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Effect of Moisture Content, Nut Size and Hot-Oil Roasting Time on the Whole Kernel "Out-Turn" of Cashew Nuts *(Anacardium occidentale)* During Shelling

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ABSTRACT

The effect of moisture content (MC), nut size and roasting time (RT) on the whole kernel out-turn (WKO) of cashew nuts during shelling was investigated in this study. Cashew nuts were graded into three sizes: small (18 – 22 mm), medium (23 – 25 mm) and large nuts (26 – 35 mm). About 3 kg of nuts from each grade was conditioned with water at 25°C to five moisture levels of 8.34, 11.80, 12.57, 15.40 and 16.84% (wb). The nuts were subjected to roasting in hot cashew nut shell liquid at a temperature range between 180 and 190°C for 0.75, 1.00, 1.25, and 1.50 min. The nuts were then shelled using a hand-operated shelling machine. The results showed that pre-shelling treatment of cashew nuts enhanced WKO. The single effect of MC, roasting time (RT) or nut size distribution is not enough for estimating WKO; it is rather by an interaction of these parameters. The average WKO of raw nuts was characteristically below 50% at all combinations of MC and RT. Pre-treatment by roasting was found to improve WKO considerably. The highest values were 96.96, 99.63 and 100% for large, medium and small-sized nuts at MC*RT of 16.84%*1 min, 16.84%*1 min and 15.4%*1.5 min respectively. As RT and MC increased, WKO increased within the experimental range.

Keywords: Moisture content, nut size, hot-oil roasting, whole kernel out-turn, cashew nuts.

Introduction

Most edible nuts require thermal treatment in the form of roasting, cooking, or drying before they can be decorticated or processed further for food (Kahyaoglu and Kaya, 2006; Shakerardekani *et al.*, 2011). The commonest in cashew nut processing involves either roasting the nuts in a medium of pre-heated air (dry roasting) or total immersion of the nuts into a pre-heated oil bath (hot-oil roasting). Cashew nut *(Anacardium occidentale)* is chief among the highly prized edible nuts in the world; it is known to be rich in crude protein (about 22 g/100 g of kernel), crude fat (about 46 g/100 g of kernel) and oleic acid is about 74% in its fatty acid composition (The Wealth of India, 1985). For cashew nuts, roasting method (Figure 1) by hot-oil involves dipping pre-conditioned nuts inside a pre-heated bath of cashew nut shell liquid at 180 – 200°C for about 1½ min (Oloso and Clarke, 1993; Kosoko *et al.*, 2009); the oil is filtered off afterwards and the nuts are allowed to cool naturally for a minimum of 12 h (Azam Ali and Judge, 2001; Kita and Figiel, 2007). Roasting is usually carried out with the view to harden the nutshell, and make it brittle and more amenable to fracture when subjected to impact load during shelling/cracking (Ogunsina, 2010; Ogunsina and Bamgboye, 2012; Akinoso *et al.*, 2004). This method of thermal treatment alters the physical, chemical, textural and sensory

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properties of the material (Nikzadeh and Sedaghat, 2008; Ogunsina and Bamgboye, 2007; Wanlapa and Jindal, 2006) depending on the oil temperature and duration within which roasting is carried out, including other parameters such as moisture content, nut size and roasting method. Roasted nuts are shelled manually by applying impact load longitudinally and transversely using a wooden mallet against a flat stone until it fails symmetrically and splits open. The commonest shelling method in the industry involves the use of manual pedal or hand operated machines that work on the principle of compression and shear.

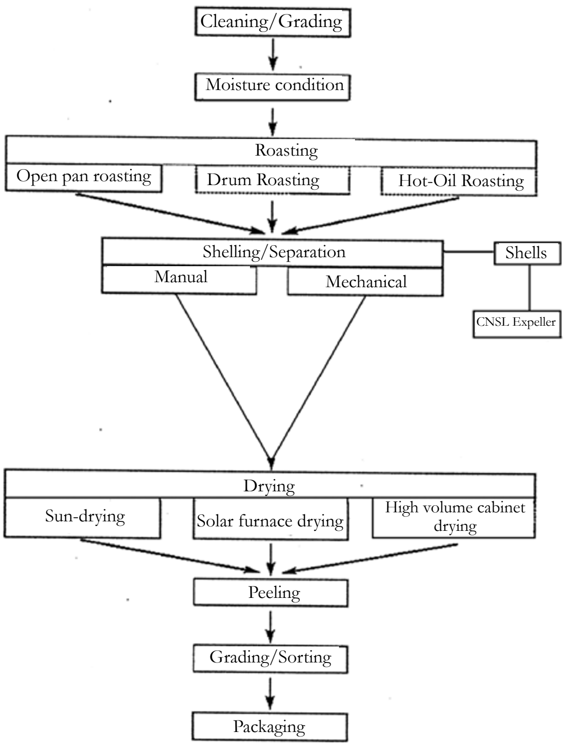

Fig. 1: Cashew nut processing by different roasting methods
Source: Intermediate Technology Development Group (2001)

The growth of the cashew nut industry in Africa has suffered great limitations with respect to the whole kernels out-turn (WKO) of shelled nuts (Ogunsina, 2010; Ogunsina and Bamgboye, 2011), whereas the case is different in India where a bulk of the world's cashew nuts are processed. The peculiar curvature of cashew nuts, the corrosive liquid in the mesocarp of the shell and the brittleness of the embedded kernel are some of the factors that make cashew nut shelling different from other nuts. Cashew nut shelling has therefore remained a manual process for ages, because 25 – 40% of the kernels get broken when the existing mechanized systems are used, whereas WKO reaches 90% with the manual system as obtained in India (Ajav and Oke, 2007; Ojolo and Ogunsina, 2007; Jain and Kumar, 1997; Ajav, 1996; Thivavarvongs *et al.*, 1995a; Thivavarvongs *et al.*, 1995b). In view of the growing need to stimulate further efforts to mechanize cashew nut processing, a good understanding of the various conditions to which nuts are subjected during processing need to be understood (Kosoko *et al.,* 2009; Ojolo *et al.,* 2010). Hitherto, the control of these parameters to improve WKO relies largely on the skill level and experience of processors rather than on clear scientific understanding of the process (Kahyaoglu, 2008). Processing parameters such as moisture content, method and conditions of pre-shelling treatment and nut size distribution were identified as having great influence on WKO (Araujo *et al.*, 2006; Balasubramanian, 2006; Oloso and Clarke, 1993; Jain and Kumar, 1997). The premium price that whole cashew kernels attract in the world's edible nuts trade is the trigger for this work. As local consumption of cashew kernel and its demand by importing countries continue to increase worldwide, this work is a step further towards establishing science-based procedures for the industry. Specifically, the focus here is on the effect of moisture content (MC), nut size and roasting time on the WKO of cashew nuts during shelling.

Materials and Methods

About 1000 kg of raw cashew nuts were procured from farm gates in Iseyin, Iwo and Oro areas of Oyo, Osun and Kwara States (Nigeria) respectively during peak harvest period (February-April 2008). The nuts were sun-dried to 8.34% MC on the average. Extraneous materials such as leaves, stones, immature and spoilt nuts were removed from the lot. The lot was sorted into three nut sizes based on their major axial dimensions: large (26 – 35 mm), medium (23 – 25 mm), small (18 – 22 mm) following the method of Balasubramanian (2001). The samples were kept on raised pallets for good ventilation until the time of use according to common practice in the industry. The experiment was a 3 × 5 × 4 factorial experiment considering three nut sizes: large, medium and small; five levels of MC: 8.34, 11.80, 12.57, 15.40, 16.84 % (wet basis); and four levels of roasting time 0.75, 1.00, 1.25 and 1.5 min. The amount of water required for moisture adjustment of samples from 8.34% to the desired MC was determined from the equation below (Ajibola *et al.*, 2002; Ogunsina *et al.*, 2008).

$$W_w = W_s\left(\frac{M_2 - M_1}{1 - M_2}\right)$$

Where, W_w = amount of water to be added; W_s = weight of sample for which moisture is to be adjusted; M_1 = initial MC of sample and M_2 = final M_C of sample. Each sample for which moisture had been adjusted was sealed in separate cellophane bags and kept under refrigeration (at 4°C) for 4 days to equilibrate (Ajibola *et al.*, 2002; Ajibola *et al.*, 2000; Adebona, 1986). All MC determinations were carried out by ASAE standards (1998).

Nuts were roasted by immersion in a pre-heated bath of cashew nut shell liquid (185 – 190°C). About 3 kg of each nut size was loaded inside a mild steel basket; the basket was dipped inside the pre-heated CNSL for 0.75 min (Ogunsina and Bamgboye, 2011; Andrighetti *et al.*, 1994; Oloso and Clarke, 1993). The oil was filtered off as the basket was removed and the nuts were discharged onto a heap of wood ash wherein the CNSL film on the shell was mopped and the nuts were cooled under ambient conditions (Andrighetti *et al.*, 1994; Oloso and Clarke, 1993). This procedure was repeated for 1.00, 1.25 and 1.5 min, each run being replicated five times.

All nuts were shelled using a hand-operated cashew nut shelling machine manned by a trained operator who was chosen based on preliminary assessment (Ogunsina and Bamgboye, 2011). Five well-trained operators of hand-operated cashew nut shelling machine drawn from three cashew nut processing factory sites of Ollam Nigeria Ltd. in Iseyin, Sepeteri and Oyo, Nigeria were assessed pro-rata using the same machine. Nut samples were chosen from a single category of nut-sizes and batch of pre-treated nuts. Each operator was tasked to shell as many number of cashew nuts as can be shelled within 1 min. This was repeated ten times for each operator. The five operators were evaluated on the basis of WKO and number of nuts shelled per min (N_n) (eq. 1 and 2).

$$WKO = \frac{W_w}{W_T} \times 100\% \quad (1)$$

Number of nuts shelled/min (N_n) =

$$\frac{\text{number of shelled nuts}}{\text{time taken in min}} \quad (2)$$

Where, W_w = weight of whole kernels

W_T = weight of the total quantity of kernels realized after shelling

The operator with the best combination of WKO and number of nuts shelled per min was chosen for all shelling activities in this investigation.

After shelling, whole and split kernels were separated from the shells and their respective weights were determined. The per cent ratio of the weight of whole kernels to the total weight of kernels recovered was estimated as WKO:

$$\frac{W_w}{W_T} \times 100 \quad (3)$$

Where, $W_T = W_w + W_s$

Results and Discussion

The average WKO for different sizes of raw cashew nuts as influenced by MC are presented in Table 1. It was observed that WKO was below 50% at all MC except for large-sized nuts for which WKO was 62% at 8.34% MC. Due to the spongy and tough nature of cashew nut shell, the intra-cellular pressure that develops within the CNSL-bearing cells in the mesocarp of the shell may offer little resistance to fracture. When the nut was compressed, rather than for it to crack, the CNSL cells ruptured and discharged their contents; as more force was applied the entire nut got compressed; damaging the wholesomeness of the kernel in the process. In addition, most of the kernels obtained were smeared by CNSL and not fit for human consumption. The essence of subjecting cashew nuts to thermal treatment is to make the shell more amenable to fracture during shelling in a manner that will keep the wholesomeness of the kernel. Needful to remark is the fact that the single effect of MC, roasting time (RT) or nut size distribution alone may not be sufficient to estimate WKO; it is rather by the interaction of these parameters.

Table 1: Effect of moisture content on the whole kernel out-turn of raw cashew nuts moisture contents (%)

Nut sizes	8.34	11.80	12.57	15.40	16.84
		WKO (%)			
Large, L	62.02	47.37	54.02	35.31	48.64
Medium, M	33.93	40.38	32	36.02	38.78
Small, S	44.67	42.58	56.75	44.64	46.95

The interaction effect of moisture content with roasting time (MC*RT) on the WKO of large cashew nuts is presented in Table 2. The highest significant ($p < 0.05$) WKO (99.64%) was obtained when nuts at 16.84% MC were roasted for 1.5 min. This was not significantly different from WKO (96.53%) when the nuts were roasted for 1 min. Implicitly, this value is not significantly ($p < 0.05$) different from the WKO of 97.63; 98.27; and 96.96% indicated at other MC*RT interactions of 15.4%*1.5 min; 15.4%*1 min and 12.57%*1 min respectively. The numerical difference shown in the WKO was not as a result of MC and roasting time, hence it makes no difference if nuts are processed at any of the MC and roasting time interactions. Considering the time, energy and labour that may be required, it can be inferred that optimum WKO of 96.96% was obtained at 12.57% MC and 1 min roasting time. In practice, it implies that conditioning large-sized nuts to MC above 12.57% may bring no significant increase in WKO. This is an improvement over the conventional industrial practice which does not consider nut sizes during pre-shelling treatment. Apart from the substantial time reduction it takes to condition nuts to desired MC, roasting time reduced by 33.3% and energy consumption is consequently reduced. This is better than the conventional practice of conditioning nuts to 15 – 20% MC and roasting for 1.5 min (Oloso and Clarke, 1993).

Nuts that were roasted at MC lower than 12% yielded WKO below 60%. The decrease in moisture content changes the texture of the product making it more crispy and brittle and susceptible to nutshell fracture after cooling (Nikzadeh and Sedaghat, 2008). The impact of the applied load by the shelling blade when brought into contact with the nut cracks the shell and injures the kernel, and consequently reduces WKO. When nuts are roasted, the tendency of brittle fracture is higher; conditioning the nuts to a higher MC however makes the embedded kernel tough but weakens the shell. During the short resident roasting time of nuts inside a bath of hot-CNSL, the shell case hardens after undergoing momentary shrinkage and turns brittle thereby becoming susceptible to brittle fracture. On the contrary, since roasting does not last long enough to transfer the heating effect inwards equally to the kernel embedded inside the inner cavity, the kernel only gets tempered during this process and becomes less susceptible to fracture during shelling. This may have been responsible for the increase in WKO.

Table 2: Least significant difference test for the effect of roasting time and moisture content on the WKO of large-sized cashew nuts

	Factor level	WKO (%)
Main effect	0	49.47[d]
Roasting Time, RT	0.75	74.98[b]
	1.00	81.21[a]
	1.25	80.18[a]
	1.5	67.84[c]
	LSD	3.482
MC	8.34	51.25[d]
	11.80	64.24[c]
	12.57	77.69[b]
	15.40	77.75[b]
	16.84	82.77[a]
	LSD	3.48
Interaction effect	0	62.02[a]
8.34* RT	0.75	56.06[a]
	1.00	43.20[b]
	1.25	63.35[a]
	1.5	31.60[c]
	LSD	11.40
11.80* RT	0	47.37[c]
	0.75	76.99 [b,a]
	1.00	71.11[b]
	1.25	84.61[a]
	1.5	41.12[c]
	LSD	12.75
12.57* RT	0	54.02[d]
	0.75	83.69b
	1.00	96.96[a]
	1.25	84.54[b]
	1.5	69.22[c]
	LSD	5.61
15.4* RT	0	35.31[d]
	0.75	75.30c
	1.00	98.27[a]
	1.25	82.22[b]
	1.5	97.63[a]
	LSD	5.24
16.84*RT	0	48.64[c]
	0.75	82.82[b]
	1.00	96.53[a]
	1.25	86.19[b]
	1.5	99.64[a]
	LSD	4.66

[a,b,c,d] Means within the same cell with different letters are significantly different ($p < 0.05$).

0.75, 1.00, 1.25, and 1.50 are roasting times (RT) in min. RT = 0 for raw nuts

Table 3: Least significant difference test for the effect of roasting time and moisture content on the WKO of medium-sized cashew nuts

	Factor level	WKO (%)
Main effect	0	36.22[b]
RT	0.75	81.21[a]
	1.00	82.91[a]
	1.25	79.63[a]
	1.5	81.06[a]
	LSD	3.78
MC	8.34	56.09[d]
	11.80	77.04[b,a]
	12.57	71.93[c]
	15.40	75.26[b,c]
	16.84	80.70[a]
	LSD	3.78
Interaction effect	0	33.93[d]
8.34*RT	0.75	69.93[a]
	1.00	68.15[b,a]
	1.25	60.67[b]
	1.5	47.78[c]
	LSD	9.07
11.80* RT	0	40.38[c]
	0.75	90.49[a]
	1.00	89.77[a]
	1.25	86.50[b,a]
	1.5	78.08[b]
	LSD	9.61
12.57* RT	0	31.40[b]
	0.75	78.08[a]
	1.00	80.10[a]
	1.25	86.51[a]
	1.5	82.96[a]
	LSD	12.56
15.4* RT	0	36.02[d]
	0.75	91.11[b]
	1.00	76.92[c]
	1.25	75.30[c]
	1.5	96.96[a]
	LSD	5.40
16.84* RT	0	38.78[d]
	0.75	76.42[c]
	1.00	99.63[a]
	1.25	89.18[b]
	1.5	99.50[a]
	LSD	8.77

[a,b,c,d] Means within the same cell with different letters are significantly different ($p < 0.05$).

Other notations in Table 2 apply

Table 4: Least significant difference test for the effect of roasting time and moisture content on the WKO of small-sized cashew nuts

	Factor level	WKO (%)
Main effect	0	47.12[c]
RT	0.75	83.05[ba]
	1.00	85.55[a]
	1.25	81.56[b]
	1.5	84.12[a]
	LSD	3.08
MC	8.34	62.20[c]
	11.80	77.27[b]
	12.57	83.26[a]
	15.40	79.23[b]
	16.84	79.43[b]
	LSD	3.08
Interaction Effect	0	44.68[b]
8.34*RT	0.75	70.36[a]
	1.00	62.03[a]
	1.25	66.72[a]
	1.5	67.24[a]
	LSD	10.50
11.80*RT	0	42.58[c]
	0.75	96.36[a]
	1.00	87.95[ba]
	1.25	78.87[b]
	1.5	80.58[b]
	LSD	10.45
12.57*RT	0	56.74[c]
	0.75	86.88[b]
	1.00	94.26[a]
	1.25	90.68[ba]
	1.5	87.72[b]
	LSD	4.91
15.4*RT	0	44.64e
	0.75	73.70d
	1.00	90.10[b]
	1.25	87.72[c]
	1.5	100[a]
	LSD	2.34
16.84*RT	0	46.95[c]
	0.75	87.93[ba]
	1.00	93.39[a]
	1.25	83.81[b]
	1.5	85.07[b]
	LSD	6.57

[a,b,c,d] Means within the same cell with different letters are significantly different ($p < 0.05$).
Other notations in Table 2 apply

The effect of MC and pre-shelling treatment on the WKO of medium-sized cashew nuts is shown in Table 3. The result shows that the highest significant ($p < 0.05$) value of WKO (99.63) was obtained when nuts at 16.84% MC were roasted for 1 min (i.e. 16.84%*1 min). Though this was not significantly different from WKO (99.5%) at 16.84%*1.5 min, it may be better to roast for 1 min; by so doing, 0.5 min reduction in processing time will be gained thereby reducing labour and energy cost. The WKO was generally high when MC was high and vice versa. This implies that the effect of MC was more on medium-sized nuts when RT was 1.5 min than at other levels of RT.

Table 4 shows the interaction effect of MC and roasting time on WKO for small-sized cashew nuts. The highest significant ($p < 0.05$) WKO of 100% was obtained when nuts at MC of 15.4% were roasted for 1.5 min (i.e. 15.4%*1.5 min). This is significantly ($p < 0.05$) different from WKO at all other 15.4*RT interactions and was the only combination that gave the 100% WKO of all treatment combinations. Comparing all the three sizes of hot-CNSL roasted nuts, small-sized nuts gave the maximum WKO (100%). High WKO at roasting time below 1.5 min for cashew nuts with MC below the conventional 17 – 20% was an improvement over previous findings reported by Oloso and Clarke (1993).

Conclusions

The effect of MC, nut size distribution and hot-oil roasting time on the whole kernel out-turn of cashew nuts during shelling have been investigated. The single effect of MC, roasting time (RT) or nut size distribution is not enough for estimating WKO; it is rather by an interaction between these parameters. The average WKO of raw nuts was characteristically below 50% at all combinations of MC and RT. The interaction of these parameters affected WKO of cashew nuts significantly ($p < 0.05$). Pretreatment by roasting was found to improve whole kernel out-turn considerably. The highest values were 96.96, 99.63 and 100% for large, medium and small-sized nuts at MC*RT of 16.84%*1 min, 16.84%*1 min and 15.4%*1.5 min respectively. As RT and MC increased, WKO increased within the experimental range.

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