Advances in Research

15(5): 1-18, 2018; Article no.AIR.41864
ISSN: 2348-0394, NLM ID: 101666096

Formulation and Evaluation of Complementary Foods from Flour Blends of Sprouted Paddy Rice *(Oryza sativa)*, Sprouted African Yam Bean *(Sphenostylis sternocarpa)* and Pawpaw Fruit *(Carica papaya)*

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Authors' contributions

This work was carried out in collaboration between all authors. Author NEO designed the study, supervised the analyses of the study, wrote the protocol and wrote the first draft of the manuscript. Author OGU managed the literature searches and analyses of the study. Author CJO wrote the last draft and tidied the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AIR/2018/41864
Editor(s):
(1) Paola Deligios, Department of Agriculture, University of Sassari, Italy.
Reviewers:
(1) Elisa Julianti, University of North Sumatra, Indonesia.
(2) Karen Breshears, University of Central Missouri, USA.
Complete Peer review History: http://www.sciencedomain.org/review-history/25255

Original Research Article

Received 6th April 2018
Accepted 17th June 2018
Published 25th June 2018

ABSTRACT

Aims: To formulate a readily available complementary food that meets infant nutritional requirements and compares favourably with a popular commercial diet (Nestlé Nutrend) from Brown rice grains *(Oryza sativa)*, African yam bean seeds *(Sphenostylis stenocarpa)* and pawpaw fruit pulp *(Carica papaya)*.
Study Design: The design of the experiment is a completely randomised design (CRD).
Place and Duration of Study: The study took place at the Department of Food Science and Technology, Michael Okpara University of Agriculture, Umudike between January and October 2017.
Methodology: Brown rice grains *(Oryza sativa)*, African yam bean seeds *(Sphenostylis stenocarpa)* and pawpaw fruit pulp *(Carica papaya)* were used to formulate a complementary food. The cereal

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and legume used were sprouted and made into flours then mixed with dried pawpaw flour. Three complementary diets in the proportion 60:30:10, 65:25:10 and 70:20:10 were formulated. Standard chemical methods were used to analyse their proximate composition, micronutrient composition and functional properties. Data were analysed using descriptive statistics and Duncan's multiple range test, with the level of significance set at p =0.05.

Results: One-hundred-gram portion of the formulated diets were analysed to contain dietary fibre in the range of 3.36% to 3.61% and thus would be easily digestible. These diets showed superiority over the commercial diet in their protein content which was 20.52%, 19.83% and 19.17% respectively following the ratio above against 14.18% for Nutrend. On the other hand, Nutrend -the commercial diet recorded 14.47 mg of iron whereas the study diets had higher iron levels of 20.42 mg for 60:30:10, 20.65 mg for 65:25:10 and 20.88 mg for 70:20:10. The flours were low in bulk density although the commercial diet was lower. Its carotenoid, thiamine and riboflavin levels fell short of Codex recommended levels for complementary foods. However, vitamin C values met the 13.34 mg Codex standard for complementary foods although the vitamin C value for the control diet-Nutrend was higher. Sensory characteristics showed that the porridges were generally slightly liked. Use of these formulated complementary foods especially diet 60:30:10 may be encouraged as an alternative to the regular poor nutrient traditional complementary foods and the expensive commercial formula.

Conclusion: Nutrient-dense complementary food can be successfully produced from brown rice, an under-utilised legume- African yam bean seeds and pawpaw fruit. The diets can be used by urban and rural mothers to feed infants during complementary feeding periods and have great potential in substituting more expensive commercial formula products while solving the problem of protein-energy malnutrition.

Keywords: Complementary foods; flour blends; sprouted paddy rice; sprouted african yam bean; pawpaw.

1. INTRODUCTION

Most substantial concern nowadays including all the developed and underdeveloped countries throughout the world is malnutrition. Irrespective of each countries socio-economic factor generally poor countries are under the threat of malnutrition. According to the World Health Organization (WHO), globally, malnutrition contributes to 45 percent of deaths of children aged under 5 years.

Malnutrition comes from the Latin words, *malus* meaning “bad” and *nutrire* meaning “to nourish”. Malnutrition is caused by eating a diet in which nutrients are not enough or are too much such that it causes health problems. It is a category of diseases that includes both undernutrition and overnutrition. Lack of sufficient food taking, following an improper diet and bad nutrition consumed falls under undernutrition category whereas obesity or overweight is due to overnutrition.

To overcome the malnutrition of undernutrition category complementary foods are introduced between the ages, six months to three years. Complementary foods are the combination of different nutrition properties which are rich in protein, fat, carbohydrate, vitamins, and minerals obtained from grains, fruits, milks and other sources.

In this study Brown rice grains *(Oryza sativa)*, African yam bean seeds *(Sphenostylis stenocarpa)* and pawpaw fruit pulp *(Carica papaya)* were used to formulate a complementary food. These raw materials were chosen because they are readily available, affordable and have the combination of different nutrients required in complementary foods. The cereal and legume used were sprouted and made into flours then mixed with dried pawpaw flour. Three complementary diets in the proportion 60:30:10, 65:25:10 and 70:20:10 were formulated. Standard chemical methods were used to analyse their proximate composition, micronutrient composition and functional properties. This study is aimed at formulating complementary diets from Rice flour, African yam beans flour and papaya fruit at different substitution levels as well as to evaluate the proximate, anti-nutritional, functional and sensory properties of the food blends.

Thus, Reformulation and fortification of these local diets can provide more nutrition and be cost-effective foods suitable not only to meet complementary needs but also rehabilitation diet for malnourished children.

2. MATERIALS AND METHODS

2.1 Sources of Raw Materials

The raw materials namely- Whole rice (*Oryza sativa*) grains were purchased at Uzuakoli market, African yam bean (*Sphenostylis stenocorpa*) seeds, firm ripe paw-paw (*Carica papaya*) fruits (see Plates 1-3) and the commercial complementary food- Nestlé Nutrend (This is formulated from whole maize and Soya and contains vitamins such as Vitamin A and minerals like Calcium) shown in Plate 4 which served as a control in the study, were all purchased from Umuahia main market, Abia State of Nigeria.

2.2 Preparation of Flour Samples

2.2.1 Production of sprouted paddy rice flour

Sprouted paddy rice flour was obtained following the steps in the flowchart (See Fig. 1). The whole rice grains were cleaned and washed then soaked in lukewarm water for 12 h, changing the soaking water every 3 h. After soaking and water drained off, then grains were spread on jute bags and left to sprout for 72 h while sprinkling water on it morning and evening. The sprouted rice was dried, dehusked and oven dried at 60^0C for 12 h. The dried grains were milled to obtain flour (see Plate 5) then sieved and packaged in polythene for further use.

Plate 1. African yam bean seeds

Plate 2. Paddy rice grains

Plate 3. Whole pawpaw fruits

Plate 4. Tin Nestle Nutrend

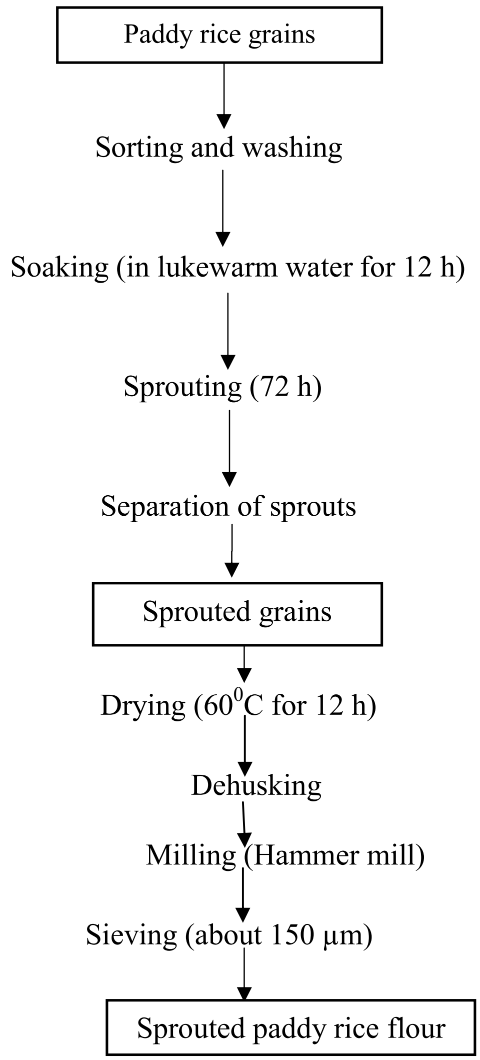

Fig. 1. Flowchart for production of sprouted paddy rice flour

2.2.2 Production of sprouted African yam bean flour

The stages shown in Fig. 2 were followed to produce desired flour sample. The African Yam bean seeds were sorted then soaked in tap water and then drained at the completion of 24 h the next day. The seeds were spread on a jute bag and kept at room temperature to sprout. The seeds were sprouted for 96 h with a constant sprinkling of tap water then when seeds were sprouted, they were sun-dried, dehulled by hand, milled then sieved to fine flour as shown in Plate 6.

2.2.3 Production of Paw-paw flour

The firm ripe paw-paw fruits were processed into pawpaw flour following the steps are shown in Fig. 3. The fruits were sorted and rotten ones removed. They were washed then peeled to expose pulp, they were cut and deseeded then the pulp diced into small 5 mm thick slices. The diced pieces were transferred to a hot air oven set at 80°C for about 12 h. The dried paw-paw was then blended to homogeneity and sieved to obtain fine flour (see Plate 7).

2.3 Formulation of Flour Blends

Formulated foods for infants and young children are expected to be suitable for use during the complementary feeding period. To make an adequate complementary food, the individual flours were mixed thoroughly into homogenous powder (see Plate 8). Formulated complementary food mixes were as stated in

Table 1. This formulation was made on the basis that it will provide additional energy and supply sufficient protein as well as other nutrients to complement family foods by providing those nutrients that are neither lacking or present in insufficient quantities as recommended by the Codex standard for processed cereal-based foods for infants and young children.

2.4 Proximate Analysis

Standard procedures of AOAC [1] were used to determine moisture content, crude fat, crude protein (N x 6.25), ash and the total carbohydrates were obtained by difference.

2.4.1 Moisture content determination

The moisture content was determined by hot air oven method as described by AOAC [1].

2.4.2 Ash content

Ash determination was carried out according to AOAC [1] procedure.

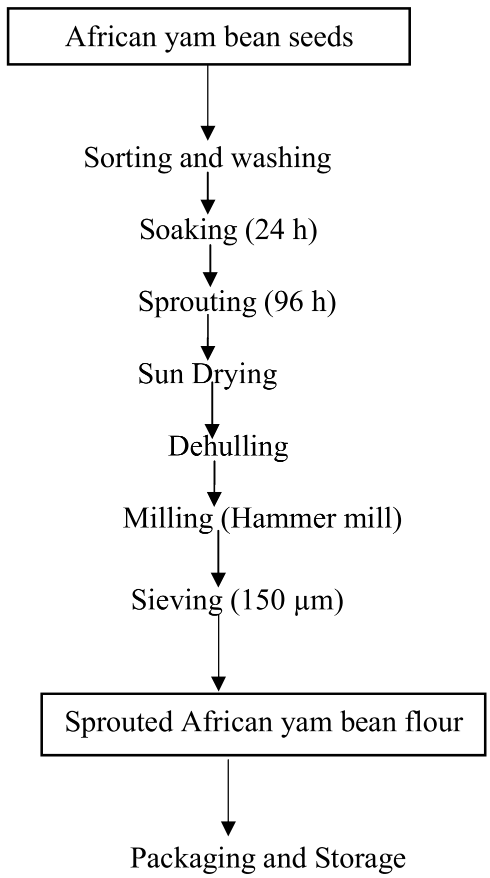

Fig. 2. Flowchart for the production of sprouted African yam bean flour

Table 1. Composition of blends

Food samples(g)	Diet 1	Diet 2	Diet 3	Nestle Nutrend*
Sprouted paddy rice flour	60	65	70	-
Sprouted African yam bean flour	30	25	20	-
Pawpaw flour	10	10	10	-
Total	100	100	100	100

**Commercial food used as control*

2.4.3 Crude fibre determination

Procedure for crude fibre determination as described by AOAC [1] was adopted.

2.4.4 Fat content determination

The Soxhlet Extraction method described by AOAC [1] was used in determining the fat content of the sample.

2.4.5 Protein content determination

The Microkjeldahl method as described by AOAC [1] was used to determine crude protein.

2.4.6 Carbohydrate determination

The carbohydrate content of samples was determined by difference using the formula-

100% - (%ash+ % protein + % moisture + % fibre)

2.4.7 Determination of total energy value

This was also gotten by difference based on the digestibility of each of the nutrients using Atwater's conversion factor.

$$EV = (CP \times 4) + (EE \times 9) + (CHO \times 4)$$

Where; Ev = energy value
CP = Crude protein;
EE = Ether extract
CHO = Carbohydrate content

2.5 Analyses of Functional Properties

Analyses of functional properties of food materials are very important for appropriateness of diet particularly for infants and growing children [2]. The procedures used were as described by Onwuka [3].

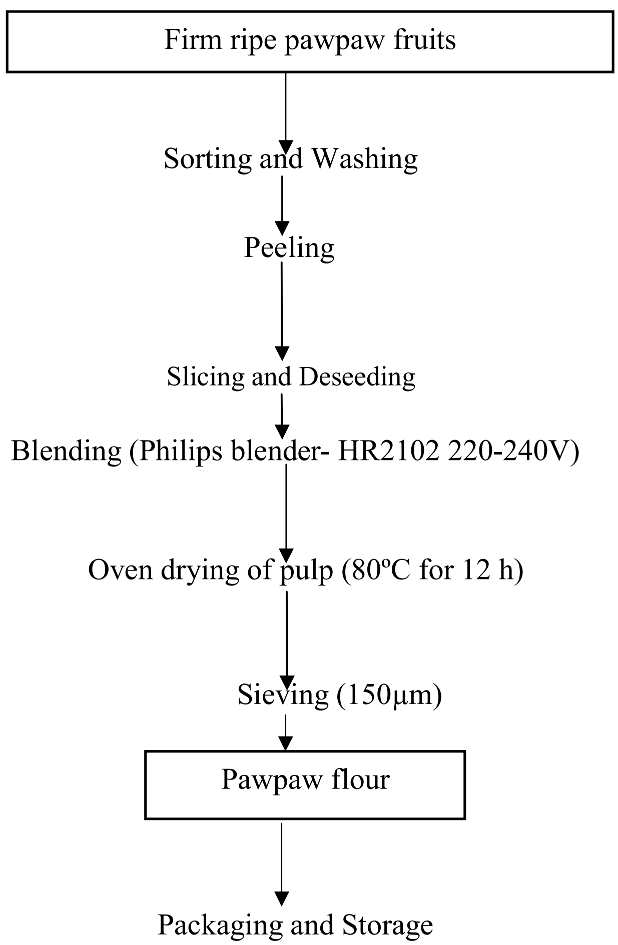

Fig. 3. Flowchart for production of paw-paw

2.5.1 Water/oil absorption capacity (WAC/OAC)

The procedures used were as described by Onwuka [3].

2.5.2 Bulk density (BD)

The procedures used were as described by Onwuka [3].

2.5.3 Foam capacity (FC)

The procedures used were as described by Onwuka [3].

2.5.4 Swelling index (SI)

This was done using the method of Iwuoha [4]

2.5.5 Gelatinization temperature (GT)

As described by AOAC [1].

2.6 Mineral Analysis

Calcium, Iron and Magnesium were determined using standard methods by AOAC [1].

2.7 Vitamin Analysis

The procedures described by Okwu [5] and Okwu and Ndu [6] were adopted in carrying out the following vitamin analyses. Determination of Determination of Thiamine (Vitamin B_1), Determination of Riboflavin (Vitamin B_2) Determination of Carotenoid (Pro-vitamin A).

2.8 Preparation of Porridges (Gruels)

The porridges were prepared from flours of the various food materials (sprouted paddy rice, sprouted African yam bean seeds and pawpaw fruit) flour blends as well as the commercial sample (Nestlé Nutrend). The complementary foods sample(50 g) each were poured into 250 ml boiling water in a pot and stirred with spoon to obtain thick smooth gruels.

2.9 Sensory Evaluation of Porridges

The complimentary food samples including the control sample were coded randomly and served hot in transparent dessert plates. Sensory evaluation was carried out by 25 semi-trained panelists including female students and mothers in Michael Okpara University of Agriculture Umudike, Abia State. The panelists were given water to rinse mouth after each sampling and they used the 9-point hedonic scale where 9 is like extremely and 1 is dislike extremely to express the degree of liking and disliking based on taste, appearance, aroma, texture/consistency and overall acceptability.

2.10 Statistical Analysis

For all data obtained from sensory, proximate, functional, vitamins and minerals, SPSS (Statistical Package for Social Sciences) Version 16.0 was used to determine their mean values and standard deviations, carry out Analysis of variance (ANOVA) to test the level of significance and also compare and separate treatment means using Duncan Multiple Range Test. Significance was accepted at 95% confidence interval.

3. RESULTS AND DISCUSSION

3.1 Nutrient Content of Raw Material

The proximate, vitamin and mineral compositions of the raw materials as seen in Plates 5 to 7 are shown in Table 2.

Ripe pawpaw is known for its high moisture content. The value obtained in this study, however, was higher than that reported by Bernard et al. [7] and this difference could be attributed to variation in ripening.

The protein content of the raw material flours differed significantly ($p<0.05$) with sprouted African yam bean flour having the highest protein (28.58%) than the other raw materials. Sprouted brown rice flour had 17.43% protein and pawpaw had the least protein content (0.61%). Thus, high protein value could be because of variation in rice type and processing method. Sprouting adopted in this study has been reported to increase protein levels owing to the release of free amino acids during the process, thus improving plant nutrient [8].

Crude fat content in the raw materials were significantly different from each other($p<0.05$) with pawpaw flour having the least value (0.81%) followed by 2.68% and 2.88% for sprouted paddy rice flour and sprouted African yam bean flour respectively. These values were within the range of values reported by Uwaegbute et al. [9] for sprouted African yam bean seeds. Increased fat content may be attributed to the increased activity of lipolytic enzymes which produced more free fatty acids during sprouting [9].

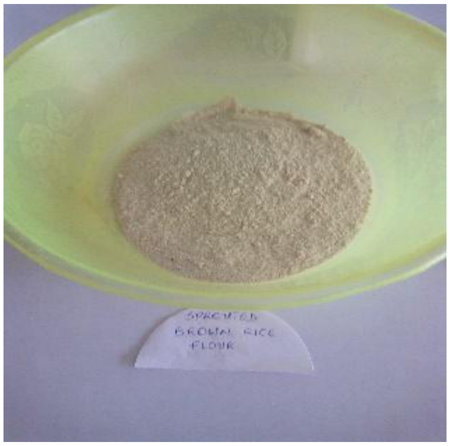

Plate 5. Sprouted Paddy rice flour

Plate 6. Sprouted African yam bean flour

Plate 7. Pawpaw flour

Table 2. Nutrient composition of flours from the raw materials

Nutrients	Sprouted paddy rice flour	Sprouted AYB flour	Pawpaw flour
Dry matter content(%)	95.57^{a}±0.03	91.58^{a}±0.01	90.99^{c}±0.01
Moisture content(%)	4.43^{c}±0.03	8.42^{b}±0.01	9.11^{a}±0.06
Crude protein(%)	17.43^{b}±0.04	28.58^{a}±0.03	0.61^{c}±0.01
Crude fibre(%)	4.91^{b}±0.01	6.98^{a}±0.01	0.62^{c}±0.03
Crude fat(%)	2.68^{b}±0.00	2.88^{a}±0.02	0.81^{c}±0.01
Ash content(%)	4.89^{a}±0.01	2.96^{b}±0.01	1.68^{c}±0.01
Carbohydrate (%)	68.35^{b}±0.03	53.06^{c}±0.01	87.98^{a}±0.18
Energy value (kcal)	367.20^{a}±0.00	352.44^{c}±0.25	361.65^{b}±0.66
Provitamin A(mg/100 g)	108.75^{c}±0.07	233.25^{b}±0.35	306.75^{a}±0.07
Thiamine (mg/100 g)	0.27^{a}±0.01	0.31^{b}±0.01	0.00^{c}±0.00
Riboflavin(mg/100 g)	0.25^{a}±0.00	0.17^{b}±0.00	0.00^{c}±0.00
Ascorbic acid (mg/100 g)	20.07^{c}± 0.01	30.19^{b}±0.01	60.97^{a}±0.01
Calcium (mg/100 g)	51.64^{c}±0.01	248.75^{a}±0.04	59.73^{b}±0.04
Magnesium(mg/100 g)	33.45^{b}±0.07	46.29^{a}±0.01	35.01^{c}±0.01
Iron (mg/100 g)	27.09^{a}±0.01	16.42^{b}±0.03	2.91^{c}±0.01

Values are mean±SD for duplicate determinations. Means with same superscript within the same row are not significantly (p>0.05) different.
Key: AYB = African yam bean

Carbohydrate contents were 68.35% for sprouted paddy rice flour, 53.06% for sprouted African yam bean flour and 87.98 for pawpaw flour. The values were significantly different at p<0.05. Carbohydrate value for African yam bean flour was lower than those reported earlier by Uwaegbute et al. [9] and Olawuni et al. [10]. The lower values may be due to different germination time as carbohydrate value has been observed to decrease with increase in germination time as reported by Inyang and Zakari [11] and Yagoub et al. [12]. The energy values of the raw materials also differed significantly (p<0.05). The sprouted rice flour recorded the highest energy value 367.20 k/cal, pawpaw flour recorded 361.65 k/cal and sprouted African yam bean flour had the least value of 352.44 k/cal. For sprouted African yam bean flour being a low carbohydrate legume, its relatively high calorific value is an indication that protein served as a significant contributor in the carbohydrate calculation by the difference.

Carotenoids are pigments present in human diets as micro-components of fruits and vegetables. In edible fruits and vegetable, they have characteristic red, orange and yellow colours. Pawpaw had the highest level of vitamin A, 306.75 mg/100 g dry weight significantly different from vitamin A values for the other flours.

3.2 Proximate Composition of the Formulated Diets and the Commercial Diet (Nestlé Nutrend)

The result of proximate composition as shown in Table 3 for the formulated diets and the commercial diet (see Plate 8) differed significantly (p<0.05). The moisture content of the diets ranged from 3.89% to 5.95%. The diet 60:30:10 had the highest moisture value of 5.95% significantly different from 5.44% obtained for diet 65:25:10 and diet 70:25:10. The commercial diet had the least moisture value of 3.89%. These values were within the range of moisture values (5.0 to 6.0%) reported by Amankwah et al. [13] for complementary diets from fermented maize, rice, soybean and fishmeal but were lower than values reported for rice and African yam bean blend by Iwe et al. [14]. The values slightly exceeded the moisture value of <5% set formulated for complementary foods [15]. This moisture value implies that these diets will not be stored for a long time because of spoilage.

The 60:30:10 had the highest protein value (20.52%) which was significantly different (p<0.05) from 19.83% for 65:25:10 and 19.17 for 70:20:10. The result shows that protein increased with increase in the proportion of sprouted African yam bean flour a high protein legume flour. These protein values were higher than 14.81% recorded for the commercial diet (Nutrend) and also up to and even higher than codex recommended protein level in complementary foods as shown in Table 3 which is not less than 15%. The blending of protein-rich brown rice and African yam bean for protein complementation must have contributed to the high protein content of these locally formulated diets. Yetunde et al. [16] reported a similar increase in protein when wheat flour and African yam bean flours were blended for cakes. The values of protein for diets in this study were higher than previous reports for cereal/legume diets mixed with the animal protein known to have high amino acids. The protein values were in range with values for rice and African yam bean flour blends presented earlier by Iwe et al. [14], but lower than protein values ranging from 23.85% to 28.84% reported by Ijarotomi and Keshinro [17] for infant formula from germinated popcorn, Bambara groundnut and African locust bean flour.

Crude fibre content for the complementary foods in Table 3 was significantly different (p<0.05). The crude fibre values were in the order 60:30:10 > 65:25:10 > 70:20:10 >commercial diet (Nutrend) with respective values of 3.61%, 3.51%, 3.36% and 2.52%. The commercial diet had the least crude fibre value of 2.52 whereas crude fibre content in the blends was observed to increase with an increase in sprouted African yam bean flour which had the highest fibre content among the raw materials (Table 2). Iwe et al. [14] reported a similar increase in fibre content following substitution with legume (AYB) flour for a rice, African yam bean and cowpea blend and he attributed it to the high crude fibre content of legumes which have a greater effect on rice. The values in this study were in range with crude fibre values obtained by Iombor et al. [18] for millet, soybeans and crayfish.

Crude Fat content of the diets 60:30:10, 65:25:10 and 70:20:10 were generally low (Table 3). They had significantly different (p<0.05) values of 1.66%, 1.41% and 1.21% respectively and differed significantly from the commercial diet which had fat value of 8.68%. 60: 30: 10 which contained more fat than the other blends may have been because of increased proportion of African yam bean flour in the composite. The values for the formulated diets were lower than values (11.7% to 24.5%) earlier reported by Solomon [19] for complimentary food from rice, maize, *acha* grain, soybean, Bambara, beniseeds, carrot, garden egg and crayfish. They were also low compared to fat values presented by various researchers including Obse et al. [20] for complimentary food from blends of maize, roasted pea and malted barley. However, the crude fat values obtained in this study do not meet the codex recommended fat level 10-25% expected in complementary foods and this could have been because of depletion of stored fat to provide energy for protein synthesis in plant growth during sprouting. However, although fat levels obtained are low, this is beneficial as it ensures long product shelf life by reducing susceptibility to oxidative rancidity.

The ash values were higher than those for cereal based complementary food with added legumes (chick pea and lentil) as reported by Gibson and Hotz [21]. Moreover, these values meet values of < 5% recommended by codex for ash level in formulated complementary foods for infants and young children.

Carbohydrate content 66.7% for 60:30:10 significantly differed ($p<0.05$) from 65:25:10 and 70:20:10 which had values 68.51% and 68.37% respectively and so did not differ from each other($p>0.05$). The carbohydrate value of the commercial diet (76.28%) differed significantly from the rest of the diets. The relatively low carbohydrate levels were likely due to the increased activities of alpha-and-beta-amylases which reduce carbohydrate level during sprouting. Moreover, it was observed that percentage increase of rice in the formulation, increased the carbohydrate level. Carbohydrate values obtained in this study fell within the range of values reported by Hussain et al. [22] for complementary diets from germinated wheat and lentils.

Energy values for the diets as shown in Table 3 ranged from 360.16 kcal to 442.46 kcal with the commercial diet having the highest value 442.46 kcal. The 65:25:10 blend had the highest energy value among the locally formulated diets. Results of this energy values well agreed with values obtained by Obse et al. [20] who formulated complementary foods from maize, roasted pea and malted barley but were higher than 211.34 k/cal, 225.57 k/cal and 241.41 k/cal values reported by Onoja et al. [23] for complementary diets from soybean, plantain, roselle calyces and *Moringa oleifera.* It has been recommended that foods fed to infants and children should be energy-dense since low energy foods tend to limit total energy intake and nutrient utilization. The total energy value calculated for the three locally formulated diets fell below the codex recommendation for energy value (400–425 kcal/100 g). This implies that to meet this requirement the infant has to eat more and this would not be possible because of their stomach size. Since calculation obtained energy value, the low fat value of the diets could have contributed greatly to increase energy value. So, reformulation is needed to meet energy requirements.

Plate 8. Formulated complementary food blends

Table 3. Proximate composition of the formulated complementary foods with quantity that should be present from the recommended codex Alimentarius commission's standards

Nutrients	60: 30: 10	65: 25: 10	70: 20: 10	Commercial diet	Codex standard
Moisture content (%)	5.95^{a}±0.01	5.44^{b}±0.01	5.44^{b}±0.01	3.89^{c}±0.01	<5%
Crude protein (%)	20.52^{a}±0.01	19.83^{b}±0.01	19.17^{c}±0.01	14.81^{d}±0.01	>15%
Crude fibre (%)	3.61^{a}±0.01	3.51^{b}±0.03	3.36^{c}±0.03	2.52^{d}±0.03	< 5%
Crude fat (%)	1.66^{b}±0.01	1.41^{c}±0.01	1.21^{d}±0.01	8.68^{a}±0.01	≤15%
Ash content (%)	3.21^{b}±0.01	2.72^{c}±0.03	3.83^{a}±0.04	2.51^{d}±0.01	< 5%
Carbohydrate (%)	66.71^{c}±0.02	68.51^{b}±0.01	68.37^{b}±0.19	76.28^{a}±0.01	≥65%
Energy value (kcal)	363.86^{c}±0.18	366.08^{b}±0.09	360.12^{d}±0.95	442.46^{a}±0.04	≥0.8kcal/g

Values are mean±SD of duplicate determinations. Means (a-d) with the different superscript on the same row significantly different (p<0.05).
Key-The compositions are in the order sprouted paddy rice: sprouted African yam bean: pawpaw Commercial diet- Nestlé Nutrend (maize and soya blend)

3.3 Functional Properties of the Formulated Complementary Foods

The results in Table 4 show the functional properties of the formulated food blends of paddy rice, African yam bean (both sprouted) and pawpaw pulp.

3.3.1 Bulk density

The results obtained were significantly different from each other (p<0.05). 60:30:10 had a bulk density of 1.02 g/ml which was significantly higher than 0.67 g/ml and 0.70 g/ml for 65:25:10 and 70:20:10 respectively while the commercial diet (Nutrend) which is the control recorded the least value 0.56 g/ml. The bulk densities obtained were found to be higher than those reported by Okafor and Usman [24] ranging from 0.17-0.29 g/ml for breakfast cereals from maize, African yam bean and coconut cake but lower than 2.45-2.60 g/ml reported earlier by Agunbiade and Ojezele [25] for maize, sorghum, soybean and AYB flour blends. The sprouting of the grains must have resulted in the low bulk density. Germination has been reported to be useful in preparation of low bulk weaning foods [26]. The values in this study were found to be similar to those reported by Ikujenola et al. [27]. The low bulk of the diets indicate that gruels made from them would have lower dietary bulk. Low bulk density is of advantage in formulating complementary foods because high bulk limits caloric intake per feed for the child and infants are sometimes unable to consume enough to satisfy energy and dietary requirements [2]. The differences in bulk densities indicate that they would require different packaging materials. The lesser the bulk density, the more packaging space required [25].

3.3.2 Water absorption capacity (WAC)

All values were significantly different at 95% confidence interval. The low WAC of diets may have resulted due to the inclusion of sprouted grains/seed flours owing to the fact that starch degradation during germination affect starch granules which affect the level of water the available starch is able to hold. This conforms to an earlier observation that inclusion of malt flours reduced water binding capacity [8]. WAC values for this study were in the range of values 124.67% to 146.33% reported by Adepeju et al. [28] for breadfruit, soybean and groundnut flour blends. Such low WAC values are desirable for making thinner gruels.

3.3.3 Oil absorption capacity (OAC)

Oil absorption capacity is an important functional property in food formulation as it enhances mouth feel while retaining food product flavour [29]. The values significantly varied from the other at p=0.05.

3.3.4 Swelling index

The values for swelling index ranges from 181.88% to 188.88% where diets 60:30:10, 65:25:10 and 70:20:10 showed a significant difference at p>0.05 whereas 60:30:10 had swelling power of 188.88% and did not significantly different (p>0.05) from the commercial diet which had swelling index of 188.50%. The values were lower than those reported by Adepeju et al. [28] for complementary foods from breadfruit but higher than those reported by Bernard et al. [7] for maize, mackerel, red beans and pawpaw diets. The swelling behavior was similar to flours based on malted maize as reported by Ikujenola et al. [27].

3.3.5 Foam capacity

Foam capacity of the samples ranged from 1.99%, 2.00%, 2.00% and 2.01% respectively for 60: 30: 10, 65: 25: 10, commercial diet and 70: 20: 10 respectively, with all values having no significant difference at p>0.05. The results obtained were lower than those obtained by Bernard et al. [7] and Okafor and Usman [24] with values ranging from 2.83%-7.69% and 2.48%-3.49% respectively. The values of the samples were in agreement with those reported for malted maize and defatted pumpkin diets by Ikujenola et al. [27]. Processing methods are reported to have reducing effect on foam capacity which could have affected the foam capacity values [24].

3.3.6 Gelation temperature

Gelation temperature values obtained from this research ranged from 60.50ºC to 71°C. 70:20:10 had the highest temperature of 71°C which was not significantly different from 70.05°C for 60:20:10 but different from 65.75°C for 65:25:10 (p > 0.05). The commercial diet had the least gelation temperature value of 60.50°C which was not significantly different from 65:25:10. This result is similar to temperatures reported by Chandra et al. [30] for composite flours from green gram, wheat and potatoes. That study reported that flours with higher starch content took the lowest gelatinization temperature. In the vein of Chandra's conclusion, the high gelation temperature presented in this study could have been due to a reduced starch content of the flours which may have occurred during sprouting.

3.4 Micro Nutrient Composition of the Formulated Diets and a Commercial Diet (Nestle Nutrend)

Table 5 shows the Micronutrient Composition of the Formulated Complementary Foods and the Control with The Codex Alimentarius Commission Guideline (CAC/GL 08-1991) For Formulated Supplementary Foods for Older Infants and Young Children. The provitamin A levels recorded for the complementary foods were high (Table 5). Provitamin A values were lower than results for banana and beans porridges used as complementary foods as reported by Adepoju and Etukumoh [31] but higher than 3.29 mg to 56.59 mg reported by Nnam [32] for maize, groundnut, pawpaw and mango blend complementary foods. Thiamine and riboflavin levels for the complementary foods differed significantly (p<0.05). The control had the highest values (1.55 mg and 0.61 mg) for thiamine and riboflavin respectively followed by diet 70:20:10 which had 0.21 mg of thiamine and 0.23 mg of riboflavin. 60:30:10 and 65:25:10 had no significant difference (p>0.05) in their values (Table 5). However, thiamine and riboflavin levels were lower than values 0.85 mg-2.23 mg and 0.29 mg-0.64 mg respectively obtained by Adepoju and Etukumoh [31] for local complementary diets from banana and those values obtained for the subject diets fell short of the codex recommended thiamine and riboflavin levels being 0.28 mg – 0.38 mg for complementary foods. Since these are water-soluble vitamins, the low values could have been due to nutrient leaching during processing.

Table 4. Functional properties of complementary foods

Samples	BD(g/ml)	WAC (%)	OAC (%)	SI (%)	FC (%)	GT(°C)
60: 30: 10	1.02^{a}±0.02	145^{c}±0.03	70.95^{c}±0.14	188.88^{a}±0.23	1.99^{a}±0.01	70.05^{a}±0.07
65: 25: 10	0.67^{b}±0.00	178^{b}±0.00	52.00^{d}±0.28	181.88^{c}±0.23	2.00^{a}±0.00	60.75^{b}±0.35
70: 20: 10	0.70^{ab}±0.02	120^{d}±0.00	89.87^{b}±0.71	185^{b}±0.00	2.01^{a}±0.06	71.00^{a}±0.00
Commercial diet	0.56^{c}±0.01	200^{a}±0.00	192.50^{a}±0.35	188.50^{a}±0.71	2.00^{a}±0.00	60.50^{b}±0.71

Values are means± SD of duplicate determinations. Means (a-d) along the same column with different superscript are significantly different (p<0.05)

Key: The diets are sprouted paddy rice: sprouted African yam bean: pawpaw flours in different ratios while the commercial diet= Nestle nutrend from maize and soya

BD=Bulk Density, WAC=Water Absorption Capacity, OAC= Oil Absorption Capacity, GT= Gelation Temperature, SI= Swelling Index, FC= Foaming Capacity

Table 5. Micronutrient composition of the formulated complementary foods and the control with the codex alimentarius commission guideline (CAC/GL 08-1991) for formulated supplementary foods for older infants and young children

Samples	60: 30: 10	65: 25: 10	70: 20: 10	Control	Codex Std.
Provitamin A(mg)	$205.40^{b}\pm0.28$	$196.35^{c}\pm0.07$	$189.35^{d}\pm0.35$	$354.25^{a}\pm0.35$	500*
Thiamine (mg)	$0.17^{c}\pm0.01$	$0.18^{c}\pm0.02$	$0.21^{b}\pm0.01$	$1.55^{a}\pm0.01$	0.28-0.38*
Riboflavin(mg)	$0.22^{c}\pm0.01$	$0.22^{bc}\pm0.00$	$0.23^{b}\pm0.00$	$0.61^{a}\pm0.00$	0.28-0.38*
Ascorbates (mg)	$47.85^{b}\pm0.01$	$45.24^{c}\pm0.06$	$38.03^{d}\pm0.04$	$50.13^{a}\pm0.01$	13.34
Calcium(mg)	$170.50^{b}\pm0.14$	$160.11^{c}\pm0.01$	$155.36^{d}\pm0.01$	$418.42^{a}\pm0.03$	170-400*
Magnesium(mg)	$34.91^{b}\pm0.01$	$30.33^{c}\pm0.16$	$26.56^{d}\pm0.01$	$210.25^{a}\pm0.07$	40-76
Iron (mg)	$20.42^{c}\pm0.01$	$20.65^{b}\pm0.02$	$20.88^{a}\pm0.01$	$14.47^{d}\pm0.01$	16

Values are mean ± SD for duplicate determinations. Means (a-d) on the same row having different superscripts are significantly different (p<0.05).
Control: A commercial diet- Nestlé Nutrend made from maize and soya blend.
Formulations are in the ratio sprouted brown rice flour: sprouted African yam bean flour: pawpaw flour
** Values are FAO/WHO [15] vitamin and mineral requirements in human nutrition*

The ascorbate level for the control (Nutrend) was the highest (50.13 mg) followed by 47.85 mg, 45.24 mg, and 38.03 mg for diets 60:30:10, 65:25:10 and 70:20:10 respectively. Ascorbate values were in the range of values 0.12 mg – 64.62 mg reported by Nnam [32] for maize, groundnut, mango and pawpaw blends. The use of fruit pulp in the mixes must have contributed to their increased ascorbate levels proving the benefit of incorporating fruits in infant food formulations to increase vitamin levels. Although the ascorbate levels obtained for the subject diets were slightly lower than that of the control, they met codex standard 13.34 mg recommended for ascorbate level in complementary foods.

Levels of calcium for the products differed significantly (p<0.05) with the control (Nutrend) having the highest content 418.42 mg/100 g and 70:20:10 had the least value of 155.36 mg/100 g. 60:30:10 had the highest value of calcium 170.50 mg/100 g among the locally formulated foods and significantly differed (p<0.05) from 160.11 mg/100 g for 65:25:10. The calcium content of formulated complementary foods developed in this study were higher than 42.01 mg to 57.12 mg/100 g, 20.11 mg to 25.10 mg/100 g, 6.44 mg to 12.4 mg/100 g and 42.60 mg to 53.8 mg/100 g reported by researchers on various formulations- maize, groundnut, pawpaw and mango blends, soybean, plantain, roselle calyces and *moringa oleifera* blends and malted millet, plantain and soybean blends respectively [32,23,33] but lower than (184.68 mg/100) reported by Adepoju and Etukumoh [31] for unripe banana porridges. This differences may be due to difference in crops and blending ratios. African yam bean and pawpaw have been reported to be good sources of calcium [34]. Table 2 agrees with such report. Only diet 60:30:10 had calcium level (170.05 mg/100 g) up to the FAO/WHO recommendations (170 mg to 400 mg/100 g) for formulated complementary foods. The rest of the diets fell below standard. Calcium is an important mineral for bone development so diet 60:30:10 will be beneficial in child bone and teeth development.

On the other hand, magnesium content of the sample blends (26.56 – 34.91 mg/100 g) were lower than that of the control sample (Nutrend) which is 210.25 mg/100 g. Table 2 showed that sprouted African yam bean is high in magnesium. Increase in sprouted African yam bean ratio in the three subject diets increased magnesium levels resulting in significantly different values of 34.91 mg/100 g, 30.33 mg/100 g and 26.56 mg/100 g respectively. The magnesium values for all the formulated diets were low relative to the Codex Alimentarius commission's recommendations which ranged from 40 mg/100 mg to 76 mg/100 g magnesium level in formulated complementary foods. The low values of magnesium recorded in this study may be attributed to low level of minerals usually found in brown rice used in the formulations. The proportion of pawpaw in the diets could be increased to improve magnesium levels since Table 2 reported relatively high magnesium content in pawpaw.

The level of iron in the local diets 60:30:10, 65:25:10 and 70:20:10 were significantly different from each other at 95% confidence interval. The values for the diets were in the order 20.88 mg > 20.65 mg >20.45 mg for the subject diets respectively. These values were significantly higher than the iron content of the control diet-Nutrend and their values met the recommended Codex standard 16 mg/100 g for iron level in formulated complementary foods. Increase in proportion of sprouted paddy rice, increased iron content in the different diets. This effect could be due to sprouting of paddy rice which increased its iron content. A similar increase was reported by Islamiyat and Sulaiman [33] on malted millets. Malting has been reported to increase in vitro extractability and bio accessibility of minerals such as calcium, iron, and zinc in finger millets and kidney beans [35,36]. The iron content of complementary food developed in this study was higher than 2.7 mg/100 g reported for complementary food formulated from Maize-Bambara groundnut blend [37]. Regular consumption of iron-rich foods has the potential of preventing infant anemia.

The vitamin and mineral levels in the diet is adequate to meet infant nutritional needs so, there will be need for further fortification with micronutrients to sufficiently complement breast milk.

3.5 Sensory Evaluation of Porridges from the Complementary Diets

The porridges prepared in varying proportions of sprouted paddy rice, sprouted African yam bean and pawpaw flours (see Plate 9) were used for sensory evaluation. Sensory scores obtained for the porridges after evaluation are shown in Table 6.

3.5.1 Appearance

Appearance is very important as a sensory property which contributes to acceptability and choice of food. Sensory qualities as appearance of complementary food formulations in addition to a sufficient energy density correspond to food preferences for infants and young children and are of prime importance. From Table 6, 70:20:10 was significantly different from 60:30:10 and 65:25:10 ($p<0.05$) The commercial sample (Nutrend) which served as the control had the best appearance rating (7.80) which was significantly different from the formulated diets 60:30:10, 65:25:10 and 70:20:10 with 6.04, 5.84 and 6.84 scores respectively. Similar scores ranging from 1-6 on the 9-point hedonic scale was reported by Rafiya et al. [38] on rice-based diets containing sprouted/unsprouted green gram. The appearance scores were also in agreement with those reported by Muhimbula et al. [39] for cereal-legume complementary foods. The appearance ratings for diets in this study coincides with “like moderately” on the 9-point hedonic scale. These values were within acceptable levels and thus would likely not be objected by infants and young children.

3.5.2 Taste

In accessing sensory attributes in food, taste is a very important property. In this case it would stimulate the child’s likeness and acceptance for the food. Indeed, even if a product is appealing and meets nutrient requirements without good taste, the product would likely not be acceptable. In this evaluation, Nestlé Nutrend the control had the highest taste score of 8.56 which differed significantly from the subject diets at 95% confidence interval. Among the subject diets, 70:20:10 had the highest taste rating of 5.36 which was not significantly different from 5.32 for 60:30:10 but significantly different from 4.40 recorded for 65:25:10. Similar reports matching “neither like nor dislike” on the hedonic scale was reported by Muhimbula et al. [39] for various available cereals and legumes in Tanzania. On the other hand, the taste values were lower than those reported by Ezeokeke and Onuoha [40] for maize, soybean, and banana based complementary foods. This relatively low rating may have been due to the presence of the seemingly unfamiliar taste of food materials used for the diet formulation especially the African yam bean. Unfamiliar tastes also resulted in low taste scores for sensory evaluation as reported by Ijarotimi and Aroge [41] for complementary foods from breadfruit and soybean. Infants are likely to reject unflavored foods, to improve taste ratings flavor enhancers may be incorporated into the formulated samples to increase palatability and acceptability.

3.5.3 Aroma

Aroma being closely linked with taste is very important in the acceptance of formulated foods [39]. The scores of aroma for the subject diets were 5.00, 5.00 and 5.28 for 65:25:10, 70:20:10 and 60:30:10 respectively as shown in Table 6 and had no significant difference at $p=0.05$ but were significantly different from Nutrend with value 7.96. The scores were within the range of scores reported earlier by Muhimbula et al. [39] for several local cereals and legumes of Tanzania. Germination is known to enhance flavor/aroma acceptability of food products as it helps reduce its beany flavor [11].

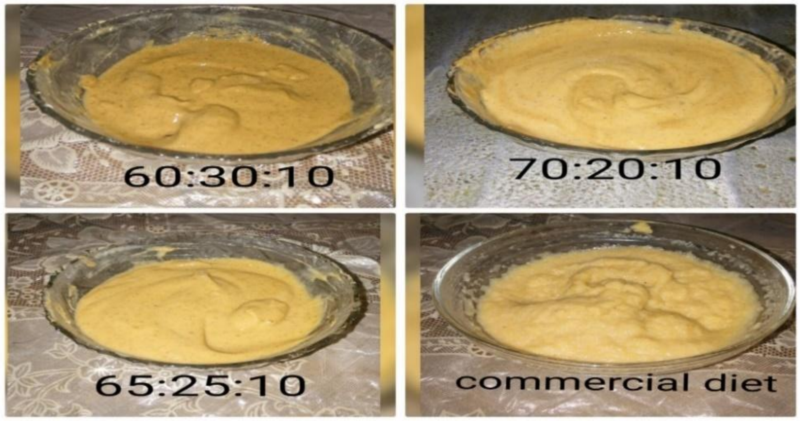

Plate 9. Complementary food porridges used for sensory evaluation

Table 6. Sensory scores of gruels made from the complementary diets

Samples	60: 30: 10	65: 25: 10	70:20: 10	Control
Appearance*	6.04^{bc} ±1.80	5.84^{c}±1.64	6.84^{b}±0.94	7.80^{a}±1.20
Taste*	5.32^{b}±1.68	4.40^{c}±1.98	5.36^{b}±1.66	8.56^{a}±0.58
Aroma*	5.28^{b}±1.46	5.00^{b}±1.47	5.00^{b}±1.66	7.96^{a}±0.84
Texture/consistency*	5.68^{b}±2.00	5.40^{b}±1.87	5.84^{b}±1.55	7.92^{a}±1.00
General acceptability*	5.52^{b}±2.02	4.84^{b}±1.77	5.72^{b}±1.65	8.24^{a}±0.78

Values are means ± SD of duplicate determinations. Means (a-c) on the same row with different superscript are significantly different (p<0.05). Scores are based on a 9-point hedonic scale where:*
9- Like extremely 6- Like slightly 3- Dislike moderately 4- Dislike slightly 7- Like moderately
8- Like very much 5- Neither like nor dislike 2- Dislike very much 1- Dislike extremely

3.5.4 Texture

Texture is very important in complementary foods as this would affect the amount of food an infant would consume. If the gruel is too thick or coarse the infant would not be able to take in enough quantity because of difficulty in swallowing [42]. From the evaluation results in Table 2, the commercial diet showed significantly higher preference with score 7.92 against the subject diets which recorded scores 5.40, 5.68 and 5.84 that were not significantly different (p>0.05) for 65:25:10, 60:30:10 and 70:20:10. The results from this study were in agreement with those reported by Obiakor-Okeke et al. [43] for soybean, sorghum and sweet potato complementary food mixes but were lower than the scores 4.13-7.57 reported by Anigo et al. [44] for malted cereals, soybean and groundnut.

3.5.5 General acceptability

General acceptability of food product depends greatly on the degree of likeness of its appearance, taste, texture and aroma. In that vein, Nutrend had the highest score for general acceptance (8.24) and for the subject diets, 70:20:10 had the highest mean score of 5.72 which was not significantly different (p>0.05) from 60:30:10 with value 5.52 and 65:25:10 with mean score of 4.84.

4. CONCLUSION

The local formulated diets compared favourably with the commercial diet which served as control and showed nutritional superiority over the control (Nestlé Nutrend) regarding protein, ash, iron and fiber. The carbohydrate, protein, iron, ascorbate and calcium content of the local formulated diets met FAO/WHO and Codex Alimentarius commission's standards specified for these nutrients in formulated complementary foods, but the diets did not meet energy, vitamin A and fat requirements. Reformulation and fortification of these local diets can provide more nutritious and cost-effective foods suitable not only to meet complementary needs but also rehabilitation diet to malnourished children. However, the foods used served as a good complement to the other in upgrading nutritional, functional and sensory attributes of the complementary foods.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/25255