Nutritional adequacy of two complementary foods developed from germinated-fermented/roasted quality protein maize and fermented/roasted pigeon pea flour

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ABSTRACT

Background: *Poor quality complementary foods contribute to high level of under-nutrition during complementary feeding period.*

OBJECTIVE: *This study examined the nutritional adequacy of two complementary foods developed from quality protein maize (QPM) fortified with pigeon pea (PP) using different processing methods.*

METHODS: *Germinated-fermented QPM/fermented-PP and roasted QPM/PP flours were combined separately with fish, carrot, pumpkin leaf powder, sucrose, and oil in the ratio 50:20:10:6:4:5:5 to formulate two diets, CompifO and CompifR using Nutri-Survey package. Nutrient (proximate, essential amino acids, iron, zinc, calcium, beta-carotene) and anti-nutrient (phytate) contents of the formulated diets were evaluated using standard procedures. The results were compared with World Health Organisation's recommendations for processed complementary food and a commercial complementary food (CCF) (control). Statistical analysis was done using ANOVA and Duncan's Multiple range tests.*

RESULTS: *CompifO had similar protein content (17.2%; 16.8%)but significantly higher iron (3.60, 1.95 mg/100 g), zinc (3.35, 1.15 mg/100 g) and vitamin A (104.21 RE, 90.61 RE) content than CompifR. The control had higher micronutrient contents than the formulated diets ($p<0.001$). CompifO had lower phytate: iron and zinc molar ratios than CompifR. CompifO and CompifR satisfied the recommended energy density (≥4 kcal/g) and protein density (> 4 g/100 kcal) for 6-8, 9-11 and 12-24 months age groups. The amino acid scores of CompifO (75%) and CompifR (74%) were similar but significantly lower ($p<0.001$) than that of the CCF (89%). The limiting amino acid in the two formulations was*

CONCLUSION: *CompifO formulated from germinated-fermented grains was better than CompifR in terms of nutritional adequacy and may contribute to reduction in undernutrition among children.*

Keyword: *Complementary foods, fermentation, pigeon-pea, roasting*

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INTRODUCTION:

Under-nutrition, particularly, micronutrient deficiency among children below five years continues to be a key public health concern in Nigeria.The rising level of under-nutrition coincides with the time complementary foods are introduced to children (1). This is a consequence of poor complementary feeding practices (1). Stewart *et al*. (2) attributed childhood stunting to poor quality complementary foods due to high level of anti-nutrients affecting bio-availability of protein and minerals, poor consumption of micronutrient-rich foods and insufficient intake of animal source foods.

Cereal gruel particularly, maize (*Zea mays*) gruel is very common as the first line of complementary food in many developing countries. The nutritional value of maize was improved through the development of Quality Protein Maize (QPM) which possesses appreciable quantities of lysine and tryptophan (3). Pigeon pea (*Cajanus cajan)* is an underutilized legume with an excellent nutrient profile (4). Blue whiting, commonly referred to as *panla* is a specie of *Micromesistius* in the cod family measuring about 22-30cm in length (5). It is a nutritious marine fish consumed widely in the Southwestern states of Nigeria with moisture, protein, fat and carbohydrate contents approximately 75.0%, 18.1%, 2.6%, and 2.4%, respectively (6). Fresh carrot *(Daucus carota*) and pumpkin leaves (*Telfairia occidentalis)* are rich in vitamins, beta-carotene, antioxidants, minerals and fibre (7).

The methods of processing of the ingredients used for the formulation of complementary foods greatly influence the properties. Fermentation and germination improve the protein and mineral digestibility and bio-availability of plant-based meals (8). It was reported that combined germination and fermentation of maize and fermentation of pigeon pea reduced greater proportion of anti-nutrients and retained more nutrients than other methods (9). Roasting is common among local women because of its low energy and time consumption.

Data on the implications of using fermentation/germinated or roasted grains on the nutritional quality of complementary foods particularly, bioavailability of micronutrients is scanty. The use of simple processing techniques that reduce anti-nutrients as well as retain the essential nutrients in complementary foods is of great importance in child nutrition. Availability of quality complementary foods would contribute to reduction in undernutrition among young children. Thus, this study aimed at examining the effect of processing methods on the nutritional adequacy of two complementary foods developed from germinated-fermented and roasted maize-pigeon pea flour blends.

2.0 MATERIALS AND METHODS

2.1 Sample collection

Quality Protein Maize (QPM) (ART 98/SW6-OB) and pigeon pea seeds (*Cajanus cajan*, 7D variety) were collected from the Institute of Agricultural Research and Training (IAR&T), MOOR Plantation, Ibadan. Blue whiting (codfish)was identified at the Institute of Oceanography, Lagos, Nigeria. Carrot and pumpkin leaves used for the study were obtained from the same stock in farms to ensure homogeneity. Grand soya oil (UAC) and granulated sugar (Dangote brand) were purchased from a supermarket in Ota, Ogun State.

2.2 Study design

The study was a laboratory experimental based research conducted in two phases: processing/analysis of major ingredients and formulation/analysis of developed complementary foods. The details of the ingredient processing have been published (9). Maize and pigeon pea seeds were fermented, germinated and germinated-fermented separately. The processed seeds were analysed to select maize and pigeon pea seeds that had lowest phytate contents (>80% reduction) and retained more iron, calcium, zinc and protein contents after processing.

2.3 Ingredient preparation and processing

Production of germinated-fermented maize seeds flour: About 1 kg of quality protein maize seeds were cleaned, soaked in excess tepid water for 24 hours (rinsed at 12th hour and 24th hour), washed and spread on moist jute bags and allowed to ferment for 72 hours. The germinated-fermented seeds were oven-dried at 60°C (L-501535, UNISCOPE, United Kingdom) for 20-22 hours, dehulled, milled using an Orange mixer grinder (IS:4250, Harsh Electricals, India) and sieved with a 450 μm pore sieve into germinated-fermented maize flour.

Production of fermented-boiled pigeon pea flour: One kilogram of pigeon pea seeds were cleaned, washed and soaked in excess tepid water (1:3 w/v) for 12 hours and allowed to ferment naturally for 72 hours at room temperature. The fermented seeds were washed and boiled for 20 minutes. The seeds were then oven-dried at 60°C (L-501535, UNISCOPE, United Kingdom)for 21 hours, cracked, dehulled, milled using an Orange mixer grinder (IS:4250, Harsh Electricals, India) and sieved with 450 μm mesh sieve into pigeon pea fermented flour.

Roasted pigeon pea and maize seeds flour: Whole maize and pigeon pea seeds were soaked separately in water for four hours , drained and roasted at about 110°C in the oven for 75 minutes with intermittent stirring. The roasted seeds were cracked, dehulled and finely milled into flour. The flour was sieved with 450 μm mesh sieve.

Pumpkin leaf powder: Fresh pumpkin leaves were washed, drained and oven-dried at 50^0C. The dried leaves were then milled and sieved with same mesh and packaged in zip lock bags

Carrot powder: Fresh carrots were cleaned with water. The outer layers were peeled with knife and the carrots were washed again. The carrots were sliced (0.3cm) dried in the hot air oven at 50^0C for 18 hours and blended to carrot flour. The prepared flour was sieved, packaged and preserved at 4°C until required for use (10).

Fish powder:. Fresh fish was descaled, beheaded and thoroughly washed to remove dirt. The cleaned fish was boiled for about 10 minutes and placed in a drying oven under 54°C for 16 hours with occasionally stirring after 30 minutes to allow even drying. The dried fish was milled and stored in the refridgerator at 4°C after removing the sample for analysis.

2.3 Formulation of complementary foods

Nutri-Survey software was used to obtain the combination ratio of maize, pigeon pea, carrot, pumpkin leaves and fish flour needed for energy, protein and fat contents of 400 kcal, 15 g and 10-25 g per 100 g, respectively with reference to the Codex Alimentarius Commission Recommendations for older infants and young children (11). This was done through material balancing based on the nutrient composition of individual ingredients determined during the preliminary study. The germinated-fermented maize/fermented-boiled pigeon pea and roasted maize/pigeon pea flours were combined separately with fish, carrot, pumpkin leaf powder, sucrose, and oil in the ratio 50:20:10:6:4:5:5, respectively, to formulate two complementary foods, CompifO and CompifR flours.

Four hundred and fifty milliliter (450 mls) gruel was poured each time in a tray (< 0.3 cm thick) and dried in the oven at 50^0C for five hours. The CompifO and CompifR flakes obtained were ground with the Orange mixer grinder and tagged CompifO and CompifR grits. Two hundred milliliters (200 mls) of complementary meals were prepared separately with 40 g CompifO and 50 g CompifR grits as follows:

40 g of CompifR grits + 150 mls hot water ------ Compif R meal (200 mls)

2.4 Chemical analysis

The unprocessed, processed flour and the complementary meal in flakes or grits were analysed for nutrient and anti-nutrient composition.

2.4.1 Determination of nutrient and anti-nutrient composition

The moisture (hot air oven method), protein (Kjedahl method), fat (Soxhlet extraction method) and ash/fibre (dry ashing, gravimetric method) were determined using AOAC standard methods (12). Carbohydrate was calculated as the difference between 100 and values of other macronutrients. Energy was determined using the Atwater factors (4 kcal per gram of carbohydrate and protein each; 9 kcal/gram of fat). The iron and zinc contents were determined using the atomic absorption spectrophotometer (AAS) (method #975.23) while calcium contents were analysed using method #975.11. Phytate, tannin, oxalate, haemaglutinnin, saponin and polyphenol contents of the formulated complementary foods were determined using standard methods as described in AOAC (2005). Beta-carotene content was determined using the method #941.15. Results were converted to retinol equivalent (RE) using the conversion factor 6 μg β-carotene= 1 μg RE.

2.4.2 Determination of amino acid content

Amino acids were determined through spectrophotometry using ninhydrin chemical reaction (13).

2.4.3 Determination of Phytate:mineral ratios

The results of the phytic acid analysis were used to calculate phytic acid to iron molar ratio and phytic acid to zinc molar ratio (14), using the formula:

$$Phyticacid: mineralmolarratio = \frac{phyticacid(g/100g)\ /\ 660.04}{Mineral\ (g/100g)\ /\ molarmass} \quad (1)$$

2.5 Statistical analysis

Data analysis was undertaken using SPSS version 20.0. Nutrient composition of the formulated diets were expressed as means and standard deviations. Differences among these variables were evaluated using a one-way analysis of variance and Duncan's Multiple Range Test was used to separate mean differences when the significance was reported as $p<0.05$.

3.0 RESULTS

3.1 Nutrient and phytate composition of ingredients for complementary foods

Table 1 displays the protein, mineral and phytate composition of ingredients used for the formulation of the complementary foods. From the table, it was observed that dried fish powder (DFP) had about 200 % more protein content than the fermented boiled pigeon pea per 100 g dried portion. It was also observed that pumpkin leaves powder had more than 10% protein content per 100 g. DFP had the highest content of calcium (362±21.14 mg/100g)., Pumpkin leaf powder (TSP) had the highest phytate content of 629 mg/100g which was about four times of the value in carrot powder (CP) (156 mg/100g). The processed products had low phytate levels (72.85-97.00 mg/100g) (Table 1).

Table 1. Protein, mineral and phytate composition of ingredients for complementary foods (dry weight basis)

Ingredients	Crude P %	Ca (mg/100g)	Fe (mg/100g)	Zn (mg/100g)	Vitamin A (RE)	Phytate (mg/100g)
GFM	9.92 ± 0.13	4.63 ± 0.11	2.93± 0.11	1.83±0.03	ND	74.50± 4.95
RM	9.85 ± 0.14	9.42± 1.22	2.13 ± 0.57	1.79 ± 0.12	NA	72.85± 2.99
FERBP	23.49 ±0.05	35.33 ± 4.25	18.40 ±2.14	1.99 ± 0.09	163.23 ±10.99	97.00± 7.07
RP	20.45± 0.04	37.57 ± 3.88	17.44 ± 1.98	1.78± 1.14	152.21± 11.24	79.81± 1.22
DFP	77.93±0.26	362.00 ± 1.14	8.15±0.07	7.85±0.16	39.43 ±0.81	97±0.42
TSP	19.50±0.14	236.50±1.20	3.20±0.15	2.95±0.24	212.73± 2.22 (638.20 μgRE)	629±2.52
CP	9.20±0.14	27.45±0.07	0.45±0.05	0.30±0.05	576.13±5.44 (1728.39 μgRE)	156±0.98

Values are expressed as mean ±SD (n=3). GFM: Germinated fermented maize flour, RM: Roasted maize, FERBP: Fermented boiled pigeon pea flour, RP: Roasted pigeon pea, DFP: Dried steamed fish powder(codfish), TSP: Dried pumpkin leaves powder, CP: Carrot powder.

ND = Not detectable

NA= Not analysed

RE= Retinol equivalent

Table 2. Proximate, mineral and vitamin content of complementary foods compared with WHO recommendation

Parameters	Compif O	Compif R	CCF[#]	Codex Standard*
Moisture	$6.97^{a} \pm 0.09$	$5.94^{b} \pm 0.05$	$4.50^{c} \pm 0.00$	< 5
Crude Protein (%)	$17.18^{a} \pm 0.04$	$16.79^{a} \pm 0.02$	$15.50^{b} \pm 0.00$	15
Crude Fat (%)	$7.75^{c} \pm 0.07$	$9.30^{b} \pm 0.28$	$10.00^{a} \pm 0.00$	10-25
Crude Fibre (%)	$2.00^{b} \pm 0.14$	$1.70^{b} \pm 0.14$	$2.20^{a} \pm 0.02$	<5
Ash (%)	$2.21^{b} \pm 0.14$	$2.50^{a} \pm 0.14$	$2.60^{a} \pm 0.00$	<3
Carbohydrate (%)	$66.01^{b} \pm 0.08$	$65.48^{b} \pm 0.50$	$67.30^{a} \pm 0.00$	60-65
Energy(kcal/100g)	$402.51^{c} \pm 0.16$	$412.76^{b} \pm 0.65$	$425.00^{a} \pm 0.02$	400-425
Ca (mg/100g)	$83.00^{c} \pm 0.14$	118^{b}	410^{a}	250 (50% of RNIs)
Fe (mg/100g)	$3.60^{b} \pm 0.00$	1.95^{c}	8.52^{a}	$1.95\text{-}5.80^{\beta}$ (50% of RNIs)
Zn (mg/100g)	$3.35^{a} \pm 0.07$	1.15^{b}	3.00^{a}	$1.20\text{-}4.15^{\beta}$ (50% of RNIs)
Vitamin A(μg RE)	312.89^{b}	271.82^{c}	370.00^{a}	200 (50% of RNIs)
Phytate (mg/100g)	179.00^{a}	146^{b}	[$] 66.92^{c}	

*Codex Alimentarius Commission (2013)

[#]Nutrition label

[$] Amagloh (2014)

Iron and zinc values given for high to low bioavailability.

RNIs (1-3 years) for Calcium, Iron, Zinc, and Vitamin A are 500 mg, 11.6 mg, 8.3 mg and 400 μg, respectively. (Nutritional Guidelines for Complementary foods Supported by GAIN (GAIN, 2014)

3.2.2 Proportion of energy and some nutrients provided by the formulated complementary foods compared to recommendations

Table 3 displays the proportion of recommended energy and nutrients provided by the formulated complementary foods. The energy density of one meal (40g dry portion) of CompifO and CompifR satisfied the recommended energy density of ≥4 kcal/g for 6-8, 9-11 and 12-24 months age groups. Two feedings of the formulated foods provided about 12% of 550 kcal as protein for 12 to 24 month children. The estimated fat intakes from the formulated foods did not meet the recommended intakes from complementary foods for age groups 9-11 and 12-24 months. The estimated daily energy intakes from CompifO and CompifR were about 81% and 83% of the recommended 200 kcal (6-8 months old infants); 67% and 69% of 300 kcal (9-11 months old infants) and 73% and 75% of the recommended 550 kcal (12-24 months), respectively

3.2.3 Essential amino acid pattern (mg/g) of formulated foods

Data on the essential amino acid pattern of the formulated foods is presented in Table 4. According to Table 4, the recommended limit for the total sulfur amino acids (27 mg/g) was met by CompifO (27 mg/g) but not CompifR (25.8 mg/g). The two formulated complementary foods had more than the recommended total aromatic amino acids (tyrosine and phenylalanine) (52 mg/g). Isoleucine contents of the two formulated complementary foods were four times higher than the reference value. There was no significant difference in the amino acid scores (AAS) of CompifO (75%) and CompifR (74%) but they differed significantly ($p<0.001$) with that of the CCF (89%). The limiting amino acid in the two formulations was lysine.

Table 3. Contribution of energy and some nutrients from formulated complementary foods compared to recommendation (6 to 24 months children, developing countries)

	6-8 MONTHS			9-11 MONTHS			12-24 MONTHS		
Energy/nutrients	CompifO	CompifR	Refvalue[ab]	CompifO	CompifR	Refvalue	CompifO	CompifR	Ref value
Quantity of food (g)	40	40	40	50	50	10-50	100	100	10-50 per feed
No of feedings	1	1	2-3	1	1	3-4	2	2	3-4
Energy density (kcal/g)	4.03	4.13	≥ 0.8	4.03	4.13	≥ 0.8	4.03	4.13	≥ 0.8
Energy(kcal/day)	161±0.0	165 ± 0.00	200	201.26	206.38	300	402.51	412.76	550
Protein (g/day)	6.87±0.04	6.72±0.02	*5 (10%) (6-15%)	8.59	8.40	*7.5(10%) (6-15%)	17.18	16.79	*13.75(10 %) (6-15%)
Protein density (g/100 kcal)	4.26	4.07	5.5	4.26	4.07	5.5	4.26	4.07	5.5
Fat (g/day)	3.10±0.04	3.72±0.05	0 (10-25%)	3.88	4.65	6.67 (20%)[x] (10-25%)	7.75	9.30	12.22 (20%) (10-25%)
Fat density (g/100 kcal)	1.93	2.25	-	1.93	2.25	4.5	1.93	2.25	4.5

[238a]PAHO/WHO(2003) (22)

[b] Codex Alimentarius Commission (2013) (14)

Energy density = energy in food/quantity or volume of food

* 10% of ref calorie from processed complementary food. 10% of 200 kcal= 5

Nutrient density= Nutrient content/Energy density x 100, Percentage= estimated calorie from one serving/recommende daily calorie for the age group x 100

Table 4. Essential Amino acid pattern (mg/g dry weight) and protein corrected amino acid score of formulated diets

Amino acid	FAO/WHO EAA pattern ð	CompifO	CompifR	CCF*
Cystine		6.4	5.6	
Methionine		20.6	20.2	
Total sulfur A.A	27	27	25.8	46.1
Lysine	57	42.8	42.0	50.5
Valine	43	45.5	42.2	59.6
Tryptophan	8.5	72.5	71.8	15.3
Tyrosine		26.1	25.1	
Phenylalanine		57.9	57.6	
Total aromatic A.A	52	84.0	82.7	96.9
Leucine	66	109.0	108.4	87.8
Isoleucine	32	150.1	148.8	47.1
Threonine	31	40.3	39.4	38.5
Histidine	20	62.5	62.8	29.5
AAS@		0.75^b	0.74^b	0.89^a
LEAA[R]		lysine	Lysine	lysine

ð Reference essential amino acid pattern for 6 months to 3 years old children
@Amino acid score (AAS) = Amino acid content of test diet divided by the reference value
[R] Limiting essential amino acid (LEAA) = The amino acid with the lowest amino acid score ratio.

Table 5. Phytate, iron, zinc and calcium molar ratios of Complementary foods

Complementaryfood	Phytate	Iron	Zinc	Calcium
CompifO (mg/100g)	179	3.60	3.40	83
CompifR (mg/100g)	146	1.95	1.15	118
CompifO (molar ratios)		4.17^b	5.32^b	0.13^a
CompifR (molar ratios)		6.31^a	12.28^a	0.08^b
P value		0.008	0.010	0.002
Maximum recommended Molar ratios		<1	<15	<0.17

3.2.4 *Phytate, iron, zinc and calcium molar ratios of formulated complementary foods*

Table 5 shows the phytate, iron, zinc and calcium molar ratios of formulated complementary foods. The two complementary foods had higher molar ratios than the recommendation for phytate:iron molar ratio (4.17, 6.31 vs<1) for plant based complementary foods. The maximum recommended phytate:zinc ratio (<15) was met for CompifO (5.32) and CompifR (12.28) (Table 5). However, there were significant differences between the two formulated complementary foods in phytate:calcium, iron and zinc ratios. The CompifO performed better in phytate:iron and phytate:zinc ratios than CompifR while CompifR was better in phytate:calcium ratio.

4.0 DISCUSSION

4.1 *Nutritional adequacy of formulated complementary foods*

The moisture values of the formulated foods were within the acceptable limit of 10% for dried powdered foods. The fat contents of the formulated diets were higher than the 4.56-4.79 % reported for complementary foods formulated from maize, pigeon pea and moringer leaves (15) as well as that of maize-pigeon pea-carrot based complementary food (3.07-4.15%) (16). The addition of oil to the foods formulated in this study could have contributed to the higher fat level. The use of oilseeds (roasted sesame) with malted maize and crayfish resulted in a blend of higher fat (25.59%) content (17). However, the lower-fat contents of the formulated diets in relation to recommendation (10-25%) did not affect the energy values. The fat content of CompifO was more than that of CompifR by 20%. This occurrence could be due to the fact that roasted maize and pigeon pea had higher contents of fat compared to germinated-fermented maize and fermented pigeon pea, respectively.It thus implies that roasting may result to higher fat content due to reduction in moisture The crude fibre contents of the formulation diets were lower than the maximum value of 5% specified in the CODEX Alimentarius guideline for processed foods for infants and young children (11) and comparable to the values (1.98-2.71%) reported by Bello et al. (16). Low dietary fibre is one of the qualities of good complementary food because high crude fibre content increases bulkiness and with limited gastric capacity of infants, energy and nutrient adequacy might be negatively affected. More importantly, high dietary fibre reduces the bioavailability of micronutrients.

The protein values of the formulated diets were higher than that of Uzokwe et al. (18) (10.63-12.90%) but lower than the complementary foods developed by Fasuan et al. (17) (20.78-28.09%).The quantity and number of protein rich sources used in some of the studies could have contributed to the higher protein values. The protein contents of the formulated diets were comparable and within the recommended value (6-15%) for processed complementary foods. This implies that germination/fermentation and roasting processes had similar effect on protein. This was also depicted in the amino acid composition of the two diets.Both foods (75%, 74%) met the minimum amino acid score of 70% as specified in the CODEX guideline using casein as reference protein. Sufficiency in protein contents of complementary foods is very essential to supply the substrates for rapid growth and development.The isoleucine values were very high, higher than those reported by Okafor et al. (19) for blends of maize and pigeon pea (38.8-43.5mg/g). This could be due to the addition of fish but further investigation is required to ascertain this finding. Surprisingly, lysine was the limiting essential amino acid in the formulated diets and commercial diet (CCF) while the limiting amino acid for a co-fermented maize/carrot-pigeon pea complementary food was tryptophan (20). The lysine contents of the formulated diets in this study were higher than that of the co-fermented maize/carrot/pigeon pea complementary food. Addition of fish, a high quality protein could have contributed to these higher levels. However, it was not expected that lysine will be limited because of the inclusion of pigeon pea, a legume and fish meal. The combination ratio of the formulation could be modified to tackle this deficit. The effect of the processing methods on amino acids might also be linked to the low lysine level. Supreeta et al. (21)

reported that dry heat treatment resulted in the loss of lysine proportional to the degree of heating. In addition, Archibong et al.(22), in their review, opined that prolonged fermentation may reduce the amino acid content of foods by leaching.

The calcium, iron and zinc values recorded in this study were higher than those reported by Bello et al.(16) for cereal-legume-vegetablebased complementary foods. The calcium, zinc and iron levels could be upgraded by increasing the proportion of fish meal in the formulation. Fish contains readily available haem iron, zinc, calcium, vitamin B_6, Vitamin B_{12} as well as high-quality protein. Also, cellular animal protein boosts iron and zinc absorption from plant-based diets. The complementary food developed from roasted grains (CompifR) had lower mineral contents than the one formulated from germinated/fermented grains. This finding supports the report by Sudha et al. (23) that roasting of foxtail millet reduced the ash composition.

The beta-carotene contents of the formulated complementary foods were lower than that of the commercial complementary food despite the inclusion of carrot powder. This might have been due to the degradation of beta-carotene during the heat process as also reported by Zhijun et al. (24) that the steaming of sweet potatoes had negative effect on the total content of carotenoids but had varying effect on the individual carotenoids. Sodipo et al. (25) also reported that fermentation reduced the amount of carotenoids in fermented maize-germinated lentil seed based complementary food. However, the retinol equivalent values recorded in this study were higher than the range of 90.84-160.97 µgRE reported by Tengashaw et al. (26) in teff-soybean-orange fleshed sweet potato based complementary foods. The low values were also attributed to the degradation of beta-carotene during the extrusion cooking, a high temperature process.

The two complementary foods had higher values than the recommendations for phytate:iron molar ratiofor plant based complementary foods by more than 100 %. This finding has implications for iron bioavailability. The phytate:iron molar ratios reported by Beruk et al.(27) for quality protein based foods were lower (1.05-1.69) than the values found in this study. This could be related to the higheriron content (6.75-7.13 mg/100g) of their formulated foods. Phytate:iron/zinc/calcium molar ratios in complementary foods should be less than 1.0, 15 and 0.17, respectively, for efficient mineral absorption based on the recommendation (28). It is noteworthy that CompifO which had higher phytate content, had better phytate:iron, zinc molar ratios compared to CompifR. This might be attributed to the higher quantities of minerals in CompifO. CompifO also had higher beta-carotene (vitamin A level), a possible iron absorption enhancer.

The energy densities of the formulated complementary foods were comparable and higher than those reported for teff-soybean-sweet potatoe based complementary foods (3.70-3.76 kcal/g) (26) and met the minimum standard of 400 kcal/100g.

5.0 CONCLUSION

Complementary food formulated from fermented pigeon pea and germinated-fermented maize was better in nutritional quality than the complementary food developed from roasted maize and pigeon pea.Thus, this study establishes that quality complementary food could be formulated from fermented pigeon pea, germinated-fermented maize, fish, carrot, and pumpkin leaf powder. However, there is need for further investigations on the effect of complementary foods developed using different traditional food processing methods on the nutritional status of young children.

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6.2 Conflict of interest

The authors have no conflict of interests to declare.

6.3 Authors' contributions

DA, GF and KF designed the research. DA conducted the research and wrote the draft paper while GF and KF revised the paper. All authors read and approved the final manuscript.

REFERENCE

1. Bhutta, Z.A., Das, J.K., Risvi, A., Gaffey, M. F., Walker, N. and Horton, S. (2013). Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? Lancet, 382: 452-457.
2. Stewart, C.P., Iannotti, L., Dewey, K.G., Michaelson, K.F. and Onyango, A.W. (2013). Contextualising complementary feeding in a broader framework for stunting prevention. Maternal and Child Nutrition, 9 (Suppl 2): 27-45.
3. Tefera, A.A. (2021). A review on quality protein maize International. Research. Journal of Plant. Sci. 11(2): 1-6.
4. Fatokimi, E.O. and Tanimonure, V.A. (2021). Analysis of the current situation and future outlooks for pigeon pea (*CajanusCajan*) production in Oyo State, Nigeria: A Markov Chain model approach. Journal of Agriculture and Food Research, 6:100218.
5. Amusan, E. E., Sanni, A. I. and Banwo, K. (2019). Prevalence of Listeria species in blue whiting (*Micromesistuspoutasou*) in Lagos State, Nigeria. FUDMA Journal of Sciences (FJS), 3 (3): 270 –275.
6. Kolade, O. Y. (2016). Biochemical composition of *Micromesistuspoutassou* from agbalata market, Badagry Lagos West, Nigeria. Food and Applied Bioscience Journal, 4(1): 12–24.
7. Rasaki, S., Eno-bong, H. and Leshi, O.O (2016). Nigerian Food Composition Table (NFCT). Nestle Foods.
8. Tufa, M.A., Urga, K.,Weledesemayat, G.T. and Mitiku, B.G. (2016). Development and nutritional assessment of complementary foods from fermented cereals and soybean. Journal of Food Science and Nutrition, 2:014.
9. Anaemene, D. and Fadupin, G. (2022). Anti-nutrient reduction and nutrient retention capacity of fermentation, germination and combined germination-fermentation in legume processing. Applied Food Research, 2(1):100059
10. Umerah, N.N., Oly-Alawuba, N.M., Asouzu, A.I. and Oluah, G.U. (2020). Rheology andFunctional Properties of Complementary Food Made from Maize (*Zea mays*) Supplemented with Crayfish (*Euastacusspp*) and Carrot (*DaucusCarota*) Flour. Asian Journal of Biotechnology and Genetic Engineering, 3(1): 41-48.
11. Codex Alimentarius Commission. (2013). Guidelines for formulated supplementary foods for older infants and young children. Rome, Italy: Codex Alimentarius Commission; CODEX STAN 008-1991, Revised 2013.
12. AOAC. (2005). Official methods of analysis of AOAC International; Horwitz W, eds. Gaithersburg, Washington, DC, USA: AOAC International.
13. Ayele, D.A., Teferra, T.F. and Coebremedhin, F. J. (2022).Optimisation of nutritonaland functional qualities of local complementary foods of Southern Ethiopia using a customised mixture design. Food Science and Nutrition, 10(1): 239-252 .
14. Rahman, S. and Shaheen, N. (2022). Phytate-iron molar ratio and bioavailability of iron in Bangladesh. Tropical Medicine and International Health, 27(5):509-514.
15. Badebo, E. D. and Eyesa, W.W. (2021). Nutritional and sensory evaluation of complementary food formulated from maize, pigeon pea and

moringastenoptela leaves in Southern Ethiopia. Research Journal of Food Science and Nutrition, 6(2): 8-13.

16. Bello, F. A., Akpaoko, N. A. and Ntukidem, E. (2020). Formulation and assessment of nutritional functional and sensory attributes of complementary foods from maize-carrot-pigeon pea flour blends Journal of Scientific Research & Reports, 26(2): 90-99.

17. Fasuan, T.O., Fawale, S.O., Enwerem, D.E., Uche,N. and Ayodele, E.A. (2017). Physico-chemical, functional and economic analysis of complementary food from cereal, oilseed and animal polypeptide.International Food Research Journal,24(1): 275-283.

18. Uzokwe, C.A., Chukwu, C.G. and Adedotu, O. (2019). Nutrients composition and sensory evaluation of white maize complementary food fortified with African palm weevil larvae and beetroot. Nigerian Journal of Nutritional Sciences, 43(1): 63-70.

19. Okafor, U.I., Omemu, A.M., Obadina,A.O., Bankole,M.O. and Adeyeye, S.A. (2018). Nutritional composition and anti-nutritional properties of maize ogi co-fermented with pigeon pea. Food Science and Nutrition, 6:424-439.

20. Oyarekua, M.A., Oni, K.O and Sani T.A. (2023). Evaluation of nutitionalproperties of co-fermented maize/carrot/pigeon and millet/sweet potatoe/pigeon pea as infant complementary food. African Journal of Agriculture and Food Science, 6(1): 1-16, DOI: 10.52589/AJAFS-VOIPEQFJ.

21. Supreetha, S., Purmima, K. and Jamuma, P. (2009). Retention of lysine in foods processed with microwave and conventional heating. International Journal of Food Engineering, 5(3).

22. Archibong, I.E., Essien, E.B., Amadi, B.A. and Anacletus, F. (2022). Nutritional composition of traditional complementary foods in Nigeria and health/developmental outcomes: A systematic Review. Scientific African, Article16 e01203

23. Sudha, K.V., Karakannavar, S. J., Yenagi, W.B. and Inamdar, B. (2021). Effect of roasting on the physico-chemical and nutritional properties of foxtail millet (*Fetariaitalica*) and bengal gram dhal flours. The Pharma Innovation Journal, 10(5): 1543-1547.

24. Zhijun, P., Yimimg, S., Fangyuan, Z., Xinbo, G. and Zhihua, L. (2019). Effect of Thermal Processing on Carotenoids and Folate Changes in six Varieties of Sweet Potatoe (*Ipomoea batata L.*). Foods, 8:215.

25. Sodipo, M., Oluwagbenga, A., Jolayemi, O. and Lawal, O. (2020). Development and nutritional evaluation of a complementary diet from fermented provitamin-a-biofortified maize (*Zea mays* L.) and germinated lentil seeds (*Lens culinaris*). Croat. Journal. Food Science of Technology, 12(1): 90-100.

26. Tengashaw, M.W., Kinyuru, J.N., Kenji, G.M., Melaku, E.T. and Susanne, H-K. (2017). Nutrient density of complementary foods formulated from a blend of teff, soybean and orange fleshed sweet potatoe. International Journal of Food Science and Nutrition Engineering, 7(4): 61-69, doi:10.5923/j.food.20170704.01

27. Beruk, D.B., Kebede, A. and Esayaf, K. (2015). Effect of blending ratio and processing technique on physicochemical composition, functional properties and sensory acceptability of quality protein maize (QPM) based complementary food. International Journal of Food Science and Nutrition Engineering, 5(3): 121-129.

28. Roos, N., Sorensen, J.C., Sorensen, H., Rasmussen, S.K. et al. (2013). Screening for anti-nutritional compounds in complementary foods and products for infants and young children. Maternal and Child Nutrition, 9 (Suppl 1): 47-71.