**Crackability and Chemical Composition of Pre-Treated Cashew Nuts**

**Using a Hand-Operated Knife Cutter**

**Abstract**

*The crackability and chemical composition of pre-treated cashew nuts was investigated considering three nut sizes (large, medium and small) and two methods of pre-shelling treatment (hot-oil roasting and steam–boiling). The pre-treated nuts were shelled using a hand operated knife cutter. Crackability was calculated on the basis of ratio by weight of completely shelled nuts to the total quantity of nuts fed into the machine. Whole kernels out-turn was calculated as the ratio of the weight of whole kernels to the total quantity of kernels recovered after shelling. Chemical analyses were carried out following standard methods in literatures. The average values of crackability for raw, roasted and steam-boiled nuts were 76, 100 and 99% respectively. For roasted nuts, crackability was higher than that of steam-boiled nuts and pre-shelling treatments affected whole kernels out-turn significantly (p<0.05). Large and medium roasted nuts exhibited the highest whole kernels out-turn (99.6 and 99.5% respectively). The least values of whole kernels out-turn were obtained for raw nuts (62, 33.9, and 44.7% for large, medium and small respectively). Pre- shelling treatments of cashew nuts made the nut more amenable to fracture; but the whole kernels out-turn of large nuts was generally higher than that of medium and small nuts. The pre-treatment showed no significant difference in the chemical composition and energy content of cashew kernels but for crude fibre and carbohydrates wherein the differences were significant (p<0.05).*

**Keyword:** Cashew nut, Pre-shelling Treatment, Crackability, Whole Kernels, Chemical Composition

**List of abbreviations**

CNSL = cashew nut shell liquid

*η =*crackability, %

*Ws* = weight of completely shelled nuts, g

*WT* = weight of total quantity of nuts fed into the machine, g

*Ww* = weight of whole kernels, g

*Wk* = weight of total quantity of kernels realized after shelling, g

*Kw* = whole kernels out-turn, %

*Bk =* percent broken kernels, %

KT = Total weight of useful kernels, g

Kg = weight of good kernels, g

Ksp = weight of spotted kernels, g

Ki = weight of immature kernels, g

KoR = kernel outturn ratio, Ibs/80 kg of cashew nuts

**1 Introduction**

Cashew nut (*Anacardium occidentale*) provides a nutritious kernel and serves as an ingredient for confectionery and baked food products (Azam-Ali and Judge, 2001; Andrighetti *et al.,* 1994; Ohler, 1979 and Agnoloni and Giuliani, 1977). With about 46 g of crude fat (about 74% of which is oleic acid), 25 g of carbohydrate, 21 g of protein and 596 kCal of energy per 100 g of intake; cashew kernel is rich in essential amino acids and minerals which are seldom found in daily diets (Holland *et al.*, 1991 and Davis, 1999). The removal of cashew kernel from the shell is a labour intensive operation involving cleaning/grading, pre-treatment by roasting or steam-boiling, shelling, separation, drying, and peeling (Agnoloni and Giuliani, 1977; Ohler, 1979; Andrighetti *et al.*, 1994; Azam-Ali and Judge, 2001 and Balasubramanian, 2006). The peculiar curvature of the nuts, the corrosive oil in its mesocarp and brittleness of the kernel make cashew nut shelling tedious; the greatest difficulty being the removal of the tough outer shell without damaging the encased kernel.

Traditional cashew nut shelling involves placing individual nut on a flat stone and applying repeated impact with a wooden mallet along the vertical and horizontal axis (Fig. 1a) until the nut cracks (Fig. 1b). Although, the task is quite arduous; especially for women who constitute 80 - 90% of the work force in most cashew nut factories, it is still common among rural processors in Asia and Africa (Ogunsina, 2010). Previous works on the development of shelling machines took little interest on the pre-shelling treatments to which cashew nuts are subjected by cottage processors. Some reports on mechanized cashew nut shelling include the hand operated knife cutter, pedal operated knife cutter, motorized knife cutters, box batch cracker and centrifugal cracker (Ojolo *et al.,* 2010; Ojolo and Ogunsina, 2007; Jain and Kumar, 1997; Ajav, 1996; Thivavarvongs, 1989; Thivavarvongs *et al.,* 1995a and Thivavarvongs *et al.,* 1995b). The commonest, which perhaps wasthe earliest and the most popular mechanical cashew nut shelling device is the hand or pedal operated knife cutter. Two people work on a machine; one Machine Operator who shells the nut and the Shelling Assistant who recovers the kernel. Nuts are fed manually one by one in-between two sets of blades machined to fit the contour of cashew nut (Fig. 2a). When the cutting lever or pedal is pressed in one stroke, the blades come together and the pointed knife-edge hits the nut on the concave side to crack and slit it (Fig. 2b). On the same stroke, the pointed knife-edge is twisted to split the nutshell into two halves along the line of symmetry and dropping it into a collector beneath. The shelling assistant separates the shell and recovers the kernels as shelling progresses (Azam-Ali and Judge, 2001). It is expected that the kernel should remain intact and whole, but with most mechanical systems, 25 - 40% of the kernels get broken; whereas whole kernels reach 90% with the traditional method (Ajav, 1996). This has limited cashew nut processing to cottage level for decades. The ridiculous price that broken cashew kernels attract in the international market and the labour intensive nature of the industry discourages large scale investors in most cashew nuts producing countries (Ajav, 1996).

Although Nigeria is second among the top ten cashew nuts producers in the world (FAO, 2009), up to 90% of her present 660,000 metric tons annual production are exported raw to India and some other parts of Asia (Ogunsina, 2010; Ogundiran, 2011). The foremost areas in Nigeria wherein cashew is largely cultivated include: Abia, Anambra, Cross River, Ebonyi, Enugu and Imo States in the East; Ekiti, Ogun, Ondo, Oyo and Osun States in the West; Benue, Kogi, Kwara, Nassarawa, Niger and Taraba in the Middle Belt and Kebbi and Sokoto States in the North; but, majority of export quality nuts come from the West and East. The export price of raw cashew nuts (free on board) varies between USD 1,000 and 1,500 per metric ton; whereas, processed kernels could attract triple that price if not more (Ogunsina, 2010).

Ojolo *et al*. (2010) remarked that the response of biomaterials to various physical treatments and conditions to which they are subjected during processing need to be fully understood in order to maximize yield and efficiency of machines associated with various unit operations. Furthermore, an understanding of the effect of these pre-treatments on the nutritional properties of processed cashew nuts will guide processors on the choice of processing method that retains or minimizes nutrients loss (Fagbemi, 2008). Alobo *et al.* (2009) investigated the physicochemical and functional properties of full fat and defatted cashew kernels. Fagbemi (2009) and Kosoko *et al.* (2009) found that processing method affects the chemical composition of cashew nuts significantly (p≤0.05); but the effect of pre-shelling treatments on the crackability of cashew nuts and chemical composition of its kernels have not been reported in literatures so far. This study therefore focuses on the crackability of pre-treated cashew nuts using the hand-operated knife cutter and investigates changes in the chemical composition of cashew kernels as influenced by the pre-shelling treatments.

**2. Materials and Methods**

* 1. **Source of materials and moisture content determination**

Samples for this investigation were obtained from raw cashew nuts harvested from Iwo cashew plantation, in Oyo state, Nigeria. The nuts were cleaned of all extraneous matter. Moisture content determination was carried out following the American Society of Agricultural Engineers Standard S410.1 Dec. 1997 (ASAE Standards, 1998).

**2.2 Determination of nut count and kernel outturn ratio**

Pre-processing quality assessment for cashew nuts was carried out following the method of Dahiya (2010) and Kratz (2013). This is to ensure that the nuts samples used for this investigation conform to acceptable quality standards. The parameters include nuts count per kg and kernel outturn ratio (KoR) which suggests the quantity in pound of good kernels obtainable per 80 kg bag of raw cashew nuts. A random sample of dried cashew nuts (8.3% moisture content) measuring 1 kg weight was taken and enumerated to obtain the nut count per kg. For KoR, the 1 kg nuts sample was cut longitudinally one by one into two equal halves to expose the encased kernel as split-in-peel. The split kernels were recovered from the shell and separated into four categories of quality indicators (good, spotted, immature and rotten/bad kernels) as shown in Table 1. Each category of kernels was weighed separately using a Mettler Toledo Electronic Balance (3100 g, accuracy 0.01 g). The total weight of useful kernels, KT was calculated as:

|  |  |
| --- | --- |
| KT = Kg + ½(Ksp + Ki) + 0(Kbr) | (1) |

where,

KT = Total weight of useful kernels, g

Kg = weight of good kernels, g

Ksp = weight of spotted kernels, g

Ki = weight of immature kernels, g

Kbr= weight of bad and rotten kernels, g

and

|  |  |
| --- | --- |
| KoR = 0.176 KT | (2) |

where,

KoR = kernel outturn ratio, Ibs/80 kg of cashew nuts

* 1. = a standard factor applied for conversion into recognized unit, Ibs

**2.3 Preparation of pre-treated samples**

The nuts were graded as large (26-35 mm), medium (23-25 mm) and small (18-22 mm) on the basis of their major axial dimensions shown in Fig. 3 (Balasubramanian, 2001). Pre-shelling treatments include steam-boiling and roasting in hot cashew nut shell liquid (CNSL). For steam-boiling, 5 kg of raw cashew nuts were cooked at 7 kPa for 30 min in a cashew nut baby-boiler in three replicates; afterwards, they were cooled naturally for 18 h (Balasubramanian, 2006; Ogunsina and Bamgboye, 2013). For roasting, 5 kg of raw cashew nuts were dipped inside a bath of pre-heated CNSL (190 – 200°C) for 1.5 min (Azam-Ali and Judge, 2001; Ogunsina and Bamgboye, 2012). The roasted nuts were discharged on saw dust to mop residual coating of CNSL on the shell. Afterwards, the nuts were allowed to cool naturally for 18 h. Some samples of raw cashew nuts from the lot were used as control.

Kernels for chemical analyses were extracted from the raw and pre-treated nuts. They were peeled, dried and kept under refrigeration till the time of use.

**2.4 Assessment for selecting an expert shelling machine operator**

Five experienced operators of hand-operated cashew nut knife-cutter drawn from three major cashew nut factories in south-western Nigeria were subjected to shelling tests pro-rata using a single machine. Nuts sample from a single nut size and batch of pre-treated nuts were drawn for this investigation. Each operator was tasked to shell as many number of cashew nuts as can be shelled within a minute in ten replicates. The operators were evaluated on the basis of whole kernels out-turn (*Kw*) and number of nuts shelled per min.

|  |  |
| --- | --- |
| % | (3) |

where, *Ww* = weight of whole kernels

*Wk* = weight of total quantity of kernels realized after shelling

Implicitly, percent broken kernels (*Bk*) obtained as shown below.

|  |  |
| --- | --- |
| *Bk* = 100 – *Kw* | (4) |

|  |  |
| --- | --- |
| $${Number of nuts shelled }/{min}=\frac{number of shelled nuts}{time taken in min}$$ | (5) |

Data were subjected to analysis of variance using SAS (2001). The operator with the highest whole kernels and number of nuts shelled per min was adjudged to be the most experienced; hence was selected to carry out all shelling activities during this investigation.

**2.5 Crackability of pre-treated nuts**

The selected expert machine operator was tasked with 1 kg of raw and pre-treated samples of cashew nuts in five replicates each. Crackability (*η*) was calculated based on the ratio by weight of completely shelled nuts to the total quantity of nuts fed into the machine as shown in equation 3 (Ojolo *et al.,* 2010; Oluwole *et al.*, 2007a; Oluwole *et al.*, 2007b).

|  |  |
| --- | --- |
| % | (6) |

where, *η=* crackability

 *Ws* = weight of completely shelled nuts,

 *WT* = weight of total quantity of nuts fed into the machine,

Nuts from which there was difficulty in getting out the kernel were regarded as partially shelled/unshelled nuts and may be obtained as: (100 – *η*).

**2.6 Chemical analyses**

The kernels obtained from pre-treated samples were analyzed for proximate composition (moisture content, crude protein, crude fat, ash and crude fibre) using the method of the Association of Official Analytical Chemists (AOAC, 2000). Carbohydrate was estimated by difference. Food energy was calculated by Atwarter factors (9fat + 4protein + 4carbohydrate) in kcal/100 g (Alobo *et al.,* 2009 and Ogunsina *et al.,* 2010). Iron and calcium were determined using methods of Alobo *et al.* (2009). Data were subjected to analysis of variance and means were separated by duncan multiple range tests using SAS (2001).

**3. Results and Discussion**

**3.1 Nut count and kernel outturn ratio**

Raw cashew nuts for this investigation had moisture content of 8.3%, nut count of 197nuts/kg and KoR of 47 Ibs (applying equation 1 and 2 to Table 1). Moisture content of 8-10% is generally acceptable as safe for cashew nuts and most edible kernels/oil seeds. Kernel outturn ratio is an export quality parameter which forms an economic basis to estimate or predict the income obtainable by producers or processors from a given lot of raw cashew nuts (Kratz, 2013 and Dahiya, 2010). Nut count stands for the number of raw nuts per kg and merely suggests the average nut size; hence, as well an important quality indicator. Balasubramanian (2006) established KoR as a very important criterion for determining the export quality in cashew nut trade. Cashew nuts with KoR≥46 Ibs attract premium price and yield good quality kernels when processed. Generally, KoR of cashew nuts in most producing countries varies from 40 - 56 Ibs per 80 kg, the higher the better the kernel quality (Dahiya, 2010).

**3.2 Selection of an operator for the hand operated knife cutter**

The average number of nuts shelled per min and corresponding *KW* for each of the assessed operators were 11 and 97.3 for shelling machine operator A; 16 and 92 for B; 14 and 93.9 for C; 9 and 82.1 for D; 17 nuts and 94.8% for E respectively (Table 2). It was observed that operator E produced the highest number of nuts (17) per min whereas operator A, though produced a lower (16) number of nuts per min, had the highest *KW* (97.3%). However, the average number of nuts shelled per min and the corresponding *KW* by operators A, B and E were not significantly different. This implies that any of these three operators was capable of giving optimum results. Operator A who had the highest *KW* (97.3%) was therefore adjudged to be the best; since shelling efficiency demands that *KW* be as high as possible. For this investigation, all shelling activities were carried out by operator A for consistency.

**3.3 Effect of pre-shelling treatments on crackability**

The average crackability of raw, roasted and steam-boiled nuts across the nut sizes was 76, 100 and 99%. It was observed in Table 3 that the crackability of roasted and steam-boiled nuts was higher than that of raw nuts. Crackability was100% for all nut sizes of roasted nuts. This is higher than 75% by Ajav (1996); 70% by Jain and Kumar (1997) and 67% by Ojolo and Ogunsina (2007) with roasted nuts. The results showed that crackability of roasted nuts was better than that of steam-boiled nuts. The sudden temperature rise that occurs during hot-oil roasting usually case-hardens the shell making brittle and amenable to fracture. For all pre-treatments, the crackability of medium nuts was higher than that of large and small nuts. This may be attributed to variations in the clearance that exist in-between the knife-cutting edge when the machine was actuated by the lever.

**3.4** **Effect of pre-shelling treatments on whole kernels out-turn**

Table 4 shows the KW of cashew nuts as influenced by pre-shelling treatments. It was observed that the pre-shelling treatments affected KW significantly (p<0.05) for the three nut nut sizes. Roasted nuts gave the highest KW (99.6 and 99.5% for large and medium nuts respectively) except for small nuts for which KW was 85.1%. During hot-oil roasting, the slight rise in temperature that the kernel experiences in the presence of moisture tends to parboil and toughen it thereby lessening its susceptibility to breakage and ultimately increasing KW. It was found that the KW of raw nuts was the least (62, 33.9, and 44.7% for large medium and small respectively). The shell of raw cashew nut is naturally spongy and tough; the intra-cellular pressure that develops within the CNSL bearing cells as force was applied through the knife-edge may offer some resistance to fracture when the nut was compressed. Rather than for the shell to fail and crack, the CNSL bearing cells ruptured and oozed out their contents. As more force was applied, the entire nut got compressed and the embedded kernel failed catastrophically. It is noteworthy that when raw kernels are cracked, contamination by CNSL is often inevitable and this makes them unfit for consumption. For all pre-treatments, KW decreased consistently with nut sizes. Overall, the KW of large nuts was highest for all pre-treatments; implying that large nuts generally give higher KW than smaller sizes.

**3.5 Effect of pre-shelling treatments on the chemical composition cashew kernel**

The chemical composition of cashew kernels as affected by pre-shelling treatment is presented in Table 5. For raw, roasted and steam-boiled kernels, crude protein was 21.32, 22.24 and 23.07%; while crude fat was 42.19 41.06 and 41.62%. These results agree with the report of Alobo *et al* (2009), and Fagbemi (2009) who had earlier worked on the proximate and nutritional properties of cashew kernels. The pre-shelling treatment showed no significant difference in the chemical composition and energy of cashew kernels but for crude fibre and carbohydrates wherein the difference was significant (p<0.05). The expected trend shown by moisture content indicates slight increase from 5.16% in raw to 5.30% in steam-boiled nuts and a decrease to 4.65% in roasted nuts. The crude protein content in cashew kernels compares favourably with almond, 20.8%; linseed, 20.3%; mustard, 20% and groundnut, 26.25% (Gopalan *et al*., 2007 and Nair, 2010). Hazel nut, macadamia and almond have lesser protein content with 12.7, 9.2 and 15.6% respectively. The crude fat content of cashew kernels stands out among most edible kernels. Almond, hazelnut, macadamia, walnut, pistachio and sunflower have 59.9, 60.9, 64.5, 78.2, 53.5 and 52.1% respectively; whereas, groundnut, mustard, nigerseed and linseed have 39.8, 39.7, 39, 37.1% respectively (Gopalan et al., 2007 and Nair, 2010). Although the crude fat in cashew kernels is lower than that of most other choice edible kernels, its high oleic acid content and nutritional benefits make it a prized food snack among peers. The relatively short duration of pre-treatment during steam boiling focuses essentially on making the shell brittle enough to crack without affecting the encased kernel. It leaves no chance to leaching of nutrients as often associated with cooking with water. Congruently, the interaction of CNSL with the shell during hot-oil roasting is limited by the semi-impervious nature of the endocarp layer which protects the kernel in the internal cavity. Since there is virtually no interaction between the roasting oil and the kernel, the kernel is able to retain originality in it chemical composition. This may be the reason why the differences in crude protein due to the pre-treatments were not significant. The slightly significant (p<0.05) decrease in the ash content of the roasted nuts reflected in the iron and calcium contents. In comparison with groundnut, sunflower and linseed, cashew kernel is high in iron and low in calcium contents.

**4. Conclusions**

The crackability of pre-treated cashew nuts and chemical composition of cashew kernels have been studied, considering three nut nuts sizes (large, medium and small) and two methods of pre-shelling treatments (hot-oil roasting and steam–boiling). The following conclusions may be drawn:

1. Pre-treated nuts generally crack more easily than raw nuts. The crackability of roasted nuts was higher than that of steam-boiled nuts and pre-shelling treatment affected KW significantly (p<0.05).
2. Roasted nuts exhibited the highest KW (99.6 and 99.5% for large and medium nuts respectively) except for small nuts for which KW was 85.1%. It was found that the KW of raw nuts: 62, 33.9, and 44.7% for large medium and small respectively were the least for all nut sizes.
3. The KW of large nuts was highest for all pre-treatments; implying that large nuts generally give higher KW than medium and small nut sizes.
4. The pre-treatment showed no significant difference in the chemical composition and energy of cashew kernels but for crude fibre and carbohydrates wherein the difference was significant (p<0.05).

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1. Axes of impact load application during traditional cashew nut shelling



(b) Typical traditional cashew nut shelling in Nigeria

Fig. 1.



1. Placement of cashew nut in-between shelling blades of the hand operated knife-cutter



(b) Cashew nut shelling using the hand operated knife-cutter in Nigeria

Fig. 2.



Fig. 3. Measurement of axial dimensions of cashew nuts

 *(l,* major axis; *w,* minor axis; and *t,* intermediate axis*)*Table 1. Cashew nuts quality indicators and their distribution by weight

|  |  |  |
| --- | --- | --- |
| Category | Characteristics | \*Quantity g/kg of nuts |
| Good kernels | matured and whole good kernels which can be consumed in totality | 245 |
| Spotted kernel | kernels bearing dark or black spots, a part of which can be consumed | 10 |
| Immature kernels | Immature, shriveled, light weight and deformed kernels, a part of which can be consumed | 24 |
| \*Bad/rotten kernels | kernels which are rotten, mouldy, which cannot be consumed | 16 |

 \*Values were average of three replicates

Table 2. Shelling machine operator’s assessment results

|  |  |  |
| --- | --- | --- |
| OperatorsIdentity | Average number of nuts shelled per min  | Whole kernels %  |
| A | 11.4c(1.2) | 97.3a(3.3) |
| B | 16.2a(0.7) | 92.0a(2.2) |
| C | 14.0b(1.1) | 93.9a(5.6) |
| D |  9.0d(1.3) | 82.1b(7.8) |
| E | 17.2a(0.7) | 94.8a(2.7) |

a,b,c,dMeans on the same column with different letters are significantly different (p<0.05).

Numbers in parenthesis are standard deviations

 Table 3. Crackability of cashew nuts on the basis of size and pre-shelling treatments

|  |  |
| --- | --- |
| Nut Sizes (mm) | Crackability of pre-treated nuts (%) |
| *Raw* | *Roasted* | *Steam-boiled* |
| Large (26-35) | 72 (28) | 100 (0)  | 100 (0) |
| Medium (23-25) | 78 (22) | 100 (0) | 100 (0) |
| Small (18-22) | 77 (23) | 100 (0) | 96 (4) |
| Average across the nut sizes  | 76 (24) | 100 (0) | 99 (1) |

Percentages of unshelled/partially shelled nuts are in parenthesis

Table 4. Whole kernels of pre-treated cashew nuts

|  |  |
| --- | --- |
| Nut sizes | KW (Bk) |
| Raw | Steam-boiled | Roasted |
| Large (26-35) | 62.0c(38) | 91.7b(8.3) | 99.6a(0.4) |
| Medium (23-25) | 33.9c(66.1) | 73.7b(26.3) | 99.5a(0.5) |
| Small (18-22) | 44.7c(55.3)  | 87.0a(13.0)  | 85.1b(14.9)  |

a,b,cMeans on the same row with different letters are significantly different (p<0.05).

*Kw* = whole kernels; *Bk*= broken kernels

Table 5. Chemical composition of pre-treated cashew kernels

|  |  |
| --- | --- |
| Chemical components |   Pre-treatment .  Raw Hot-oil roasted Steam boiled |
| Protein, % | 21.32a(0.80) | 22.24a(1.31) | 23.07a(1.01) |
| Crude Fibre, % | 4.35b(1.41) | 5.13a(0.11) | 4.51b(0.05) |
| Crude Fat, % | 42.19a(0.4) | 41.06a(0.96) | 41.62a(0.32) |
| Ash, % | 2.79a(0.38) | 2.71a(0.29) | 2.62b(0.19) |
| Moisture Content, % | 5.16a(0.85) | 4.65b(0.14) | 5.30a(0.02) |
| CHO, % | 24.19a(0.44) | 24.21a(0.89) | 22.88b(0.63) |
| Iron, mg/100g | 5.61a(0.02) | 5.52a(0.04) | 5.12b(0.02) |
| Calcium, mg/100g | 52.1a(0.82) | 50.6a(1.23) | 51.2a(0.90) |
| Energy, kCal/100g | 561.75a(0.88) | 555.34a(0.1) | 558.38a(0.24) |

a,bMeans on the same row with different letters are significantly different (p<0.05).

Numbers in parenthesis are standard deviations