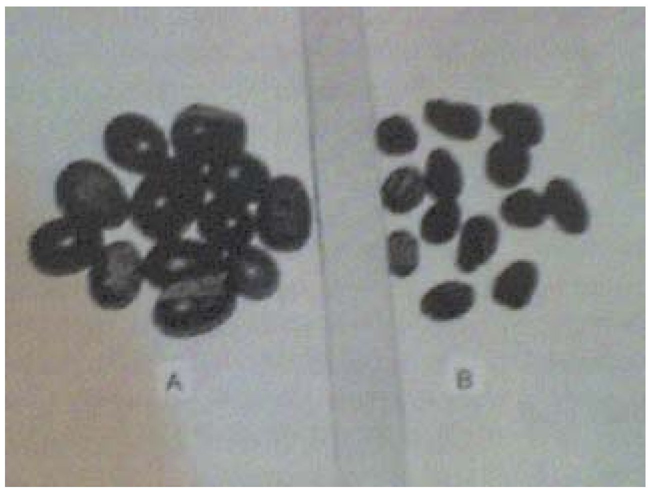
Results showed that moisture content and impact energy have significant effect on the crackability of sheanut. The optimum impact energy for cracking was found to be 0.52J. The dry basis moisture content that gave the best result combination of high whole kernel yield and low kernel breakage ranged from 13.0-22.7%.

The study shows that the development of a spinning disc cracker, which uses impact to crack sheanut is possible. It suggests that the radius and speed of the spinning disc should be such that will not allow the impact energy of 0.52J to be exceeded and sheanuts should be conditioned to the dry basis moisture content of about 22.7% prior to cracking for optimum efficiency.

Keywords: Crackability, impact energy, moisture content, sheanut, kernel, cracker, Nigeria.

1. INTRODUCTION

Sheanut tree (*Butyrospernum paradoxum*) is a member of the family Sapotaceaes (Purseglove, 1979). It is known locally as 'kadanya', 'emi', 'osisi' and 'chammal', among the Hausas, Yorubas, Igbos and Tivs, respectively (Adgidzi *et al*, 2003). It is an important oil bearing tree crop, commonly found in the savannah zone of West Africa, where rainfall is not excessive. In Nigeria, sheanut is obtained abundantly in Oyo State and most of the Northern States (Oluwole, 2004). It contains 45-60% fat and 9% protein (Purseglove, 1979). A photograph of some sheanuts and kernels are shown in Figure 1.



A B

Figure 1. Sheanut and kernel (A, nut and B, kernel)

The locally extracted fat is known as sheabutter. The Yorubas refer to it as 'oori', the Hausas call it 'man kadanya', and Fulanis and Arabs call it 'karehi' and 'quariti' respectively (Lewicki, 1974).

Peter and Ann (1992) reported that sheabutter is used as a cooking fat, illuminant, medical ointment, hairdressing cream and as raw material in the manufacture of soap, candle and cosmetic products. It also serves as a constituent of filling for chocolate creams. At present, there is no plantation of sheanut and little information is available on the existence of commercial plants for the purpose of processing the oil (Oluwole, 2004). As a result, the present status of sheanut processing remains the extraction of sheabutter, which is performed by women and children, using traditional methods of extraction (Adgidzi *et al.* 2003). These methods involve the collection and drying of nuts, cleaning of nuts by removal of unwanted materials such as stones and dirts, cracking of nut to obtain clean kernel – an operation usually carried out using stones and woods (Lucas, 1991) and which Phillips (1977) reported as capable of handling sheanut at the rate of about $14kgh^{-1}$ including the separation of shells. When the use of pestle and mortar to crack the nut is involved, the capacity could be up to 110kg of nuts per day including winnowing – and roasting of the kernel obtained from the nut, an operation that is normally carried out by women using firewood and clay pots or pans. This is followed by the crushing of kernel to form paste, using pestle and mortar or crushing stones, and the extraction of oil from the kernel paste which involves the kneading of paste, boiling it in water, scooping off the oil and drying it by heating to 130^0C to remove all traces of moisture (Wiemer and Korthals, 1989).

As could be observed, all the operations mentioned above are currently carried out manually. Among these, the cracking of nuts and separation of shells from the shell – kernel mixture seems to be the most laborious and time consuming operation. The development of a mechanical cracker with winnowing system would, therefore, drastically reduce the drudgery of the manual cracking of sheanut to obtain the kernels. The moisture content of agro materials has been reported to have influence on the adjustment and performance of processing equipment (Aviara *et al.* 1999). As a result, the determination of the moisture content at which sheanut could be cracked with a combination of high whole kernel yield and minimum kernel damage is necessary, as it would be of important consideration in the design of the cracker.

Akani *et al.* (2000) reported that inadequate engineering data such as rupture force, cracking energy, and deformation energy on indigenous crops have greatly retarded the development of indigenous technologies for the processing of these crops. When these data are available, the design and development of machines for processing indigenous crops will receive the needed boost. Adigun and Oje (1993) reported that some nuts cannot be easily broken by the roller cracker, so such nuts are usually cracked by the centrifugal cracker. In the centrifugal cracker, the material to be cracked is directed to a spinning disc, which throws the material onto a hard cracking surface. This surface absorbs most of the kinetic energy in the material during impact and the shell is cracked and the kernel released. For the material to crack, the spinning disc must generate the velocity that will subject the material to the required impact energy.

Makanjuola (1975) evaluated some centrifugal impaction devices for shelling melon seeds and concluded that impaction method could be used to shell melon seeds. Odigboh (1979) designed, constructed and tested a prototype egusi shelling machine that shells the seeds and winnows off the chaffs. These two researchers did not investigate the maximum impact energy that the melon seed can withstand without causing damage to the kernel. Oluwole *et al.* (2007) however, showed that moisture content has significant effect on the crackability of Bambara groundnut and reported an effective shelling of the pods using a centrifugal impact device.

Several investigations have been carried out on the physical properties of sheanut. These include Olajide *et al.* (2000), Aviara *et al.* (2000) and Aviara *et al.* (2005). The effect of moisture content and applied energy on the crackability of the nut appears to have received little attention. But, plant nuts and seeds are biological materials, which are usually subjected to various physical treatments involving the use of mechanical, thermal, electrical, optical and sonic techniques and devices right from their production on the farm to the consumer at home. Their response to physical treatments need to be understood so that the machines, processes and handling operations of these biological materials can be designed for maximum efficiency and high quality end product.

The objective of this study was, therefore, to investigate the effect of moisture content and impact energy on the crackability of sheanut and determine the moisture level and impact energy at which a combination of high whole kernel yield and minimum kernel damage is obtained. This will provide an important data needed in the design and development of a sheanut cracking machine.

2. MATERIALS AND METHOD

A 100kg bag of sheanut at market stable storage condition was obtained from Minchika in Minchika Local Government of Adamawa State, Nigeria. The nuts were divided into four portions labeled A, B, C and D each weighing 25kg. These portions which formed the samples of the nuts were then prepared for tests by soaking in clean water at room temperature for different time durations. Sample A was left at the market stable storage moisture content, while B, C and D were soaked for 30, 60 and 90 minutes respectively, in order to obtain nuts at different moisture levels. After soaking, the nuts were air dried in thin layer under shade to eliminate the free water from the surface.

The moisture content of each sample was determined using the method described by ASAE (1983), Ajibola *et al.* (1990), Oje (1993) and Aviara *et al.* (2005). Since sheanut is an oil-bearing nut, the method involved the oven drying of nut samples at 130^0C for 6 hours, with weight loss monitored on hourly basis to give an idea of the time at which the weight began to remain constant. Weight of samples was found to remain constant after oven drying for a period of about 4 hours. After oven drying for 6 hours, the nuts were weighed using an electronic balance with an accuracy of 0.001g to determine the final weight. The moisture content was determined using the formula

$$M_{wb} \approx \frac{(W_i - W_f)}{W_i} \times 100 \qquad (1)$$

where M_{wb} = Wet basis moisture content, %
W_i = initial weight of sample, g
W_f = final weight of dry sample, g
It was converted to the dry basis moisture content using the formula

$$M_{db} \approx \frac{M_{wb}}{1 - M_{wb}} \times 100 \qquad (2)$$

where M_{db} = dry basis moisture content, %

The experiment was replicated three times for each sample and the average values of the moisture contents obtained were determined. For each sample now of different moisture content, thirty nuts were randomly selected and each nut was subjected to impact from a hammer by placing it on the loading platform of a specially constructed impact test apparatus (Figure 2) in the longitudinal orientation. This orientation has been reported to pose the most resistance to either potential energy or kinetic energy (Adigun and Oje, 1993).

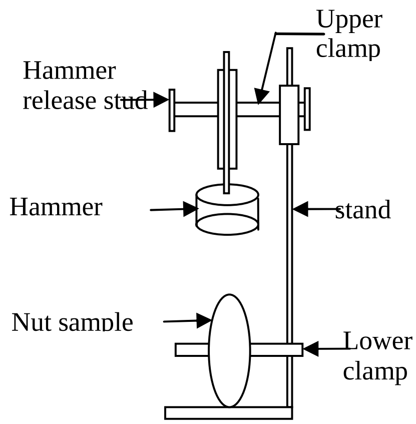


Figure 2. Schematic diagram of the impact test apparatus

A hammer of mass, M, of 0.44kg was allowed to fall freely from a height 'h' onto the nut using the hammer release stud and the impact energy was determined using the following equation.

$$E \approx Mgh \tag{3}$$

where

E = impact energy, J
M = mass of hammer, kg
g = accelerated due to gravity, 9.81 ms^{-2}
h = height of fall, m

The height of fall was varied from 0.03m to 0.15m at an incremental rate of 0.03m. Each cracking run was replicated three times and the quantities of nuts fully cracked nuts with unbroken kernels, fully cracked nuts with broken kernels and uncracked nuts obtained for each sample were collected and recorded. The data obtained was used in the computation of the nut crackability indicators measured on the basis of the following:
Percentage of fully cracked nuts with unbroken kernels,

$$P_C \approx \left(\frac{N_1}{N_O}\right) \times 100 \tag{4}$$

Percentage of fully cracked nuts with broken kernels,

$$P_b \approx \left(\frac{N_2}{N_O}\right) \times 100 \tag{5}$$

Percentage of uncracked nuts, $$P_u \approx \left(\frac{N_3}{N_O}\right) \times 100 \tag{6}$$

where No = Total number of nuts

N_1 = Number of fully cracked nuts with unbroken kernels
N_2 = Number of fully cracked nuts with broken kernelss
N_3 = Number of uncracked nuts

A randomized complete block (RCB) design was applied in the experiment to investigate the effect of moisture content and impact energy on the crackability indices. The Duncan's Multiple Range Test (DMRT) was applied to determine the levels at which the effects are significantly different.

3. RESULTS AND DISCUSSION

The average dry basis moisture content of the samples A, B, C and D were found to be 6.2, 13.0, 22.7 and 27.9% respectively. The percentage of fully cracked sheanuts with unbroken kernels obtained at the above moisture contents and different impact energy levels are presented in Table 1. The table shows that for the impact energies below 0.52J, the percentage of fully cracked nuts with unbroken kernels decreased as the moisture content increased. For the impact energy of 0.52J, the percentage of fully cracked nuts with unbroken kernels increased from 60.7% to 97.3% as the moisture content increased from 6.2% to 22.7%. Thereafter, it decreased with further increase in moisture content. Above the impact energy of 0.52J, the percentage of fully cracked and unbroken nuts increased with increase in moisture content up to an optimal point and decreased with further increase in moisture content. The maximum value of the percentage of fully cracked nuts with unbroken kernels was obtained at the moisture content of 22.7% and impact energy of 0.52J.

Table 1. Percentage of fully cracked sheanuts with unbroken kernels at different dry basis moisture content and impact energy level

Impact energy, J	Percentage of fully cracked nuts with unbroken kernels, %			
	MC_A 6.2%	MC_B 13.0%	MC_C 22.7%	MC_D 27.9%
0.13	53.3	40	30	2.8
0.26	80	56.7	43.3	6.7
0.39	83.3	65	53.3	15.7
0.52	60.7	93	97.3	57.3
0.65	58.3	86.7	92	83.3

In a pack of fully cracked nuts, the percentage of broken kernels is shown in Table 2 for different combinations of moisture content and impact energy. There are no broken kernels for the impact energies of 0.13J and 0.26J at any employed moisture content. For the impact energies of 0.39J and 0.52J, the percentage of broken kernels were from 16 and 39.3% respectively at the moisture content of 6.2%. At 13.0% moisture content and above, the impact energy of 0.39J did not produce any broken kernel, while similar result was obtained for the impact energy of 0.52J at the moisture content of 22.7% and above. For the impact energy of 0.65J the percentage of broken kernels decreased continuously with increase in moisture content, from 41.7% at the moisture content of 6.2% to 5.7% at 27.9% moisture content. At the moisture content of 6.2%, no broken kernel was recorded from the impact energy of 0.13J up to the impact energy of 0.26J. After this level, the breakage of kernel increased with further increase in impact energy.

Table 2. Percentage of fully cracked sheanuts with broken kernels at different dry basis moisture content and impact energy level

Impact energy, J	Percentage of fully cracked nuts with broken kernels			
	MC_A 6.2%	MC_B 13.0%	MC_C 22.7%	MC_D 27.9%
0.13	0	0	0	0
0.26	0	0	0	0
0.39	16	0	0	0
0.52	39.3	5.3	0	0
0.65	41.7	13.3	6.7	5.7

The percentage of uncracked nuts at different moisture content and impact energy level is presented in Table 3. From the table, it can be seen that the percentage of uncracked nuts increased with increase in moisture content at all employed impact energy levels. It is shown that the percentage of uncracked nuts decreased continuously with increase in impact energy at all the employed moisture contents. The highest percentage of uncracked nuts (97.3%) was obtained at the lowest impact energy (0.13J) and highest value of the employed moisture levels (27.9%), while the lowest percentage (0%) was obtained at higher impact energy levels (0.52 and 0.65J) and lower moisture contents (6.2 and 13.0%).

Table 3. Percentage of uncracked sheanuts at different moisture content and impact energy level

Impact energy, J	Percentage of uncracked sheanuts, %			
	MC_A 6.2%	MC_B 13.0%	MC_C 22.7%	MC_D 27.9%
0.13	46.7	60	70	97.3
0.26	20	43.3	56.7	93.3
0.39	0.7	35	46.7	84.3
0.52	0	1.7	2.7	42.7
0.65	0	0	1.3	11

The F-ratios obtained from the randomized complete block design analysis of the data on the number of fully cracked nuts with unbroken kernels, fully cracked nuts with broken kernels and uncracked nuts, respectively were used to determine whether the effect of moisture content and impact energy on the sheanut crackability indices are significant or not (Table 4). From this table, it can be seen that the effect of moisture content and impact energy are significant at 5% level of significance.

Table 4. Summary of F-ratios obtained from the RCB analysis of sheanut impact cracking tests

F-ratio			
Source of variation	Cracked nuts with unbroken kernels	Cracked nuts with broken kernels	Uncracked nuts
Impact energy	11.49*	4.01*	30.99*
moisture content	36.24*	3.7*	81.40*

*Significant at 5% level

The result of the DMRT on the effect of moisture content on the crackability parameters are presented in Table 5.

Table 5. Effect of moisture content on the crackability of sheanut

Moisture content %	Percentage of fully cracked nuts with unbroken kernels	Percentage of fully cracked nuts with broken kernels	Percentage of uncracked nuts
6.2	67.12^{ab}	19.4^{a}	13.48^{d}
13.0	68.28^{a}	3.72^{b}	28.00^{c}
22.7	63.18^{b}	1.34^{bc}	35.48^{b}
27.9	33.16^{c}	1.14^{c}	65.72^{a}

Values in the vertical column with the same superscript letters are not significant at 5% level.

From this table, it can be seen that for the fully cracked and unbroken nuts, the effect of moisture content is significantly different at 5% level. For the fully cracked but broken nuts, the effect of moisture content at the levels of 6.2 and 13.0%, 6.2 and 22.7% and 6.2 and 27.9% is significant at 5% level, while there is no significant difference between the effect of moisture contents of 13.0 and 22.7%, and that of the moisture contents of 22.7 and 27.9%.

The effect of moisture content on uncracked nuts is also found to be significant at 5% level. The moisture content of 13.0% gave the highest mean percentage of cracked nuts with unbroken kernels of 68.28%, while the moisture content of 27.9% gave the least mean percentage of 33.16%. The moisture content of 6.2% gave the highest mean percentage of fully cracked nuts with broken kernels, while the moisture content of 27.9% gave the highest mean percentage of uncracked nuts. The above analysis also shows that the moisture content of 13.0% gave the best combination of high whole kernel yield and minimum kernel damage followed by the moisture content of 22.7%.

Table 6 shows the result of Duncan Multiple Range Tests (DMRT) on the effect of impact energy on the percentage of fully cracked nuts with unbroken kernels, fully cracked nuts with broken kernels and uncracked sheanuts.

Table 6. Effect of impact energy on the crackability of sheanut

Impact energy (J)	Percentage of fully cracked and unbroken nuts	Percentage of fully cracked but broken nuts	Percentage of uncracked nuts
0.65	80.09[a]	16.85[a]	3.08[e]
0.52	77.08[a]	11.15[b]	11.35[d]
0.39	54.33[b]	4.00[c]	42.11[c]
0.26	46.68[c]	0.00[d]	53.33[b]
0.13	31.53[d]	0.00[d]	68.50[a]

From Table 6 it is seen that for the cracked nuts, the mean and by implication, the effect of all applied impact energy levels differed at 5% level of significance except for the impact energies of 0.52 and 0.65J. This shows that the effect of impact energy 0.65J on the percentage of fully cracked nuts with unbroken kernels is not significantly different from that of the 0.52J impact energy.

For the fully cracked nuts with broken kernels, the effect of applied impact energy differed significantly at 5% level, while the effect of the impact energies of 0.26 and 0.13J did not have significant difference. For the uncracked nuts, the effect of impact energies was significant at 5% level. The implication of the above is that the observed difference between the mean of impact energies of 0.52 and 0.65J, 0.39 and 0.52J for fully cracked nuts with broken kernels is significant at 5% level, but the observed difference between the impact energies of 0.13 and 0.26J is not significant. This confirms that the impact energy of 0.65J gave the highest percentage of broken kernels. Based on the above fact, the impact energy of 0.52J could be considered be the best cracking energy for sheanut, because it gave the best combination of high whole kernel yield and minimum kernel damage. This could be of important application in the optimization of the performance of the sheanut cracker developed by Oluwole *et al.* (2004).

4. CONCLUSION AND RECOMMENDATIONS

From the results obtained in this study, it could be concluded that both moisture content and impact energy had significant effect on the crackability of sheanut. The moisture content that gave the combination of high whole kernel yield and minimum kernel damage ranged from 13.0 - 22.7%. The impact energy of 0.52J gave the best combination of high whole kernel yield and minimum kernel damage.

Based on the results obtained and the conclusion drawn from the study, the following recommendations are made:

1. A spinning disc cracker (centrifugal impaction device) could be used for cracking sheanut.
2. In designing the sheanut cracker, the radius and speed of the spinning disc should be such as would ensure that the impact energy generated and imparted on the nuts will not exceed 0.52J.
3. The cracking of sheanuts that are at the stable storage moisture content will require conditioning to the moisture content range of 13.0 - 22.7% for the efficient operation of the cracking equipment.

5. REFERENCES

Adgidzi, D; Balami, A. A. and Esemikose, R. M. 2003. Development and performance evaluation of sheabutter extraction. *Proceedings of the 4th International Conference of the Nigerian Institution of Agricultural Engineers,* 25: 251-257.

Adigun, Y. J. and Oje, K. 1993. Thevetia fruit processing: Energy requirements for cracking the nut. *Proceedings of the Nigerian Society of Agricultural Engineers (NSAE),* 15: 128 – 139.

Ajibola, O. O.; Eniyemo, S. E.; Fasina, O. O. and Adeeko, K. A. 1990. Mechanical expression of oil from melon seeds. *Journal of Agricultural Engineering Research,* 45 (1): 45-53.

Akani, A. O.; Ohanwe, C. N. and Omoniyi, I. O. 2000. Determination of optimum impact for decortication of bambara groundnut. *Proceedings of the Nigerian Institution of Agricultural Engineers,* 22: 87 – 89.

ASAE 1983. ASAE Standards: ASAE 352.1 Moisture measurement - Grains and seeds. American Society of Agricultural Engineers. St. Joseph, Michigan.

Aviara, N. A., Gwandzang, M. I. and Haque, M. A. 1999. Physical properties of guna seeds. *Journal of Agricultural Engineering Research* 73: 105-111.

Aviara, N. A., Haque, M. A. and Izge, I. A. 2000. Physical and frictional properties of sheanut. *Agroscience*, 2(1): 19 – 34.

Aviara, N. A., Oluwole, F. A. and Haque, M. A. 2005. Effect of moisture content on some physical properties of sheanut (*Butyrospernum paradoxum*). *International Agrophysics,* 19: 193-198.

Lewicki, T. 1974. *West African Food in the Middle Ages*. Cambridge University Press, U.K.

Lucas, Z.B 1991. *Design and construction of sheabutter extraction machine*. B.Eng. thesis, University of Maiduguri.

Makanjuola, G. A. 1975. An evaluation of some centrifugal impaction devices for shelling melon seeds. *Journal of Agricultural Engineering Research*, 20: 71-77.

Odigboh, E. U. 1979. Impact egusi shelling machine. *Transactions of the ASAE,* 22 (6): 1264 - 1269.

Oje, K. 1993. Some engineering properties of thevetia nut. *Journal of Agricultural Engineering and Technology,* 1: 38 - 45.

Olajide, J. O., Ade-Omowaye, B. I. O. and Otunola, E. T. 2000. Some physical properties of shea kernel. *Journal of Agricultural Engineering Research*, 76(4): 419 – 421.

Oluwole, F. A., Abdulrahim, A. T. and Olalere, R. K. 2007. Effect of moisture content on the crackability of bambara groundnut using a centrifugal cracker. *International Agrophysics,* 21(2): 179 – 184.

Oluwole, F. A., Aviara, N. A. and Haque, M. A. 2004. Development and performance tests of a sheanut cracker. *Journal of Food Engineering*, 65(1): 117 – 123.

Oluwole, F. A. 2004. *Design, Construction and Performance Evaluation of a Sheanut Cracker*. M.Sc thesis, University of Maiduguri.

Peter, F. and Ann, H. 1992. *Small-scale food processing. A guide to appropriate equipment*. International Technology Publications, London.

Philips, T. A. 1977. *An Agricultural Notebook*. New edition. Longman Group Limited, London.

Purseglove, J. W. 1979. *Tropical Crops: Dicotyledons*. Longman Group Limited, London.

Wiemer, H. and Korthals, F. W. 1989. *Small-scale processing of oil fruits and oil seeds*. Friedr. Vieweg and sohn verlagshgesell-schaff mbh, Braunschweig, Germany.