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CHARACTERIZATION OF THE EFFECT OF MODULATED DRY HEAT PROCESSING CONDITIONS ON ESSENTIAL AND NON ESSENTIAL AMINO ACID PROFILE OF UNSEASONED BREADFRUIT (V. DECNE) SNACK SEEDS

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Abstract:
The objective of this study was to determine the functional relationship between Roasting temperature (RT), Roasting time (RM) and Feed quantity (FQ) and the yield of all essential and non-essential amino-acids obtainable through modulated roasting of breadfruit seeds harvested from undomesticated breadfruit tree. Roasted seeds of breadfruit (V. Decne) consumed as snacks represent an important source of protein/amino acids needed for good health in humans. However, these amino acids are needed in certain levels in order to achieve their metabolic usefulness. Processing methods influence their useful concentrations. Central Composite Design at 3 process variables (RT, RM, FQ) and 5 levels (-1.682, -1, 0, 1, 1.682) was used for the experimental runs. Amino acid assay was conducted and the results obtained from experimentation were statistically analyzed. Similar amino-acids but in different contents were present both in raw and roasted seeds. Roasting temperature, time and feed quantity were significant ($p < 0.05$) terms in the models which influenced the quantum of amino acid, either in linear, squared or interactive terms. Cysteine and methionine showed some heat stability. Other non-essential amino acids were observed at concentration range of 0.29 g to about 7.0 g. Tryptophan was not detected at temperatures higher than a hundred and forty degrees Celsius. The predicted optimum total of amino acids of roasted seed samples was 66.02 % of the total amino acids of the control. The predicted values for optimum process condition were in good agreement with experimental data. Hence, roasting of breadfruit seeds for snacking at the identified optimum variable combination will supply safe and recommended daily levels of amino acids in humans.

Keywords: *breadfruit seeds, roasting, essential, non -essential amino-acids.*

1. Introduction

In Nigeria, breadfruit (v.Decne) seeds are consumed in roasted forms as snacks. The roasted snack seeds are popular convenient snacks among travellers and commuters or when packaged in bottles shared as social gifts. Roasted breadfruit (V. *decne*) seeds is an important source of protein/amino acids for consumers. The reported amino acids of breadfruit and other legume seeds include alanine, arginine, aspartic acid, glutamic acid, cysteine, glycine, histidine, isoleucine, leucine, lysine, methionine phenylalanine, proline, serine, threonine, tyrosine,tryptophan and valine [1,2].

Histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine and valine are essential amino acids that must be provided in the human diets for metabolic development, immune boosting, neurotransmission, fertility, inhibition of reactive oxygen species, anti-inflammation etc. [3.4.5.6.7]. Only methionine, cysteine and tryptophan are limited in most legumes including breadfruit seeds [8]

Other studies that explored the extraction and composition of breadfruit seeds [8,9] reported important health nourishing nutrients of breadfruit seeds. The protein content of breadfruit (v. Decne) is comparable to other legumes [10]. Breadfruit seeds maybe seasoned with salt or spices before roasting. Usually the seeds are roasted without being hulled. After roasting the breadfruit seeds are consumed as snacks. Traditional roasting of legume seeds and nuts for snacking takes about 30-40 min at very high temperatures with obvious deleterious effect on the nutrients [11]

The outcome of processing treatments are influenced by the processing parameters of temperature, time, heat transfer rates, moisture content, seed chemistry, seed physics, processors skill etc. [12,13].

Previous studies focused more on parboiled seeds with little attention on roasted seeds. Studied of Iwe and Ngoddy [12] and Nwabueze [13] successfully optimized the process conditions nutritive properties of parboiled breadfruit (v.Decne) seeds but no such magnitude of research efforts on dry heat processing are recorded for roasted seeds. This suggests that consumers of roasted seeds may be accessing low nutrients.

As the global food trend tilts towards convenience food, emphasis is put now on roasted high energy density convenient snacks such as roasted breadfruit seeds, groundnuts, almonds etc. More studies are needed to determine optimum process variable combination for enhanced yield of amino-acids and other health promoting factors of roasted breadfruit seeds consumed as snacks.

Heat treatment improves protein digestibility, amino acid availability in diets [14,15, 16], reduces the amino acids content of our diet to levels that are non-toxic in humans [17,18]. As most safe levels of amino acids fall within 5g-10g/ day [19], it is important to determine the processing points of convergence as processing variable optima between safety and critical needs of amino acids from roasted breadfruit (v. Decne) seeds consumed as snacks. For instance, essential amino acids such as methionine, histidine and cysteine which are very toxic to human in higher concentrations and they could be modified to tolerable and useful levels by roasting. Roasting though leads to denaturation and decomposition of amino acids, still it remains an indispensable food processing operation for the production of roasted breadfruit snack seeds.

This study was designed as an evolving study carried out to determine and characterize the process variable combinations for optimum dry heat processing spectrum and yield of essential and non-essential amino acids in the roasting of breadfruit seeds by using overall desirability approach.

Desirability function approach is used to transform multi- responses problem into a single response objective function (overall Desirability) by means of mathematical transformation. Overall desirability approach has been successfully applied in many optimization studies [20]. It involves the optimization of the desired product quality within conflicting operational process variables in the processing region. ([21]. The results of this study are envisaged as a guide to breadfruit seed processors for the production of safe and nutritionally adequate levels of amino acids in roasted breadfruit snack seeds.

2. Materials and methods

Collection of materials

Freshly pulped seeds of breadfruit (V. Decne) were provided from undomesticated breadfruit tree growing in Umudike, Nigeria. The seeds were screened for stones, sands, debris etc, washed with portable water and dried under shade at 28±4^{0}C for 34 hours. Seeds were not seasoned with salt or spices for flavour.

Experimental Design

The central composite Rotable Design was used for the study. Three (3) variables 5 levels experimental layout at 8 factorial, 6 axial and 6 replications at the centre (Table 1) were employed. Effects of roasting temperature, roasting time and feed quantity on amino acids content of roasted seeds were examined. Definition of operational variables were carried out by using Minitab statistical software version 15.

The input variable values were chosen based on the information in literature and reasonable enough to accommodate statistically valid deductions [22]. The range and values at star, axial and center points were calculated using the equation (1) as outlined in Table 2

$$x_1 = \underline{x_i - x_{10}} \qquad (1)$$

Where x_1= Independent variable code value

x_i= Independent variable actual value

x_{io}= Independent variable actual value of centre point

= Step change value

Experimental Roasting of samples

The unseasoned seeds (samples) were roasted in electric oven (Fishers Scientific Co. UK) according to the experimental layout. The roasted seeds are cooled, hulled using a locally fabricated huller. The roasted hulled seeds are edible snacks. For amino acid assays, the hulled seeds were milled and sieved into flour using a 200mm mesh. The flour samples were placed in sterilized plastic bowls, appropriately labeled and stored at ambient 28 ± 2^{0}C) temperature before use.

Table 1

Central Composite Rotable Design

Code Variables			**Combination**	**Replications**	**Experiments**
X_1	**X_2**	**X_3**			
±1	±1	±1	8	1	8
±1.682	0	0	2	1	2
0	±1.682	0	2	1	2
0	0	±1.682	2	1	2
0	0	0	1	6	6

Table 2

Range and Levels of Experimental Runs

	Codes	**-1.682**	**-1**	**0**	**1**	**1.682**
Roasting Temperature RT (^{0}C)	X_1	123.36	140	160	180	193.64
Roasting Time RM (min)	X_2	31.59	35	40	45	48.4
Feed Quantity FQ (g)	X_3	331.80	400	500	600	668.2

Determination of amino- acid profile:

The amino-acids profile of raw and roasted breadfruit flour were determined using the method described by [23, 24]. The samples were dried to constant weights in oven, defatted, hydrolyzed, and then evaporated using rotary evaporator. Thirty milligrams of each sample were mixed with 7ml of ***HCl*** in a glass ampoule. Oxygen was expelled from the mixture by passing nitrogen into the ampoule. The glass ampoule was heat sealed using a Bunsen burner flame and placed in an oven (105^{0}C) for 22 hours. After heating, the glass ampoules were let to cool, the tip was opened and the content was filtered. The filtrate was evaporated to dryness using rotary evaporator at 40^{0}C.

The residue was dissolved in 5ml acetate buffer (pH. 2.0) and stored in refrigerator using plastic bottle. 5-10 microliters of each sample were placed in amino-acid cartridge and loaded into amino- acid analyzer. The TSM analyzer separated and analyzed the amino-acids in samples. The data generated from the Technicon Sequential Multi-sample analyzer were quantitatively determined against the standard Technicon auto analyzer (No 011-648-0) chart.

Statistical analysis of results

Data of the study were analyzed and presented as tables. For statistical evaluation, data of study were analyzed using Minitab statistical software (version 15 of Minitab Inc.Pen. USA) which described the optimized global setting for input variables and predicted optimum yield of amino acids at 0.0 - 1.0 desirability bar. The effect of roasting condition on amino acids of breadfruits was described in regression terms by

$$+ \qquad (2)$$

Where Y= response, β_0 = intercept, xiji= Independent variables, e=error

Maximization of the fitted models was performed using unified goals with defined (0.1-1.0) limits. Adequacy of models was defined by co-efficient of determination R^2 and adjusted R^2. The significant ($p<0.05$) variables were identified and their effects described in Linear, squared or cross product terms. The coefficients of determination were complemented with their adjusted values and Standard error of estimate S in judging the adequacy of fitted models.

3. Results and Discussion

Adequacy of regression models of amino acids

The co-efficient of determination R, adjusted R^2 and standard error of estimate **s** were adequate to predict the variability in amino acid content of the processed breadfruit snack seeds. The co-efficient of determination of R^2 ranged from70% to 95% and all adjusted R^2 values were above 65%. All S values indicated that data points were 0.23 to 1.16% of the fitted line and less than 7% which statistically satisfied the prediction intervals. Significance ($p=0.5$) of input process variables X are described in linear, squared and interaction terms.

The amino acid profile of the processed breadfruit seeds flour is shown in Table 3. All amino acids in the control were contained in the processed flour samples in varying proportions. The amino acids identified were: histidine, isoleucine, leucine, lysine, methionine, phenylalanine, cysteine, threonine, aspartic acid, glutamic acid, glycine, proline, serine, threonine, tyrosine, tryptophan, arginine and valine. The values of all the amino acids analyzed progressively reduced as the roasting temperature, roasting ***duration*** and mass were extended simultaneously from 140^{0}C, 160^{0}C and 180^{0}C to 31.59 min, 53 min, 40 min , 45 min, 48 min and 331.80g. 400g, 500g, 600g 668.20g for roasting temperature, roasting time and feed quantity, respectively.

Table 3

Amino acid profile of processed samples (g/16 gN)

S/N	**Essential amino acids** **Experimental Runs**	**H**	**Is**	**Iu**	**Ly**	**Me**	**Ph**	**Th**	**Tp**	**Va**
1	140^{0}C/35m/400g	2.23	2.90	5.70	4.18	0.73	3.99	2.70	Trace	3.18
2	140^{0}C/35m/600g	2.25	3.01	6.00	4.27	0.75	4.05	2.73	Trace	3.25
3	140^{0}C/45m/400g	2.00	2.89	5.10	3.11	0.70	3.80	2.57	ND	3.04
4	140^{0}C/45m/600g	2.03	2.77	5.15	4.00	0.71	3.89	2.57	ND	3.10
5	180^{0}C/35m/400g	1.80	1.70	4.03	3.30	0.60	3.20	2.21	Trace	3.05
6	180^{0}C/35m/600g	1.82	1.77	4.33	3.21	0.61	3.50	2.33	ND	3.90
7	180^{0}C/45m/400g	1.10	2.30	3.46	2.88	0.55	3.86	2.10	ND	2.96
8	180^{0}C/45m/500g	1.50	2.38	3.59	2.91	0.57	3.39	2.01	ND	2.95
9	126^{0}C/40m/500g	2.29	3.11	4.16	3.87	0.81	3.90	1.81	Trace	2.90
10	19364^{0}C/40m/500g	1.00	1.30	2.79	2.16	0.43	2.64	1.14	ND	2.03
11	160^{0}C/31.59m/500g	2.30	3.11	7.53	3.64	0.69	3.47	2.71	ND	2.97
12	160^{0}C/48.41m/500g	1.19	2.05	3.60	2.51	0.61	3.10	2.55	ND	2.90
13	160^{0}C/40m/331.80g	2.13	2.11	3.37	3.00	0.59	3.05	1.95	ND	2.47
14	160^{0}C/40m/668.20g	2.16	2.49	3.66	3.81	0.65	3.59	2.69	ND	2.95
15	160^{0}C/40m/500g	2.20	2.28	3.49	3.49	0.63	3.35	2.31	ND	2.59
	Control	3.16	3.60	6.8	7.10	1.53	6.10	3.22	0.4	4.5

S/N	**Non-Essential** **Experimental Runs**	**Al**	**Ar**	**As**	**Cy**	**Gl**	**Gy**	**Pr**	**Sr**	**Ty**
1	140^{0}C/35m/400g	2.66	5.58	6.00	1.50	8.10	3.97	2.00	3.63	2.35
2	140^{0}C/35m/600g	3.01	5.62	6.10	0.95	8.20	4.05	2.53	3.30	2.41
3	140^{0}C/45m/400g	2.35	5.15	5.58	0.90	7.71	3.93	2.30	3.56	2.25
4	140^{0}C/45m/600g	2.33	5.10	5.91	0.95	7.60	4.00	2.41	2.30	2.17
5	180^{0}C/35m/400g	2.07	4.60	5.40	0.90	6.70	3.41	2.37	2.41	2.07
6	180^{0}C/35m/600g	2.17	4.71	5.70	0.91	6.48	3.53	2.39	2.37	1.99
7	180^{0}C/45m/400g	1.85	4.14	5.30	0.80	6.00	2.91	2.30	2.30	2.10
8	180^{0}C/45m/500g	1.88	4.25	5.35	0.88	6.16	2.94	2.29	2.28	1.71
9	126^{0}C/40m/500g	2.05	4.77	5.99	0.90	7.60	3.99	3.01	3.01	2.51
10	19364^{0}C/40m/500g	1.80	3.25	3.01	0.45	5.13	2.21	1.21	1.20	1.07
11	160^{0}C/31.59m/500g	2.04	4.90	5.90	0.80	7.61	3.19	2.60	2.60	2.41
12	160^{0}C/48.41m/500g	1.19	3.90	3.89	0.65	5.88	3.00	2.67	2.66	2.07
13	160^{0}C/40m/331.80g	1.85	3.17	3.96	0.71	6.40	3.01	2.21	2.23	1.97
14	160^{0}C/40m/668.20g	1.90	3.53	4.01	0.75	6.72	3.10	2.33	2.33	2.13
15	160^{0}C/40m/500g	2.01	3.28	3.99	0.73	6.88	3.20	2.27	2.27	2.01
	Control	4.5	9.86	11.01	2.00	19.50	5.15	4.00	5.10	3.5

Key *H = Histidine, Is= Isoleucine, Lu = Leucine, Ly = Lysine , Me = Methionine, Ph = Phenylalaine, Th = Threonine, Tp = Tryptophan, Va = Valine; Al= Alanine; Gy = Glycine; Tyrozine, Ag =Arginine; As= Aspartic acid; Cy = Cysteine, Gl = Glutamic acid, Pr = Proline, Sr = Serine; Ty = Tyrosine*

Effect of processing variable of amino acid of roasted breadfruit seeds

Basic amino acids (basic side chains at neutral pH)

Histidine content of processed sample ranged from 1.0 to 2.29g/16N. Roasting temperature had significant effect on the contents of histidine and accounted for 95% variations in histidine content. Increases in temperature resulted in loses of histidine. The maximum (68.35%) loss occurred at 193.640C with less than 50% of such losses occurring below 160^0C. The author [25] reported a lesser reduction of 16.5% for roasted groundnuts at similar temperature.

The relationship between histidine content and process variables is described by equation 3.

$$His = 16.8033 + 0.153\ X_1 - 0.005X_1^2 - R^2\ (0.90) \qquad (3)$$

Lysine content in processed samples ranged from 2.16 to 4.18g. Lysine content of control was 7.10g/16g N. Roasting condition was responsible for 90% per unit change of lysine of processed seeds. Simultaneous increases in roasting temperature, time and feed quantity resulted in losses of lysine with a maximum (60.42%) loss observed at 193.64°C at 45min mark. The presence of the highly reactive 6-HN2 group of lysine may be responsible for observed reductions in lysine value. Drawing from the significant terms the relationship between processed variables and lysine content of samples can be written as:

$$Lys = 5.650 + 0.0418X_1 – 0.1142X_2 – 0.030X_3 – 0.023X_1X_2 - R^2\ (0.90) \qquad (4)$$

The content of arginine in the processed seed samples, varied between 3.17 to 5.62g/16g N which represents about 32 – 57.35% of the value of control. About 70.94% variation in arginine content was attributable to their roasting condition. However, no significant ($p>0.05$) effect of roasting variables on arginine was observed.

Acidic amino-acids (Acid side chains at neutral pH)

Aspartic acid loss of processed seeds was 50% of its original content in control. The maximum loss in value of aspartic acid occurred at the extreme (193.64%) temperature. All roasting variables showed no significant effect on aspartic acid content of roasted breadfruit seeds.

Glutamic acid was observed to be heat susceptible with losses as much as 66.0% of its initial value in raw samples (19.50g/16g N) at 120^0C -140^0C. However, as it was observed with aspartic acid, roasting condition did not significantly reduce glutamine acids. The most probable reason could be an inherent ability of certain amino acids to inhibit the Maillard reactions.

Hydroxyl- containing amino acids

Threonine content of roasted seeds was influenced by the processing conditions. Though relatively heat stable at low temperature, threonine showed significant reductions at 160^0C. Threonine content in roasted seed sample ranged from 1.14g to 2.81g compared with 3.22g/16g N of control. The significant effect of roasting temperature and time on threonine can be described using the equation.

$$Thre = 6.4176 – 0.0642X_1 – 0.3954X_2 - (R^2)\ (0.85) \qquad (5)$$

Increasing roasting temperature and time significantly influenced threonine content by about 50%.

Serine content in roasted breadfruit seeds showed losses attributable to roasting variable conditions. Computed loss variations showed a spread of between 1.47g to 3.9g/16g N, from 123^0C to 193.64^0C, respectively.

Branched chain amino acids
Isoleucine content of roasted breadfruit seed samples was between 1.30 and 3.11g/16gN. After processing isoleucine content varied from 13. 61% to 63.88% of control value (2.60g/16g N). The range of losses of isoleucine in roasted breadfruit seeds was comparable with the reports on groundnuts (25) and Luffa seeds [26]. The roasting variables showed linear and interactive effects on isoleucine as:

$Iso = 26.8837 – 1.0131X_1 – 0.6994X_2 – 0.0580X_3 + 0.0185X_1X_2$- .$R^2$ (0.83) (6)

Leucine was relatively more heat liable than Isoleucine. Maximum loss (4.01g) occurred at 193.64^{0}C which showed the rate of change as each unit change of process variable reflecting 72% variability in leucine content of roasted samples. The significant relationship between leucine and process variables is expressed using equation 7, as:

$Leu = 62.3574 – 0.2441X_1 – 1.5157X_2 – 0.0188X_1X_2$- R^2 (0.72) (7)

Neutral non polar amino-acids
Valine losses in roasted seeds were between 35.55% and 54.89%. It was observed that increases in roasting temperature and time simultaneously resulted in reduction of valine content of samples. Roasting temperature and time significantly influenced valine content in a manner described by the equation:

$Val = 24.9529 – 0.0489X_1 – 0.7546X^2 + 0.0550X_1X_2$- R^2 (0.79) (8)

Alanine and glycine contents of roasted breadfruit seeds responded similarly to the effect of processing variables.

Alanine in samples was reduced to about 43.5% at temperature range of 160^{0}C and 180^{0}C, respectively. Roasting variables of temperature, time and feed quantity did not significantly influence alanine contents of seed samples.

Aromatic amino acids
Phenylalanine content in roasted seeds was influenced by roasting variables. The relationship between contents of phenylalanine with roasting temperature, time and feed quantity using significant terms can be described by equation 9, as:

$Phy = 19.3587 – 0.0919X_1- 0.2623X_2 – 0.850X_3 + 0.290X_1X_2$- R^2 (0.78) (9)

Increases in roasting temperature and time resulted in linear, quadratic and interactive effects. The linear and quadratic effect occurred below 160^{0}C. Above 160^{0}C the model described an interactive effect between the roasting variables. A maximum loss of 56.72% occurred at 193.64%.

Tyrosine content of control was 3.5g/16g N. After roasting tyrosine values were between 1.0 and 2.5g with a maximum loss at 193.64^{0}C. Tyrosine values of roasted seeds were related to processing conditions without observing any significant influence of roasting temperature, time and mass on the tyrosine content. The range of losses of tyrosine in breadfruit as observed by this study is in agreement with the findings of Passmore and Eastwood [27] in legumes.

Heterocyclic amino acids
Tryptophan content of raw unprocessed seeds was 0.4g/16g N, but it was undetected at processing temperatures above 123.64^{0}C. Though breadfruit seeds are low in tryptophan, the rapid reduction observed for roasted breadfruit seeds could be due to the highly reactive NH-group of the inidole ring of tryptophan [28].

Proline content of processed samples ranged from 1.21g to 4.9g/1.6gN (control). Proline values were related to treatment conditions but they were not significantly (p>0.05) influenced by any processing variable (Temperature, time and feed quantity). Maximum loss (75.30%) of proline occurred at 193.64^{0}C. Proline was more heat sensitive than histidine.

Sulphur-containing amino acid

Methionine contents of processed seed flour samples were influenced by roasting temperature and time. The loss variations of methionine depicted heat stability with content of processed seeds ranging from 0.81 to 1.53g/16g N of control. The summarization of the effects of roasting temperature and time using significant terms results in the equation 10 as:

$$Meth = 2.3326 - 0.0534X_1 - 0.4203X_2 - 0.0330X_1X_2 - R^2\ (0.93) \qquad (10)$$

Increase in roasting temperature and time sequence resulted in initial linear effect up to 140^{0}C. The observed square effect above that temperature was probably due to the sustained oxidation of sulphur fraction of methionine [28]. The result contrasted with the reported ones for methionine during roasting of legumes [29].The cysteine content of control was 2.0g/16g N. After roasting the cysteine content ranged between 0.45 and 1.50g which showed a loss range of 33.04% to 67.12% of cysteine at extreme conditions of 140°C to193.64°C. The results comply with the heat stability of cysteine up to 160^{0}C and plausible for the fact that cysteine is limited in legumes. Although the roasting variables had no significant effect on cysteine values of processed seeds, they significantly influenced similar sulphur containing methionine content of samples. The high toxicity risk factor of methionine in muscular damage should be a nutritional concern over high consumption of roasted breadfruit snack seeds.

The global optimum for process variables and amino acids are summarized in Table 4. Optimum process variables resided at -1, -1, 1 at the composite Desirability of 0.96. The optimum variable combination was 142.45^{0}C (temperature) 40.12mm (time) and 509.27g (feed quantity).

Table 4

Experimental and predicted optimum process variables for amino acids

Process variables	**Optimum values**		
Non-coded	**Coded**		
Roasting temperature (^{0}C)	142.45	-1	
Roasting time (min)	40.12	-1	
Feed quantity (g)	509.29	1	
Amino acids	**Experimental (g/16gN)**	**Predicted (g/16gN)**	**RDA (mg/kg Adult)**
Alanine	3.10	2.99	
Arginine	5.62	4.87	
Aspartic acid	6.10	7.03	
Glutamic acid	8.21	9.11	
Phenyalanine	4.05	3.98	3.0
Histidine	2.29	2.00	10.0
Gylcine	4.05	4.16	
Lysine	4.27	4.19	30.0
Threonine	2.81	2.30	15.0
Methionine	0.75	0.89	4.1
Proline	3.01	3.2	
Cysteine	0.95	1.02	0.4
Serine	3.63	4.10	
Leucine	6.00	5.99	39.0
Isoleucine	3.10	4.03	20.0
Tyrozine	2.51	1.99	25.0
Valine	3.25	4.16	26.0

The predicted optimum total of amino acids was 66.02% of control. For technical convenience, the processed variables could be adjusted to 140C, 40min and 500g. The experimental and predicted values are comparable (Fig.1). Hence the content of amino-acids in roasted breadfruit as revealed by the study satisfied about two-thirds of the needed safe aggregates of amino-acids for humans [30]

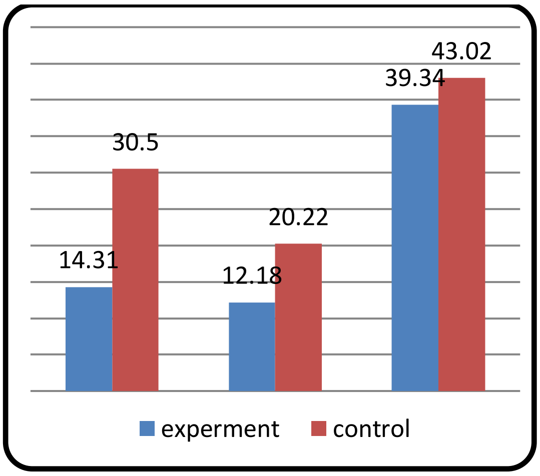

Fig 1: Total variation in different classes of Amino acid of processed samples

Nutritional implication of amino-acid profile of roasted snack seeds

The observed variations in amino acids are indicative of the influence of processing conditions on breadfruit seeds. Oxidation, Maillard reaction and formation of cross linkages involving amino acid side chains are some of the reported reasons for observed reductions of amino acid content during heat processing [28]. The high protein, carbohydrate [31] and anti-nutrients [32] of breadfruit seeds infer the concomitance of oxidation, Maillard reaction and cross linking of the active sites of amino acid side chains during dry heat processing of breadfruit snack seeds. The losses in amino-acid content are comparable with values reported for roasted groundnuts [25] bambara groundnuts [33], cashew [34] benniseeds [35] and sphenostylic stenocarpa [36]. Under optimum roasting conditions (142.450C, 40.12mm500g) high contents of arginine (5.62g), aspartic acid (6.102g), glutamic acid (8.21g), leucine (6.0g) were in agreement with the reported information on those amino acids in the literature for roasted leguminous seeds and nuts [37, 38,39,40]. Reports of studies under similar roasting conditions showed that roasted breadfruit seeds have higher content of lysine, arginine, threonine, glycine and serine than roasted groundnuts, almonds, cashew and sphenostylis stenocarpa.

This study confirms the positive correlation between heat susceptibility and essential amino acids of roasted legumes but disagreed with the changes in methionine and threonine content of roasted groundnuts as reported by Anatharaman and Capenter [29]. The high susceptibility of the sulphur fraction of methionine and cysteine to oxidation contests their finding on methionine.

The prominence of breadfruit roasted seeds snack as an important source of amino-acids needed for good health cannot be contested. The safe concentration levels of amino acids observed at optimum roasting conditions are able to satisfy the RDA of amino acids for humans. The presence of histidine essential for infants and children [41] phenylalanine an important constituent of thyroid hormones, methionine an antioxidant needed for thiamine synthesis and mineral absorption, lysine essential for tryptophan and niacin metabolism, arginine an antioxidant immune booster and vasodilator and tyrosine need for neurotransmission and hormonal synthesis point to the nutritional importance of roasted breadfruit snack seeds. The leucine-isoleucine ratio as observed promotes the sustenance of the complimentary role of leucine and isoleucine as a protection against high leucine induced adverse mental and physical disorder in population whose diets contain more of breadfruit seeds [41,42]

The possibility of a nitrogen imbalance in the amino acid pool resulting from low lysine initiated pressure between methionine and lysine is inhibited by the high contents of methionine and lysine in roasted breadfruit seeds.

Roasted breadfruit snack seeds would be unable to satisfy the RDA of cysteine for humans. The low glutamic acid content is also a minus for the proper development of skin and immune system in human [43,44] However, the observed concentrations of cysteine and glutamic acid of roasted breadfruit seeds pose no adverse toxicity risks of breadfruit to humans.

It could be inferred through observed amino acid values that roasted snack seeds of breadfruit are nutritionally more wholesome in amino acid density, safety, digestibility and toxicity as compared with commonly consumed snack seeds of roasted groundnuts, almonds, cashews, sphenostylis stenocarpa and walnuts.

The important nutritional contributions of roasted groundnuts, Bambara groundnuts, almonds, cashews, sphenostylic stenocarpa and walnuts are limited by their low content of histidine, lysine, threonine, glycine and leucine. Many physiological diseases have been traced to the deficiency of these important amino-acids in humans and experimental animals. Moreover infants and growing children would need to consume large amounts of roasted almonds, cashews, groundnuts or other commonly consumed roasted snack seeds in order to achieve their RDA for histidine. While roasted breadfruit seeds are able to deliver about 66% of total amino-acids, almonds with their high content of 23g glutamic acid, 0.26g tryptophan [37] can only deliver 37.25% total amino acids for humans. Walnuts, cashews, sphenostylis sternocarpa and Bambara groundnuts can only deliver between 11-24%, total amino-acids on consumption.

The high content of glutamic acid and aspartic acid in almonds, cashews and walnuts are physiological risk factor for the development of mental and physical stressful conditions in humans. However the ability of the human body to convert glutamic acid to glutamine through the glutamate ammonium ligase reaction during trauma underscores the need for high content of glutamic acids in diets. Glutamine is rapidly depleted during trauma [44] which emphasizes the need for high glutamic acid in the body for the maintenance of proper neurotransmission and brain functions. The usefulness of high glutamic acid in diet for the maintenance of glutamine homeostasis during trauma does not however challenge the findings which associate high glutamic acid with adverse neuro-physiological functions. Under traumatic conditions roasted almonds are snacks of choice.

Digestibility of amino acids in animal gut is reduced by the presence of high lipid and dietary fibers in the fed diets [45 ,46] The reported lipid values in the literature are 14-54% almonds [37], 34% groundnuts [25],13% cashews [34] ,16% Bambara groundnuts [33] as compared with 9 – 11% of roasted breadfruit seeds [9,47,]. The nutritional implication is that other roasted snack seeds could potentially impair amino acid digestibility in humans. Groundnuts and almonds have higher soluble dietary fibers (about 50% of their 3.5 -5% raw fiber values) than breadfruit seeds. Soluble fibers have higher impeding actions on nutrient metabolism than other forms of fibers. The inhibitory actions of lipid and dietary fibers on nutrient metabolism occur at the enzyme-nutrient interface, blocking the active side chains and the promotion of physical barriers at nutrient absorption sites in humans. Another nutritional risk factor for other roasted snack seeds is atherogenesis [48].The atherogenic implications of roasted nuts with high lipid contents could probably be ameliorated by the presence of high dietary fiber (9-13%) in nuts. The presence of high fibers though important in preventing atherogenic reactions does not prevent the initiation of the Maillard reaction during roasting and the development of some undesirable metabolites.

During roasting of seeds, the Maillard reaction occurs between sugars and amino-acids resulting in production of metabolites and color development through different biochemical reaction pathways. Acrylamide, a carcinogenic toxic [49] has been shown to get formed in food during roasting [50]. Acrylamide accumulation in roasted seeds is defined by roasting temperature, time, seed architecture and chemical composition of seeds [51]. High fat content is a risk factor for accumulation of acrylamide during the roasting process [52]. Seed architecture on the other hand influences heat transfer rates and substrate interactions inside the seed. Thick seed hull inhibits accumulation of acrylamide in seeds transiting the acrolein metabolic pathway [53,54]. High lipid contents of roasted almonds, groundnuts, cashews and walnuts are suggestive of high accumulation of acrylamide in them. Also the roasting of almonds or of walnuts without shells offers no protection against acrylamide accumulation. In addition to these nutritional drawbacks of other snack seeds and nuts, some studies have reported walnuts, almonds, groundnuts and cashew as major sources of food allergens [55]. No such implicating reports for roasted breadfruit seeds as allergenic to humans have been documented.

4. Conclusion

The process parameters used in this study demonstrated good performance. Identified optimum process variables combination occurred at about 140^0C and 40min. Above 140° - 40 min. point, roasting of breadfruit seeds results in significant reductions in amino acid concentration to levels below the values needed to satisfy the RDA of amino acids for humans. The results of this study are an important template for proper dry heat processing of unseasoned breadfruit seeds for human consumption as snacks.

5. References

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