

## EFFECT OF COOKING AND ROASTING ON THE AMINO ACID COMPOSITION OF RAW GROUNDNUT (*ARACHIS HYPOGAEA*) SEEDS

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**Background.** As a food, groundnut is one of the most concentrated products, since it is very high in calories due to its high fat and protein content. One gram of groundnut supplies 6.03 kcal (25.2 kJ) compared with 4 kcal (16.7 kJ) for pure cane sugar, 3.6 kcal (15.1 kJ) for polished rice, 3.5 kcal (14.6 kJ) for maize flour and 2.7 kcal (11.3 kJ). Groundnut flour is used as food and 2.7 kcal (11.3 kJ). Groundnut flour is used as food in soup or stew, sauces, confectionaries, puddings, bakery products and in various other ways for human consumption. These uses of groundnut necessitate the determination of the general composition of groundnut.

**Material and methods.** About 1.0 kg dried seeds of groundnut was involved in the analysis of the sample. It was divided into three parts for the dry, dry cooked and dry roasted samples. Defatted groundnut seeds were used using standard analytical method in which chloroform/methanol (2:1 v/v) was used as extraction solvent. Ion exchange chromatography method was used in the analysis of the amino acid composition using the Technicon Sequential Multisample (TSM) Amino Acid Analyser. Various methods were used to determine the quality parameters of the protein. Other parameters were the predicted protein efficiency ratio (P-PER), essential amino acid index (EAAI) and the isoelectric point (pI). The statistical analysis was also carried out.

**Results.** Total amino acid was as follows: (g/100 g crude protein, cp): 83.5 (raw seeds, Rs), 85.9 (cooked seeds, Cs) and 66.8 (roasted seeds, Rt.s) with corresponding essential amino acids as: 39.4 or 47.2% (Rs), 38.3 or 44.6% (Cs) and 30.0 or 44.9% (Rt.s). Predicted protein efficiency ratios were 2.55 (Rs), 3.00 (Cs) and 2.31 (Rt.s) and essential amino acid index of 1.18 (Rs), 1.08 (Cs) and 0.83 (Rt.s). Cooking enhanced the amino acid levels of Asp, Ser, Glu, Pro, Arg, Ala, Cys, Val, Leu and Phe. The following essential amino acids were reduced by both cooking and roasting: Lys (15.9-27.6%), His (4.23-16.5%), Thr (40.1-60.6%), Met (38.0-63.4%) and Ile (13.3-31.8%). All the parameters between Rs/Cs and most of the parameters between Rs/Rt.s were significantly different at  $\Gamma=0.05$ .

**Conclusions.** Processing of raw groundnut seeds particularly roasting is deleterious to the amino acid composition and quality. The protein values (g/100 g) were: 29.0 (raw), 28.4 (cooked) and 26.9 (roasted). When a 30 kg child consumes 100 g of raw seeds per day, his FAO/WHO requirements of Val and Ile would be met by 135% and 138% respectively; for roasted seeds it would be 135% (Val) and 117% (Ile); for roasted seeds it would be 101% (Val) and 87.2%. Raw groundnut seeds are recommended in complementing cereals for weaning foods, followed by cooked seeds but not roasted seeds.

**Key words:** groundnut seeds, amino acid composition, raw, cooked, roasted

## INTRODUCTION

The cultivated species of the groundnut plant, *Arachis hypogaea*, is an annual herb belonging to the Papilionaceae division of the family Leguminosae. It is a spreading, sun-loving plant, widely grown in tropical, sub-tropical, Mediterranean and warm temperate climates. Groundnut is also known as *earth-nut*, *peanut*, *monkey-nut*, *Manilla-nut*, *Chinese nut*, *goober pea*, *pindar*, *pistache de terre*, *larachide*. In various Nigerian vernaculars: *epa* (Yoruba); *gya'da* (Hausa); *okpa* (Ibo) [Oyenuga 1978].

The groundnut is a legume with seed rich in oil (48-49%) and protein (about 26%). Groundnuts are the main export crop of Nigeria's northern states and the bulk of the crop is produced north of latitude 11°N. The crop does best in light sandy soils, which allow good drainage and ease of harvesting; 500 mm of rain can be sufficient if well distributed. Production in excess of village market sales has varied from less than 100 000 tons in an unfavourable year to 1 000 000 tons of shelled groundnuts in a favourable year. Nearly all this commercial crop is processed in local oil mills and the oil and cake sold at home and abroad [Phillips 1977].

The groundnut is widely consumed in Nigeria and in various other parts of West Africa. Its nutty, agreeable flavour makes it a particularly suitable vegetable food when roasted. It is often cooked and eaten mixed with maize. Its high protein content makes it especially valuable as a tissue builder.

The amino acid components of groundnut from three different geographical areas have been reported: Samaru (Nigeria) [Busson 1968], United States [Altschul 1986] and India [Busson 1968]. However, no report is available on the amino acid components of cooked and roasted groundnut seeds. It is therefore the aim of this research to report on the effect of cooking and roasting on the kernels of dry groundnut and compare the results with raw but also dried groundnut kernels.

## MATERIAL AND METHODS

Groundnut cultivar used: there are three main types:

- a) the long season;
- b) the short season sequentially branched early-maturing types with a more determinate growth pattern;
- c) new types bred from crosses between short and long season forms.

The long season, alternately branched types with indeterminate growth pattern. Erect varieties and runner varieties in this group are capable of giving good yields but the erects are handled more easily with machines. Nearly all the crop grown in Nigeria is of this long season type. The long season runner variety was used for these experiments [Phillips 1977].

**Collection of samples.** Dried pods of groundnut (approximately 1.0 kg) were collected from Iworoko market, Ekiti State, Nigeria. These sun-dried pods were then further oven-dried to constant weight, and any broken pods were removed.

**Treatment of samples.** The samples were treated as follows: after the groundnut had been divided into three parts.

About 300 g of the groundnut pod was shelled and the kernel collected. The kernels were oven-dried to constant weight and homogenised into flour. The homogenized sample was then packed in plastic bottles and kept in freezer ( $-4^{\circ}\text{C}$ ) pending analysis. This is the raw sample.

About 350 g of the dried groundnut pods were put into an iron pot and mixed with clean fine sand and stirred to prevent burning of the sample and to ensure uniform distribution of heat. The groundnut pods were roasted for about 30 min at  $120\text{-}130^{\circ}\text{C}$  using Gallenkamp thermostat hot plate until a characteristic brownish nutty smell seed was obtained which indicated complete roasting. The sand was then separated from the groundnut using a sieve and the groundnut pods were allowed to cool. Thereafter, the pods were shelled and the seeds collected. The seeds were then homogenised and packed in plastic bottles and kept in freezer ( $-4^{\circ}\text{C}$ ) pending analysis. This is the roasted sample.

About 350 g of the dried groundnut pods were put in aluminum pot, tap water added (groundnut pods/water ratio 1:5 w/v), and cooked at  $85\text{-}90^{\circ}\text{C}$  on a Gallenkamp thermostat hot plate. The groundnut pods got cooked after about 20 min. The seeds were considered cooked when they became soft to touch on pressing between the thumb and fingers. At the end of cooking time, the boiling water was drained and seeds were removed, sun-dried and later oven-dried to constant weight. The seeds were then homogenised and packed in plastic bottles and kept in freezer ( $-4^{\circ}\text{C}$ ) pending analysis. This is the cooked sample.

**Sample preparation for amino acid analysis.** About 2.0 g of each sample were weighed into the extraction thimble and the fat extracted with chloroform/methanol (2:1 v/v) mixture using a Soxhlet apparatus [AOAC... 2005]. The extraction lasted for 5-6 h. About 30 mg of the defatted sample was weighed into glass ampoules. Seven millilitres of 6 M HCl were added and oxygen expelled by passing nitrogen gas into the samples. The glass ampoules were sealed with a Bunsen flame and put into an oven at  $105 \pm 5^{\circ}\text{C}$  for 22 h. The ampoule was allowed to cool; the content was filtered to remove the humins. The filtrate was then evaporated to dryness at  $40^{\circ}\text{C}$  under vacuum in a rotary evaporator. Each residue was dissolved with 5 ml acetate buffer (pH 2.0) and stored in a plastic specimen bottle, and kept in the deep freezer.

**Amino acid analysis.** Amino acid analysis was by ion exchange chromatography (IEC) [FAO/WHO 1991] using the Technicon Sequential Multisample (TSM) Amino Acid Analyser (Technicon Instruments Corporation, New York). The period of analysis was 76 min for each sample. The gas flow rate was 0.50 ml/min at  $60^{\circ}\text{C}$  with reproducibility consistent within  $\pm 3\%$ . The net height of each peak produced by the chart recorder of the TSM (each representing an amino acid) was measured and calculated. The amino acid values reported were the averages of two determinations. Tryptophan was not determined because of cost. Norleucine was the internal standard.

## Determination of quality parameters

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

$$\text{Amino acid score} = \frac{\text{amount of amino acid per test protein (mg/g)}}{\text{amount of amino acid per protein in reference pattern (mg/g)}}$$

In this method, Met + Cys and Phe + Tyr were each taken as a unit. Also, only essential amino acids determined were scored. Amino acid score was also calculated based on the composition of the amino acids obtained in the samples compared with the suggested pattern of requirements for pre-school children (2-5 years). Here, Met + Cys and Phe + Tyr were each taken as a unit. 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 test protein to the reference protein for each of the eight essential amino acid plus histidine in the equation that follows [Steinke et al. 1980]:

$$\text{Essential amino acid index} = 9 \sqrt{\frac{\begin{array}{l} \text{mg lysine} \\ \text{in 1 g} \\ \text{test protein} \\ \text{mg lysine in 1 g} \\ \text{reference protein} \end{array} \times \begin{array}{l} \text{etc. for all} \\ \text{8 essential amino acids} \\ \text{+ His} \end{array}}$$

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

**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], i.e. P-PER = -0.468 + 0.454 (Leu) - 0.105 (Tyr).

## Other determinations

Determination of the total essential amino acid (TEAA) to the total amino acid (TAA), i.e. (TEAA/TAA); total sulphur amino acid (TSAA); percentage cystine in TSAA (% Cys/TSAA); total aromatic amino acid (TArAA), etc; the Leu/Ile ratios were calculated while the isoelectric point (pI) was calculated using the equation of the form [Olaofe and Akintayo 2000]:

$$IP_m = \sum_{i=1}^n IP_i X_i$$

where  $IP_m$  is the isoelectric point of the mixture of amino acids,  $IP_i$  is the isoelectric point of the  $i^{\text{th}}$  amino acid in the mixture and  $X_i$  is the mass or mole fraction of the  $i^{\text{th}}$  amino acid in the mixture [Finar 1975].

## Statistical analysis

Calculations made were the mean, standard deviation (SD) and coefficients of variation in percentage (CV%). The summary of the amino acid profiles into factors A and B were also reported. The data obtained were also subjected to the determination of linear correlation coefficient ( $r_{xy}$ ), linear regression coefficient ( $R_{xy}$ ) and the  $r_{xy}$  calculated compared to  $r_{xy}$  table at  $r=0.05$  and at  $n-2$  degrees of freedom to see if significant differences occurred among the samples; both the coefficient of alienation ( $C_A$ ) and index of forecasting efficiency (IFE) were also calculated [Oloyo 2001].

## RESULTS AND DISCUSSION

The crude protein levels of the samples are shown in Table 1. The crude protein levels in the samples showed close comparison with the value reported by Oyenuga [1978] which was 27 g/100 g for raw groundnut. Five to 12% of the nitrogen of groundnut is said to occur as non-protein nitrogen. Two globulins, arachin, which represents 63% of the total protein, and conarachin, representing about 33%, were found to comprise the bulk of groundnut protein. Conarachin, the more soluble fraction, contains about three times as much sulphur as arachin and its basic nitrogen content of 6.55% is considered to be among the highest found in seed globulins. It has been reported that arachin from groundnut protein contained 1.51 g/100 g Cys and 0.67 g/100 g Met while conarachin contained 2.92 g/100 g Cys and 2.12 g/100 g Met [Oyenuga 1978].

There was a progressive reduction in the level of protein from raw to cooked and from raw to roasted. Maillard reactions which lead to a type of browning are an interaction between the carbonyl group of a reducing sugar and the free amino group from an amino acid or protein. The resulting condensation product is converted by the Amadori rearrangement to the 1-deoxy-2-ketosyl compound. Browning then proceeds along complex pathways, the exact sequence being dependent on pH, temperature, concentration and the identity of the reactants [Muller and Tobin 1980]. The crude protein results showed that the Maillard reactions were mild in the cooked groundnut seeds (cooked at 85-90°C for about 20 min) but the reactions were high in the roasted samples (roasting at 120-130°C for about 25 min), hence protein reduction in both cooked and roasted, in fact the colour of roasted groundnut is normally brown. This type of reduction had been observed in the protein of processed cocoa nibs. Process-line cocoa nibs (P-LCN) had protein level of 23.2 g/100 g whilst processed cocoa cake samples (PCCS) had protein level of 18.4 g/100 g, meaning a reduction of 4.8 g/100 g or 20.7% [Adeyeye et al. 2010].

Table 1 shows the amino acid (AA) compositions for raw, cooked and roasted whole seeds of groundnut. Glutamic acid and aspartic acid had the highest concentrations among their groups and both are acidic AA. Leucine constituted the highest single essential amino acid (EAA) in all the samples. For Glu, Asp and Leu, the pattern of concentration was cooked > raw > roasted. However, the pattern of the crude protein levels were raw > cooked > roasted.

The amino acid profiles of groundnut from Samaru (Nigeria) [Busson 1968], United States [Altschull 1968] and India [Busson 1968] also showed that Glu and Asp were the

Table 1. Amino acid profiles of raw, cooked and roasted groundnut seeds (g/100 g crude protein) dry matter

Amino acid	Raw seeds	Cooked seeds	Roasted seeds	Mean	S.D.	CV%
Lysine (Lys) <sup>a</sup>	4.34	3.65	3.14	3.71	0.60	16.2
Histidine (His) <sup>a</sup>	2.36	2.26	1.97	2.20	0.20	9.21
Arginine (Arg) <sup>a</sup>	5.92	6.52	4.89	5.78	0.82	14.3
Aspartic acid (Asp)	9.09	10.7	8.43	9.41	1.17	12.4
Threonine (Thr) <sup>a</sup>	4.24	2.54	1.67	2.82	1.31	46.4
Serine (Ser)	3.38	3.54	2.66	3.19	0.47	14.7
Glutamic acid (Glu)	14.9	15.7	13.2	14.6	1.28	8.74
Proline (Pro)	3.53	4.31	2.77	3.54	0.77	21.8
Glycine (Gly)	4.64	3.48	2.85	3.66	0.91	24.8
Alanine (Ala)	3.69	4.70	2.99	3.79	0.86	22.7
Methionine (Met) <sup>a</sup>	1.42	0.88	0.52	0.94	0.45	48.2
Cystine (Cys)	1.39	1.68	1.09	1.39	0.30	21.2
Valine (Val)	4.60	4.72	3.90	4.41	0.44	10.0
Isoleucine (Ile)	4.28	3.71	2.92	3.64	0.68	18.8
Leucine (Leu)	7.54	8.45	6.77	7.59	0.84	11.1
Phenylalanine (Phe)	4.70	5.59	4.20	4.83	0.70	14.6
Tyrosine (Tyr)	3.51	3.51	2.80	3.27	0.41	12.5
Tryptophan (Try)	–	–	–	–	–	–
Protein, g/100 g	29.0	28.4	26.9	28.1	1.08	3.85

<sup>a</sup>Essential amino acid.  
– not determined.

two most concentrated AA like the present report. The following AA was more concentrated in the present report than the literature just cited: His, Lys, Thr, Gly, Val, Ile and Leu. Despite the effect of processing the coefficient of variation (CV%) levels were relatively close with hot spot at 48.2 in methionine whereas others ranged from 3.85-46.4.

Table 2 shows the differences in the amino acid profiles between raw and cooked, and between raw and roasted samples. Raw seeds amino acids were better concentrated than the cooked seeds in Lys, His, Thr, Gly, Ile, Met but equivalent level in Tyr, whereas Arg, Asp, Ser, Glu, Pro, Ala, Cys, Val, Leu and Phe were better in cooked than raw; between raw and roasted, all the amino acid parameters were better concentrated in the raw groundnut seeds than the roasted. The most affected non-essential AA by the processing methods was Gly which was reduced between 25.0-38.6% whilst the most affected EAA was Met whose value was reduced between 38.0-63.4%.

Table 2. Differences in the amino acid profiles between raw and cooked, and between raw and roasted samples of groundnut seeds

Amino acid	Raw-cooked seeds	Raw-roasted seeds	Mean	SD	CV%
Lys	0.69 (15.9%)	1.20 (27.6%)	0.95	0.36	38.0
His	0.10 (4.23%)	0.39 (16.5%)	0.25	0.21	83.7
Arg	-0.61 (-10.1%)	1.03 (17.4%)	0.82	0.30	36.2
Asp	-1.61 (-17.7%)	0.66 (7.26%)	1.14	0.67	59.2
Thr	1.70 (40.1%)	2.57 (60.6%)	2.14	0.62	28.8
Ser	-0.16 (-4.73%)	0.72 (21.3%)	0.44	0.40	90.0
Glu	-0.80 (-5.37%)	1.70 (11.4%)	1.25	0.64	50.9
Pro	-0.78 (-22.1%)	0.76 (21.5%)	0.77	0.01	1.84
Gly	1.16 (25.0%)	1.79 (38.6%)	1.48	0.45	30.2
Ala	-1.01 (-27.4%)	0.70 (19.0%)	0.86	0.22	25.5
Met	0.54 (38.0%)	0.90 (63.4%)	0.72	0.25	35.4
Cys	-0.29 (-20.9%)	0.30 (21.6%)	0.30	0.01	2.40
Val	-0.12 (-2.61%)	0.70 (15.2%)	0.41	0.41	100
Ile	0.57 (13.3%)	1.36 (31.8%)	0.97	0.56	57.6
Leu	-0.91 (-12.1%)	0.77 (10.2%)	0.84	0.10	11.8
Phe	-0.89 (-18.9%)	0.50 (10.6%)	0.70	0.28	39.7
Tyr	0.00	0.71 (20.2%)	-	-	-
Protein	0.60 (2.07%)	2.1 (7.24%)	1.35	1.06	78.6

Table 2 shows cooking only affected four or 44.4% of the essential amino acids reducing them from the level of raw sample values; for non-essential amino acids, six or 75% of the amino acids were affected. For the roasted seeds, all the AA values were less than in the raw. The CV% was variously varied with a range of 1.84-100. All the AA were reduced from the raw from a percentage level of 0.00-63.4. Highlights of the reduction were (in percentage values): Lys (15.9-27.6), His (4.23-16.5), Thr (40.1-60.6), Met (38.0-63.4) and Ile (13.3-31.8). However, cooking enhanced some AA shown as follows (percentage enhancement): Arg (10.1), Asp (17.7), Ser (4.73), Glu (5.37), Pro (22.1), Ala (27.4), Cys (20.9), Val (2.61), Leu (12.1) and Phe (18.9). Of the total AA enhanced by cooking, four or 40% were EAA.

Nutritionally, little damage is said to be done during Maillard reactions unless the heat treatment causes the reaction to go beyond the deoxy-ketosyl stage. Then large amounts of Lys and Arg are destroyed and, to a lesser extent, tryptophan, cystine and histidine [Muller and Tobin 1980]. From the present result, roasting reduced the AA mentioned above as follows (values in percentage); Lys (27.6), Arg (17.4), Cys (21.6) and His (16.5). Worse than these four were Thr (60.6), Met (63.4) and Ile (31.8). Severe heat treatments at high temperatures cause isomerisation of amino acid residues. This involves the deamination reaction and formation of a carbanion, which after protonation

leads randomly to L or D forms. When the reaction is complete, a racemic mixture of the AA residue is obtained. Since most D-amino acids have no nutritional value, racemization of the residue of an essential AA thus reduces its nutritional value to about 50% [Principles... 1985]. Only L-amino acids have been obtained from animal and plant proteins under conditions that do not produce racemization [Principles... 1985]. This means that the present report could only be reporting the L-amino acid without the D-amino acid. Also, the loss of amino acid concentration from P-LCN to PCCS goes thus (g/100 g cp): Lys, 12.8 (78.7%); His, 0.73 (62.4%); Arg, 1.69 (36.6%); Thr, 0.72 (45.3%); Ile, 3.14 (49.6%); Cys, 0.45 (29.4%); Val, 36.8 (90.9%); Met, 0.06 (1.40%); Tyr, 0.15 (11.0%) and Phe, 0.70 (32.1%) [Adeyeye et al. 2010].

Table 3 shows the concentrations of total AA (TAA), total essential AA (TEAA), total acidic AA (TAAA), total neutral AA (TNAA), total sulphur AA (TSAA), total aromatic AA (TArAA) and their percentage values. The Leu/Ile ratios, their differences and percentage differences are contained in Table 3.

Table 3. Concentrations of essential, non-essential, acidic, neutral, sulphur, aromatic, etc. (g/100 g crude protein) of groundnut samples (dry matter of sample)

Amino acid	Raw seeds	Cooked seeds	Roasted seeds	Mean	SD	CV%
1	2	3	4	5	6	7
Total amino acid (TAA)	83.5	85.9	66.8	78.7	10.4	13.2
Total non-essential amino acid (TNEAA)	44.1	47.6	36.8	42.8	5.51	12.9
Total essential amino acid (TEAA)						
with His	39.4	38.3	30.0	35.9	5.14	14.3
no His	37.0	36.1	28.0	33.7	4.96	14.7
% TNEAA	52.8	55.4	55.1	54.4	1.42	2.61
% TEAA						
with His	47.2	44.6	44.9	45.6	1.42	3.12
no His	44.3	42.0	41.9	42.7	1.36	3.18
Total neutral amino acid (TNAA)	46.9	47.1	35.1	43.0	6.87	16.0
% TNAA	56.2	54.8	52.6	54.5	1.81	3.33
Total acidic amino acid (TAAA)	24.0	26.4	21.6	24.0	2.4	10.0
% TAAA	28.7	30.7	32.4	30.6	1.85	6.05
Total basic amino acid (TBAA)	12.6	12.4	10.0	11.7	1.45	12.4
% TBAA	15.1	14.5	15.0	14.9	0.32	2.16
Total sulphur amino acid (TSAA)	2.81	2.56	1.61	2.33	0.63	27.2



Table 3 – cont.

	1	2	3	4	5	6	7
% TSAA		3.36	2.98	2.41	2.92	0.48	16.4
% Cys in TSAA		49.5	65.6	67.7	60.9	9.96	16.3
Total aromatic amino acid (TArAA)		8.21	9.10	7.00	8.10	1.05	13.0
% TArAA		9.83	10.6	10.5	10.3	0.42	4.06
P-PER <sup>a</sup>		2.55	3.00	2.31	2.62	0.35	13.4
Leu/Ile ratio		1.76	2.28	2.32	2.12	0.31	14.7
Leu-Ile (diff.)		3.26	4.74	3.85	3.95	0.75	18.9
% Leu-Ile (diff.)		43.2	56.1	56.9	52.1	7.69	14.8
pI <sup>b</sup>		4.69	4.78	3.69	4.39	0.61	13.8
EAAI <sup>c</sup>		1.18	1.08	0.83	1.03	0.18	17.5

<sup>a</sup>Predicted protein efficiency ratio.

<sup>b</sup>Isoelectric point.

<sup>c</sup>Essential amino acid index.

The contents of TEAA of 39.4, 38.3 and 30.0 g/100 g crude protein (cp) without tryptophan were close to the value for egg reference protein (56.6 g/100 g cp) [Paul et al. 1976]; for soya bean, it is 44.4 g/100 g cp [Altschull 1968]. The TAA here (66.8-85.9 g/100 g cp) were close to the TAA in the dehulled African yam beans (AYB) with values of 70.3-91.8 g/100 g [Adeyeye 1997]. The contents of TSAA (1.61-2.81 g/100 g cp) were lower than the 5.8 g/100 g cp recommended for infants [FAO/WHO/UNU 1985]. The ArAA range suggested for ideal infant protein (6.8-11.8 g/100 g cp) [FAO/WHO/UNU 1985] has current values better than the minimum, i.e. 7.00-9.10 g/100 g cp.

The ArAA are precursors of epinephrine and thyroxin [Robinson 1987]. The percentage ratios of TEAA to TAA in the samples were 47.2%, 44.6% and 44.9% which were well above 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 egg (50%) [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 cylindrica* seeds [Olaofe et al. 2008].

Most animal proteins are low in Cys and hence in Cys in TSAA [Adeyeye 2005 a, b, Adeyeye and Adamu 2005, Adeyeye and Afolabi 2004, Adeyeye 2009]. In contrast many vegetable proteins contain substantially more Cys than Met, for example, 62.9% in coconut endosperm [Adeyeye 2004], thus particularly agreeing with the present report in cooked seeds (65.6%) and roasted seeds (67.7%). Information on the agronomic advantages of increasing the concentration of sulphur-containing amino acids in staple foods shows that Cys has positive effects on mineral absorption, particularly zinc [Mendoza 2002, Sandstrom et al. 1989].

The P-PER values were higher than 1.21 (cowpea), 1.82 (pigeon pea) [Salunkhe and Kadam 1989]; 1.62 (millet *ogi*) and 0.27 (sorghum *ogi*) [Oyarekua and Eleyinmi 2004]. The presence of D-isomers also reduces the digestibility of the protein, because peptide bonds involving D residues are less easily hydrolysed *in vivo* than those containing only L residues. Moreover, certain D amino acids exert a toxic action, in proportion to the amount absorbed through the intestinal wall [Principles... 1985]. This elucidates a word of caution on the excessive consumption of roasted groundnut seeds.

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 an amino acid imbalance from excess leucine might be a factor in the development of pellagra [FAO 1995]. Clinical, biochemical and pathological observations in experiments conducted in humans and laboratory animals showed that high leucine in the diet impairs the metabolism of tryptophan and niacin and is responsible for niacin deficiency in sorghum eaters [Ghafoorunissa and Narasinga Rao 1973]. High leucine is also a factor contributing to the pellagrigenic properties of maize [Belavady and Gopalan 1969]. These studies suggested that the leucine/isoleucine balance is more important than dietary excess of leucine alone in regulating the metabolism of tryptophan and niacin and hence the disease process. The present Leu/Ile ratios were low in value. The pI value range was 4.78-3.69. The pI of any organic matter is important when the protein isolate is to be prepared. The EAAI can be useful as a rapid tool to evaluate food formulations for protein quality. The EAAI for soy flour is 1.26 [Nielsen 2002] which is better than the current result of 0.83-1.18.

Table 4 shows that methionine had the lowest score among all the samples with values of 0.14 (raw seeds), 0.28 (cooked seeds) and 0.16 (roasted seeds). To correct for the AA needs from the samples, it becomes 100/14 or 7.14 times as much raw seed protein, 100/28 or 3.57 times as much cooked seed protein and 100/16 or 6.25 times as much roasted protein to be taken (eaten) when they are the sole protein in the diet [Bingham 1977].

In Table 5 Lys had the lowest essential amino acid score (EAAS) of 0.79 (79%) in raw seeds, Thr in both cooked and roasted seeds with respective EAAS of 0.64 (64%) and 0.42 (42%). The essential amino acid scores (EAAS) in Table 5 shows that Lys was limiting in raw seeds and would need a correction of 100/79 or 1.27, Thr in cooked seeds with 100/64 or 1.56 and Thr in roasted seeds with 100/42 or 2.38 corrections.

Table 6 shows that Lys (0.75, 75%) was the EAAS in raw and 0.63 (63%) in cooked seeds whereas EAAS was Thr (0.49, 49%) in roasted seeds. Table 6 shows that the samples would be able to supply more than the required EAA for the pre-school child as shown by their EAAS. For the raw groundnut seeds only Lys would supply less than 100% requirement and would supply 75% which can be corrected by 1.33; in the cooked seeds both Lys (0.63) and Thr (0.75) would supply less than 100% but the correction would come through Lys with a multiplying value of 1.59; in roasted seeds, Lys (0.54), Met + Cys (0.64) and Thr (0.49) would supply less than 100% requirement, however, since Lys is the first limiting amino acid [Bingham 1977] it would be the AA to be corrected for the requirement with a correction value of 1.85.

The summary of the amino acid profiles into factors A and B in Table 7 shows that Factor A means ranged from 33.4 (roasted) to 43.0 (cooked) and Factor B means ranged from 35.9 to 42.8.

Table 4. Amino acid scores of the groundnut seeds samples based on whole hen's egg amino acid

Amino acid	Raw seeds	Cooked seeds	Roasted seeds	Mean	SD	CV%
Lys	0.70	0.59	0.51	0.60	0.10	15.9
His	0.98	0.94	0.82	0.91	0.08	9.15
Arg	0.97	1.07	0.80	0.95	0.14	14.4
Asp	0.85	1.00	0.79	0.88	0.11	12.3
Thr	0.83	0.50	0.33	0.55	0.25	46.2
Ser	0.43	0.45	0.34	0.41	0.06	14.3
Glu	1.24	1.31	1.10	1.22	0.11	8.76
Pro	0.93	1.13	0.73	0.93	0.20	21.5
Gly	1.55	1.16	0.95	1.22	0.30	25.0
Ala	0.68	0.87	0.55	0.70	0.16	23.0
Cys	0.77	0.93	0.61	0.77	0.16	20.8
Val	0.61	0.63	0.52	0.59	0.06	9.93
Met	0.14	0.28	0.16	0.19	0.08	39.9
Ile	0.76	0.66	0.52	0.65	0.12	18.5
Leu	0.91	1.02	0.82	0.92	0.10	10.9
Tyr	0.88	0.88	0.70	0.82	0.10	12.7
Phe	0.92	1.10	0.82	0.95	0.14	14.9

Table 5. Essential amino acid scores of the groundnut seeds samples based on FAO/WHO (1973) standards

Amino acid	Raw seeds	Cooked seeds	Roasted seeds	Mean	S.D	CV%
Ile	1.07	0.93	0.73	0.91	0.17	18.8
Leu	1.08	1.21	0.97	1.09	0.12	11.0
Lys	0.79	0.66	0.57	0.67	0.11	16.5
Met + Cys	0.80	0.73	0.46	0.66	0.18	27.2
Phe + Tyr	1.37	1.52	1.17	1.35	0.18	13.0
Thr	1.06	0.64	0.42	0.71	0.33	46.0
Try	–	–	–	–	–	–
Val	0.92	0.94	0.78	0.88	0.09	9.91
Total	1.03	0.99	0.77	0.93	0.14	15.1

Table 6. Essential amino acid scores of the groundnut seeds samples based on requirements of pre-school child (2-5 years)

Amino acid	Raw seeds	Cooked seeds	Roasted seeds	Mean	SD	CV%
Ile	1.53	1.33	1.04	1.30	0.25	23.7
Leu	1.14	1.28	1.03	1.15	0.13	10.9
Lys	0.75	0.63	0.54	0.64	0.11	16.5
His	1.24	1.19	1.04	1.16	0.10	8.97
Met + Cys	1.12	1.02	0.64	0.93	0.25	27.2
Phe + Tyr	1.30	1.44	1.11	1.28	0.17	12.9
Thr	1.25	0.75	0.49	0.83	0.39	46.5
Try	–	–	–	–	–	–
Val	1.31	1.35	1.11	1.26	0.13	10.2
Total	1.17	1.13	0.88	1.06	0.16	14.8

Table 7. Summary of the amino acid profiles into factors A and B

Amino acid composition	Groundnut seeds (Factor A)			Factor B means
	Raw	Cooked	Roasted	
Total essential amino acid	39.4	38.3	30.0	35.9
Total non-essential amino acid	44.1	47.6	36.8	42.8
Factor A means	41.8	43.0	33.4	39.4

Table 8. Statistical summary of the data in Tables 1-6

Table	Parameter	$r_{xy}$	$r_{xy}^2$	$R_{xy}$	X	Y	$C_A$	IFE	Remark
1	Rs/Cs	0.9914	0.98	0.09	6.25	6.35	14.1	85.9	*
	Rs/Rt.s	0.9962	0.99	-0.74	6.25	5.20	1.00	99.0	*
2	Rs-Cs/Rs-Rt.s	0.4855	0.24	0.61	0.70	1.05	87.2	12.8	*
3	(pI)Rs/Cs	0.9568	0.92	-2.07	27.6	28.1	28.3	71.7	*
	Rs/Rt.s	0.9655	0.93	-2.79	27.6	21.7	26.5	73.5	*
4	Rs/Cs	0.8305	0.68	0.20	0.83	0.85	55.7	44.3	*
	Rs/Rt.s	0.8691	0.76	0.08	0.83	0.65	24.0	76.0	*
5	Rs/Cs	0.8207	0.67	-0.39	1.02	0.95	57.4	42.6	*
	Rs/Rt.s	0.7519	0.57	-0.31	1.02	0.73	65.6	34.4	*
6	Rs/Cs	0.7106	0.50	-0.01	1.20	1.12	70.7	29.3	*
	Rs/Rt.s	0.5991	0.36	0.01	1.20	0.88	80.0	20.0	NS

Rs – raw sample, Cs – cooked sample, Rt.s – roasted sample,  $R_{xy}$  – linear correlation coefficient,  $R_{xy}^2$  – coefficient of determination,  $R_{xy}$  – linear regression coefficient,  $C_A$  – coefficient of alienation, IFE – index of forecasting efficiency, \* – significant  $r_{=0.05}$  at n-2 degrees of freedom, NS – not significant at  $r_{=0.05}$ .

Table 8 depicts the statistical summary of the data in Tables 1-6. The  $r_{xy}$  levels were mostly positively high (0.4855-0.9962) whereas the  $R_{xy}$  ranged between -2.77 to 0.61. All the  $r_{xy}$  values were significant except one at  $r_{=0.05}$  and  $n-2$  degrees of freedom. The coefficient of alienation ( $C_A$ ) ranged from 1.00-87.2% whereas the corresponding index of forecasting efficiency (IFE) ranged between 12.8-99.0%.

Table 8 is actually a comparative analysis between raw seeds/cooked seeds (Rs/Cs) and between raw seeds/roasted seeds (Rs/Rt.s). Let us look at the results from Table 1. The Rs/Cs (serial no 1, Table 8), shows the  $r_{xy}$  as a high positive value (0.9914),  $r_{xy}^2$  (coefficient of determination) of 0.98, had an  $R_{xy}$  of 0.09 meaning that for every one unit increase in the raw seeds amino acid value, there was a corresponding increase of 0.09 in the cooked seeds; for the coefficient of alienation ( $C_A$ ), the value of 14.1 was low whereas the index of forecasting efficiency (IFE) was high at 85.9 meaning that the forecasting of relationship was high. The IFE is actually the reduction in the error of forecasting efficiency; the higher the IFE, the lower is the error in the forecasting efficiency. For Rs/Rt.s, all these were high;  $r_{xy}$ ,  $r_{xy}^2$  and IFE, both  $R_{xy}$  and  $C_A$  was low. For  $C_A$  of 1.00, it made the IFE high thereby giving a reduction of 99.0% in the error of prediction of relationship between raw seeds and roasted seeds amino acid profiles. The  $R_{xy}$  of -0.74 showed that for every one unit increase in the amino acid level of raw groundnut seeds, there was a reduction of 0.74 in the roasted seeds. This type of reasoning goes down through the results in serial numbers 1-6.

## CONCLUSIONS

Groundnut flour is used as food in soup or stew, confectionaries, puddings, bakery products and in various other ways for human consumption. The flour is being used increasingly to fortify or supplement such carbohydrate foods as cassava flour (*gari*), maize and yam flour to raise their content of protein for the use of infants and children and other vulnerable groups. The World Health Organisation recommended Val and Ile requirements for school children aged 10-12 years, of 33 and 30 mg amino acid/kg body weight/day [FAO/WHO/UNU 1985, FAO/WHO 1973]. For example, a 30 kg child will require 990 and 900 mg of Val and Ile per day. The protein for the groundnut seed samples (from proximate composition, g/100 g) were 29.0 (raw), 28.4 (cooked) and 26.9 (roasted) all on dry extract basis. Consumption of 100 g raw seeds would provide about 1334 mg, cooked seeds gave 1340 mg and roasted gave 1049 mg (all for Val); for Ile, it would be 1241 mg (raw), 1054 mg (cooked) and 785 mg (roasted). If a 30 kg child therefore consumes 100 g of raw groundnut seeds per day, his FAO/WHO requirements of Val and Ile would be met by 135% and 138% respectively; for cooked seeds it would be 135% (Val) and 117% (Ile) and for roasted groundnut seeds it would be 101% (Val) and 87.2% (Ile). On the whole, on the critical areas specially considered like TAA, TEAA, P-PER, EAAI, amino acid scores (AAS) based on whole hen's egg, based on scoring pattern, and based on suggested requirements for pre-school child (2-5 years old), in these seven parameters, raw seeds were best in four or 57.1% and cooked seeds were best in three or 42.9% while roasted groundnut seeds were always last in each parameter. Raw groundnut seeds are recommended in complementing cereals for weaning foods, followed by cooked seeds but not roasted seeds.

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## WPLYW GOTOWANIA I PIECZENIA NA SKŁAD AMINOKWASOWY ORZECHÓW ZIEMNYCH (*ARACHIS HYPOGAEA*)

**Wstęp.** Orzechy ziemne są produktem o bardzo dużej gęstości energetycznej ze względu na dużą zawartość tłuszczu i białka. Jeden gram orzeszków zapewnia aż 6,03 kcal (25,2 kJ), gdy czysty cukier trzcinowy to 5 kcal (16,7 kJ), biały ryż – 3,5 kcal (15,6 kJ), a mąka kukurydziana to 2,7 kcal (11,3 kJ). Mączka z orzechów ziemnych zapewnia 2,7 kcal (11,3 kJ) i jest używana powszechnie jako dodatek do zup i potraw z duszonym mięsem i warzywami, w produkcji piekarniczej, w produkcji budyniów i wielu innych produktach żywnościowych. Dlatego ważne jest poznanie jej wartości odżywczej i składu, szczególnie aminokwasowego.

**Material i metody.** Do analiz użyto około 1 kg orzechów ziemnych bez łuski. Orzechy wysuszono i podzielono na trzy grupy: jedna była analizowana na surowo (Rs), druga została ugotowana (Cs), a trzecia upieczona (Rt.s). W celu ich odfuszczenia zastosowano typową metodę analityczną z wykorzystaniem roztworu chloroform/metanol (2:1), który był używany jako rozpuszczalnik. Do analizy aminokwasów wykorzystano metodę chromatografii jonowej, używając analizatora aminokwasów Technicon Sequential Multisample (TSM). Do oceny jakości białka użyto metod: wydajności wzrostowej białka P-PER, wskaźnika aminokwasowego Osera (EAAI) oraz punktu izoelektrycznego (pI). Przeprowadzono analizę statystyczną wyników.

**Wyniki.** Całkowita zawartość aminokwasów wynosiła (g/100 g białka ogółem): Rs – 83,5, Cs – 85,9, Rt.s – 66,8, w tym aminokwasów egzogennych odpowiednio: od 39,4 do 47,2% (Rs), od 38,3 do 44,6% (Cs) i od 30,0 do 44,9% (Rt.s). Współczynnik P-PER wynosił: 2,55 (Rs), 3,00 (Cs) i 2,31 (Rt.s), a wskaźnik aminokwasu egzogennego: 1,18 (Rs), 1,08 (Cs) i 0,83 (Rt.s). Gotowanie zwiększało poziom Asp, Ser, Glu, Pro, Arg, Ala, Cys,

Val, Leu i Phe. Aminokwasy były redukowane przez gotowanie i pieczenie odpowiednio: Lys (15,9-27,6%), His (4,23-16,5%), Thr (40,1-60,6%), Met (38,0-63,4%) i Ile (13,3-31,8%). Wszystkie różnice pomiędzy orzechami surowymi i gotowanymi oraz większość różnic pomiędzy orzechami surowymi i pieczonymi były istotne statystycznie ( $p < 0,05$ ).

**Wnioski.** Przetwarzanie orzechów ziemnych ma negatywny wpływ na zawartość i jakość aminokwasów. Zawartość białka wynosiła odpowiednio: 29,0 g/100 g w orzechach surowych, 28,4 g/100 g w orzechach gotowanych i 26,9 g/100 g w orzechach pieczonych. Dziecko o masie 30 kg, spożywające 100 g orzechów ziemnych dziennie, zrealizowało by 135% normy FAO/WHO Val i 138% Ile, dla gotowanych orzechów byłoby to odpowiednio 135% (Val) i 177% (Ile), a dla pieczonych – 135% i 117%. Orzechy ziemne mogą być rekomendowane jako dodatek do produktów zbożowych w żywieniu początkowym. Jeżeli istnieje konieczność poddawania ich zabiegom kulinarnym, jest zalecane ich gotowanie, a nie pieczenie.

**Słowa kluczowe:** orzeszki ziemne, aminokwasy, gotowanie, pieczenie

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