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Nutritional profile, protein quality, and biological value of raw and roasted cashew kernels (*Anacardium occidentale)* grown in southwest Nigeria

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ABSTRACT

Cashew kernels are one of the most concentrated food products due to their fat and protein content and they are used in puddings and bakery products, hence the determination of their protein quality is an important nutritional factor in dietary protein requirements. Therefore, the study aimed at evaluating the effect of roasting conditions on the protein quality of cashew kernels at the temperature of 100–160 °C and time (20–60 min), and then analysing for the amino acid profile by GC-FID; protein predicted efficiency ratio (P-PER), essential amino acid index (EAAI), and the Isoelectric point (pI). About 2.0 kg of dried cashew kernels used were defatted using chloroform/methanol (2:1/v/v) as the extraction solvent and then analysed using standard methods. The results showed that seventeen amino acids were present in cashew nuts, where glutamic acid (15.27g/100gN); aspartic acid (12.20g/100gN); lysine (6.09g/100g N), and phenylalanine (5.06g/100g N) were predominant. Eight essential amino acids were present in cashew kernels, the highest value of 7.33g/100g were for lysine (6.09g/100gN); 1.70g/100gN (histidine); 3.42g/100gN (threonine); 3.63g/100gN (valine); 3.57 g/100gN (isoleucine); 7.33g/100gN (leucine); and 5.06g/100gN (phenylalanine). Roasting reduced the lysine content by 18.4%, phenylalanine by 12.06%, and aspartic acid by 41.4% at 160°C for 60 min, while serine (58.9%); glutamic acid (19.7%); arginine (47.4%), and histidine (115.9%) were increased, suggesting that cashew nuts contain high quality protein. P-PER results were 2.57 (raw), 171-2.61 (roasted); EAAI is 1.55(raw) and 1.38-1.55 (roasted), BV% is 76.15 (raw) and 67.61-76.89 (roasted); the Isoelectric points were 4.65 (raw) and 3.87- 4.54 (roasted), The Leu/Ileu ratio was 2.12 (raw) and 2.01-2.67 (roasted). It was concluded that the heat treatment used does not significantly affect the amino acid profile of cashew kernels, thus preserving their nutritional quality.

Introduction

Nutrients are the building blocks of the human body, they usually come from food and are divided into macronutrients (proteins, fats, carbohydrates) and micronutrients (vitamins and minerals). They are absorbed into a body cell where they regulate the body function by providing the body cell with needed energy. Nutrients may be destroyed or lost when foods are processed because of their sensitivity to heat, light, oxygen, pH of the solvent, or a combination of these (Malomo and Alamu, 2016). Nutrient losses may also occur between harvesting and distribution, during household and industrial handling, as well as in catering and during storage (Somogyi, 1990). The purpose of heat-treating certain foods is to promote flavour changes that ultimately increase the overall palatability of the product. Many products are treated in this

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manner, such as peanuts, hazelnuts, almonds and other nuts, including coffee, cocoa, and other like products. During heat treatment, volatile compounds common to all these products affect their aroma and characteristic taste. Knowledge of the effect of roasting on the sensory attributes would therefore not only be desirable, but necessary to maintain the quality control and overall flavour acceptability; or where duplication and/or modification of a particular flavour is desired.

Roasting is the most important step in cashew nut processing. The improvement of the roasting process will contribute to the improvement of processed cashew nut products. The use of inappropriate temperature and time combination leads to quality defects such as short shelf life, discoloration, rancidity, and poor flavour. Roasting alters and substantially improves the flavour, texture, colour, and appearance, and is one of the most common forms of processing for cashew nuts. These nuts contain large amounts of lipids which may undergo a number of degradative changes during heat processing and may have important effects on their palatability and wholesomeness. Heated lipids are unavoidably exposed to adverse conditions during heat processing, which may produce certain undesirable changes. Roasting significantly increases the overall palatability of nuts by enhancing their flavour, colour, texture, and appearance characteristics. These changes are mainly related to drying and non-enzymatic browning during roasting (Buckholz et al., 1980; Mayer, 1985; Moss and Otten, 1989; Perren and Escher, 1996ab). Therefore, the determination of roasting conditions (temperature-time combinations) more precisely and adhering to optimum conditions for roasting would ensure the production of good quality cashew nuts. Currently, integrated studies are lacking on the elucidation of the effects of the roasting degree of cashew nuts under different time-temperature conditions on the chemical properties of cashew nuts. Temperature and time of roasting are two of the main factors that affect the industrial roasting processes; they affect drying, heat transfer rate, and physicochemical changes in protein, the amino acid profile, and the protein quality, which have not been documented. Since roasting affects product quality, control of the roasting process is significant because the producers of cashews consider that determining optimum conditions for roasting cashew is a major problem. Yet this information is necessary for the improvement and the design of the roasting process for maximizing nutrient retention.

The three main cashew products traded in the international market are: raw cashew nuts, cashew kernels, and cashew nut shell liquid (Azam-Alli and Judge, 2001). Cashew nuts are widely consumed as roasted, fried, salted, or sugared snacks, as material for confectionery and bakery products, and as a food ingredient (Azam-Alli and Judge, 2001), especially because they contain vital minerals which are seldom found in daily diets (Holland et al., 1991; CEPC, 1992; Davis, 1999). Processing raw cashew nuts into kernels involves the heat treatment of the nuts, shelling, peeling, grading, and packaging; however, shelling has presented the greatest processing problem. This is due to the peculiar kidney-shape configuration of the nut, the presence of a tough, leathery outer shell and the corrosive cashew nut shell liquid it contains (Ohler, 1979; Jain and Sivala, 1997). Though several studies have been done on cashew nut shelling and a number of appropriate technologies have been developed (Ajav, 1996; Thivavarvongs et al., 1995a), the quality of yield in terms of percentage of whole kernels still remains a major challenge. Changes in free amino and total amino acid composition during roasting of several nuts have been studied, there is limited research about the changes in amino acid composition of cashew nuts during roasting. The results from the study can be used to provide valuable information on food and protein quality for analysis, which may contribute to nutrition and health research, and health programs in Nigeria. The determination of the amino acid content of several Nigerian foods has been documented over the years, but little information has been published on the subject matter, hence the need to evaluate the amino acid profile of nuts consumed in Nigeria. The objective of this study was to evaluate the influence of the roasting temperature and the time combination on the amino acid profile and protein quality of cashew nuts grown in Nigeria, in order to incorporate the data into the food composition table used in Nigeria.

Materials and methods

Materials

Freshly harvested and sun dried "Brazilian Jumbo" cashew nuts (*Anacardium occidentale L.*) were purchased at maturity from the plantation of the Cocoa Research Institute of Nigeria (CRIN), Ibadan, Nigeria. Dried raw cashew nuts were sorted, and the diseased and immature nuts were discarded and spread on the floor until further processing was required.

Cashew nut processing

Raw cashew nuts were steam-boiled using a steam boiler at the pressure of 0.62 MPa during 40 mins of contact time between the steam and the cashew using the modified method of Kosoko et al. (2009). The steamed nuts were cooled for 24 h and shelled using a foot-pedalled shelling machine. It uses of a pair of knives, each shaped into the contour of a half nut. When the knives come together by means of a foot operated lever, they cut through the shell around the nut, leaving the kernel untouched. The kernel is then removed from the shell using a small metal tool resembling a pen knife to remove the kernel from the nuts. The kernels were then pre-dried in a cabinet drier (model LEEC F2, LEEC Ltd, Colwick, Nottingham), at a temperature of 60 °C for 3 h, to allow for the easy removal of the peels from the kernel. The peeled kernels were then packaged in glass bottles for the roasting process. Cashew kernels were roasted using a forced air pilot scale roaster (Model SM9053 UNISCOPE Laboratory oven SURGIFRIEND MEDICALS ENGLAND), at the roasting air temperature of 100, 120, 140, and 160 °C for 20, 40, and 60 min, which represents the range commonly used in the nut industry. Prior to placing the sample in the roasting chamber, the roaster was allowed to run for at least 2 h to obtain the steady state condition. The kernels were placed as a single layer in the roasting chamber, in a Pyrex Petri dish (8.0 cm diameter). Then every 20 min, for a period of 1h, one petri-dish was removed from the roasting chamber in less than 10s so that the steady state conditions were maintained during sampling. After the completion of roasting, the roasted cashew nuts were cooled to room temperature immediately by blowing ambient air with minimum fan capacity.

Chemical analysis

Determination of protein content

A protein analyser was used for protein analysis. The analysis was carried out according to the method of AOAC (2005). Approximately 1.0 g of the sample was burnt at 420 °C for 45 min after the addition of a catalyser (3.5g K_2S0_4 and 0.0038g Se). About 12 ml of 95% H_2S0_4 and 5 ml of H_20_2. The sample was cooled to room temperature and 75 ml of distilled water was added. The sample was put into the protein analyser. The amount of 0.1 M HCl consumed was read from the analyser. The protein content was then calculated using the formula:

$$\text{Protein (\%, db)} = \frac{100 * (1.40 * V * 5.3)}{w * (100 - MC_i)}$$

where V is the volume of the 0.1M HCl consumed, and W, is the weight of the sample.

Determination of the amino acid composition

The amino acid profile of roasted cashew nuts was determined by defatting, hydrolysis, evaporating in a rotary evaporator, and then loading into a gas chromatograph. Approximately 2.0 g of roasted cashew nuts were weighted into the extraction thimble and the fat was extracted with chloroform /methanol (2:l v/v) mixture using a soxhlet apparatus (AOAC, 2005). The extraction lasted for 6 hr. About 30 mg of defatted sample was weighed into glass ampoules, 7 mL of 6 M HCl was added, and oxygen was expelled by passing nitrogen into the ampoule. This is to avoid possible oxidation of some amino acids during hydrolysis. The glass ampoule was then sealed with Bunsen burner flame and put in an oven pre-set at 105±5 °C for 22 h to effect hydrolysis. The ampoule was allowed to cool before it was broken open at the tip and the content was filtered. The filtrate was then evaporated to dryness at 40 °C under vacuum in a rotary evaporator. The residue was dissolved with 5 mL of acetate butter (pH 2.0) and stored in a plastic specimen bottle for Gas Chromatography analysis.

Determination of the quality parameters of roasted cashew nuts

Determination of amino acid scores

Determination of amino acid scores was first based on a whole hen's egg (Paul et al., 1976). In this method, both essential and non-essential amino acids were scored. Secondly, the amino acid score was calculated using the following formula (FAO/WHO, 1973):

$$Aminoacidscore = \frac{Amountofaminopertestprotein(mg/g)}{Amountofaminoacidperproteininreferencesample(mg/g)}$$

In this method, Met+Cys and Phe+Tyr were each taken as units. Also, only the determined essential amino acids were scored. The amino acid score was also calculated based on the composition of the amino acids obtained in the samples compared with the suggested pattern of requirement for pre-school children (2-5 years). Here, Met+Cys and Phe+Tyr were each taken as units. Also, only essential amino acids with (His) were scored.

Determination of the essential amino acid index

The essential amino acid index (EAAI) was calculated by using the ratio of the test protein to the reference protein for each of the eight essential acids plus histidine in the equation below (Steinke et al., 1980):

$$\text{EAAI} = \sqrt[9]{\frac{mg\ lysine\ in\ 1g\ test\ protein}{mg\ lysine\ in\ 1g\ reference\ protein}} \times 8\ essntial\ amino\ acid + Histidine$$

Methionine and cystine are counted as a single amino acid value in the equation, as are Phe + Tyr.

Determination of biological value

The biological values of raw and roasted cashew kernels were determined by the formula given below, as described by Oser (1959):

$$Biological\ value = 1.09(EAAI)-11.7$$

Determination of the predicted protein efficiency ratio

The predicted protein efficiency ratio (P-PER) was determined using one of the equations derived by Alsmeyer et al. (1974):

$$P\text{-}PER = -0.468 + 0.454\ (Leucine) - 0.105\ (Tyrosine)$$

Determination of the total essential amino acid (TEAA) to the total amino acid (TAA), the total sulphur amino acid (TSAA), the percentage of cystine in TSAA (%Cys/TSAA), the total aromatic amino acid (TArAA), and the Leu/IIe ratio were calculated.

Statistical Analysis

Data was expressed as means±standard deviation (SD) from three replicate experiments. Statistical analyses were carried out using the statistical program SPSS version 11.5 for Windows (SPSS Corporation, Chicago, IL). Significant differences among the samples were analysed by using one-way (analysis of variance) ANOVA with Duncan's post hoc test. The criterion for statistical significance was set at $p<0.05$.

Results and discussion

Changes in the amino acid profile of cashew kernels roasted at different conditions

The results of the analysis of the effect of roasting temperature and time on amino acid content of roasted cashew kernels revealed that seventeen amino acids were present (Tables 1 and 2). The amino acid composition generally indicates the nutritive value of a protein source (Bodwell et al., 1980). The chemical content and the amino acid index are widely used for screening potential protein foods. The essential amino acid score was computed with reference to the FAO/WHO (1985) standard amino acid profile established for humans. The amino acid profile showed methionine and cystine as the limiting amino acids. The results are comparable to those of earlier researchers (Amjad et al., 2006). Amino acid deficiency can be met by consuming a large amount of cashew nuts or by taking a mixture, or by employing the complementarity that exists between amino acids from cereals and nuts. The results of the analysis have shown that there was a significant difference between the treatment for the content of essential and non-essential amino acids at $p<0.05$. The content of non-essential and essential amino acid compositions increased in the early stage of roasting and decreased with prolonged roasting. However, total typical, essential, and non-essential content of amino acids and the variation were shown in Table 3. Among the non-essential amino acids, glutamic acid and arginine accounted for about 45% of the total amino acids, which also increased in the early stages of the roasting and then decreased at the later stages of roasting. There could advance to the just that most of the moisture is evaporated within the first 20min of roasting, and polypeptide are hydrolysed to release amino acid in the period (Ozdemir, 2000). The prolonged roasting time brought about a decrease in amino nitrogen content due to the involvement of a flavour development reaction (Chiou et al., 1991a; Ozdemir, 2000). Roasting time significantly affected the essential and non-essential amino acids, generally at $p<0.05$. The results indicated that the longer roasting at the same temperature decreased the amino acid content more among the essential amino acids; lysine, tyrosine, and methionine levels decreased more than 30% compared to the control sample when roasted longer; among the essential amino acids, only the methionine content was not significantly affected by the roasting time at 100 and 120 °C, but a longer roasting time also resulted in a lower content of methionine in the samples roasted at 160 °C (Table 2). Among the non-essential amino acids, alanine, arginine, and glutamic acid levels decreased more than 15% compared to the control sample when roasted longer (Table 1). Similarly, among the non-essential amino acids, the contents of glycine at 100 °C and proline at 120 °C did not significantly differ when roasted for a longer time (Table 1). Similarly, among the non-essential amino acids, glycine at 100 °C and proline at 120 °C did not significantly differ when roasted for a longer time (Table 1). Kubanlon (1998) also reported a significant loss of total amino acids of hazelnuts roasted at 135 °C for longer than 20mm. Also, Ozdemir, 2001 reported the same result for hazelnuts. The losses were higher for essential amino acids compared to non-essential amino acids. Losses in essential amino acids were 10 and 62 % for 20 min and 30 min of roasting, respectively; losses in non-essential acids were 5 and 22% for 20 min and 30 min of roasting, respectively. Roasting time also reduced most of the free essential amino acids, namely lysine, methionine, cystine, isoleucine, valine, leucine, phenylalanine, and tyrosine content of hyping seed during roasting at 80-90 °C up to 40 min. Among the non-essential amino acids, only free arginine decreased significantly upon roasting for a longer time (Yanez et al., 1986). Lysine loss in roasted maize (26.7%) and in roasted sunflower (31%) was also reported by Ayatse et al. (1983) and Madhusudham et al. (1986), respectively. The loss in lysine was attributed to the Maillard reaction (Madhusudhan et al., 1986). Moreover, a large decrease in glutamic acid and peptides was observed in roasting peanuts (Qupadissakoon and Young, 1984), Ayatse et al. (1983) reported a decrease in the level of a most amino acids, and an increase in methionine (32%) and proline (15%) in the roasted maize. The losses in amino acids of roasted maize were related to thermal destruction (Ayatse et al. (1983). Roasting temperature for the samples was 20 min, samples were roasted at 160 °C and 120 °C. Similarly, except for proline, non-essential amino acids were higher at the higher roasting temperature for the sample roasted for 20 min or 40 min.

Table 1. Analysis of non-essential amino acids (g/100g, db) of cashew nuts roasted at different roasting conditions

T (°C)	Time (min)	Aspartic Acid	Serine	Glutamic acid	Proline	Glycine	Alanine	Histidine	Arginine	Cystine
Control		12.20±0.50^{c}	2.77±0.21^{a}	15.27±0.50^{a}	2.67±0.34^{a}	2.57±0.20^{a}	3.61±0.20^{abc}	1.70±0.01	5.25±0.00^{a}	1.78±0.00^{b}
100	20	8.36±0.01^{b}	4.98±0.03^{de}	18.89±0.15^{e}	4.10±0.08^{c}	4.55±0.00^{d}	4.27±0.00^{bcd}	3.90±0.00	8.74±0.00^{e}	1.62±0.00^{a}
	40	7.57±0.21^{a}	4.00±0.01^{b}	17.24±0.13^{b}	3.24±0.06^{b}	3.45±0.05^{ab}c	4.40±0.01^{bcd}	3.07±0.01	7.16±0.17^{bc}	1.70±0.41^{bc}
	60	7.15±0.08^{a}	3.72±0.36^{b}	18.24±0.06^{cd}	3.24±0.05^{b}	3.15±0.03^{ab}c	4.20±0.05^{bcd}	4.87±0.05	7.59±0.11^{cd}	1.55±0.01^{a}
120	20	8.37±0.01^{b}	5.07±0.06^{de}	18.95±0.10^{e}	4.15±0.01^{c}	4.47±0.02^{d}	4.35±0.71^{cd}	3.90±0.02	9.19±0.00^{ef}	1.67±0.03^{bc}
	40	7.49±0.11^{a}	3.66±0.15^{b}	18.02±0.08^{cd}	3.39±0.15^{b}	3.43±0.03^{ab}	4.50±0.31^{d}	3.75±0.11	8.21±0.21^{d}	1.78±0.11^{bc}
	60	7.29±0.21^{a}	3.64±0.13^{b}	17.78±0.26^{c}	3.60±0.02^{b}	3.10±0.04^{abc}	4.29±0.31^{bcd}	4.12±0.21	8.75±0.21^{e}	1.60±0.11^{a}
140	20	8.89±0.05^{d}	5.16±0.17^{e}	18.35±0.28	4.03±0.01^{d}	4.64±0.05^{d}	4.05±0.71bc^{d}	3.96±0.11	9.33±0.37^{f}	1.66±0.12^{bc}
	40	7.21±0.11^{b}	4.72±0.11^{cd}	17.90±0.13^{cd}	3.26±0.02^{b}	3.80±0.05^{c}	3.84±0.01^{a}	3.24±0.40	7.33±0.41^{b}	1.70±0.13^{bc}
	60	7.06±0.11^{a}	4.28±0.12^{c}	18.90±0.04^{e}	3.32±0.02^{b}	3.20±0.04^{bc}	4.39±0.14^{bcd}	4.41±0.51	7.81±0.11^{cd}	1.55±0.10^{bc}
160	20	8.64±0.28^{b}	5.18±0.01^{de}	18.92±0.03^{e}	3.99±0.01^{c}	4.55±0.21^{d}	4.12±0.01^{bcd}	4.38±0.22	8.81±0.22^{e}	1.55±0.04^{bc}
	40	7.71±0.21^{a}	4.81±0.11^{cd}	17.83±0.02^{cd}	3.03±0.02^{b}	3.57±0.21^{c}	3.88±0.02^{ab}	3.32±0.11	7.88±0.15^{cd}	1.65±0.11^{bc}
	60	7.15±0.36	4.40±0.29^{e}	18.27±0.02^{e}	2.85±0.02^{c}	3.38±0.21^{d}	4.17±0.21^{bcd}	3.67±0.11	7.74±0.17^{e}	1.53±0.02^{bc}

Values in the same column with different lower-case letters (a-g) are significantly different at p<0.05.

Table 2. Analysis of essential total amino acids (g/100g, db) of cashew nuts roasted at different roasting conditions

T (°C)	Time (min)	Lysine	Leucine	Isoleucine	Threonine	Valine	Phenylalanine	Tyrosine	Methionine
Control	0	6.09± 0.07	7.33±0.6^{cd}	3.57±0.05	3.42±0.06	3.63±0.06^{a}	5.06±0.05	3.1±0.02	1.39±0.07^{a}
100	20	4.38±0.04	7.57±0.44^{d}	3.38±0.07	3.87±0.13	4.99±0.04	4.11±0.70	2.32±0.11	1.53±0.07^{ab}
	40	4.68±0.03	6.56±0.44^{b}	2.43±0.08	3.39±0.14	3.60±0.01	4.01±0.08	2.97±0.11	1.36±0.06^{a}
	60	4.28±0.03	5.66±0.09^{a}	2.87±0.14	2.67±0.05	4.26±0.05	4.01±0.14	2.96±0.11	1.77±0.04^{d}
120	20	4.54±0.06	7.36±0.04^{cd}	3.47±0.03	3.87±0.13	4.99±0.03	4.11±0.13	2.32±0.12	1.53±0.07^{ab}
	40	4.95±0.11	6.56±0.05^{b}	2.94±0.06	2.76±0.06	3.85±0.35	4.04±0.12	2.60±0.12	1.61±0.08^{bcd}
	60	4.10±0.01	6.37±0.04^{b}	2.68±0.06	2.87±0.17	3.62±0.06	3.69±0.04	2.51±0.05	1.75±0.06^{cd}
140	20	4.59±0.02	7.15±0.06^{c}	3.55±0.01	3.39±0.01	4.78±0.05	3.62±0.09	2.21±0.12	1.58±0.20^{bc}
	40	4.37±0.07	6.61±0.21^{b}	2.98±0.14	3.31±0.04	3.84±0.22	3.95±0.04	2.35±0.41	1.45±0.01^{ab}
	60	4.80±0.01	5.55±0.06^{a}	2.18±0.14	2.94±0.07	4.09±0.05	4.10±0.16	3.10±0.41	1.60±0.01^{bc}
160	20	4.69±0.06	7.36±0.05^{cd}	3.31±0.06	3.64±0.05	5.06±0.05	4.03±0.04	2.17±0.71	1.50±0.01^{ab}
	40	4.73±0.05	6.27±0.05^{b}	2.57±0.05	2.76±0.05	3.75±0.06	4.23±0.05	2.79±0.21	1.40±0.01^{a}
	60	4.97±0.07	7.35±0.04^{cd}	3.25±0.04	3.65±0.06	3.84±0.05	4.45±0.04	3.04±0.41	1.48±0.05^{ab}

Values in the same column with different lower-case letters (a-g) are significantly different at p<0.05.

Table 3. Calculated nutritional quality of cashew nuts roasted at different temperatures and time combinations

Amino acid	0	1C20	1C40	1C40	2C20	2C40	2C60	4C20	4C40	4C60	6C20	6C40	6C60
TAA (mg/100g)	81.41	93.47	81.41	83.36	93.39	83.00	81.00	91.67	81.22	85.29	92.92	81.81	92.93
TNEAA (mg/100g)	48.80	57.86	51.98	51.87	58.49	53.04	52.14	58.11	51.84	53.50	57.71	52.45	57.71
TEAA (Histidine)	32.16	34.61	29.44	31.39	34.90	29.97	28.86	33.86	29.47	31.77	35.22	29.36	35.23
TEAA (No Hist.)	30.96	30.71	26.34	26.34	31.00	26.17	24.76	29.66	26.27	27.37	30.82	26.06	30.83
TNAA (mg/100g)	32.73	40.41	33.76	33.00	40.71	34.12	33.29	39.70	35.26	33.98	40.17	33.48	40.17
TAAA	27.06	27.25	25.04	25.28	27.24	25.39	24.58	27.87	24.87	25.86	27.57	24.92	27.37
TBAA	13.04	16.98	14.79	16.72	17.56	16.87	16.97	17.84	14.89	16.99	17.87	16.16	17.87
TSAA	3.11	3.10	3.00	3.28	3.15	3.34	3.32	3.10	3.14	3.14	3.03	3.03	3.03
TarAA	8.14	7.82	7.72	8.28	7.88	6.62	6.20	7.09	6.29	8.47	7.53	7.25	7.53
P-PER	2.57	2.61	2.09	1.76	2.61	2.22	2.14	2.52	2.28	1.71	2.57	2.09	2.64
Leu/Ile ratio	2.02	2.20	2.67	2.02	2.12	2.26	2.40	2.01	2.21	1.73	2.26	2.43	2.26
EAAI (%)	1.55	1.48	1.45	1.52	1.55	1.38	1.44	1.52	1.44	1.50	1.40	1.44	1.42
Isoelectric point	4.65	4.45	3.87	4.25	4.35	4.10	4.15	4.22	4.05	4.52	4.00	4.54	4.55
BV (%)	76.15	76.57	71.10	67.62	76.57	72.47	71.62	75.63	73.10	67.10	76.15	71.10	76.89

TAA (Total amino acid); TNEAA (Total non-essential amino acid); TAAA (Total acidic amino acid); TNAA (Total neutral amino acid); TBAA (Total basic amino acid); TSAA (Total sulphur amino acid); TArAA (Total aromatic amino acid); P-PER (Predicted protein efficiency ratio); BV (Biological value), EAAI (Essential amino acid index).

Table 4. Essential amino scores of roasted cashew kernels based on requirements of a pre-school child (2–5 years)

Amino acid		**100 °C**			**120 °C**			**140 °C**			**160 °C**			**Ref FAO/WHO (1985)**
		20 min	40 min	60 min	20 min	40 min	60 min	20 min	40 min	60 min	20 min	40 min	60 min	
Isoleucine	1.28	1.21	0.87	1.03	1.24	1.05	0.96	1.27	1.06	0.78	1.18	0.92	0.80	2.8
Leucine	1.11	1.15	0.99	0.86	1.12	0.99	0.97	1.08	1.00	0.84	1.12	0.95	1.11	6.6
Lysine	1.05	0.76	0.81	0.74	0.78	0.85	0.71	0.79	0.75	0.83	0.81	0.82	0.86	5.8
Histidine	0.89	2.05	1.62	2.56	2.05	1.97	2.17	2.08	1.71	2.32	2.31	1.75	1.93	1.9
Met+Cys	1.27	1.26	1.22	1.33	1.28	1.36	1.34	1.30	1.26	1.26	1.22	1.22	1.20	2.5
Phe+Tyr	1.30	1.02	1.11	1.11	1.02	1.05	1.02	0.93	1.00	1.44	0.98	0.67	0.72	6.3
Threonine	1.01	1.14	1.00	0.79	1.14	0.81	0.79	1.00	0.97	0.87	1.07	0.81	0.78	3.4
Tryptophan	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.1
Valine	1.04	1.43	1.03	1.22	1.43	1.10	1.03	1.37	1.10	1.17	1.45	1.07	1.10	3.5

Moreover, the trend for the non-essential amino acids of the sample roasted for 40 min was also dyke that of essential amino acids; the sample roasted at 140 °C contained equal to or more content of non-essential amino acid than the sample roasted at 160 °C and 100 °C. The increase in methionine, arginine, and phenylalanine during roasting of hazelnuts, and some free amino acids of cystine, tyrosine, and phenylalanine during coconut roasting, were also observed by Ozdemir et al, (2000b) and Jayclekshry & Mathew (1990). Respectively, the reason for the increase in some of the total amino acids during the early stages of roasting is however unexplained. The changes in the amino acids may be attributed to hydrolysis of polypeptides, resulting in an increase and subsequently undergoing a serve of chemical reaction that results in a decrease of the total amino acids (Chiou et al., 1991a). Lower amino acid and sucrose content at darker co lower sample were also observed by Chiron (1992) and darker co lower was also related to higher antioxidant activity in roasted peanuts (Chiou et al., 1991b; Chiou, 1992).

Table 4 shows the calculated nutritional quality of total amino acids (TAA), total essential amino acids (TEAA), total acidic amino acids (TAAA), total neutral amino acids (TNAA), total sulphuric amino acids (TSAA), total aromatic amino acids (TArAA), and their percentage values. The leucine/isoleucine ratio (Leu/IIe ratio), the predicted-protein efficiency ratio (P-PER), the isoelectric point, the biological value, and the essential amino acid index (EAAI) are presented in Table 6. The content of TEAA is between 32.16 and 35.22 mg/100g, with histidine close to the value for the egg reference protein (56.6 g/100 g) (Paul et al., 1976); for soya bean, it is 44.4 g/100 g (Altschull, 1968) and for peanut it is 39.4 g/100 g (Adeyeye, 2010), and greater than the *Prosopis africana* concentrate (31.9 g/100 g) reported by *Aremu* et al., 2007. However, it is less than that of some legumes: lima bean (44.88 g/100 g), African yam bean (48.28 g/100 g), and pigeon pea (48.11 g/100 g), reported by Oshodi et al., 1998. The TAA were 81.41–93.47 g/100g, which is close to the TAA in dehulled African yam beans, with values of 70.3–91.8 g/100 g

(Adeyeye, 2010); 66.8–85.9 g/100 g (Adeyeye, 2010). The contents of TSAA (3.03–3.34 g/100 g) were lower than the 5.8 g/100 g crude protein recommended for infants (FAO/WHO/UNU, 1985). The ArAA determined in this study, 6.20–8.28 g/100 g, is lower than the protein value recommended for infants (6.8–11.8 g/mg) (FAO/WHO/UNU, 1985). The ArAA are precursors of epinephrine and thyroxin (Robinson, 1987). The percentage ratio of TEAA to TAA in the samples was 35.63 to 39.80 %, which was close to the 39% considered to be adequate for ideal protein food for infants, 26% for children, and 11% for adults (FAO/WHO/UNU, 1985). The TEAA/TAA percentage contents were strongly comparable to that of eggs (FAO/WHO, 1990), and 43.6% reported for pigeon pea flour (Oshodi et al., 1993), 43.8–44.4 % reported for beach pea protein isolate (Chavan et al., 2001) and 28.4% in luffa cylindrical seeds (Olaofe et al., 2008). Most animal protein are low in cystine and therefore also low in TSAA (Adeyeye, 2005 a, b; Adeyeye and Adamu, 2005, Adeyeye and Afolabi, 2004; Adeyeye, 2009).

In contrast, many vegetable proteins contain substantially more cystine than methionine, for example, 62.9% in coconut endosperm (Adeyeye, 2004). This result agrees with the present report for raw nuts (57.24%) and roasted cashew nuts (47.26–54.46 %), and 65.6% for cooked peanuts and 67.7% for roasted peanuts (Adeyeye, 2010). Information on the agronomic advantage of increasing the concentration of sulphur containing amino acid in staple foods shows that cystine has a positive effect on mineral absorption, particularly zinc (Mendoza, 2002, Sandstron et al., 1989).

The predicted protein efficiency ratio (P-PER) is known to be a biological method used to express the growth-promoting value of protein numerically. This is the simplest and most convenient method of measuring the nutritive value of protein. The results show that P-PER values were higher than 1.21 (cowpea) and 1.82 (pigeon pea) (Salunkhe and Kadam, 1989), 1.62 (millet Ogi), and 0.27 (Sorghum Ogi) (Oyarekua and Eleyinmi, 2004) and in close agreement with the study by Adeyeye (2010) on peanuts (2.55–3.0). A common feature of sorghum and maize is that the proteins of these grains contain a relatively high proportion of leucine, it was therefore suggested that the amino acid imbalance from excess leucine might be a factor in the development of pellagra (FAO, 1995). Clinical, biochemical, and pathological observation in experiments conducted on humans and laboratory animals showed that a high content of leucine in the diet impairs the metabolism of tryptophan and niacin, and is responsible for the niacin deficiency in sorghum eaters (Cihaforunisaa and NarasingaRao, 1973). High levels of leucine are also a factor contributing to the pellugragenic properties of maize (Belavady and Gopalan, 1969). These studies suggested that the leucine/ isoleucine balance is more important than the dietary excess of leucine alone in regulating the metabolism of tryptophan and niacin, and hence the disease process. The present leu/Ile ratio was low in value and similar to the report of Adeyeye (2010) on roasted peanuts. The Isoelectric point (pI) range was 3.87–4.65, and it is in close agreement with the report of Adeyeye (2010) for peanuts (4.78–3.68). The isoelectric point of any organic matter is important when the protein isolate is to be prepared. This is useful in predicting the pI for the protein, in order to check for a quick precipitation of protein isolate from biological samples (Olaofe and Akintayo, 2000). The EAAI can be useful as a rapid tool to evaluate food formulations for protein quality. The EAAI in the present study was 1.42 to 1.55, which is similar to soy flour (1.26) (Nielsen, 2002); 0.83–1.18 in peanuts (Adeyeye, 2010). Table 6 shows that lysine (0.89; 89%) was the EAAI in raw nuts and that it ranged from 0.74 to 0.86 (86%) in roasted samples, whereas EAAI for threonine ranged from 0.74 to 1.14 (114%) for roasted nuts. Table 6 shows that the samples would be able to supply more than the required EAAI for a pre-school child, as shown by their EAAI. Of all the raw cashew nuts, only lysine would supply less than the required 100% and would supply 86%, which can be corrected by biological value as a measure of the proportion of absorbed protein from a food which becomes incorporated into the protein of the organism body. It summarizes how readily the broken-down protein can be used for protein synthesis in the cells of the organism. BV provides a good measure of the usability of proteins in a diet and also plays a valuable role in detection of some metabolic diseases. It varies and depends on age, weight, health, sex, recent diet, and current metabolism of the organism. From the results shown in Table 3, biological values of cashews varied between 67.62% and 76.89%, with samples roasted at 100 °C for 40 mins having the lowest value of 67.62%, while the sample roasted at 160 °C for 60 mins had the highest value of 78.89%, which compares favourably with samples roasted at 160 °C for 20 mins, 120 °C for 20 mins, and raw cashew samples. Biological value (BV) is a measure of the proportion of absorbed protein from a food which becomes incorporated into the proteins of the organism's body. It captures how readily the digested protein can be used in protein synthesis in the cells of the organism.

Table 5. Essential amino scores of roasted cashew kernels based on the FAO/WHO, 1973 standard

Amino acid		**100 ˚C**			**120 ˚C**			**140 ˚C**			**160 ˚C**			**Ref FAO/WHO (1973)**
		20 min	40 min	60 min	20 min	40 min	60 min	20 min	40 min	60 min	20 min	40 min	60 min	
Isoleucine	1.28	1.21	0.87	1.03	1.24	1.05	0.96	1.27	1.06	0.78	1.18	0.92	0.80	4.0
Leucine	1.11	1.15	0.99	0.86	1.12	0.99	0.97	1.08	1.00	0.84	1.12	0.95	1.11	7.0
Lysine	1.05	0.76	0.81	0.74	0.78	0.85	0.71	0.79	0.75	0.83	0.81	0.82	0.86	5.5
Histidine	0.89	2.05	1.62	2.56	2.05	1.97	2.17	2.08	1.71	2.32	2.31	1.75	1.93	3.5
Met+Cys	1.27	1.26	1.22	1.33	1.28	1.36	1.34	1.30	1.26	1.26	1.22	1.22	1.20	2.5
Phe +Tyr	1.30	1.02	1.11	1.11	1.02	1.05	1.02	0.93	1.00	1.44	0.98	0.67	0.72	6.0
Threonine	1.01	1.14	1.00	0.79	1.14	0.81	0.79	1.00	0.97	0.87	1.07	0.81	0.78	4.0
Tryptophan	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.0
Valine	1.04	1.43	1.03	1.22	1.43	1.10	1.03	1.37	1.10	1.17	1.45	1.07	1.10	5.0

Table 6. Essential amino scores of roasted cashew nuts based on the FAO/WHO, 1973 standard

Amino acid	0	1C20	1C40	1C60	2C20	2C40	2C60	4C20	4C40	4C60	6C20	6C40	6C60	**Ref FAO/WHO (1973)**
Isoleucine	0.89	0.85	0.61	0.72	0.87	0.74	0.67	0.89	0.75	0.55	0.83	0.64	0.56	4.0
Leucine	1.05	1.08	0.94	0.81	1.05	0.94	0.91	1.02	0.94	0.79	1.05	0.90	1.05	7.0
Lysine	1.11	0.80	0.85	0.78	0.83	0.90	0.75	0.84	0.80	0.87	0.85	0.86	0.90	5.5
Met +Cys	0.91	0.90	0.87	0.95	0.91	0.97	0.96	0.93	0.90	0.90	0.87	0.87	0.86	3.5
Phe +Tyr	1.36	1.07	1.16	1.16	1.07	1.11	1.07	0.97	1.05	1.20	1.03	1.17	1.25	6.0
Threonine	0.86	0.97	0.85	0.67	0.97	0.69	0.67	0.85	0.82	0.74	0.91	0.69	0.66	4.0
Tryptophan	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.0
Valine	0.73	1.00	0.72	0.85	1.00	0.77	0.72	0.96	0.77	0.82	1.01	0.75	0.74	5.0

FAO/WHO, (1973) Amino acid reference pattern of protein for human diet. ND=Not Detected 0 (control)**,** 1C20 (Sample roasted at 100 °C for 20 min); 1C40 (Sample roasted at 100^0 for 40 min); 1C60 (Sample roasted at 100^0 for 60 min); 2C20 (Sample roasted at 120^0 for 20 min); 2C40 (Sample roasted at 120^0 for 40 min); 2C60 (Sample roasted at 120^0 for 60 min); 4C20 (Sample roasted at 140^0 for 2 0min); 4C20 (Sample roasted at 140^0 for 40 min); 4C60 (Sample roasted at 140^0 for 60 min); 6C20 (Sample roasted at 160^0 for 20 min);6C40 (Sample roasted at 160^0 for 40 min); 6C60 (Sample roasted at 160^0 for 60 min)

Conclusion

The results obtained from the project have shown that cashew kernels contain appreciable quantities of major nutrients, like proteins and carbohydrates, and have a high nutrient density and a high content of quality protein. The amino acid analysis revealed that cashew kernel flour contains a good quantity of histidine, which is essential for infants. The utilization of cashew kernel flour should be encouraged for use in infant food formulation only when other analyses on the biological value (BV) have been completed, which is very high in this study for cashew kernels and similar to other tree nuts. The chemical score of the amino acids also revealed that lysine is the first limiting amino acid. The use of the amino acid profile and amino scores for evaluating protein quality of roasted cashew nuts for human consumption will provide added value to the nutritional food composition table. The protein quality of nuts for human consumption through the use of the amino acid profile and amino acid scores may be used to provide added value to the Nigerian food composition table and international food databases, and can also be used to improve the nutritional value of diets and for improving nutrition through intervention programmes or public health policies.

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