

## Comparative Quality Evaluation of Roasted Cashew Nut Kernel: Effect of Roasting Methods

<sup>1</sup>S.B. Kosoko, <sup>1</sup>O.B. Oluwole, <sup>1</sup>A.O. Daramola, <sup>1</sup>M.A. Adepoju, <sup>2</sup>A.J. Oyelakin, <sup>1</sup>A.O. Tugbobo-amisu, <sup>1</sup>G.O. Alagbe and <sup>1,2</sup>G.N. Elemo

<sup>1</sup>Department of Food Technology,

<sup>2</sup>Department of Production, Analytical Services and Laboratory Management,  
Federal Institute of Industrial Research, Oshodi, Lagos State, Nigeria

**Abstract:** This study was conducted to determine the effect of two roasting methods on the chemical, microbial as well as the sensory qualities of cashew nut kernels. Raw cashew nut was processed to obtain the plain cashew kernels and was divided into two portions which were subjected to different roasting treatments using conventional-air oven and halogen oven at a temperature of 200°C for 40 min, respectively. Proximate analysis showed that the conventional-oven roasted cashew kernel had higher moisture content, protein and crude fiber values of  $4.68\pm0.18$ ,  $18.34\pm0.94$  and  $2.11\pm0.08$ , respectively than the roasted sample using halogen-oven. In halogen-oven roasted kernel, the fat, carbohydrate, fatty acid and metabolizable energy contents were higher ( $45.62\pm0.98$ ,  $2.53\pm0.08$ ,  $30.04\pm0.95$ ,  $39.23\pm0.85$  and  $2480.04\pm2100$ , respectively). The mineral analysis indicated that the halogen-oven roasted kernels had higher values except in the case of Magnesium (Mg), which was higher in the conventional-oven roasted cashew nuts. The microbial assessment of the cashew kernels showed that halogen-oven cashew roasted kernel had a reduced value in all the microbiological analysis carried out with the exception of staphylococcus count. However, *E. coli* was not present in any of the cashew kernel samples. Based on the sensory rating, halogen-oven roasted cashew kernel had the highest overall acceptability sensory rating. It was observed that chemical parameters of fat, fatty acid and metabolizable energy show positive correlation at both ( $p<0.01$ ) and ( $p<0.05$ ) for the sensory attributes of color, taste, crispiness, flavor and overall acceptability while the chemical parameters of moisture content protein and crude fibre showed a negative correlation for all the sensory attributes. The results of this study indicated that halogen-oven will be better option for producing nutritious and wholesome roasted cashew nut kernels with acceptable sensory qualities.

**Keywords:** Cashew nut kernel, chemical, conventional-oven, halogen oven, microbial, sensory

### INTRODUCTION

Adequate nutrition has been generally accepted as being central to good and healthy living (Oniang'o *et al.*, 2003). Recent drastic and rapid changes in the way of living and general lifestyle of the populace and its consequent effect on the eating pattern and habit have culminated into housewives and women trying to finding less cumbersome and quicker means of food processing especially at household level.

In recent times, people have been increasingly aware of the quality, nutritional composition and health-promoting components of foods and proper processing of such food is necessary in order to obtain or retain maximum nutritional benefits from such foods (WHO, 2007; Singh *et al.*, 2007); highlighting the importance of proper and adequate food processing.

Nuts have been recognized as a class of food that are rich in important nutrients including proteins and unsaturated fatty acids (Shakuntala and Shadadsharaswamy, 1987; Brufau *et al.*, 2006). Globally, cashew nut kernel (among other nuts) is an

esteemed and highly priced food delicacy valued because of its pleasant taste and flavor (Irtwange and Oshodi, 2009). Also, nuts have been said to constitute a good source of chemical constituents and certain vital bioactive compounds of important health benefits in human beings (Yang, 2009; Nascimento *et al.*, 2010); with scientific investigations showings that the nut kernels have beneficial effects on health, particularly on chronic diseases such as hypertension and obesity, coronary heart disease and diabetes due to their and high content of unsaturated fatty acids (Oliete *et al.*, 2008; Mexis and Kontominas, 2009).

Generally, food processing and preparation methods have been reported to have a direct effect on the quality characteristics (physical, chemical and sensory) of most foods (Singh *et al.*, 2007; Kosoko *et al.*, 2009) and due to the nutritional requirement and necessity of the population, there is need to critically assess both the conventional (conventional oven) and the novel (halogen oven) methods to be employed for the cashew kernel processing (roasting).

**Corresponding Author:** S.B. Kosoko, Department of Food Technology, Federal Institute of Industrial Research, Oshodi, Lagos State, Nigeria

Roasting from time in memorial remains one of the common processing methods for nuts. During the process, the nuts become more crunchy and brittle leading to an overall increase palatability (Ozdemir and Devres, 2000; Saklar *et al.*, 2001; Abayomi *et al.*, 2002).

Halogen oven is one of the multi-purpose novel home cooking equipment that performs roasting of food as one of its major operations. The mode of operation is based on the tremendous and efficient circulation of heat that is generated from the halogen bulb housed under lid by a fan housed on top of the lid, while conventional oven use dry heat and there is no forced air/heat circulation on a constant basis resulting in heat energy transfer which is much slow from product surface to center as heat only migrates by conduction from the outside of the food toward the centre (Giese, 1992).

Therefore, this study is aimed at comparing the effect of halogen-oven roasting and conventional-oven roasting on some qualities (chemical, sensory and microbiological) of the roasted cashew kernels.

## MATERIALS AND METHODS

**Procurement of cashew nut:** Good quality cashew nuts were obtained from produce farmer in Abeokuta, Ogun State, Nigeria, after some preliminary quality test (floatation and cut test) were done to ascertain the wholesomeness of the raw cashew nut.

**Cashew nut processing and roasting:** Cashew nuts were processed using the modified method of Kosoko *et al.* (2009) as highlighted in Fig. 1, while the roasting of the cashew kernel were done using the modified method of Tsimidou and Papavergou (1995) where 2.5 kg of the kernels were roasted for 40 min at a temperature of 200°C using both the conventional-air oven (Memmert, Model DIN 40050-IP 20) and halogen oven (Homotech, Model-HT-A11). The kernels were turned after every 10 min to allow for even and uniform roasting. To ensure adequate control of the roasting conditions, the temperature of the oven was initially raised by about 4°C at each treatment to compensate for

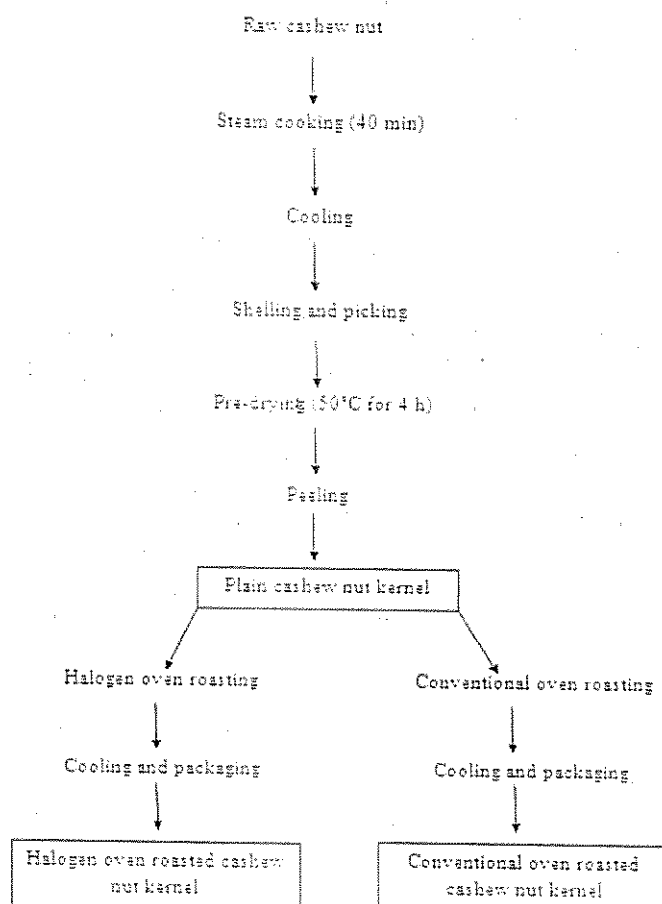


Fig. 1: Flow chart for the production of plain and roasted cashew kernels (Kosoko *et al.*, 2009; Tsimidou and Papavergou, 1995)

temperature drop when the nuts were first placed in the oven.

#### Analyses:

##### Chemical composition:

**Proximate analysis:** Proximate composition (moisture, crude protein, crude fat, ash and total carbohydrates) of the samples were determined using the methods recommended by the A.O.A.C (2000). The nitrogen content was determined by the micro Kjeldahl method which was subsequently converted to protein by multiplying by a factor of 6.25 while the Carbohydrate content was determined by difference. Fatty acid and metabolizable energy (KJ/100 g) was calculated as using the formulation described by Aremu *et al.* (2006) as shown below:

$$\begin{aligned} \text{Calculated fatty acids} &= (0.86 \times \text{crude fat}) \\ \text{Calculated metabolizable energy (KJ/100 g)} \\ &= ((\text{Protein} \times 17) + (\text{Fat} \times 37) + (\text{Carbohydrate} \times 17)) \end{aligned}$$

**Mineral analysis:** The minerals were analyzed by dry ashing the samples at 550°C to constant weight and dissolving the ash in volumetric flask using distilled, de-ionized water with a few drops of concentrated hydrochloric acid. Calcium, magnesium, iron and phosphorous were determined by Atomic Absorption Spectro-photometry (Agte *et al.*, 1995), while sodium and potassium were determined using flame photometry (Chapman and Pralt, 1961) using NaCl and KCl to prepare the standards.

**Microbiological enumeration:** Both plain and roasted cashew kernels samples were subjected to total viable count, yeast and mould count and coliform count tests as described by Harrigan and MacCance (1976); while *Staphylococcus* count was determined using the method of Macfaddin (1990).

**Sensory analysis:** The cashew kernel samples were subjected to sensory evaluation to determine consumer preference among the different samples. Parameters such as color, taste, crispiness, flavor and overall acceptability were determined using a 9-point hedonic scale where (9) represented 'liked extremely' and (1) representing 'disliked extremely' (Larmond, 1980). The

samples were presented in coded identical white saucer plates and the samples were tested individually. The order of presentation of the three samples was completely randomized and water was provided to enable the panelists rinse their mouth after tasting each sample.

**Statistical analysis:** The data were analyzed using SPSS (Statistical Package for Social Scientist) version 15.0. The mean of the analyses were calculated and Analysis of Variance (ANOVA) was performed to determine the level of significant differences (5% significance level) between different mean of cashew kernel samples using Duncan Multiple Range Test. Correlations between chemical composition and sensory attributes of the cashew kernel samples were also evaluated.

## RESULTS AND DISCUSSION

The results of the analyses showed that the different roasting treatments the cashew kernels were subjected to have significant effect on their chemical, mineral, microbial and sensory qualities.

#### Chemical analysis:

**Chemical composition:** Table 1 shows the results of the chemical composition of the plains and two roasted cashew kernels. The ranges of the chemical compositions are moisture content (%) 3.23±0.21 to 6.17±0.12, protein (%) 16.55±0.51 to 23.38±0.94, Fat (%) 38.69±0.69 to 45.62±0.98, crude fibre (%) 2.03±0.05 to 2.39±0.09, ash (%) 2.27±0.06 to 2.53±0.08, Carbohydrate (%) 27.10±1.26 to 30.04±0.95, fatty acid (%) 33.27±0.60 to 39.23±0.85 and Metabolizable energy (KJ/100 g) 2289.63±11.88 to 2480.04±21.00.

Generally, the proximate composition of the cashew nut kernels obtained in this study was comparable to those reported by USDA (2010). However, the results revealed a significant difference ( $p < 0.05$ ) of the effect of different roasting methods (conventional-oven and halogen-oven roasting methods) on the cashew kernel and this might probably explain the variation in some of the results obtained.

Table 1. Chemical composition (%) of plain and roasted cashew kernel samples

Parameter (%)	Plain cashew kernel	Conventional oven roasted cashew kernel	Halogen oven roasted cashew kernel
Moisture content	6.17 <sup>a</sup> ±0.12	4.68 <sup>b</sup> ±0.18	3.23 <sup>c</sup> ±0.21
Protein	23.38 <sup>a</sup> ±0.94	18.39 <sup>b</sup> ±0.94	16.55 <sup>b</sup> ±0.51
Fat	38.69 <sup>a</sup> ±0.69	43.25 <sup>b</sup> ±0.51	45.62 <sup>b</sup> ±0.98
Crude fibre	2.39 <sup>a</sup> ±0.09	2.11 <sup>b</sup> ±0.08	2.03 <sup>b</sup> ±0.05
Ash	2.27 <sup>a</sup> ±0.06	2.47 <sup>a</sup> ±0.05	2.53 <sup>a</sup> ±0.08
Carbohydrate	27.10 <sup>b</sup> ±1.26	29.10 <sup>ab</sup> ±1.18	30.04 <sup>a</sup> ±0.95
Fatty acid	33.27 <sup>a</sup> ±0.60	37.20 <sup>b</sup> ±0.22	39.23 <sup>b</sup> ±0.85
Metabolizable energy (KJ/100 g)	2289.63 <sup>c</sup> ±11.88	2407.58 <sup>b</sup> ±5.08	2480.04 <sup>a</sup> ±21.00

Values are mean of triplicate samples±S.D. values. Mean values having different superscript within the same row are significantly different ( $p < 0.05$ )

The moisture content values of the various cashew kernel samples showed that roasting methods significantly ( $p < 0.05$ ) affected this parameter with cashew kernel roasted with halogen-oven possessing the least moisture content followed by cashew nut roasted with conventional-oven and lastly the plain cashew kernel. Moisture content in the roasted cashew samples was less than in the plain cashew sample. This is obviously due to the drying effect of the roasting method. Drying has been identified as one of the processes occurring during roasting operation (Saklar *et al.*, 1999) and the reduction in moisture content of the roasted cashew kernels samples can be attributed to the effect of heat supplied during the roasting operation which helps in lowering the moisture content of the product. This result is in agreement with the findings of Damame *et al.* (1990), Sanders *et al.* (2002) and Adegoke *et al.* (2004) who separately reported that roasting processes decreased moisture content of peanut. However, halogen-oven roasted cashew kernel had the least moisture content probably due to a better and efficient drying as a result of the efficient and rapid heat circulation rates which allows for efficient, effective and better removal of moisture from the product as against the conventional-oven roasted cashew kernels (Giese, 1992).

The moisture content of the cashew nut kernels were generally below the safe moisture content range of 5.8% as given by both Pixton (1982) and Henderson (1985) as acceptable for safe storage of nuts. These results indicated that halogen-oven roasted kernels would be better preserved.

There was a reduction in the protein content of both the roasted cashew kernels when compared to the plain cashew kernel with halogen-oven roasted kernel having a lesser protein content than conventional-oven roasted kernel. This finding supports the report of Famurewa and Raji (2011). The decrease in protein content may be as a result of high roasting temperature ( $>100^{\circ}\text{C}$ ) which may lead to the destruction/denaturation of proteins and some amino acids inherent in the cashew kernel as a result of heat (Mauron, 1982). This view was also supported by Ihekoronye and Ngoddy (1985) as they suggested the possibility of the destruction of the protein due to application of high temperature. This is however contrary to the findings of Damame *et al.* (1990), Jui-Yueh *et al.* (2002) and Adegoke *et al.* (2004) who reported that roasting of peanuts generally increases the protein content.

Fat is an important constituent of diets as it promotes the absorption of fat soluble vitamin as well as contributes to overall energy value of foods (Shittu and Lawal, 2007), without adding to the bulk of the diet. They also play a structural role in providing fatty acids and cholesterol for the formation of cell membranes in all organs and much of fat necessary for the formation of these tissues are essential fatty acids,

which cannot be synthesized by the body and must be supplied by the diet (Bogert *et al.*, 1994; Adjou *et al.*, 2012). There was a significant ( $p < 0.05$ ) increase in the fat content of the two roasted cashew kernels when compared with the plain cashew kernel with the halogen-oven roasted cashew kernel having the highest value. This increase in fat content in roasted cashew kernel may be due to the fact that at high temperature there is disruption of cell structures and membranes partitions of the kernel leading to the release of more free fat molecules causing the fat to be easily extracted from the kernel. This result is in agreement with those documented by Damame *et al.* (1990), Abayomi *et al.* (2002), Jui-Yueh *et al.* (2002) and Adegoke *et al.* (2004) who reported that there was an increase in crude oil of peanut after heat treatments.

The crude fibre is the percentage/quantity of indigestible sugar present in any food sample and it helps in maintenance of internal distension for a normal peristaltic movement of the intestinal tract (Edem *et al.*, 1984). The quantity of crude fibre present in the samples varied significantly ( $p < 0.05$ ). It is highest in the plain cashew kernel with halogen-oven roasted cashew kernel having the least value. The result of this finding is in agreement with the outcome of a similar study reported by Ayoola and Adeyeye (2010).

The result revealed that there was a significant increase in the ash content of the roasted cashew kernels as against the plain cashew kernel; though, halogen-oven roasted cashew kernel had the higher value. There were no significant difference between its value and that of conventional-oven roasted cashew kernels. This increase in the ash content of the roasted cashew kernels might not be unconnected with the reduced moisture content of roasted cashew kernels. The report of Abayomi *et al.* (2002) also agrees with the findings of this study and he reported that the ash content of raw peanut increased as a result of roasting process.

The carbohydrate values obtained for the cashew kernels revealed a significant difference between the two roasted kernels and the plain cashew kernel with halogen-oven having the highest value.

The fatty acid contents of the cashew kernel samples as expected follows the same trend as the crude fat content since it is derived from crude fat.

The energy values showed an increase in the energy value of both roasted cashew kernel samples with halogen-oven roasted cashew kernel having the highest value. These values also highlight the importance of nuts in supplying the energy requirement of human beings.

**Mineral composition:** The result of the mineral content (Table 2) of the cashew kernel samples revealed a significant difference in some of the mineral

Table 2 Mineral content (mg/100 g) of plain and roasted cashew kernel samples

Mineral element	Plain cashew kernel	Conventional oven roasted cashew kernel	Halogen oven roasted cashew kernel
Calcium (Ca) (mg)	30.19 <sup>a</sup> ±0.95	34.44 <sup>a</sup> ±0.49	36.21 <sup>a</sup> ±0.82
Magnesium (Mg) (mg)	116.81 <sup>a</sup> ±0.47	118.09 <sup>a</sup> ±0.82	117.04 <sup>a</sup> ±0.71
Potassium (K) (mg)	355.91 <sup>a</sup> ±0.84	360.49 <sup>b</sup> ±0.70	367.18 <sup>a</sup> ±0.45
Phosphorus (P) (mg)	317.15 <sup>a</sup> ±0.96	319.12 <sup>a</sup> ±0.65	318.15 <sup>a</sup> ±0.80
Iron (Fe) (mg)	5.83 <sup>a</sup> ±0.42	5.78 <sup>a</sup> ±0.54	5.92 <sup>a</sup> ±0.55
Sodium (Na) (mg)	14.39 <sup>a</sup> ±0.56	10.06 <sup>b</sup> ±0.88	8.75 <sup>a</sup> ±0.55
Ca/P	0.085	0.108	0.114
Na/K	0.040	0.028	0.024

Values are mean of triplicate samples ±S.D. values; Mean values having different superscript within the same row are significantly different ( $p < 0.05$ )

analyzed. Calcium (mg/100 g) content ranged from 30.19±0.95 to 36.21±0.82, potassium content (mg/100 g) content ranged from 355.91±0.84 to 367.18±0.45, sodium (mg/100 g) content ranged from 8.75±0.55 to 14.39±0.56 while magnesium, phosphorous and iron do not show any significant difference.

Minerals have been identified to play an important role in human nutrition. Both enzymatic activities and electrolyte balance of the blood fluid are related to adequacy of some minerals (Na, K and Mg) (Adjou *et al.*, 2012). The mineral content of the nut is also significantly ( $p < 0.05$ ) affected by roasting methods. The calcium content of the plain cashew kernel is close to what is reported by Aremu *et al.* (2006). The calcium content of the kernel increases with roasting methods with halogen-oven roasted cashew kernel having a higher value though not significant from that of conventional oven method. This result is in line with the findings of Momoh *et al.* (2012) (Beniseed), Adegunwa *et al.* (2012) (Beniseed) and Ayoola and Adeyeye (2010) (peanut) who separately reported the increases of calcium due to roasting. However, Audu and Aremu (2011) reported a decrease in calcium content of roasted red kidney bean.

Physiologically, magnesium helps in maintenance of the electrical potential in nerves and activation of some enzyme systems (Ferro *et al.*, 1987; Shills and Young, 1992). The result of the magnesium content revealed that roasting methods do not have any significant difference in the magnesium content of the cashew kernel samples. Though, conventional-oven roasted cashew nut kernel had the highest value it does not differ significantly ( $p > 0.05$ ) with that of plain and halogen-oven roasted cashew kernel samples. This result is in line with the findings of Adjou *et al.* (2012) but contrary to the report of Ayoola and Adeyeye (2010) and Audu and Aremu (2011) who reported an increase and decrease respectively in magnesium content of product with roasting.

It can be observed from the result that Potassium (K) content of cashew kernel sample increased significantly for both halogen-oven and conventional-oven roasting methods with halogen-oven roasted cashew kernel having a highest value. A similar observation was reported by Ayoola and Adeyeye (2010) and Adegunwa *et al.* (2012) on peanut and

beniseed respectively on the increase in potassium content with roasting.

Both phosphorus and iron contents of the cashew kernel samples were not significantly ( $p > 0.05$ ) affected by the two roasting methods.

The sodium content of the cashew kernel sample showed a significant difference ( $p < 0.05$ ) with roasting as the sodium content decreases with roasting. However, both conventional-oven roasted cashew kernel and halogen-oven roasted cashew kernel do not reveal any significant difference from one another. This trend is in line with the work of both Ayoola and Adeyeye (2010) and Audu and Aremu (2011) who reported a decrease of sodium content with roasting of peanut and andred kidney bean, respectively.

Majorly, calcium and phosphorous in conjunction with other minerals (magnesium, manganese and vitamins (A, C and D)) are responsible for bone formation (Ogunlade *et al.*, 2005; Akinhanmi *et al.*, 2008). However, modern foods rich in animal protein and phosphorus can promote the loss of calcium in urine (Shills and Young, 1992). This lead to the concept of calcium to phosphorous (Ca/P) ratio and its inherent health implication, where low Ca/P ratio means low calcium in relation to high phosphorus intake, this leads to calcium loss in the urine more than normal. Generally and if the (Ca/P) ratio of any food is above (1) that food is considered "good" and "poor" if the ratio is less than 0.5 (Audu and Aremu, 2011). The result from the study showed that the (Ca/P) ratio is poor and this could be supplied and supplemented with other food sources that are rich in calcium.

Sodium and potassium are required for the maintenance of osmotic balance of body fluids, the pH of the body to regulate muscles and nerves irritability, control glucose absorption and enhance normal retention of protein during growth (NRC, 1989). The sodium to potassium ratio in the body is of great concern for the prevention of high blood pressure. The Na/K ratio of less than one is recommended (Audu and Aremu, 2011). The Na/K ratios for the raw and processed seeds were all above the recommended level. Only the roasted sample has the Na/K ratio less than one. This suggests that all the samples may not have capacity to prevent blood pressure.

Likewise, the ratio of sodium to potassium (Na/k) in the body is of great importance in the prevention of

Table 3 Microbial analysis of plain and roasted cashew kernel samples

Microbial enumeration	Plain cashew kernel	Conventional oven roasted cashew kernel	Halogen oven roasted cashew kernel
Total viable count	$6.2 \times 10^2$	$4.2 \times 10^2$	$4.1 \times 10^2$
Yeast and mould count	$8.2 \times 10^1$	$7.2 \times 10^2$	$6.8 \times 10^2$
Coliform count	$2.7 \times 10^2$	$8.4 \times 10$	$7.8 \times 10$
<i>E. coli</i> count	0	0	0
Staphylococcus count	$2.5 \times 10^2$	$1.2 \times 10^2$	$1.4 \times 10^2$

high blood pressure. Na/k ratio of less than (1) is recommended (Nieman *et al.*, 1992). In this study, the Na/k ratio in this study is less than one, an indication that consumption of the roasted nut would probably be beneficial to health.

Generally, the observed increase in some of the mineral composition of the roasted cashew kernels might be due to the fact that roasting may lead to increase in some mineral in foods. Some volatile compounds would be lost through heating process thereby increasing the concentration of the minerals (Derise *et al.*, 1974; Obiajuwa *et al.*, 2005; Umoren *et al.*, 2007). However, the mineral content value obtained in this study is less than reported by Olife *et al.* (2013) as the USDA standard but higher than those reported by Aremu *et al.* (2006). This difference might be due to the varietal differences as well as soil and other environmental variables.

**Microbiological enumeration:** The microbiological enumeration of the plain and roasted cashew nut kernels as presented in Table 3 revealed that the kernels are within the safe microbial standard and limits.

Nuts and nut products in general are highly susceptible to microbial contamination primarily due to their high nutritional content as well as their pH which is conducive for microbial growth and activities and (Fraizer and Westhoff, 1978). This coupled with the high ambient temperature and relative humidity in the absence of proper processing might lead to problem of microbial growth in processing nut and nut products (Ogundero, 1987).

Generally, the total viable count indicates the microbiological quality of any food product and the presence of a high number of total viable counts is an indicator for low expected shelf life of the product (Moore *et al.*, 2001; Abdel-Moneim *et al.*, 2012). The result of the total viable count of the cashew kernel samples are within the microbial limits/standard of  $10^4$  to less than  $10^6$  cfu/g of ready-to-eat food products given by Fyde Borough Council as extracted from manual of PHLSG (2008). Though, plain cashew kernel showed a higher value, which may be connected with the effect of roasting which the other two samples were subjected to result in a reduction in their microbial load.

It was observed that yeast and mould count of all the samples were less than the maximum standard of  $10^7$ /g set by ICMSF (1986) as acceptable for packaged nuts fit for human consumption. This shows that the nuts are safe and thus present no any health hazard.

though; the higher moisture content of the plain cashew kernel when compared to the other roasted kernel could present a problem as it would encourage and promote microbial growth and deterioration if the product is not stored properly (Sultan and Magan, 2010).

The presence of large numbers of *Coliform* bacteria in foods is suggestive of unhealthy sanitary conditions or practices during food production stages (Thomas *et al.*, 1971). However, the values obtained in this study were less than  $10^3$  set by CODEX (1991). *E. coli* is an important member of the *Coliform* group forming part of the normal flora of the intestine of human and vertebrates. The presences of *E. coli* in foods samples may be considered as an indicator microorganism of faecal contamination and other enteric pathogens. Some strains of *E. coli* have been implicated in cases of gastroenteritis, diarrhea and urinary tract infections (Pelczar *et al.*, 1993). The absence of *E. coli* in the cashew kernel samples showed that the samples are safe for human consumption (PHLS, 2000).

*Staphylococcus aureus* is a normal flora of the body and mucous membrane and a common aetiological agent of septic arthritis (Alice, 1976; Ellen and Sydney, 1990). The organisms can pass onto the food during harvesting, processing or even storage. The presence of *Staphylococcus aureus* in the samples, but well below maximum limits of  $>10^4$  cfu/mL (Han *et al.*, 2005) may be attributed to handling operation during production. This result indicates that cashew kernel samples were produced under good manufacturing practices.

Generally, the low microbial level in both the roasted samples as compared with the plain cashew kernel sample may be as a result of low moisture content of the food samples as well as the probable destruction of the microorganisms during the roasting of the cashew kernel samples irrespective of the roasting methods (oven) used.

**Sensory analysis:** The sensory result (Fig. 2) showed that there were significant differences in the sensory rating of the cashew kernel samples. It showed that halogen-oven roasted cashew kernel received the highest sensory rating in terms of overall acceptability and differs significantly ( $p < 0.05$ ) from the other two samples. This rating might not be unconnected with the fact that the panelist also significantly rated the sample highest in terms of color and crispiness. This perception is also supported by previous workers (Ozdemir and Devres, 2000; Saklar *et al.*, 2001;

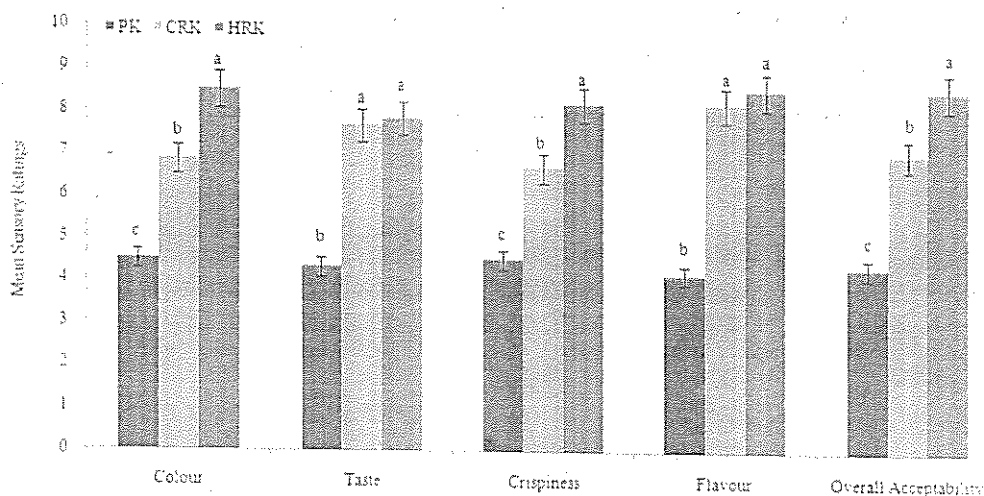


Fig. 2: Mean sensory scores of plain and roasted cashew kernel samples

Columns having different letter for a given sensory attribute are significantly different ( $p < 0.05$ ); PK: Plain cashew nut kernel; CRK: Conventional-air oven roasted cashew nut kernel; HRK: Halogen oven roasted cashew nut kernel

Table 4: Pearson's correlation matrix between chemical parameters and sensory attributes of cashew kernel samples

Parameter/attributes	MC	PRO	Fat	CF	Ash	C	FA	ME	Col	Tas	Cri	Fla	Ova
Moisture (MC)	1												
Protein (PRO)	0.926**	1											
Fat	-0.961**	-0.988**	1										
Crude Fibre (CF)	0.874*	0.852*	-0.844*	1									
Ash	-0.782	-0.703	0.704	-0.816*	1								
Carbohydrate (C)	-0.682	-0.516	0.548	-0.688	0.958**	1							
Fatty Acid (FA)	-0.978**	-0.984**	0.997**	-0.876*	0.745	0.597	1						
Metabolizable Energy (ME)	-0.946**	-0.901*	0.907*	-0.881*	0.923**	0.822*	0.932**	1					
Color (Col)	-0.965**	-0.933**	0.940**	-0.866*	0.877*	0.757	0.959**	0.993**	1				
Taste (Tas)	-0.848*	-0.927**	0.910*	-0.829*	0.841*	0.692	0.909*	0.915*	0.912*	1			
Crispiness (Cri)	-0.976**	-0.941**	0.961**	-0.840*	0.846*	0.736	0.972**	0.979**	0.991**	0.919**	1		
Flavor (Fla)	-0.877*	-0.896*	0.888*	-0.907*	0.913*	0.794	0.904*	0.946**	0.927**	0.977**	0.924**	1	
Overall acceptability (Ova)	-0.956**	-0.942**	0.947**	-0.861*	0.880*	0.757	0.962**	0.991**	0.997**	0.939**	0.993**	0.946**	1

\*\* Correlation is significant at the 0.01 level (2-tailed); \* Correlation is significant at the 0.05 level (2-tailed)

Abayomi *et al.*, 2002) who reported that roasting generally have a way of increasing the overall palatability of the products while altering and significantly enhancing its sensory attributes.

**Correlation analysis:** The correlation analysis (Table 4) on the chemical and sensory analysis of the cashew kernel samples was carried out to highlight the relationship between the chemical composition and sensory scores of the cashew kernel samples. In this study, correlation analyses of the chemical composition parameters and the sensory qualities revealed generally significant linear correlation between both chemical composition parameters and sensory qualities.

The chemical parameter of fat and fatty acid, had a positive correlation ( $p < 0.05$ ) with sensory attributes of taste and flavor while also showing a strong positive correlation ( $p < 0.01$ ) with sensory attributes of color, crispiness and overall acceptability. The chemical parameter of ash had a positive correlation ( $p < 0.05$ ) with all the sensory parameters. Metabolizable energy

also shows a positive correlation ( $p < 0.05$ ) for sensory attribute of taste only with it showing a strong positive correlation ( $p < 0.01$ ) for all the other sensory attributes.

Moisture had a negative correlation ( $p < 0.05$ ) for sensory attributes of taste and flavor while it showed a strong negative correlation ( $p < 0.01$ ) for all the other sensory attributes. Protein had a negative correlation ( $p < 0.05$ ) for only flavor with it showing a strong negative correlation ( $p < 0.01$ ) for all the other sensory attributes. Likewise, crude fibre had a negative correlation ( $p < 0.05$ ) for all the sensory attributes.

This correlation analysis indicated that some chemical composition parameters can be used as a tool in evaluating the sensory quality of the cashew nut kernel sample.

## CONCLUSION

This study however reveals that there is a significant difference in the chemical and sensory characteristics of the cashew nuts roasted using the

halogen oven, suggesting that the halogen oven is better equipment for roasting the nuts. The halogen oven also provides an environment that helps reduce the microbial contamination during roasting. In general, the study, helps to ascertain that that roasting using halogen oven or under controlled temperature and time is most suitable for cashew nut roasting.

#### ACKNOWLEDGMENT

The authors wish to express their gratitude to the Director-General and the entire management staff of Federal Institute of Industrial Research Oshodi, Lagos for funding this project. Also, Dr. (Mrs) O. Oladunmoye is highly appreciated for allowing the use of halogen oven for the research work.

#### REFERENCES

- Abayomi, P., A. Isaac and O. Ayodele, 2002. Effects of processing conditions and packaging materials on the quality attributes of dry-roasted peanuts. *J. Food Sci. Agric.*, 82: 1465-1471.
- Abdel-Moneim, E.S., A.A. Itimad and M.A. Awad, 2012. Comparative study on five Sudanese date (*Phoenix dactylifera* L.) fruit cultivars. *Food Nutr. Sci.*, 3(9): 1245-1251.
- Adegoke, G.O., K.O. Falade and O.C. Babalola, 2004. Control of lipid oxidation and fungal spoilage of roasted peanut (*Arachis hypogaea*) using the spice *Aframomum danielli*. *Food Agr. Environ.*, 2(1): 128-131.
- Adegunwa, M.O., A.A. Adebawale and E.O. Solano, 2012. Effect of thermal processing on the biochemical composition, anti-nutritional factors and functional properties of beni-seed (*Sesamum indicum*) flour. *Am. J. Biochem. Mol. Biol.*, 2(3): 175-182.
- Adjou, E.S., E. Dahouenon-Ahoussi and M.M. Soumanou, 2012. Investigations on the mycoflora and processing effects on the nutritional quality of peanut (*Arachis Hypogaea* L. Var. Ts 32-1). *J. Microbiol. Biotechn. Food Sci.*, 2(3): 1025-1039.
- Agte, V.V., M.K. Gokhale, K.M. Paknikar and S. Cheplonkar, 1995. Assessment of pearl millet versus rice-based diets for bio availability of four trace metals. *Plant Food Hum. Nutr.*, 48: 149-158.
- Akinhanmi, T.F., P.O. Akintokun and N.V. Atasi, 2008. Chemical composition and physicochemical properties of cashew nut (*Anacardium occidentale*) oil and cashew nut shell liquid. *J. Agric. Food Environ. Sci.*, 2(1): 1-10.
- Alice, L.S., 1976. *Microbiology and Pathology*, 11th Edn., CV Mosby Co., pp: 202-203.
- A.O.A.C., 2000. Association of Official Analytical Chemists. 17th Edn., Official Methods of Analysis. Washington, D.C. U.S.A.
- Aremu, M.O., A. Olonisakin, D.A. Bako and P.C. Madu, 2006. Compositional studies and physicochemical characteristics of cashew nut (*Anacardium occidentale*) flour. *Pak. J. Nutr.*, 5(4): 328-333.
- Audu, S.S. and M.O. Aremu, 2011. Effect of processing on chemical composition of red kidney bean (*Phaseolus vulgaris* L.) flour. *Pak. J. Nutr.*, 10(11): 1069-1075.
- Ayoola, P.B. and A. Adeyeye, 2010. Effect of heating on the chemical composition and physico-chemical properties of *Arachis hypogaea* (Groundnut) seed flour and oil. *Pak. J. Nutr.*, 9(8): 751-754.
- Bogert, J.L., G.M. Briggs and D.H. Galloway, 1994. Nutrition and physical fitness. *Int. J. Food Sci. Nutr.*, 45: 223-230.
- Brufau, G., J. Boatella and M. Rafecas, 2006. Nuts: Source of energy and macronutrients. *Brit. J. Nutr.*, 96: 524-528.
- Chapman, D.H. and P.F. Pratt, 1961. *Methods of analysis of soils, plants and waters*. University of California, Division of Agricultural Science, Riverside, CA.
- CODEX, 1991. Codex alimentarius: Guidelines on formulated supplementary foods for older infants and young children. CODEX CAC/GL 08. 1991.
- Damame, S.V., J.K. Chavan and S.S. Kadam, 1990. Effects of roasting and storage on proteins and oil in peanut kernels. *Plant Food Hum. Nutr.*, 40(2): 143-148.
- Derise, N.L., H.A. Lau and S.J. Ritchie, 1974. Proximate composition and mineral element content of three cultivars of raw and roasted peanut. *J. Food Sci.*, 39: 255-264.
- Edem, D.O., O.U. Eka and E.T. Ifon, 1984. Chemical evaluation of the value of fruit of African Star apple (*Chrysophyllum albidum*). *Food Chem.*, 14: 303-311.
- Ellen, J.B. and M.F. Sydney, 1990. *Bailey and Scott's Diagnostic Microbiology*. 8th Edn., Mosby, St. Louis, pp: 293-294.
- Famurewa, J.A.V. and A.O. Raji, 2011. Effect of drying methods on the physico-chemical properties of soyflour. *Afr. J. Biotechnol.*, 10(25): 5015-5019.
- Ferro, S.E.M., A.M.B.C. Ferro and A.M.G. Antunes, 1987. Bambara groundnut (*Vigna subterranean*) aspect of its nutritional value. *Agronomic*, 14: 35-39.
- Fraizer, W.C. and D.C. Westhoff, 1978. *Food Microbiology*. 3rd Edn., Tata McGraw-Hill Publishing Co., New Delhi.
- Giese, J., 1992. Advances in microwave food processing. *Food Technol.*, 9: 118.
- Han, B.Z., B. Sesenna, R.R. Beumer and M.J.R. Nout, 2005. Behavior of *Staphylococcus aureus* during sufu production at laboratory scale. *Food Control*, 16: 243-247.

- Harrigan, W.F. and M.E. MacCance, 1976. Laboratory Methods in Food and Dairy Microbiology. Academic Press, London.
- Henderson, S., 1985. The relationship between moisture content and equilibrium relative humidity of pig feed. J. Stored Prod. Res., 21: 131-134.
- ICMSF, 1986. Microorganisms in Foods 2: Sampling for Microbiological Analysis: Principles and Specific Applications. 2nd Edn., The International Commission on Microbiological Specifications for Foods. University of Toronto Press, Toronto.
- Ihekoronye, A.I. and P.O. Ngoddy, 1985. Integrated Food Science and Technology for the Tropics. MacMillan Educ. Ltd., London and Oxford, pp: 47-127.
- Irtwange, S.V. and A.O. Oshodi, 2009. Shelf-life of roasted cashew nuts as affected by relative humidity, thickness of polythene packaging material and duration of storage. Res. J. Appl. Sci. Eng. Technol., 1(3): 149-153.
- Jui-Yueh, Y., P.R. Dixon, V.A. Anna and H. Yen-Con, 2002. Physicochemical and sensory characteristic changes in fortified peanut spreads after 3 months of storage at different temperatures. J. Agr. Food Chem., 50: 2377-2384.
- Kosoko, S.B., L.O. Sanni, A.A. Adebawale, A.O. Daramola and M.O. Oyelakin, 2009. Effect of period of steaming and drying temperature on chemical properties of cashew nut. Afr. J. Food Sci., 3(6): 156-164.
- Larmond, E., 1980. Laboratory Methods of Sensory Evaluation of Food. Dept. Agric. Publications, Research Branch, Canada.
- Macfaddin, J.T., 1990. Biochemical Test for the Identification of Medical Bacteria. William and William Co., Baltimore, USA.
- Mauron, J., 1982. Effect of Processing on the Nutritive Value of Food Protein. In: Rechagal, M. (Ed.), Handbook of Nutritive Value of Processed Foods. CRC Press, Boca Raton, Florida, 1: 429-471.
- Mexis, S.F. and M.G. Kontominas, 2009. Effect of g-irradiation on the physicochemical and sensory properties of cashew nuts (*Anacardium occidentale* L.). Lebensm. Wiss. Technol., 42: 1501-1507.
- Momoh, A.O., T.T. Adebolu and A.O. Ogundare, 2012. The effects of different treatments on the phytochemicals, proximate, and mineral contents of beniseeds (*Sesamum indicum* linn). Global Adv. Res. J. Biotechnol., 6(1): 8-11.
- Moore, G., C. Grith and L. Fielding, 2001. A comparison of traditional and recently developed methods for monitoring surface hygiene within the food industry: A laboratory study. Dairy, Food Environ. Sanitation, 21(6): 478-488.
- Nascimento, A.N., J. Naozuka and P.V. Oliveira, 2010. In vitro evaluation of Cu and Fe bioavailability in cashew nuts by off-line coupled SEC-UV and SIMAAS. Micro-Chem. J., 96: 58-63.
- Nieman, D.C., D.E. Butter-Worth and C.N. Nieman, 1992. Nutrition. Wm. C. Brown Publisher, Dubuque, 9: 540.
- NRC, 1989. National Research Council (NRC). Recommended Dietary Allowances. 10th Edn., National Academic Press, Washington, DC, pp: 24.
- Obiajuwa, E.I., F.M. Adebisi and P.E. Omode, 2005. Determination of essential minerals and trace elements in Nigerian sesame seeds, using TXRF technique. Pak. J. Nutr., 4: 393-395.
- Ogundero, W.W., 1987. Temperature and aflatoxin production by *Aspergillus flavus* and *A. parasiticus* strains from Nigerian groundnuts. J. Basic Microb., 27: 511-514.
- Ogunlade, I., O. Olafe and I. Fadare, 2005. Chemical composition, amino acids and nutritional properties of selected seafoods. J. Food Agric. Environ., 3: 130-133.
- Oliete, B., M. Gómez, V. Pando, E. Fernández-Fernández, P.A. Caballero and F. Ronda, 2008. Effect of nut paste enrichment on physical characteristics and consumer acceptability of bread. Food Sci. Technol. Int., 14: 259-269.
- Olife, L.C., M.A. Jolaoso and A.P. Onwuolu, 2013. Cashew processing for economic development in Nigeria. Agric. J., 8(1): 45-50.
- Oniang'o, R. K., J. M. Mutuku and S.J. Malaba, 2003. Contemporary African food habits and their nutritional and health implications. Asia Pac. J. Clin. Nutr., 12(3): 231-236.
- Ozdemir, M. and O. Devres, 2000. Kinetics of color changes of hazelnuts during roasting. J. Food Eng., 44: 31-38.
- Pelczar, M.J., C.S. Chane and R.K. Noel, 1993. Microbiology. 5th Edn., McGraw-Hill Publishing Co., New Delhi, pp: 272.
- PHLS, 2000. Guidelines for the microbiological quality of some ready-to-eat foods sampled at the point of sale. PHLS Advisory Committee for Food and Dairy products. Comm. Dis. Pub. Health., 3: 163-167.
- PHLSG, 2008. The Microbiological Quality of Ready-to-eat Foods Sampled at the Point of Sale. (Public Health Laboratory Service Guidelines). Brough Council, United Kingdom.
- Pixton, S.W., 1982. The importance of moisture and equilibrium relative humidity in stored product. Trop. Stored Prod. Int., 43: 16-29.
- Saklar, S., S. Ugan and S. Katnas, 1999. Instrumental crispness and crunchiness of roasted hazelnuts and correlations with sensory assessment. J. Food Sci., 64: 1015-1019.
- Saklar, S., S. Katnas and S. Ugan, 2001. Determination of optimum hazelnut roasting condition. Int. J. Food Sci. Tech., 36: 271-281.
- Sanders, T.H., K. Hendrix, T.D. Raush and T.A. Katz, 2002. Effect of microwave energy on blanchability, shelf life and roast quality of peanuts. Am. Peanuts Res. Educ. Soc. Pro., 34: 112.

- Shakuntala, M.N. and M. Shadadsharaswamy, 1987. Food, Facts and Principles. Wiley Eastern Ltd., New Delhi.
- Shills, M.Y.G. and V.R. Young, 1992. Modern Nutrition in Health and Disease. In: Nieman, D.C., D.E. Butterworth and C.N. Nieman (Ed.), Nutrition. Wm. C. Brown Publishers, Dubuque, U.S.A., pp: 276-282.
- Shittu, T.A. and M.O. Lawal, 2007. Factors affecting instant properties of powdered cocoa beverages. *Food Chem.*, 100: 91-98.
- Singh, S., S. Gamlath and L. Wakeling, 2007. Nutritional aspects of food extrusion: A review. *Int. J. Food Sci. Tech.*, 42: 916-929.
- Sultan, Y. and N. Magan, 2010. Mycotoxigenic fungi in peanuts from different geographic regions of Egypt. *Mycotoxin Res.*, 6: 133-140.
- Thomas, S.B., R.G. Druce and M. Jones, 1971. Influence of production conditions on the bacteriological quality of refrigerating farm bulk tank milk: A review. *J. Appl. Bacteriol.*, 34: 659-677.
- Tsimidou, M. and B.D. Papavergou, 1995. Evaluation of oregano antioxidant activity in mackerel oil. *Food Res. Int.*, 28(4): 431-433.
- Umoren, U.E., O.O. Effiong and I.A. Akpan, 2007. Nutritional evaluation of the horse eye bean (*Mucuna urens*): Effect of processing on the chemical composition. *J. Food Agric. Environ.*, 3: 128-131.
- USDA, 2010. USDA National Nutrient Database for Standard Reference. Retrieved from: <http://www.nal.usda.gov/fnic/foodcomp/search/> (Accessed on: March 12, 2013).
- WHO, 2007. Protein and amino acid requirements in human nutrition: Report of a joint FAO/WHO/UNU expert consultation. WHO Technical Report Series No. 935.
- Yang, J., 2009. Brazil nuts and associated health benefits: A review. *Lebensm. Wiss. Technol.*, 42: 1573-1580.