ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 21 No. 9
October 2021
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2021; 21(9): 18748-18766 https://doi.org/10.18697/ajfand.104.19955

A MIXTURE DESIGN APPROACH TO DEVELOPING A CEREAL- BASED COMPLEMENTARY MEAL FOR BETTER NUTRITIONAL QUALITY

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ABSTRACT

Adequate nutrition is imperative during infancy and childhood because a short period of malnutrition could have a long-term effect on growth, development and health in the adult life. A mixture design approach was deployed to optimize the composition of a complementary food produced from available food ingredients – for better nutritional quality. A complementary meal was formulated from a mix of yellow maize, sorghum, millet, soybean, groundnut, crayfish and fish. The complementary food was analyzed for nutritional composition and anti-nutritional factors alongside traditional *ogi* (a fermented maize porridge popularly used as food for children) and another commercially available baby food. Quadratic models were able to explain the moisture and protein content of the complementary food with a R^2 of 0.8177 and 0.7284, respectively. Special cubic models were able to explain the ash, fat and crude fibre content of the complementary food with R^2 of 0.9022, 0.8352, and 0.8228, respectively. Multi-response optimization was deployed to obtain an optimised complementary meal. The multi-response optimization was set to minimize moisture while it maximized the ash, protein, crude fibre, and fat of the flour blend. The optimized complementary meal had higher ash, fat, fibre and protein content compared to *ogi*. A 100 g portion of the complementary meal contained 20.26 g crude protein, 8.13 g fat, 55.75 g carbohydrates and yielded up to 377.21 kcal of energy while a 100 g portion of the *ogi* contained 5.71 g crude protein, 1.04 g fat, 83.86 g carbohydrates and energy yield of 367.64 kcal. The mineral contents of the optimized blend per 100 g portion included potassium (406.10 mg), calcium (50.80 mg), iron (1.04 mg), and zinc (7.53 mg). The optimised complementary meal also had higher protein, ash, crude fibre and fat when compared to the commercially available baby food. Compared to *ogi*, utilization of this complementary meal for children could offer affordable food with adequate nutrients.

Key words: Mixture design, optimization, cereal, complementary food, proximate analysis, anti-nutrients

BACKGROUND

Adequate nutrition during infancy and childhood is fundamental to development of a child to its full potential [1]. Infancy period (0-2 years) is a "critical window" for promotion of optimal growth, health and behavioural development [2]. Poor feeding practices during this vulnerable period can increase the risk of undernutrition, morbidity and mortality of infants and young children [3]. Complementary foods in most developing countries are based on staple cereal or root crops. Although commercial foods of high quality are occasionally available, they are often expensive and therefore unaffordable by low-income rural households [4]. Most complementary foods used are locally produced based on local staples, which are cereals that are processed into porridges. Other than their bulkiness reported as a probable factor in the aetiology of malnutrition [5], cereal-based gruels are generally low in protein and limiting in some essential amino acids, particularly lysine and tryptophan. It has been emphasized that the use of local foods formulated in the home should be guided by the following principles: high nutritional value to supplement breastfeeding; acceptability, affordability and use of local food items [6,7].

A complementary diet in Nigeria can be made up by blending readily available foods such as yellow maize (*Zea mays*), sorghum (*Sorghum bicolor*), groundnut (*Arachis hypogea*), soy beans (*Glycine max*), millet (*Panicum miliaceum*), bonga fish (*Ethmalosa fimbriata*) and crayfish (*Cambarus angularis*). Most complementary diets produced in Nigeria and developing nations are cereal based and the blends and proportion of these cereals can only provide the required daily allowance for energy and sometimes fat. Data from observed intake studies according to Osendarp *et al*. [8], indicated that children aged 6 to 24 months met requirements of energy, while diets were inadequate in protein, calcium, iron, and zinc.

The objective of this study was to develop a complementary meal by applying mixture design to optimize the ratios of yellow maize (*Zea mays*), millet (*Panicum miliaceum*), sorghum (*Sorghum bicolor*), soybeans (*Glycine max*), and crayfish (*Cambarus angularis*), groundnut (*Aeachis hypogea*) and bonga fish (*Ethmalosa fimbriata*) for better nutritional quality. The study also evaluated the mineral content and anti-nutrients of the optimized blend and compared some of these parameters with that of the common traditional cereal porridge (*ogi*) – and a commercially available weaning food.

MATERIALS AND METHODS

Sample

Maize, sorghum, groundnut, soybeans, millet and *bonga* fish were procured from Boundary market in Ajegunle, Lagos State. All the materials were sorted for dirt, physical defects and foreign materials. This was done by hand picking and winnowing. The grains (maize, millet and sorghum) were then washed and oven-dried at 60°C for 24 hrs. The dried grains were cooled and milled into fine powder before passing the milled powders through a 0.5 mm sieve. The sorted soybeans were washed, boiled for 15 min, de-hulled, oven-dried at 60°C for 24 hrs and then roasted under an open flame for 30 min until golden brown. The roasted beans were cooled, milled into fine powder and sieved through a 0.5 mm sieve. Groundnuts were roasted on medium heat till they turned light brown. They were then sorted to remove burnt ones, and then allowed to cool down before de-hulling and milling.

Crayfish were dry-milled and sieved with a 75 µm aperture sieve in order to remove large particles so as to obtain smooth powder. Bonga fish was also dry milled into fine powder. Similarly, *ogi* was also prepared as described by Oyarekua and Eleyinmi [9]. Two kilograms of maize, millet and sorghum were each steeped in 6 L of distilled water for four days at 30°C. The steep water was discarded and grains were washed in fresh distilled water followed by wet milling and then wet sieving through a 500 µm sieve screen. The obtained fines from this traditional process were allowed to settle and ferment (24 hrs). The slurry obtained was dewatered and oven dried (55°C).

Proximate analysis determination
The proximate composition of the complementary foods was determined using standard AOAC methods [10]. Moisture content of the 20 samples obtained from the experimental runs was determined by air oven method at 105°C (967.08). The crude protein of the samples was determined using micro-Kjeldahl method (988.05), crude lipid was determined by Soxhlet extraction method (2003.06), while the ash content was determined by weighing 5 g of sample in triplicate and heated in a muffle furnace at 550°C for 4 h (942.05). Crude fibre was also determined by extraction of 1 g sample with ether (958.06). The carbohydrate content was obtained by difference. Gross energy of the samples was determined using ballistic bomb calorimeter.

Mixture design
A D optimal design approach was used to generate 20 experimental runs, consisting of 10 model runs, 5 center points and 5 replicates. Seven components were blended to generate each of the experimental runs. The following constraints were used for the components when generating the mixture design: groundnut, crayfish and *bonga* fish were set at constant of 13, 3 and 13%, respectively; the yellow corn, millet, and sorghum were constrained to be between 0 to 20%; and soybeans was constrained to be between 25 to 33%. All the runs were then subjected to proximate analysis.
The data obtained were fitted to different models. The models evaluated were linear, quadratic and three- factor interaction (special cubic). An analysis of variance (ANOVA) at $p > 0.05$ was then used to select the best model. Backward regression was applied to the special cubic models to remove the redundant variables [11]. The multiresponse optimization was carried out using the desirability concept [11]. The multi-response optimization was set to maximize protein, ash, fat, crude fiber, and carbohydrate; and to minimize moisture content - within the experimental range. All the proximate analysis parameters were all given an equal weighting of one for the optimization. Model quality was evaluated using the F-value, lack- of- fit, the coefficient of determination (R^2) and, adjusted R^2.

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 21 No. 9 October 2021 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

Analysis of optimized mix and ogi

Determination of potassium and sodium

The ash of the sample was digested by adding 5ml of 2 M HCl in a crucible and heated to dryness on a heating mantle. Five millilitres of the 2 M HCl was added again, heated to boil, and filtered through Whatman No. 1 filter paper into a 100ml volumetric flask. The filtrate was made up to mark with distilled water. The concentration of potassium and sodium was read on the Jenway Digital Flame Photometer (PFP7 Model) using the filter corresponding to each mineral element [10].

Determination of Ca, Mg, Mn, Fe, Zn, I, Pb, Cd and Se

The digest of the ash of each sample above as obtained in calcium and potassium determination was washed into 100ml volumetric flask with deionised water and made up to mark. This diluent was aspirated into the Buck 200 Atomic Absorption Spectrophotometer (AAS) through the suction tube. Each of the trace mineral elements was read at their respective wavelengths with their respective hollow cathode lamps using appropriate fuel and oxidant combination [10].

Anti-nutritional analysis

Phytate was determined by titration with ferric chloride solution while trypsin inhibitory activity was determined on casein and comparing the absorbance with that of trypsin standard solutions read at 280 nm. The tannin content was determined by extracting the samples with a mixture of acetone and acetic acid for 5 hours, measuring their absorbance and comparing the absorbance of the sample extracts with the absorbance of standard solutions of tannic acid at 500 nm on spectronic20. Saponin was determined by comparing the absorbance of the sample extracts with that of the standard at 380 nm [12].

Statistical analysis

For the proximate analysis and mineral content of the optimised complementary meal, sample analyses were done in triplicates and data were subjected to analysis of variance (ANOVA) at 5% level of significance and the means separated by Duncan Multiple Range Test, using Statistical Package for Social Science (SPSS) 20.0 software package.

RESULTS AND DISCUSSION

Flour composition optimization

Three different cereals (sorghum, millet and maize) were used in the formulation as this could help create synergistic effect in terms of nutritional and organoleptic property of the meal [13-15]. The mixture models for the moisture, ash, fat, crude fibre and protein contents are shown in equations 1 to 5. The ANOVA for the mixture models are also shown in Tables 1 to 5. Different models were used for the different nutrients as a result of the F statistics. All variables were included in the quadratic models. For the special cubic models, a backward regression was used to remove redundant variables (three-factor interaction variables with p values greater than 0.10) in order to obtain improved special cubic models. Quadratic models were able to explain the moisture and protein, while special cubic models were able to explain the ash, fat and crude fibre.

Moisture = 2.56A + 0.25B + 0.48C + 0.42D - 0.046AB - 0.042AC - 0.066AD - 0.017BC + 0.00098BD - 0.0081CD Eqn.1

Ash = 6.20A + 3.79B + 1.40 C + 1.11D - 0.35AB - 0.22AC - 0.19 AD - 0.10BC - 0.12BD - 0.037CD + 0.0056ABC + 0.0081 ABD + 0.0038ACD Eqn.2

Fat = 8.68A - 6.66B + 9.83C + 1.85D + 0.082 AB - 0.90AC - 0.35AD + 0.044BC + 0.14BD -0.38CD + 0.032ACD Eqn.3

Crude Fibre = -6.44A - 0.31B - 7.51C - 1.30D + 0.14AB + 0.58AC + 0.21AD + 0.17BC + 0.23CD - 0.011ABC - 0.015ACD Eqn.4

Protein = 0.85A + 1.30B + 3.08C + 1.43D - 0.023AB - 0.029AC - 0.038AD - 0.040BC -0.046BD - 0.11CD Eqn.5

A = yellow corn, B = millet, C = sorghum, D = soybeans

The moisture content of the composite flours ranged from 7.17 and 11.21%. A quadratic model (where, in addition to the four ingredients, interaction effects were included for all possible pairs of ingredients) was able to explain the moisture content of the composite flour with R^2 and adjusted R^2 values of 0.8177 and 0.6537, respectively. Ash content of the composite flours ranged from 1.74% to 4.76%. A special cubic model (which, in addition to the four ingredients and all the possible pairwise combinations, included all possible interaction effects of three ingredients) was able to explain the ash content of the composite flour with R^2 and adjusted R^2 values of 0.9022 and 0.7345, respectively. The interaction between yellow corn, millet and soybeans had the highest impact on the ash content as depicted by the high F-value of 9.92 (Table 2). The fat content from the experimental runs was between 2.04% and 10.33%. A special cubic model with R^2 and adjusted R^2 of 0.8352 and 0.6521, respectively, was able to explain the fat content of the flours. The interaction between yellow corn, sorghum and soybeans had the highest impact on the fat content – as indicated by the value of the high F-value (Table 3).

Crude fibre content for the flours from the experimental runs ranged from 0.86% to 4.60%. A special cubic model was also able to explain the crude fibre content the composite flour with R^2 and adjusted R^2 values of 0.8228 and 0.6259, respectively. Also, the interaction between yellow corn, sorghum and soybeans had the highest impact on the fibre content (Table 4). The protein content of the composite flours from the experimental runs was between 15.27% and 22.33%. A quadratic model (Table 5) was able to explain the protein content of the composite flour with R^2 and adjusted R^2 values of 0.7284 and 0.4839, respectively. The model revealed that the interaction between sorghum and soybean had the highest impact ($p<0.05$) on the protein content of the composite flour. However, no suitable model was obtained that could explain the carbohydrate content of the composite flour.

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Volume 21 No. 9
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PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

From the multi-response optimization, the optimum mix (optimized complementary meal) obtained was: 18.24 g yellow maize flour, 17.28 g millet, 5.65 g sorghum, 29.77 g soy beans, 13.00 g groundnut, 3.00 g of crayfish, 13.00 g of *bonga* fish, with a desirability of 0.65 (Fig. 1). The content of the groundnut, crayfish and *bonga* fish were not varied in this study.

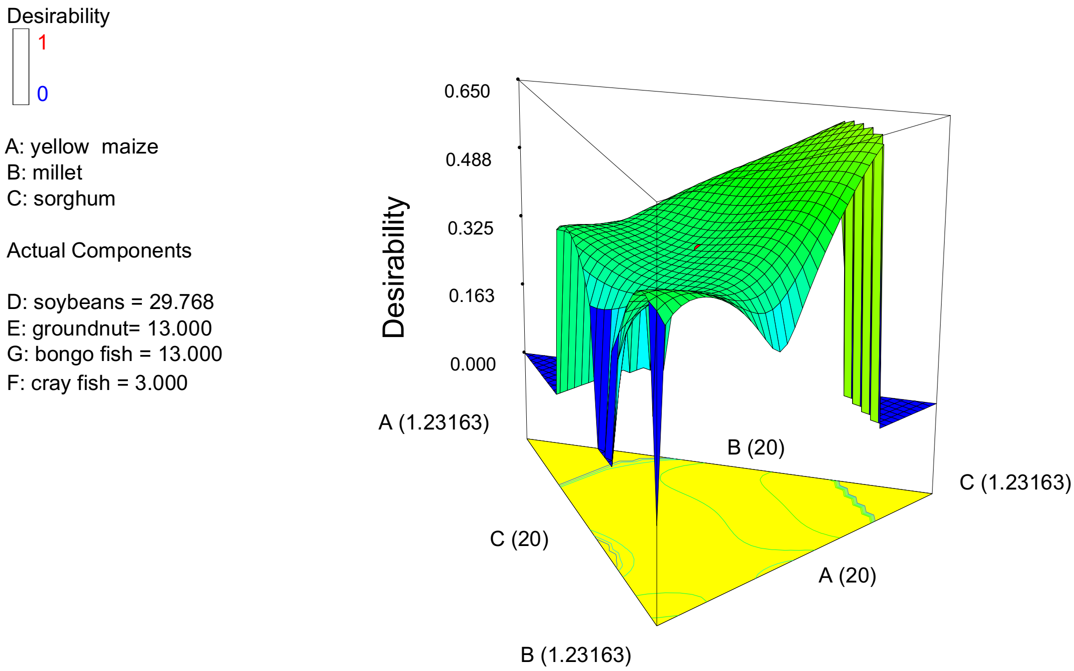

Figure 1: Desirability graph of multi-response optimization

The multi-response optimization, using the desirability concept, was set to minimize moisture while it maximized the ash, protein, crude fibre, and fat of the flour blend. The moisture was minimized so as to reduce the rate of spoilage of the composite flour [16]. High moisture content can encourage microbial attack and growth. The ash content was maximized in the optimization because it is an indication of minerals in a particular sample. The protein content was also maximized because diets with high content of protein are important for infants and young children to prevent protein energy malnutrition. Fat was also maximized because it provides essential fatty acids, facilitates absorption of fat soluble vitamins, and enhances dietary energy density and sensory qualities. Fibre content was also maximized because adequate amount of dietary fibre in the food helps normal bowel movement, thereby reducing constipation problems among children.

Based on the multi-response optimization, the optimized complementary meal (OCM) was expected to have a moisture, ash, fat, crude fibre, and protein content of 8.51%, 3.13%, 7.28%, 3.93%, and 20.26%, respectively. To validate this, the optimum flour blend was prepared and proximate analysis was carried out. The proximate analysis

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ISSN 1684 5374

result from the validation experiment was 8.60%, 3.15%, 8.13%, 4.12% and 20.26% (Table 6) for moisture, ash, fat, crude fibre, and protein content, respectively. The validation results were close to the predicted results.

Proximate composition of optimized complementary meal, *ogi* and the commercial weaning food

The proximate composition of the OCM, *ogi* and a commercially available weaning food is shown in Table 6.

The moisture content of the OCM was 8.60% while that of *ogi* and commercial weaning food was 5.83% and 3.28%, respectively. The ash content of the OCM (3.15 %) was significantly higher ($p<0.05$) than *ogi* (0.62%) and the commercial weaning food (1.85%). The protein content of the OCM (20.26%) was significantly higher than that of *ogi* (5.71%), and the commercial weaning food (16.84%). The fat content of the OCM (8.13%) was higher than the commercial weaning food (4.71%) while that of *ogi* was much lower (1.04%). The crude fibre content of OCM (4.12%) was significantly higher than that of *ogi* (2.94%). *Ogi* had a significantly higher carbohydrate content (90.31%) when compared to the OCM (55.75%) and the commercial weaning food (73.31%). The energy value for the three products being compared ranged from 304.68 Kcal / 100 g to 403.08 Kcal / 100 g, with the commercial weaning food having the highest energy value.

Low moisture content (less than 12%) makes a food sample withstand microbial spoilage [16]. Low moisture content is an important consideration in local feeding methods in developing nations, because most mothers often prepare large quantities of dry complementary foods and keep in containers to avoid frequent processing in order to have spare time for other domestic activities [1].

High ash content was observed in the OCM, this might be due to inclusion of crayfish and *bonga* fish. The ash content can provide an estimate of the quality of the product; since high ash content gives an indication of minerals. The observed increase in protein content of the OCM can be explained by the inclusion of soybean and groundnut which are good sources of plant protein and also the inclusion of *bonga* fish and crayfish which are good sources of animal protein. This suggests that the OCM can be used as source of protein in infants' food and for children suffering from protein energy malnutrition. This agrees with the report that crayfish is a very good source of protein [17].

The high fat content in the OCM could be attributed to the inclusion of oil dense soybeans and groundnut. High dietary fibre could be attributed to the high amounts of fibre contained in the cereals and legumes. Carbohydrate is the principal component of the OCM. The carbohydrate content in the OCM could be attributed to the fact that the blend consists of foods that have high carbohydrate content which includes maize, sorghum, and millet. Food with higher calorie is needed as the infant increases in age due to the fact that more energy is required in carrying out their activities such as playing and as growth continues [17].

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 21 No. 9 October 2021 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

Mineral content of optimized complementary meal, *ogi* and commercial weaning food

The OCM had the highest zinc, potassium and iodine content while the commercial weaning food had the highest sodium, calcium, magnesium, iron and selenium content (Table 7). The mineral composition of the OCM showed that potassium was the predominant mineral; same for the *ogi* and the commercial weaning food. The high content of potassium and other minerals in the commercial weaning food could be attributed to the fortification practices carried out on it. The potassium content in the OCM could be attributed to the addition of crayfish and *bonga* fish to the blend as they have high potassium content.

Na/K for the three samples was lower than 1 while that of the OCM was the lowest (0.038). Na/K ratio in the body is of great concern for prevention of high blood pressure. Na/K ratio less than one is recommended. Hence, the OCM would probably pose no high blood pressure risk because it had Na/K less than one [16]. Selenium and iodine contents of the OCM were (0.003 mg / 100 g and 5.208 mg / 100 g) respectively. Cadmium and lead were not detected in the OCM, *ogi* and commercial weaning food.

Anti-nutritional analysis of optimized complementary meal, *ogi* and commercial weaning food

The OCM had lower tannin and higher saponin, phytate and trypsin inhibitor as compared to *ogi* and the commercial weaning food (Table 8). Cereals and legumes are known to contain significant levels of antinutrients [18]. The soybean could be implicated in the higher level of anti-nutrient observed in the OCM. Maize not fortified with pigeon peas (a legume) was found to have lower levels of antinutrients compared to maize fortified with pigeon peas [19]. It is reported that 10-50 mg phytate per 100 g will not have a negative effect on zinc and iron [20]. The phytate content of the OCM is 0.1 mg / g (10 mg / 100 g) which is still within the acceptable range. The tannin content of the OCM is also lower than the lethal dose of 0.7-0.9 mg / 100 g reported by Pikuda and Ilelaboye [20]**.**

CONCLUSION

This study examined the formulation, proximate composition, mineral content, and anti-nutritional content of complementary food blends from mixture of maize, sorghum, millet, soybeans, groundnut, crayfish and *bonga* fish. The research showed that complementary food products formulated from cereals, legumes and animal protein have the potential to meet the macro nutritional needs of infants and young children. The OCM compared to *ogi* is a high-protein, high calorie product, with better micronutrient content. Complementary food also has the advantage in that it is affordable and easy to prepare because the inputs are locally available. Mothers can be encouraged to use this complementary meal for their children through seminars organized by government and public health experts especially at the grassroots level. The usage of this weaning food can also be promoted by giving incentives to local processors to produce this complementary meal.

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Table 1: **Analysis of variance for mixture quadratic model for moisture content**

Source	Sum of Squares	Df	Mean Square	F	p-value (Prob > F)	
Model	22.9	9	2.54	4.98	0.0097	significant
Linear Mixture	1.61	3	0.54	1.05	0.4116	
AB	8.32	1	8.32	16.31	0.0024	
AC	4.88	1	4.88	9.56	0.0114	
AD	2.34	1	2.34	4.58	0.058	
BC	1.53	1	1.53	3	0.1139	
BD	5.49E-04	1	5.49E-04	1.08E-03	0.9745	
CD	0.04	1	0.04	0.078	0.7851	
Residual	5.1	10	0.51			
Lack of Fit	1.58	5	0.32	0.45	0.8013	not significant
Pure Error	3.53	5	0.71			
R^2	0.8177					
Adjusted R^2	0.6537					

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ISSN 1684 5374

Table 2: **Analysis of variance for mixture special cubic model for ash**

Source	Sum of Squares	df	Mean Square	F	p-value (Prob > F)	
Model	8.21	12	0.68	5.38	0.0169	significant
Linear Mixture	0.36	3	0.12	0.94	0.4719	
AB	0.21	1	0.21	1.62	0.244	
AC	0.05	1	0.05	0.4	0.5489	
AD	0.29	1	0.29	2.25	0.1769	
BC	0.076	1	0.076	0.6	0.4655	
BD	0.8	1	0.8	6.3	0.0404	
CD	0.52	1	0.52	4.09	0.0828	
ABC	0.6	1	0.6	4.7	0.0667	
ABD	1.26	1	1.26	9.92	0.0162	
ACD	0.17	1	0.17	1.34	0.2854	
Residual	0.89	7	0.13			
Lack of Fit	0.5	2	0.25	3.16	0.1297	not significant
Pure Error	0.39	5	0.079			
R^2	0.9022					
Adjusted R^2	0.7345					

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Table 3: **Analysis of variance for mixture special cubic model for fat**

Source	Sum of Squares	df	Mean Square	F	p-value (Prob > F)	
Model	117.14	10	11.71	4.56	0.016	significant
Linear Mixture	39.87	3	13.29	5.17	0.0238	
AB	18.66	1	18.66	7.27	0.0246	
AC	21.56	1	21.56	8.39	0.0177	
AD	36.1	1	36.1	14.06	0.0046	
BC	8.64	1	8.64	3.36	0.0999	
BD	11.57	1	11.57	4.51	0.0628	
CD	34.22	1	34.22	13.32	0.0053	
ACD	42.59	1	42.59	16.58	0.0028	
Residual	23.12	9	2.57			
Lack of Fit	9.45	4	2.36	0.86	0.5432	not significant
Pure Error	13.66	5	2.73			
R^2	0.8352					
Adjusted R^2	0.6521					

Table 4: **Analysis of variance for mixture special cubic model for crude fibre**

Source	Sum of Squares	df	Mean Square	F	p-value (Prob > F)	
Model	18.5	10	1.85	4.18	0.0212	significant
Linear Mixture	7.49	3	2.5	5.64	0.0187	
AB	7.19	1	7.19	16.23	0.003	
AC	8.34	1	8.34	18.85	0.0019	
AD	6.3	1	6.3	14.23	0.0044	
BC	8.34	1	8.34	18.83	0.0019	
CD	6.14	1	6.14	13.86	0.0048	
ABC	6.74	1	6.74	15.22	0.0036	
ACD	6.69	1	6.69	15.12	0.0037	
Residual	3.98	9	0.44			
Lack of Fit	1.39	4	0.35	0.67	0.64	not significant
Pure Error	2.59	5	0.52			
R^2	0.8228					
Adjusted R^2	0.6259					

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Table 5: Analysis of variance for mixture quadratic model for protein

Source	Sum of Squares	df	Mean Square	F	p-value (Prob > F)	
Model	70.67	9	7.85	2.98	0.052	not significant
Linear Mixture	31.77	3	10.59	4.02	0.0409	
AB	2.13	1	2.13	0.81	0.3894	
AC	2.26	1	2.26	0.86	0.3762	
AD	0.77	1	0.77	0.29	0.6008	
BC	8.93	1	8.93	3.39	0.0955	
BD	1.24	1	1.24	0.47	0.5079	
CD	7.69	1	7.69	2.92	0.1183	
Residual	26.35	10	2.64			
Lack of Fit	13.69	5	2.74	1.08	0.467	not significant
Pure Error	12.66	5	2.53			
R^2	0.7284					
Adjusted R^2	0.4839					

Table 6: Proximate composition and energy value of optimized complementary meal, *ogi* and commercial weaning food

Parameters	Optimum blend	*Ogi*	Commercial Weaning Food
Moisture (%)	8.60^{a} ± 0.08	5.83^{b} ± 0.02	3.28^{c} ± 0.01
Ash (%)	3.15^{a} ± 0.14	0.62^{c} ± 0.22	1.85^{b} ± 0
Fat (%)	8.13^{a} ± 0.07	1.04^{c} ± 0.02	4.72^{b} ± 0.02
Fibre (%)	4.12^{a} ± 0.35	2.94^{b} ± 0.06	0
Protein (%)	20.26^{a} ± 0.86	5.71^{c} ± 0.14	16.84^{b} ± 0.11
Carbohydrate (%)	55.75^{c} ± 2.40	83.86^{a} ± 0.02	73.31^{b} ± 0.08
Energy (Kcal/100g)	377.21	367.64	403.08

Values represent mean ± standard deviation of triplicate measurements. Values in a row followed by different letters are significantly different ($p<0.05$)

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 21 No. 9 October 2021 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

Table 7: Mineral content of optimized complementary meal, *ogi* and commercial weaning food

Minerals (mg/100g)	Optimum blend	*Ogi*	Commercial weaning food
Na	$15.30^{b} \pm 0.141$	$3.16^{c} \pm 0.04$	$62.70^{a} \pm 0.17$
Ca	$50.80^{b} \pm 0.141$	$12.00^{c} \pm 0.92$	$105.30^{a} \pm 0.36$
K	$406.10^{a} \pm 0.00$	$69.24^{c} \pm 1.05$	$239.63^{b} \pm 0.99$
Fe	$1.045^{b} \pm 0.141$	$0.07^{c} \pm 0.65$	$3.31^{a} \pm 0.07$
Zn	$7.53^{a} \pm 0.043$	$0.07^{c} \pm 0.01$	$0.54^{b} \pm 0.02$
Mg	$7.50^{c} \pm 0.141$	$40.19^{b} \pm 2.59$	$58.64^{a} \pm 0.07$
Se	$0.03^{b} \pm 0.001$	ND	$0.084^{a} \pm 0.00$
Cd	ND	ND	ND
Pb	ND	ND	ND
I	$5.20^{a} \pm 0.141$	ND	$3.39^{b} \pm 0.12$
Na:K	0.038	0.045	0.595

Values represent mean ± standard deviation of triplicate measurements. Values in a row followed by different letters are significantly different ($p<0.05$)

ND- Not detected

Na: K- Sodium and potassium ratio values

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Volume 21 No. 9
October 2021
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 8: Anti-nutritional composition of the optimized complementary meal, *ogi* and commercial weaning food

Anti-nutrients	Optimum blend	*Ogi*	Commercial weaning food
Tannin (mg / g)	0.01 ± 0.00	0.03 ± 0.00	0.02 ± 0.00
Saponin (mg / g)	0.15 ± 0.00	0.002 ± 0.00	0.002 ± 0.00
Phytates (mg / g)	0.10 ± 0.00	0.03 ± 0.00	0.03 ± 0.00
Trypsin (TIU / g)	0.31 ± 0.03	0.03 ± 0.00	0.03 ± 0.00

REFERENCES

1. **Adepoju OT and AU Etukumoh** Nutrient composition and suitability of four commonly used local complementary foods in Akwa Ibom state, Nigeria. *Afr. J. Food Sci*. 2014; **14(7):** 9544-560.

2. **Onabanjo OO, Oguntona CRB, Maziya-Dixon B, Olayiwola IO, Oguntona EB and AGO Dixon** Nutritional evaluation of four optimized cassava-based complementary foods. *Afr. J. Food Sci.* 2008; **2(12):** 136-143.

3. **Onoja US and IC Obizoba** Nutrient composition and organoleptic attributes of gruel based on fermented cereal, legume, tuber and root flour. *J Trop. Agric. Food Environ. Extension*. 2009; **8(3):** 162-168.

4. **Muhimbula HS, Issa-Zacharia A and J Kinabo** Formulation and sensory evaluation of complementary foods from local, cheap and readily available cereals and legumes in Iringa, Tanzania. *Afr. J. Food Sci.* 2011; **5:** 26-31.

5. **WHO.** Global strategy for infant and young child feeding. 2003: 9.

6. **Dewey KB and KH Brown** Update on technical issues concerning complementary feeding of young children in developing countries and implications for intervention programs. *Food Nutr. Bull.* 2003; **24:** 5-28.

7. **Pelto GH, Levitt E and L Thairu** Improving feeding practices: current patterns, common constraints, and the design of interventions. *Food Nutr. Bull*. 2003; **24(1):** 45-82.

8. **Osendarp SJM, Broersen B, van Liere MJ, De-Regil LM, Bahirathan L, Klassen E and LM Neufeld** Complementary feeding diets made of local foods can be optimized, but additional interventions will be needed to meet iron and zinc requirements in 6- to 23-month-old children in low- and middle-income countries. *Food Nutr. Bull*. 2016; **37(4):** 544-570.

9. **Oyarekua MA and AF Eleyinmi** Comparative evaluation of the nutritional quality of corn, sorghum and millet *ogi* prepared by a modified traditional technique. *J. Food Agric. Environ*. 2004, **2(2):** 94-99.

10. **AOAC**. Association of official analytical chemists official methods of analysis of AOAC International, Gaithersburg, Md. USA. 2005

11. **Makanjuola SA, Enujiugha VN, Omoba OS and DM Sanni** Optimization and prediction of antioxidant properties of a tea-ginger extract. *Food Sci. Nutr*. 2015; **3**: 443–452.

12. **Makkar HP and K Becker** Nutritional value and anti-nutritional components of whole and ethanol extracted *Moringa oleifera* leaves. *Anim. Feed Sci. Technol*. 1996, **63:** 211-228.

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ISSN 1684 5374

13. **Makanjuola SA and VN Enujiugh**a Enhancing sensory perception of plant based nutraceutical drinks by combining plants from different sources: a preliminary study of tea and ginger blend. *Prev. Nutr. Food Sci*. 2017; **22(4)**: 372-375.

14. **Makanjuola SA, Enujiugha VN, Omoba OS and DM Sanni** Combination of antioxidants from different sources could offer synergistic benefits: a case study of tea and ginger blend. *Nat Prod Commun.* 2015; **10**: 1829-1832.

15. **Liu RH** Health benefits of fruit and vegetables are from additive and synergistic combinations of phytochemicals. *Am J Clin Nutr*. 2003; **78 (suppl)**, 517S-520S.

16. **Fasuan O, Fawal O, Enwerem E, Uche N and A Ayodele** Physicochemical, functional and economic analysis of complementary food from cereal, oilseed and animal polypeptide. *Int. Food Res J*. 2017; **24(1):** 275-283.

17. **Folorunso AS, Akintelu SA and AK Oyebamiji** The nutritional, mineral composition and growth response of blended infants and weaning foods made from the combinations of crayfish, maize and millet grains. *Int. J. Food Nutri. Saf*. 2019; **10(1):** 1-10.

18. **Adeyemo SM and AA Onilude** Reduction of anti-nutritional factors in fermenting soybeans by *lactobacillus plantarum* isolates from fermenting cereals. *Niger. Food J*. 2013; **31(2):** 84-90.

19. **Okafor UI, Omemu AM, Obadina AO, Bankole MO and SAO Adeyeye** Nutritional composition and antinutritional properties of maize *ogi* cofermented with pigeon pea. *Food Sci Nutr*. 2018; **6**: 424–439.

20. **Pikuda O and N Ilelaboye** Proximate and chemical composition of *OGI* prepared from whole and powdered grains (Maize, Sorghum and Millet). *Ann. Biol. Res.* (2013); **4**: 239-242.

https://doi.org/10.18697/ajfand.104.19955