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Physico-Chemical and Sensory Evaluation of Maize-Pigeon Pea Based Complementary Foods Fortified with Milk and Fish powder

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Abstract

Undernutrition among young children during the complementary feeding is high. Quality cereal-legume based complementary food fortified with fish or milk would contribute towards reduction of undernutrition in young children. There is need for information on the animal source food that confers the best nutritional value on cereal-legume based complementary foods. This study assessed the physico-chemical and sensory characteristics of maize-pigeon pea based complementary foods fortified with either milk or fish. Two complementary foods fortified with milk (COMPIM) and fish (COMPIF), were formulated from germinated maize, fermented pigeon pea, carrot and date powder using NutriSurvey application. The formulated diets were evaluated for nutrients, anti-nutrients, functional and sensory properties using standard methods and compared with commercial complementary food (CCF) and maize gruel (HCF). Data was analysed using Analysis of variance (ANOVA) and significant means were separated via Duncan's multiple range test at p<0.05. COMPIF AND COMPIM were comparable in nutrient contents except in beta-carotene, lysine and methionine. Both formulated diets compared favourably with the commercial complementary food in crude protein, ash and moisture contents but had significantly (p<0.05) lower calcium and iron values. COMPIF had the highest lysine (0.57%) and methionine (0.21%) contents as well as lower anti-nutrients content compared to COMPIM. COMPIF had lower Water Absorption Capacity (WAC) and viscosity than COMPIM (86.67 mg/100 g; 9.50 ml/s vs 93.75%; 13.30 ml/s). COMPIM was rated higher than COMPIF in terms of taste, aroma and overall acceptability. The maize-pigeon pea complementary food fortified with fish was better than the one fortified with milk in terms of beta-carotene, lysine, methionine, functional and anti-nutritional properties but was less accepted. Further work is needed to improve the organoleptic properties of complementary foods fortified with fish.

Keywords: Maize, Complementary foods, Fish, Milk, Pigeon pea, Fortified foods

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INTRODUCTION

Complementary feeding period is the period starting from six months of age when the infant is gradually introduced to other foods including family meals while still breastfeeding. Infants and young children are particularly vulnerable to under-nutrition during this period because of increased energy and nutrient needs required for rapid growth and development (World Health Organisation, (WHO), 2023). It is recommended that the complementary food mix should contain at least four food groups out of the seven food groups (National Population Commission (NPC/ICF), 2019). The seven food groups include grains, roots and tubers, legumes and nuts, dairy products, flesh foods, eggs, vitamin A-rich fruits and vegetables, and other fruits and vegetables (WHO, 2021).

Pigeon pea (*Cajanus cajan L.*) is a nutritionally important grain in the tropics, rich in protein and minerals (Anaemene, 2020). Pigeon pea, though indigenous to many communities in Nigeria, is grossly underutilized and unknown to many people in Nigeria. The use of Pigeon pea to improve the protein quality of starchy staples has been reported (Ibironke *et al*., 2014). Yellow maize contains 74.70 g carbohydrate, 9.26 g protein and 3.95 g fat per 100 g (Nigeria Food Composition Table (NFCT), 2017) and is rich in beta-carotene. Maize (*Zea mays*) is a staple cereal food consumed throughout the world. It contains potassium, magnesium, iron, B vitamins, vitamin C and E. Yellow maize contains 74.70 g carbohydrate, 9.26 g protein and 3.95 g fat per 100 g (NFCT, 2017) and is rich in beta-carotene. Carrots (*Daucus carota*) are root vegetables and orange may be their best-known colour, but they also come in other kinds, including purple, yellow, red, and white. They are rich in vitamins, antioxidants, minerals and fibre (Krishan, 2012). Dates (*Phoenix dactylifera*) is a flowering plant species in the palm family, *Arecaceae*, cultivated for its edible sweet fruit (Hussain *et al.,* 2019)). Date palm fruit is an edible fruit, rich in sugar, vitamins B and antioxidants (Iftikhar *et al.,* 2015).

Milk is a good source of many essential nutrients, including calcium, protein, and vitamin D (Paul *et al*., 2020). Milk has been found to be a good source of nutrients for bone and brain health (Tumuhimbise *et al*., 2019). Fish contains omega-3 fatty acids, vitamins; B2 (riboflavin) and D, a great source of minerals; calcium, phosphorus, iron, zinc, iodine, magnesium, and potassium (Cartmill *et al*., 2022) which are essential for children's brain and neurological development (Maulu, 2021).

Adequate supply of dietary protein is vital for maintaining cellular function and integrity and for ensuring optimal health and growth (Williams, 2018). Animal based proteins are of very good quality. Thus, inclusion of animal source foods is recommended in complementary foods.

Food based strategies such as germination, fermentation and fortification of cereal/legume with Animal Source Foods (ASF)/vegetables improve the nutritional quality of complementary foods/snacks (Addis *et al*., 2013). Germination and fermentation cause positive changes in the nutritional and chemical composition of foods (Nkhata *et al*., 2018) as they result in the reduction of anti-nutritional factor.

Extensive work has been done on developing quality complementary foods using various foods from the seven food groups. Emphasis has been laid on the need to include ASFs in complementary foods. These ASFs have varying costs and availability. There is need to know if they confer relatively same nutritional and sensory quality when added to complementary mix. There are very few works that compared exclusively the effect of using different animal food sources in complementary food formulations on their nutritional and physical characteristics. Therefore, this study examined the physico-chemical and sensory properties of complementary foods formulated from maize, pigeon pea, carrot, dates and fortified with either milk or fish.

MATERIALS AND METHODS

Collection of Materials

Maize and pigeon pea seeds were purchased at Ijoko market, Sango Ota, Ogun State. Cod fish was purchased from a cold room while powdered milk, carrots and dates were purchased from the local market. The ingredients were stored prior to their use.

Sample Preparation

Germinated-fermented maize and fermented maize flour production

Germinated-fermented maize flour was produced using the methods described in a previous work (Anaemene and Fadupin, 2020). Briefly, 3 kg of maize seeds were sorted manually, washed, soaked for 24 hours and spread on jute bags for 72 hours to sprout. After the germination period, the seeds were soaked for 24 hours, oven dried ((Ignis ACF040-MB) at 60 ^{o}C for 21 hours, dehulled manually, milled with Orange mixer grinder (IS:4250, Harsh Electricals, India) and sieved (60 mesh) to obtain a fine flour. The product was packaged and labelled accordingly. Another batch of maize seeds was steeped for 72 hours for fermentation to take place. The fermented seeds were washed, drained, dried in the hot air oven, milled and sieved to produce fermented maize flour referred as in this work as homemade complementary food (HCF).

Fermented pigeon pea flour production

About 1 kg of Pigeon pea was sorted to remove stones and dirt. It was then washed and soaked in distilled water (1:3 w/v), put in a plastic bowl for 72 hours and allowed to ferment. The fermented seeds were washed, drained, spread on a tray, and oven dried at 60 ^{o}C for 20 hours. The hulls of the seeds were removed by rubbing them in-between the palms. The dried seeds were milled, sieved, packaged and stored at 4 °C.

Carrot powder production

Fresh carrots were cleaned with water, the outer layers were scraped and washed again. The carrots were sliced (0.3 cm), drained and placed on trays. They were dried at 50 °C for 18-20 hours and blended to attain carrot flour. The prepared flour was sieved, packaged, labeled and stored at 4 °C until required for use.

Fish powder production

Fresh *panla* fish (cod fish) was descaled, beheaded and thoroughly washed to remove dirt and bones. The cleaned fish was boiled for about 10 minutes, deskinned and deboned manually before placing in a drying oven under 54 °C for 16 hours with occasional stirring every 30 minutes to allow even drying. The dried fish was milled, sieved, packed in zip pock bags and stored at 4°C.

Date flour production

Date palm fruits were washed with water to remove dirt. The fleshy part of the fruit was removed manually and cut into tiny pieces with a knife before drying at 60 °C for 72 hours.

The dried product was ground with a blender. The powder was packaged for later use after being sieved to fine flour (Ihuoma *et al.*, 2021).

Formulation of Maize-Pigeon Pea Based Complementary Foods
An application called NutriSurvey was used to calculate the combination ratio of the processed ingredients. Results of the chemical analysis of the processed ingredients per 100 g were added to the database of the NutriSurvey App. Using material balancing, the ratio of ingredients that gave energy, protein and fat contents of 400 kcal, 15% and 20%, respectively per 100 g of formulated food was determined (Global Alliance for Improved Nutrition (GAIN), 2014). The quantity of fish and milk that provided 7g protein to complement protein from plant protein from maize and pigeon pea were 10 g and 30 g, respectively (Table 1). The products were referred to as COMPIF (Maize-Pigeon Pea Complementary food fortified with fish) and COMPIM (Maize-Pigeon Pea Complementary food fortified with milk). Fermented homemade maize complementary food (HCF) and a commercial complementary food (CCF) were used as controls.

Table 1. Composition of the diet Grits (1000 g)

Ingredients	Proportion (100%)	Quantity(g)	Proportion (100%)	Quantity(g)
	COMPIM		COMPIF	
Germinated Fermented Maize	40	400	50	500
Fermented Pigeon pea	20	200	20	200
Date powder	4.5	45	5	50
Carrot powder	4.5	45	5	50
Vegetable Oil	1	10	10	100
Milk	30	300	0	0
Fish	0	0	10	100
Total	**100**	**1000**	**100**	**1000**

1000 g COMPIM flour + 1500 mls water $\Longrightarrow$ COMPIM paste
1000 g COMPIF flour + 1500 mls water $\Longrightarrow$ COMPIF paste
The pastes were spread into trays containing foil and was dried at 60 °C for 22 hours. The flakes achieved were blended to form grit.

Methods of Analysis

Proximate analysis
The moisture, fat, crude protein (N x 6.25), crude fibre and ash contents of the formulated foods were determined according to the methods described in the official methods of analysis (Association of Analytical Chemists (AOAC), 2016). The protein content was determined using Kjeldahl method. The fat content determination was done by Soxhlet extraction technique using petroleum ether (60 °C), the fat content was calculated using:

$$\frac{W_1 - W_0}{\text{Weight of sample}} \times 100$$

W_1= initial weight; W_0 = final weight
The ash content was determined using incineration of five grams of each sample in a muffle furnace set at 900 °C for six hours till a white greyish matter was obtained. Formula indicated below was used:

$$\frac{Ma - Mo}{Ms} \times 100$$

Where Ma = mass of crucible plus Ash; Mo = mass of empty crucible; Ms = mass of sample.

The total sugar and starch contents were determined using the method of Chow & Landhäusser (2004).

Mineral Analysis
Calcium, zinc and iron were determined using Atomic Absorption Spectrophotometer (AAS) (AOAC, 2016).

Determination of anti-nutrient composition
Phytate, oxalate and hemagglutinin contents were determined using methods described by AOAC (2016).

Functional Analysis
Bulk density determination (Loose and packed density)
Fifty grams (50 g) of each blend was filled into 25 mL measuring cylinder noting their weights (W1). The bottom of the cylinder was tapped continuously to eliminate space between the flour (Ngakou *et al*., 2011). The bulk density was computed with the equation:

$$\text{The bulk density(g/ml)} = \frac{\text{Weight of sample (g)}}{\text{Volume of sample (mL)}}$$

Determination of viscosity
Determination of viscosity was done by heating water slurry containing 10% sample solids in a boiling water bath with continuous stirring and cooling to room temperature. The viscosity was measured with digital viscometer (NDJ.8S) with spindle at 30 rpm (Kweku *et al*., 2013).

Determination of least gelatinization concentration (LGC)
Least gelatinization concentration (LGC) was determined by the method described by Shinde (2001). One gram each of the samples was weighed in triplicates and then transferred into 20 mL screw capped tubes and about 10 mLs of water added into tubes containing the samples. The suspension was inverted for 20 minutes and left to stand for a further 30 minutes. The volume occupied by the sample was taken after 30 minutes.

Sensory Evaluation
The sensory evaluation of the samples was carried out using forty trained panelists from the Bells University of Technology, Ota who tested for the following attributes: appearance, flavour/aroma, taste, texture and overall acceptability. They were provided with a mouth rinse in between each tasting. The attributes were scored using a nine-point hedonic scale where nine equals like extremely and one equals dislike extremely.
Statistical Analysis
Statistical analysis was conducted on means of triplicates values of the experimental results. The Analysis of Variance (ANOVA) was determined using SPSS 20.0 software and where significant differences existed, Duncan's Multiple range test was conducted for separation.

RESULTS AND DISCUSSION

Nutrient Composition of the Formulated Complementary Foods Diets
The moisture content of COMPIF and COMPIM were below the minimum limit of moisture content for dried flour (10%). The values are therefore low for adequate shelf life stability if packaged in moisture proof containers. COMPIF AND COMPIM were comparable in crude protein, crude fibre, crude fat, ash, iron, zinc and calcium contents. Both formulated diets

compared favourably with the commercial complementary food in crude protein, ash and moisture contents but had significantly ($p<0.05$) lower calcium and iron values. The crude protein content of HCF, fermented maize was very low because no protein source was added. This study shows that that addition of about 10 g fish powder improves the protein content of maize meal to the same level as milk powder. The formulated foods, COMPIF and COMPIM had higher crude fat than CCF (Table 2). The fat contents of the formulated diets were higher than those of the commercial complementary diet (CCF), complementary foods formulated from sorghum, soya bean, pigeon pea and skimmed milk (4%) (Addis *et al*., (2013) and sorghum, pigeon pea, soya bean flours (2.57-2.94%) (Adeola *et al*., (2017). The addition of oil could have contributed to the higher fat level. Diets with fish provides the necessary polyunsaturated fatty acids (PUFAs), such as omega-3 and omega-6 fatty acids, for infants and young children's proper brain and neural development (Okoye and Ene, 2018). These are desirable qualities for complementary foods. The crude fibre contents of the formulated diets were low. Low dietary fibre is one of the qualities of good complementary food because high crude fibre content increases bulkiness and with a limited gastric capacity of infants, energy and nutrient intake might be affected. The crude protein contents of the formulated diets were higher than the protein contents reported for sorghum/mucuna and maize-pigeon pea blends (10.38 and 10.32 g/100 g, respectively) (Oyerakua, 2013). Addition of legumes and animal protein foods contributed to the higher protein values. It was observed that adding only 10 g fish resulted in the same protein content as adding 30 g powdered milk. This finding has economic implications because the cost of 10 g of fish is lower than that of 30 g milk powder. Small dried fish is more available and cheaper compared to milk powder. The starch content of HCF was quite high compared to the other diets. This underscores the importance of fortification of maize meal with quality foods. Mothers should be discouraged from giving unfortified cereal based gruel to their young children because of high starch content. Consumption of low quality cereal gruel will worsen undernutrition among infants.

The mineral content of the formulated diets as well as HCF were quite low compared to that of the commercial complementary diet (CCF). The calcium content of the commercial complementary diet was observed to be higher than COMPIF and COMPIM by about 80.5% and 82.7%, respectively. It was expected that the inclusion of pigeon pea, dates and carrot would improve the micronutrient content of the formulated diets without micronutrient supplementation. It is noteworthy that the fish based diet (COMPIF) had the highest beta-carotene content of 128.65 ug/100 g.

Table 2: Nutrient Composition of the Formulated Diets

Parameters	HCF	CCF	COMPIM	COMPIF
Crude Protein %	$8.67^{b} \pm 0.01$	$15.50^{a} \pm 0.01$	$16.00^{a} \pm 0.01$	$17.00^{a} \pm 0.02$
Crude Fat%	$2.56^{c} \pm 0.01$	$8.05^{b} \pm 0.02$	$11.59^{ab} \pm 0.01$	$13.39^{a} \pm 0.01$
Crude Fibre %	$0.82^{a} \pm 0.01$	$0.48^{a} \pm 0.02$	$0.56^{a} \pm 0.02$	$0.43^{a} \pm 0.01$
Total Ash %	$1.34^{b} \pm 0.01$	$2.47^{a} \pm 0.02$	$2.59^{a} \pm 0.01$	$3.26^{a} \pm 0.02$
Moisture Content %	$12.37^{a} \pm 0.01$	$9.69^{b} \pm 0.01$	$9.14^{b} \pm 0.01$	$9.03^{b} \pm 0.01$
Dry Matter %	$87.63^{b} \pm 0.00$	$90.31^{a} \pm 0.02$	$90.86^{a} \pm 0.01$	$90.97^{a} \pm 0.01$
Total Sugar %	$5.29^{a} \pm 0.01$	$3.88^{b} \pm 0.02$	$3.16^{b} \pm 0.01$	$2.27^{c} \pm 0.02$
Starch %	$73.68^{a} \pm 0.02$	$44.17^{b} \pm 0.02$	$37.29^{b} \pm 0.02$	$29.15^{c} \pm 0.01$
Ca (mg/100 g)	$11.40^{c} \pm 0.07$	$196.00^{a} \pm 0.12$	$33.90^{b} \pm 0.06$	$38.2^{b} \pm 0.15$
Zn (mg/100 g)	$1.84^{c} \pm 0.01$	$6.18^{a} \pm 0.01$	$5.72^{ab} \pm 0.02$	$5.42^{b} \pm 0.01$
Fe (mg/100 g)	$5.20^{c} \pm 0.01$	$15.45^{a} \pm 0.01$	$12.10^{b} \pm 0.09$	$13.60^{b} \pm 0.09$
Beta Carotene (ug/100g)	$56.78^{c} \pm 0.01$	$62.38^{b} \pm 0.01$	$78.92^{b} \pm 0.01$	$128.65^{a} \pm 0.02$

Values indicate mean ± standard error (n=3). Means in the same row with different superscripts are significantly different ($p < 0.05$). HCF: Fermented Homemade Maize Complementary Food, CCF: Commercial Complementary Food, COMPIM: Maize-Pigeon Pea Complementary Food Fortified with Milk, and COMPIF: Maize-Pigeon Pea Complementary Food Fortified with Fish.

Amino acid and anti-nutrient composition of formulated foods

COMPIF had the highest lysine and methionine contents. This may imply that fish has more of these essential amino acids compared to milk. The fish based complementary food, COMPIF also had lower anti-nutrient contents. However, both formulated diets had low anti-nutrient contents (Table 3). The processing of maize and pigeon pea using fermentation, germination, and combined germination-fermentation could have reduced these anti-nutrient contents. Similar findings were reported by several researchers including Tufa *et al.* (2016) and Gbadamosi, *et al*. (2017) among others. High anti-nutrient content of foods affects nutrition as it results in the chelation of vital minerals such as calcium, zinc, and iron including proteins forming complexes and making them unavailable (Gibson *et al.,* 2010).

Table 3: Amino acid and Anti-nutrient Composition of the Formulated Diets

Parameters	CCF	COMPIM	COMPIF
Lysine (%)	0.28^{b} ±0.02	0.40^{b} ±0.01	0.57^{a} ±0.11
Methionine (%)	0.13^{b} ±0.02	0.15^{b} ±0.08	0.21^{a} ±0.04
Phytate (%)	0.26^{a} ±0.23	0.18^{a} ±0.19	0.18^{a} ±0.20
Oxalate (%)	0.18^{b} ±0.15	0.42^{a} ±0.20	0.11^{b}±0.22
Haemagglutinin (HU/mg)	0.24^{a} ±0.01	0.18^{a}±0.01	0.13^{a} ±0.01

Values indicate mean ± standard error (n=3). Means in the same row with different superscripts are significantly different ($p < 0.05$). CCF: Commercial Complementary Food, COMPIM: Maize-Pigeon Pea Complementary Food Fortified with Milk, and COMPIF: Maize-Pigeon Pea Complementary Food Fortified with Fish.

Functional Properties of the Formulated Complementary Diets

The water absorption capacity (WAC) values of the formulated diets were lower than that of control (CCF) (Table 4). The WAC values were lower than that of fermented maize flour (235 g/100g) reported by Tufa *et al.*, (2016). The lower WAC could be attributed to germinated-fermented maize and fermented pigeon pea used. COMPIF had lower WAC and viscosity than COMPIM. Low WAC and viscosity are desirable functional characteristics of complementary food. Less quantity of water would be required to make gruel, thus the energy and nutrient density of the complementary foods would not be reduced.

Table 4: Functional Properties of the Formulated Complementary Diets

Sample ID	HCF	CCF	COMPIM	COMPIF
WAC (g/100g)	126.74^{a} ±0.01	114.29^{ab} ±0.00	93.75^{b} ±0.01	86.92^{c} ±0.02
LGC (%)	15.28^{a} ±0.01	11.37^{b} ±0.01	7.25^{c} ±0.01	3.46^{d} ±0.00
Viscosity (mL/s)	21.80^{a} ±0.06	17.20^{b} ±0.07	13.30^{c} ±0.06	9.50^{d} ±0.12
Bulk Density (g/mL)	0.49^{a} ±0.17	0.52^{a} ±0.14	0.52^{a} ±0.18	0.53^{a} ±0.13

Values indicate mean ± standard error (n=3). Means in the same row with different superscripts are significantly different ($p < 0.05$). HCF: Fermented Homemade Maize Complementary Food, CCF: Commercial Complementary Food, COMPIM: Maize-Pigeon Pea

Complementary Food Fortified with Milk, and COMPIF: Maize-Pigeon Pea Complementary Food Fortified with Fish.

Sensory Evaluation of the Formulated Complementary Diet
Sensory attributes of the formulated complementary diets presented in Table 5 show a progressive decrease in the scores with inclusion of pigeon pea of flour in the formulated complementary diets. The values recorded by panelists for COMPIF were low for taste, texture, aroma, appearance and overall acceptability. The presence of fish in the mix might be responsible for the poor sensory attributes of COMPIF.

Table 5: Sensory Evaluation of the Formulated Complementary Diets

Sample ID	HCF	CCF	COMPIM	COMPIF
Appearance	$6.35^{ab} \pm 0.24$	$7.70^{a} \pm 0.16$	$6.58^{ab} \pm 0.24$	$4.63^{c} \pm 0.33$
Taste	$6.03^{b} \pm 0.09$	$7.56^{a} \pm 0.18$	$5.28^{c} \pm 0.27$	$4.05^{d} \pm 0.09$
Aroma	$5.90^{ab} \pm 0.57$	$7.33^{a} \pm 0.09$	$5.63^{ab} \pm 0.09$	$3.90^{c} \pm 0.18$
Texture	$6.73^{b} \pm 0.00$	$7.23^{a} \pm 0.24$	$5.82^{c} \pm 0.42$	$5.05^{c} \pm 0.24$
Overall acceptability	$6.13^{b} \pm 0.38$	$7.23^{a} \pm 0.33$	$5.63^{b} \pm 0.16$	$4.73^{c} \pm 0.16$

Values indicate mean ± standard error (n=3). Means in the same row with different superscripts are significantly different ($p < 0.05$). HCF: Fermented Homemade Maize Complementary Food, CCF: Commercial Complementary Food, COMPIM: Maize-Pigeon Pea Complementary Food Fortified with Milk, and COMPIF: Maize-Pigeon Pea Complementary Food Fortified with Fish.

CONCLUSION

The maize-pigeon pea complementary food fortified with fish was better than that fortified with milk in terms of beta-carotene, lysine and methionine, functional properties and low anti-nutrient contents. However, the fish based complementary food was the least accepted. Quality complementary food could be produced from maize, pigeon pea, carrots, dates with either fish or milk. Further studies should be carried out on how to improve the sensory properties of home based complementary foods prepared with fish and pigeon pea.

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