Asian Food Science Journal

Volume 22, Issue 4, Page 1-9, 2023; Article no.AFSJ.59172
ISSN: 2581-7752

Optimization of African Breadfruit Based Complementary Food Using Mixture Response Surface Methodology

Kuyik Solomon Abasiekong [a*], Titus Ugochukwu Nwabueze [a] and Enoch Nwankwo Akobundu [a]

[a] *Department of Food Science and Technology, Michael Okpara University of Agriculture, Umudike, Nigeria.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AFSJ/2023/v22i4626

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/59172

Original Research Article

Received: 19/05/2020
Accepted: 20/07/2020
Published: 01/04/2023

ABSTRACT

Aims: To model and optimize complementary foods based on their mixture ingredients viz. African breadfruit, soybean and maize, and their depending quality characteristics namely, energy, carbohydrate, fat, ash, protein, flavor, taste, general acceptability and paste viscosity, and determine the amino acid qualities of the optimized formula.
Study Design: Experimental research (controlled experiment).
Place and Duration of Study: The Department of Food Science and Technology, Michael Okpara University of Agriculture, Umudike between 2011 and 2015.
Methodology: The D-optimal three factor mixture design fitted into the second order canonical model was adopted, and the factor ranges were set at 64-80 % (African breadfruit), 19-35 %

**Corresponding author: Email: kuyiksolo@yahoo.com;*

(soybean) and 1-9 % (maize) which yielded twenty blends (including replications) based on the mixture design combination. Each mixture component was expressed as a proportion of the mixture such that the sum was equal to 100 %.
Results: The results of the analyses were: 379.51-411 kcal/100 g (energy), 53.59-63.62 % (carbohydrate), 8-6 % (fat), 3.03-4.28 % (ash), 10.31-14.64 % (protein), 6-like slightly to 8-like very much (flavor, taste and general acceptability) and 5770-5800mPa.s (paste viscosity). Protein and energy were exceptionally high with all the values of protein exceeding the minimum standard recommended for complementary foods. The models for energy, fat, taste and paste viscosity were excellent for prediction due to the quality of their PRESS and predicted r-squared hence their selection for the numerical optimization which resulted in the prediction of 69:24:7 (African breadfruit: soybean: maize) as the optimized formula. Amino acid evaluation of this optimized formula showed that the values compared favourably with standards (WHO/FAO/UNU reference pattern and egg reference protein).
Conclusion: The selection of 69:24:7 as the optimized formula indicates that complementary food can be produced with the African breadfruit as a base at 69% inclusion, while its amino acid profile suggests that its protein could be nutritionally adequate.

Keywords: African breadfruit; complementary food; response surface methodology; optimization; protein energy malnutrition.

1. INTRODUCTION

The problem of protein energy malnutrition which has been associated with as much as 50-60 % of under-five mortality in poor countries, has for long been pronounced a public health problem in most developing countries such as Nigeria [1, 2]. Recent reports show that the problem is still prevalent in Nigeria especially among infants and children, and most common in low socioeconomic families who are barely surviving with low purchasing power [3]. Due to such socioeconomic factors, households resort to the feeding of infants with portions of family diets which are mainly cereal based and grossly inadequate as the nutritional and physiological conditions of the child are not usually considered during preparation. Legumes are usually avoided due to the problem of indigestibility resulting in gruels with low protein, high bulk and low energy density. Food and nutrition education has also not made the right impact as it ends up in teaching people to eat what they cannot afford or do not have [4].

The feeding of suitably prepared complementary foods from mixtures of locally available foods to infants alongside breast milk is being considered in many scientific circles as a potential solution. Food mixtures from legumes and carbohydrate sources processed using appropriate traditional technologies have also been established to possess the right balance of nutrients and functional properties useful as complementary foods. The choice of the African breadfruit which is a tree legume as the main ingredient is quite strategic in alleviating hunger as it is available during the period when most staples are under cultivation. The seeds are edible and are eaten in different forms especially as porridge and mainly as a main dish in homes and in ceremonies in different parts of Africa. Moreover, it is grown widely in the rain forest zone of Nigeria and other African countries, and is accepted by all classes of people in the rural and urban areas of Nigeria as well as African consumers in the diaspora.

Optimization can be defined as a series of steps for obtaining the best result under a given set of constraints. Most mathematical and statistical methods available for optimization are not effective in a multivariate system, and the conventional technique which follows one factor at a time, demands more time and requires more data to determine optimal level and results are likely to be unreliable. The response surface methodology which is a collection of mathematical and statistical techniques used in optimization, provides designs that are appropriate for optimization in a multivariate system. This experiment was on food mixture hence the choice of the mixture response surface methodology which is widely used in food mixture modeling and optimization. In mixture RSM, the independent factors are the proportions of the mixture ingredients which must always sum to 1 or 100 % [5]. Meanwhile the blending surface is modeled with empirical equation models that are useful in predicting the optimized mixture as well as determining the influence of the factors on the responses.

This study is part of a larger research, and the objective was to optimize the African breadfruit based complementary food using the mixture response surface methodology.

2. MATERIALS AND METHODS

2.1 Material Collection and Preparation

African breadfruit seeds were purchased from local producers while soybean and maize were obtained from a sales outlet in Umuahia town all in Abia state, Nigeria. The seeds were manually sorted and cleaned. Maize and African breadfruit were steeped with potable water at room temperature (25 ± 2^{0}C) for 16 h and the water changed at 8 h, then drained and spread on wet jut bags and covered with muslin clothes and allowed to sprout. The bed was kept wet by spraying water at 12 h interval and the grains turned at 8 h interval to discourage mould growth. At the end of the germination period (40 h for maize and 6 days for the African breadfruit), the sprouts were dried in hot air oven at 50^{o}C for 24 h, then toasted at 180^{0}C for 20 minutes and the rootlets removed. Soybean was parboiled at 100 ^{0}C for 15 minutes, then dehulled manually and dry-fermented for 48 h. It was then washed, drained, dried at 50^{0}C for 24 h in a hot air oven, and then toasted at 180^{0}C for 20 minutes in the same oven.

The grains were milled and sieved using a 300 µm mesh size then blended into composite flours based on the RSM mixture design layout which yielded 20 blends. These composite flours were then used in the formulation of the complementary foods based on the formula: composite flour containing 10 % protein (X g), sugar (sucrose) (12 g), salt (2 g), oil (9 g), vitamin-mineral mix (2 g), and corn starch [100-(25 +X)] g.

2.2 Experimental Design and Optimization

The D-optimal mixture design was adopted as the experimental design. The factor ranges for the 3 mixture components, African breadfruit-x_1, soybean-x_2 and maize-x_3 were 64-80%, 19-35% and 1-9% respectively while the responses were energy, carbohydrate, fat, ash, protein, flavour, taste, general acceptability and paste viscosity. Each mixture component was expressed as a fraction of the mixture such that the sum was equal to 100 %. Twenty formulations (including replications) of the complementary foods were prepared based on the mixture design ratios (Table 1). The second order canonical model (Eqn. 1) was used to approximate the unknown function.

$$Y = \sum_{i=1} \beta_i x_i + \sum_{i=1} \sum_{i<j} \beta_{ij x_i x_j} \quad (1)$$

Where Y is the response, β_i and β_{ij} are the coefficients of the linear (x_i) and quadratic ($x_i x_j$) effects respectively (where i = 1-3, j =1-3 and i≠j).

The response surface plots were used to provide visualization of the responses. Optimization of the responses was carried out via the desirability function approach. Only predictive models with good predictive capacity namely energy, carbohydrate, fat, taste and paste viscosity were used for the numerical optimization of which carbohydrate and fat were maximized while others were left in range. The factors, African breadfruit and maize, were also placed in range while soy alone was maximized.

2.3 Chemical, Sensory and Physical Analysis

The methods of [6] were used for the determination of fat and ash while the methods described in [7] were used for the determination of the paste viscosity, crude protein, carbohydrate and crude fibre. Energy determination was by multiplying the number of carbohydrate, protein, and fat by 4, 4, and 9 respectively and taking the sum of the result as the energy value of the food expressed in kilocalories per 100 g (kcal/100 g).

Flavour, taste and general acceptability were determined using 20 panelists evaluating alongside a reference sample (Nutrend) based on a nine point hedonic scale with the highest point (9) representing like extremely and the lowest point (1) representing dislike extremely.

Amino acid determination was carried out by drying the samples to constant weight, defatting using the soxhlet extraction procedure as described by [8], hydrolyzing to dryness [9], and loading the hydrolysate into the TSM analyser designed for the separation and analysis of free acidic, neutral and basic amino acids [10]. The amino acids were then calculated from the chromatogram peaks and expressed as g ⁄ 100 g of protein [11].

3. RESULTS AND DISCUSSION

The predictive models for energy, carbohydrate, fat and paste viscosity have certain things in common which include the significance (*P* = .05) of the model type and the linear model, and the non-significance (*P* = .05) of the lack of fit. The significance (*P* = .05) of the linear model implies that the main effects (individual ingredients) rather than the interactions (blends) had significant (*P* = .05) effects on the corresponding responses. This fact is conveyed in their predictive model equations (eqn. 2, 3, 4, and 5) as the blends are not included in the equations.

$$\text{Energy} = 385.11x_1 + 406.08x_2 + 401x_3 \qquad (2)$$

The value of energy ranged between 379.51 and 411 kcal/100g (Table 1) with most of the products exceeding the 400 kcal per 100 g energy benchmark for complementary foods as recommended by [12]. This compares with those of [13], 211.34 – 420.98 kcal/100 g, and [14], 394 – 560 kcal/100 g. The high energy (411.3 kcal/100 g) content of 64:35:1 (African breadfruit: soybean: maize) complementary food may be attributed to high fat content which was probably contributed by soybean of which the product had the highest proportion.

The energy model with a C.V. % as low as 2.32 (Table 2) which implies reproducibility of the model, and adequate precision of 5.870 which was greater than 4 - the limit, was adequate for the analysis. The surface plot (Fig. 1) shows that African breadfruit and soybean increased with increasing values of energy.

Carbohydrate has now overtaken fat as the chief energy source in complementary foods. The range of 53.59 – 63.62 % (Table 1) in the products compared with 57.3 - 66.1 % of [15]. This was quite moderate as compared to 30.10 – 32.87 of [13] and 78.55 – 80.87 % of [16]. The class of carbohydrates in the products are essential for infants especially those with cow-milk allergy as it is lactose free since being of plant origin. Also, it is highly digestible due to partial hydrolysis through fermentation and germination. The predictive model for carbohydrate (Eqn. 3) shows the significance (*P* =.05) of the African breadfruit, soybean and maize. Fat, a main source of energy of infants of less than 6 months of age (about 50 % in breast milk) ranged between 8 to 16 % in the complementary foods constituting between 23.79 and 35.04 % of proportions of energy from fat in these diets. The range of values of fat of 30-45 % (proportions of energy) has been suggested for complementary foods within which most of these products lay. [17] reported a range of 2.07 – 8.34 %, much lower than the range of fat recorded in this study. The predictive model for fat (Eqn. 4) though with a low R-squared, had adequate precision of 7.839 (Table 2) a value greater than 4, implying that the model was adequate. The surface plot for fat (Fig. 1) shows a linear decrease in fat along the African breadfruit axis against a linear increase in fat along the soybean axis.

$$\text{Carbohydrate} = 60.87x_1 + 54.78x_2 + 57.53x_3 \qquad (3)$$

$$\text{Fat} = 9.80x_1 + 15.34x_2 + 13.99x_3 \qquad (4)$$

Paste viscosity is essential in complementary foods as infants prefer foods of low viscosity unlike adult. The products ranging from 5770 to 5800 mPa.s (Table 1) were within the range of gruels with thick spoonable, poor-batter consistency which mothers prefer to feed their children. Also, the narrow range of viscosity may be attributed to malting and air-dry fermentation used in the processing of the flours which are close in terms of impact on viscosity reduction. The predictive model for paste viscosity (Eqn. 3) had a very high adequate precision of 8.085 (Table 2) indicating an adequate model. The absence of interactive terms in the predictive model suggests that blending did not have any significant effect (*P* = .05) on paste viscosity. The surface plot for paste viscosity (Fig. 1) shows that the most significant (*P* = .05) factors were the African breadfruit and soybean which increased with increasing paste viscosity. Although this suggests that the lower proportions of these ingredients are needed to achieve low paste viscosity, this is not be a problem as the range of paste viscosity (Table 1) falls within the requirement for complementary foods.

$$\text{Paste viscosity} = 9837.74x_1 + 9818.72x_2 + 9838.04x_3 \qquad (5)$$

Taste ranged between like slightly (6) to like very much (8) (Table 1), the same range reported by [18]. The taste model (Eqn. 3) had R-squared of 0.6040 and adequate precision of 6.355 (Table 2) indicating a good predictive model. The binary mixture, African breadfruit∗soybean (x_1x_2), was the only significant (*P* = .05) term in the model which implies synergy (blending improved the taste of the products). The relationship is shown in the response surface plot for visualization (Fig. 1).

$$\text{Taste} = 4.93x_1x_2 \qquad (6)$$

Table 1. Mixture design layout: Factors and responses

COM	Factors			Responses					Flav	Tas	GA	Visco mPa.s
	ABF	Soy	Mz	Energy kcal/100g	Carb %	Fat %	Ash %	Prot %				
1	67	30	3	407.13	53.59	15.25	3.53	13.88	6	7	7	5780
2	70	25	5	398.41	57.22	13.25	3.33	12.57	7	8	7	5790
3	70	25	5	400.88	56.51	14.00	3.58	12.21	7	7	7	5780
4	72	19	9	390.77	61.44	11.25	3.28	10.94	7	7	7	5800
5	64	27	9	410.05	55.29	15.25	3.38	12.91	6	6	7	5790
6	70	25	5	401.27	56.44	13.75	3.38	12.94	7	8	6	5790
7	80	19	1	379.51	60.55	8.00	3.28	14.64	6	6	6	5800
8	80	19	1	388.09	59.65	10.25	3.03	14.31	6	7	6	5800
9	70	25	5	401.79	56.87	13.75	3.36	12.64	7	7	7	5800
10	73	22	5	403.01	58.28	14.25	3.53	10.41	7	7	7	5790
11	70	25	5	397.76	55.65	14.00	3.53	12.29	7	7	7	5780
12	64	27	9	389.2	58.8	11.00	3.28	13.75	6	6	7	5790
13	72	27	1	384.39	61.18	10.75	4.28	10.73	7	8	8	5790
14	64	35	1	411.31	55.06	15.75	3.28	12.33	6	7	7	5770
15	70	25	5	381.77	59.38	10.25	3.50	13.00	8	8	7	5790
16	76	19	5	387.71	63.62	10.25	3.03	10.31	6	7	7	5800
17	69	24	7	381.71	59.42	10.75	3.48	11.82	7	7	7	5790
18	64	31	5	402.86	55.49	15.50	4.03	10.35	6	7	7	5790
19	72	19	9	410.25	55.31	15.25	3.33	12.94	7	7	7	5800
20	64	35	1	411.00	55.01	16.00	3.35	11.74	7	6	6	5790

[a]*Com = Complementary Food;* [b]*ABF = African breadfruit;* [c]*Mz = Maize;* [d]*Soy = Soybean;* [e]*Carb = Carbohydrate;* [f]*Flav = Flavour;* [g]*GA = General Acceptability;* [h]*Visco = Paste Viscosity*

Table 2. Diagnostic parameters for the fitted model

Parameters	C.V.	PRESS	R-squared	Pred. R-Squared	Adeq. Precision
Energy	2.32	2012.71	0.3344	0.0744	5.870
Carbohydrate	3.39	2225.67	0.6997	-16.3234	6.948
Fat	14.13	80.80	0.4725	0.2485	7.839
Ash	3.15	107.36	0.9262	-66.6371	16.083
Protein	4.92	2544.37	0.8857	-78.1123	9.971
Flavour	5.88	6.79	0.6966	-0.0363	6.483
Taste	6.80	7.07	0.6040	0.1158	6.355
General Acceptability	5.00	4.67	0.6651	-0.0256	9.233
Paste Viscosity	0.11	917.06	0.5078	0.2918	8.085

Flavour and general acceptability (Eqn. 7) models both had insignificant (*P* = .05) lack of fit, significant (*P* = .05) model type and insignificant (*P* = .05) linear model. Flavour ranged between like slightly-6 and like very much-8 (Table 1) with the 70:25:5 African breadfruit: soybean: maize complementary food having the highest score. Flavour had no model term significant besides the significance (*P* = .05) of the model type hence the exclusion of its predictive model. A good number of the model terms of general acceptability were significant (*P* = .05). These include the binary mixture, African breadfruit ∗ soybean (x_1x_2), with a positive coefficient implying synergy and the tertiary mixture, African breadfruit ∗ soybean ∗ maize ($x_1x_2x_3$) with a negative coefficient implying antagonism. These suggests that the blend of African breadfruit and soybean significantly (*P* = .05) improved the general acceptability of the products.

$$\text{General acceptability} = 6.60x_1x_2-27.99x_1x_2x_3 \quad (7)$$

Ash and protein both had insignificant (*P* = .05) lack of fit and significant (*P* = .05) quadratic terms. Ash, an important nutritional indicator of mineral content, ranged between 3.03 to 4.28 % (Table 1). This was higher than the ash composition of traditional complementary foods reported by [19] which was 1.03 – 2.54 %. The model for ash had a very high R-squared (0.9262) and adequate precision (16.08) (Table 2); the R-squared quite close to 1 indicates repeatability of the model. The highest value of protein in the complementary foods was 14.64 % (Table 1) corresponding to 3.66g/100kcal while the lowest value was 10.31 % corresponding to 2.58g/100kcal which were above the minimum standards of 6-15 g/100 g and 6-11 g/100 g stipulated by [12], and [20] respectively for complementary foods. [18] reported a range of 7.34 – 16.73 % protein for complementary foods in Ethiopia. The model for protein with R-squared as high as 0.8857, and adequate precision of 9.971 showed that the model was adequate. The negative signs of the binary mixtures, African breadfruit ∗ soybean (x_1x_2), African breadfruit ∗ maize (x_1x_3) and soybean ∗ maize (x_2x_3) imply antagonism. It is notable that the African breadfruit∗soybean∗maize ($x_1x_2x_3$) had positive coefficient which shows that this blend could improve the protein value of the complementary foods.

$$\text{Protein} = -10.12x_1x_2-231.84x_1x_3-221.27x_2x_3+348.42x_1x_2x_3 +122.63x_1x_3(x_1-x_3)+122.69x_2x_3(x_2-x_3) \quad (8)$$

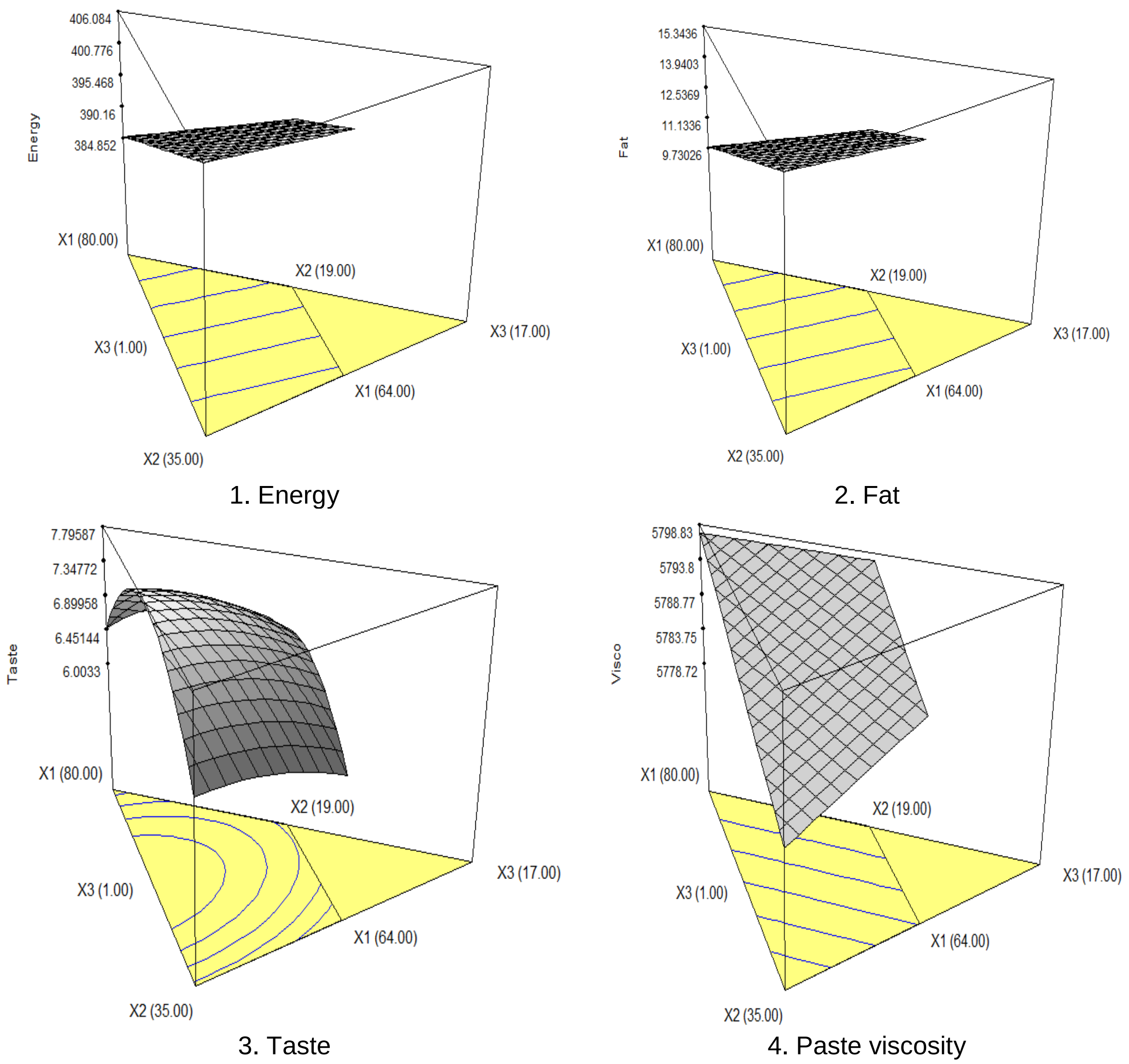

Fig. 1. Energy, fat, taste and paste viscosity surface plots
X1 – African breadfruit, X2 – Soybean, X3 – Maize

Table 3. Amino acid profile and nutritional indices calculated from amino acids

Amino Acids (g/100g)	69:24:7 (Optimized complementary food)	Reference Pattern [21]
Amino acid profile		
Lysine	6.66 ±0.050	6.9
Histidine	3.01 ±0.014	2.1
Arginine	6.64 ±0.127	2.3
Aspartic acid	10.91±0.014	9.0
Threonine	3.55±0.070	4.4
Serine	5.10±0.141	5.0
Glutamic acid	17.07±0.199	17.8
Proline	3.93±0.042	8.0
Glycine	3.40±0.28	2.3
Alanine	4.05±0.070	3.8
Cysteine	1.46±0.084	1.7
Valine	4.39±0.280	5.5
Methionine	1.30±0.141	1.6
Isoleucine	4.02±0.228	5.5
Leucine	7.85±0.212	9.6
Tyrosine	3.38±0.170	5.2
Phenylalanine	5.58±0.169	4.2
Nutritional Indices Calculated from Amino Acids		
Total Amino Acid (TAA)	92.30±1.004	-
Total Sulphur Amino Acid (SAA)	2.76±0.1670	-
Total Essential Amino Acids(EAA)	36.36±0.933	-
$^{EAA}/_{TAA}$ %	39.4±0.566	-
ArAA (Phyny + Tyro)	8.96±0.849	-

Values are mean ± standard deviation of duplicate determination

The result of the simultaneous optimization showed that 69:24:7 (African breadfruit: soybean: maize) was selected as the optimized complementary food implying that the optimal conditions were 69% for the African breadfruit, 24 % for the soybean and 7 % for bread. Also shown was that at this optimal condition, the energy, carbohydrate, fat, taste, and paste viscosity were 397.62, 59.70, 13.10, 7.17, and 5791.91 respectively.

Amino acid composition is a principal factor in the quality of a protein. The amino acid profile of the optimized formula (Table 3), 69:24:7 African breadfruit: soybean: maize, competed favourably with the [21] amino acid reference pattern for the infant with some exceeding these values. Arginine, histidine, and phenylalanine, all essential amino acids for infant, all had values higher than the amino acid reference pattern. This is important as the capacity of arginine synthesis is low in infants. Also phenylalanine is a precursor for tyrosine and infants lack the capacity to synthesize histidine. Also observed, was the increasing values of the amino acids with increasing levels of soybean which may be attributed to the excellent quality of soybean as a complete protein. The sulphur containing amino acids though lower than the reference pattern, equally increased with increasing levels of maize which may be associated with the high levels of sulphur containing amino acids in maize – a cereal, suggesting the possibility of increase with proportionate increase of maize in the formula.

4. CONCLUSION

The predictive models for taste, general acceptability and protein seem to suggest by the significance of their blends that the blending of ingredients for the production of the complementary food was successful. Also the selection of 69:24:7 African breadfruit: soybean: maize as the optimized formula indicates that 69 % inclusion of the African breadfruit was appropriate for the formulation of African breadfruit based complementary food. The presence of such levels of amino acid suggests that its protein has the right balance to sustain the life of an infant; however, a biological studies of the protein is recommended to ascertain this.

ACKNOWLEDGEMENTS

This research was carried out in Michael Okpara University of Agriculture Umudike as well as the University of Nigeria Nsukka. The author sincerely appreciates these Institutions for graciously allowing the use of their facilities for this research.

COMPETING INTERESTS

The authors of this manuscript hereby declare that no competing interests exist.

REFERENCES

1. Ijarotimi OS and Olopade AJ. Determination of amino acid content and protein quality of complementary food produced from locally available food materials in Ondo, Nigeria. Malaysian Journal of Nutrition. 2009;15(1):87–95.
2. Faruque AS, Ahmed AM, Ahmed T, Islam MM, Hossain MI, Roy SK. Nutrition: Basis for Healthy Children and Mothers in Bangladesh. J. Health Popul Nutr. 2008;26:325-39.
3. Abubakar N, Atiku MK, Alhassan AJ, Mohammed IY, Garba RM, Gwarzo GD. An assessment of micronutrient deficiency: A comparative study of children with proteinenergy malnutrition and apparently healthy controls in Kano, Northern Nigeria. Trop J Med Res. 2017;20:61-5.
4. Gurung G. Social determinants of protein-energy malnutrition: Need to attack the causes of the causes. J Health Popul Nutr. 2010; 28:308-9.
5. Li Y, Raghavarao D, Chervoneva I. Extensions of D-optimal minimal designs for symmetric mixture models. Journal Communications in Statistics – Theory and Methods. 2017;46(5): 2542-2558. DOI: 10.1080/03610926.2014.988258
6. AOAC. Official Methods of Analysis. 14th edn. Washington DC: Association of Official Analytical Chemists; 1984.
7. Onwuka GI. Food Analysis and Instrumentation: Theory and Practice. Lagos: Naphthali Prints; 2005.
8. AOAC. Official Methods of Analysis. 18th edn. Washington DC: Association of Official Analytical Chemists; 2006.
9. Ogunwende HN, Omowole BM. Chemical, functional and amino acid composition of periwinkle (*Tympanotonus fuscatus varradula*) meat. International Journal of Pharmaceutical Sciences Review and Research. 2012;13(2):128-132.
10. Ekeanyanwu RC. Evaluation of the crude protein and amino acid composition of Nigerian *Monodora myristica* (*Ehuru*). Pakistan Journal of Nutrition. 2013; 12(3):219-223.
11. Gabriel A, Dedeke SO, Kayode BO. Amino acids profile of four earthworms species from Nigeria. Agriculture and Biology Journal of North America. 2010;1(2):97-102.
12. Food and Agricultural Organization/World Health Organization. Guidelines on formulated complementary foods for older infants and young children: CAC/GL 8-1991. In Food and Agricultural Organization of the United Nations. 2013;1-10.
13. Onoja US, Akubor PI, Gernar DI, Chinmma CE. Evaluation of complementary food formulated from local staples and fortified with calcium, iron and zinc. Journal of Nutrition and Food Sciences. 2014;4:326.
14. Yohannes T. G, Makokha A. O, Okoth J. K, Tenagashaw M. W. Developing and nutritional quality evaluation of complementary diets produced from selected cereals and legumes cultivated in Gondar province, Ethiopia. Curr Res Nutr Food Sci. 2020; 8(1). DOI:http://dx.doi.org/10.12944/CRNFSJ.8.1.27.
15. Gebrezgi D. Proximate composition of complementary food prepared from maize (*Zea mays*), soybean (*Glycine max*) and Moringa leaves in Tigray, Ethiopia. Cogent Food and Agriculture. 2019; 5(1):1627779.
16. Ojinnaka MC, Ebinyasi CS, Ihemeje A and Okorie SU. Nutritional evaluation of complementary food gruels formulated from blends of Soybean flour and ginger modified cocoyam starch. Advance Journal Food Science and Technology. 2013;5(10):1325-1330.
17. Ikujenlola AV, Oguntuase SO and Omosuli SV. Physico-chemical properties of complementary food from malted quality protein maize (*Zea mays L.*) and defatted fluted pumpkin flour (*Telfairia occidentalis* Hook, F). Food and Public Health. 2013; 3(6):323-328.
18. Turfa MA, Urga K, Weledesemayat GT, Mitiku BG. Development and nutritional assessment of complementary foods from fermented cereals and soybean. J Food Science Nutrition. 2016; 2:014.

19. Alamu EO, Gondwe T, Akello J, Sakala N, Munthali G, Mukanga M and Maziya-Dixon B. Nutrient and aflatoxin contents of traditional complementary foods consumed by children of 6-24 months. Food Science and Nutrition. 2018; 6(4):834-842.
20. World Food Programme. Technical specification for the manufacture of Super Cereal Plus: Corn soya blend. 2015; 1987:1-8.
21. World Health Organization (WHO)/Food and Agricultural Organization (FAO)/United Nations University (UNU). Proteins and Amino Acids Requirements in Human Nutrition. Geneva: Report of Joint WHO/FAO/UNU Expert Consultation; 2007.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/59172