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Formulation and Nutritional Evaluation of Instant Weaning Foods Processed from Maize (*Zea mays*), Pawpaw (*Carica papaya*), Red Beans (*Phaseolus vulgaris*) and Mackerel Fish Meal (*Scomber scombrus*)

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Abstract The aims of this study were to evaluate the functional, nutritional and sensory qualities of five Instantaneous Complementary Foods formulated from blends of fermented maize, beans, fishmeal, pawpaw, and sugar. The different ingredients -fermented maize, beans, fishmeal, pawpaw and sugar- were incorporated in the proportions of 70-10-10-5-5 for diet A, 30-50-10-5-5 for diet B, 65-15-10-5-5 for diet C, 40-40-10-5-5 for diet D and 60-20-10-5-5 for diet E, respectively. A commercial weaning food, Phosphatine® served as control. Results of the proximate analysis showed that the formulated diets contained 363.82kcal, 333.97kcal, 362.01kcal, 341.96kcal and 358.06kcal of energy for diets A, B, C, D, and E respectively; 17.88%, 23.71%, 18.61%, 22.25%, and 19.34% of protein content for diets A, B, C, D and E respectively; 58.04%, 47.11%, 56.79%, 49.87%, 55.41% of carbohydrates for diets A B, C, D and E respectively; 4.46%, 3.41%, 4.49%, 3.72%, 4.34% of fats for diets A, B, C, D and E respectively. All the formulations contained the following elements range: Zinc (0.91-2.27mg); Sodium (31.43-492 mg), Manganese (0.27-7.70 mg), Phosphorus (85.35-756.21mg), Iron (0.00-31.7 mg), Magnesium (0.00-253 mg), Calcium (0.00-419.11mg) and Potassium (201.17-1484.01mg). Sensory analysis showed ratings within acceptable limits using a 9-point hedonic scale. The bulk density values were comparable (though slightly higher) to that for the control. The water absorption capacity ranged from 2.00 to 3.30 with diet E having the highest value while diet C had the lowest and the control had the highest WAC value with 4.65. The Oil absorption capacity ranged from 2.30 for diet E to 3.00 for diet C while the commercial weaning diet had an oil absorption capacity of 2.90. The Swelling Index ranged from 0.91 (diet A) to 1.25 (diet E) while that for the control diet was 1.00. The Foam capacity values ranged between 2.83 for diet D and 7.69 for diet E, while that for the control was 13.56. The dispersibility was within the range 94.0 (diet A) and 98.0 (diet E) while the control had a dispersibility value of 171.0. Animal feeding experiments revealed that the formulated diets gave the higher weight gain compared with the control diet as well as the higher PER (Protein Efficiency Ratio) values and higher body organ weights. The study concluded that the formulated diets could be used as alternatives to the weaning foods to improve the nutritional status of children and help to prevent protein-energy malnutrition.

Keywords: *malnutrition, weaning food, formulated diets, proximate analysis, complementary foods*

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1. Introduction

Malnutrition comes from the Latin words, *malus* meaning "bad" and *nutrire* meaning "to nourish". Malnutrition as defined by Dorland's medical dictionary is a condition that results from eating foods that are either not enough or are too much, such that the diet causes health problems. Not enough nutrients is called Undernutrition, while too much is Overnutrition. Malnutrition is often specifically referred to Undernutrition. Malnutrition in children is a consequence of a range of factors, which are often related to poor food quality, insufficient food intake due to social factors like food taboos and terrorism, and environmental factors like droughts, floods, tsunamis and earthquakes [1].

The major risk factors associated with infant and early childhood mortality and morbidity are poor infant feeding practices as well as childhood and maternal undernutrition [2]. Unlike developed countries where there are many children affected by obesity, most children in developing countries such as sub-Saharan Africa and Southeast Asia are conversely affected by lack of food or inadequate supply of energy and nutrients. Malnutrition is one of the major problems facing infants and young children of developing countries. Following a study conducted for 12 consecutive years (1980 to 1992), WHO has reported that more than one third of children aged less than five years in developing countries, suffer from chronic malnutrition [3]. UNICEF indicated that more than 4.6 million annual deaths of children occur in Africa [4]. Malnutrition in many developing countries is as a result of limited sources of protein, vitamins and minerals of high biological values, particularly those of animal origin [5].

Malnutrition is a major health problem in developing countries such as Cameroon and contributes to infant mortality, poor physical and intellectual development of infants, as well as lowered resistance to diseases and consequently retarded development. Protein energy malnutrition (PEM) the ''silent emergency of the world'' which may have haunted mankind since the dawn of history is by far the most lethal form of malnutrition. It is an imbalance between the supply of energy and protein, and the body's demand for them to ensure normal growth and function. It is currently the most widespread and serious health problem of children in the world be it the moderate or severe forms [6,7]. PEM is associated with poverty and poor nutritional knowledge, resulting in early weaning, delayed introduction of complementary foods, a low protein diet and severe or frequent infections [8,9]. In some developing countries such as Cameroon and Nigeria, the traditional weaning food is made of thin cereals (which are highly deficient in protein) usually made from maize (Zea mays) or soya beans (Glycine max). Unfortunately, the traditional methods of their preparation are accompanied by severe nutrient loss which affect the nutritional quality of the diet ([10], thus leading to a vicious circle of malnutrition and infection possibly leading to death, resulting to high infant mortality and morbidity amongst weaning age children [11].

In developing countries, traditional beliefs more often than not, play a pivotal role in the choice of food type consumed. This often results in children being fed with high carbohydrate foods containing little or no protein. According to the protein Advisory Group, guidelines for weaning foods should be 20% of proteins, fat levels of up to 10%, moisture content 5% to 10% and total ash content not more than 5% [12]. Several studies, however have reported that most of the weaning foods consumed by children in many parts of developing countries are deficient in essential macronutrients and micronutrients [13,14]. In developing countries, commercial weaning foods such as Cerelac and Phosphatine are expensive and out of reach of low –income families. The unavailability of nutritious food and the high cost of commercial complementary foods and animal protein are the main causes of Protein-Energy Malnutrition in children in the developing countries [6]. Therefore, developing nutrient-dense, safe, affordable and accessible complementary food from locally produced ingredients using household or small to medium scale production technologies has been strongly recommended as a viable and sustainable approach to address the problem of malnutrition [15]. Thus, in this study, a cereal based weaning food is prepared (based on maize (*Zea mays*), pawpaw (*Carica papaya*), red beans (*Phaseolus vulgaris*) and mackerel fish meal (*Scombers combrus*)) to ensure the availability of low cost weaning food to reduce malnutrition and mortality rate in infants. There shall also be a comparison of the nutritive value of the formulated weaning food with an imported commercial weaning food in Cameroon.

2. Materials and Methods

2.1. Sample Collection, Preparation, Processing and Formulation

2.1.1. Sample Collection

Red Beans (*Phaseolus vulgaris*), Red corn (*Zea mays*), Pawpaw (*Carica papaya*) and Mackerel fish were all purchased at the local market in Muea, Buea, South West Region of Cameroon. The wistar albino rats (21-25 days old) of both sexes weighing between 21 and 50g were ordered from Laboratory of biology, University of Buea, South West Region of Cameroon.

2.1.2. Sample Preparation and Processing

Beans: 3kg of red beans was washed and checked for defects and infection, then soaked for 12 hours. The soaked beans seeds were then boiled in 2 litres of water for 1 hour, after which they were roasted in a hot pot for 1 hour. The roasted beans were sun-dried for 2 days, after which they were placed in a hot-air oven set at 100°C for 24 hours to disinfect. The dried portions were ground and sieved in order to get a very fine powder.

Red Corn: 3kg of red corn was sorted for stones, dirt, insects and defects. The grains without defect were cleaned. The Red Corn was dehulled at a local mill and winnowed to separate the hulls from the grain. The red corn was then soaked in 2l of water for 2 days for germination and fermentation to take place. The water was changed every 8 hours. The germinated seeds were boiled at 100°C for 30 minutes and then dried. The dried grains were transferred to a hot-air oven set at 100°C for 48 hour. The grains were then milled to a fine powder and sieved to remove the larger bits so as to obtain smooth flour.

Pawpaw: Pawpaw was screened for rot, insects, and other defects. The pawpaw was then peeled to expose the flesh, and then sliced. The diced pieces were transferred to a hot air oven set at 80°C for 7 hours. The dried pawpaw was then blended to homogeneity, and sieved to remove large bits and to obtain smooth flour.

Fishmeal: The dried fish was cleaned and separated from the bones, after which the flesh was flaked into bits and dried in a hot pot at 100°C for 15 minutes. The flakes and bones were then milled using a hand mill to obtain the meal. The meal obtained was sieved using a 1mm sieve so as to get a fine powder. Figure 1 is a flow chart showing how the raw ingredients were processed to get the final product.

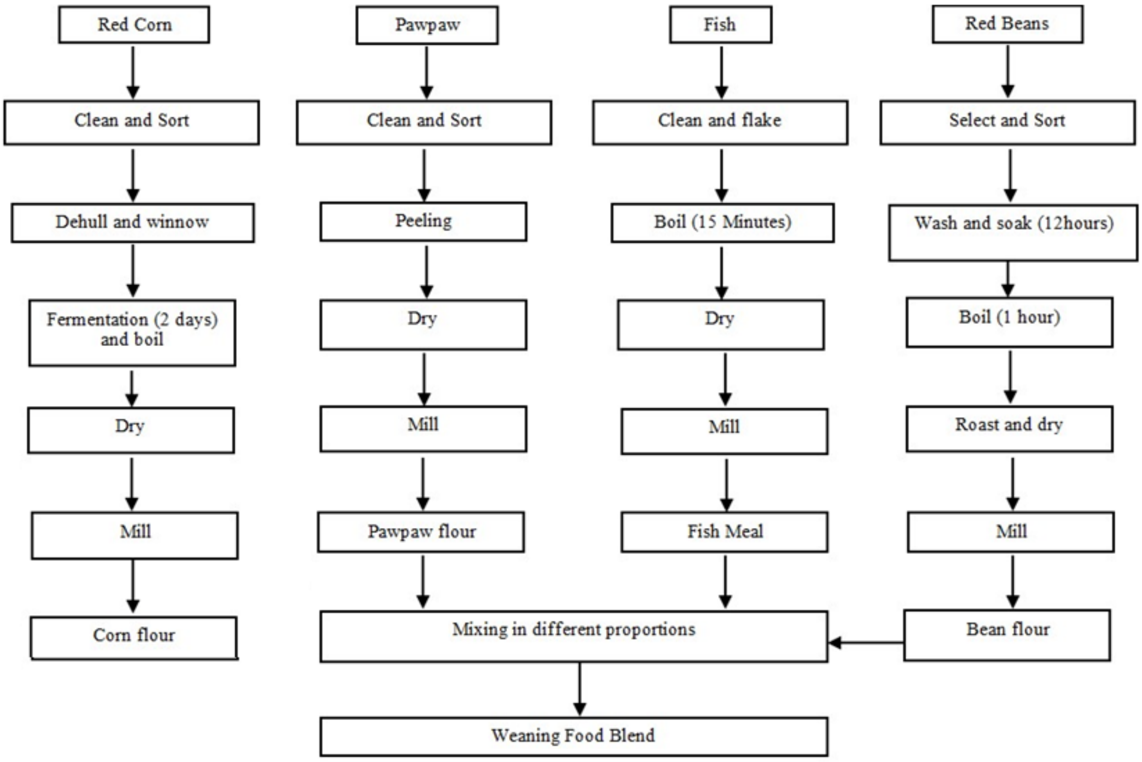

Figure 1. Process flowchart on the preparation of diets

2.1.3. Blends Formulation

The blends were prepared from the individual ingredients in the percentages or proportions as shown in Table 1 below.

Table 1. Composition of Blend

Food samples (g)	Blend A	Blend B	Blend C	Blend D	Blend E	Phosphatine
Maize	70	30	65	40	60	/
Beans	10	50	15	40	20	/
Fish meal	10	10	10	10	10	/
Pawpaw	5	5	5	5	5	/
Sugar	5	5	5	5	5	/
Total (g)	100	100	100	100	100	100

2.2. Physicochemical Analysis

2.2.1. Proximate Analysis

Standard procedures of AOAC were used to determine the moisture content, crude fat, crude protein (N x 6.25), ash and the total carbohydrates have been obtained by difference [16]. Energy value was calculated using the Atwater's conversion factors [17,18]. Minerals were determined by Atomic Absorption Spectrophotometer, Hitachi Model 180-80, and Ion Chromatographic Analyzer ICA model IC 100 [19].

Crude fiber determination: 2g of sample was put into 200mL of 1.25% of H_2SO_4 and boiled for 30 minutes. The solution was poured into the bucheur funnel equipped with muslin cloth and secured with an elastic band. This was allowed to filter and the residue washed with hot water to free it from acid. The residue was then put into 200ml boiling NaOH (1.25%), boiled for 30 minutes then filtered. It was then washed twice with alcohol; the material obtained was washed thrice with petroleum ether. The residue obtained was put in a clean dry crucible and dried in a moisture extraction oven to a constant weight. The dried crucible was removed, cooled and weighed. Then the difference in weight (i.e. loss in ignition) was recorded as crucible fiber and expressed in percentage of the original weight:

$$\%\text{Fiber} = \left(W_1 - W_2\right) x100 / W_t$$

Where:
W_1 = Weight of sample before incineration
W_2 = Weight of sample after incineration
W_t= Weight of sample.

2.2.2. Determination of Functional Properties

Functional properties of food materials are very important for the appropriateness of diet, particularly, for the growing children [20]. The consistency of energy density (energy per unit volume) of the food and the frequency of feeding are also important in determining the extent to which an individual will meet his or her energy and nutrient requirements [20].

-Water absorption capacity (WAC): It was determined using a modified method described by Lin et al. [21].

-Oil absorption capacity (OAC): It was determined using a modified method described by Lin et al. [21] and the Lipophilic: Hydrophilic Index was calculated as a quotient between the Oil and Water Absorption capacity.

-Bulk Density (BD): It was determined using the modified method described by Wang & Kinsella [22].

-Foaming Capacity (FC): According to Kinsella [23] and Cherry & McWatters [24].

-Swelling Index (SI): The method of Abbey & Ibeh (1998) was employed.

-Dispersibility: The Dispersibility of the blends was determined as described by Kulkarni *et al.* [25].

2.3. Rat Bioassay

Rats were divided into six (6) groups of 6, with five different composed diets and commercial formula (phosphatine), and five different blends were prepared and used for animal feeding experiments. Weaning six Wistar rats (21-23 days old) were randomly distributed into five groups, with 6 rats per group. The rats were housed individually in buckets with grill-covered tops and were kept under usual management conditions in conventional animal house of the practical's Laboratory of life sciences, Buea University. The rats were acclimatized and then fed the formulated Blends for one month *ad libitum* and their weights recorded at the end of the study. A comparative experiment was carried out on 6 other rats, using Phosphatine, and their weights recorded as well on a weekly basis. At the end of the study, the rats were dissected and the weights of their kidneys, hearts and livers were taken. The protein quality of the diets was analysed using the Protein Efficiency Ratio (PER) calculated using the formula: PER=Weight gain by test group/protein consummed

2.4. Sensory Analysis

Porridges were prepared from both the composite flours and phosphatine. 100 grams of each diet were mixed with 400ml of deionized boiled water. 5 grams of granulated sugar for taste were added to the porridge. The samples were allowed to cool at room temperature (27 ±2°C).The porridges were kept separate in thermos flasks to maintain the serving temperature of 40°C. The formulated foods were evaluated alongside a commercial complementary food (Phosphatine).The samples were coded in random order and then served hot. Sensory evaluation was carried out by a trained 50 Man panel, consisting of students, mothers and teachers using a 9-point Hedonic scale rating for colour, taste, flavour, consistency/texture and overall acceptability ranging from 1 (Dislike Extremely) to 9 (Like Extremely). The colour of the blends was evaluated by matching the samples with a Munsell Colour Chart. The values were reported in Munsell notations for hue, chrome and value. The panelists were given water to rinse their mouth after each sampling. The evaluation was done in a teaching Lab room in the Biochemistry Department.

2.5. Statistical Analysis

Data obtained in two replicates and was analysed with the aid of Microsoft® Excel 2010 software for windows. Results were calculated and expressed as Mean ± Standard Deviation using the software graphpad Insat 2000.

3. Results and Discussion

3.1. Proximate Analyses

3.1.1. Nutrient content of Raw Material Flours

The results from the chemical analyses of maize, beans, pawpaw and fishmeal flours for the formulation are as shown in Table 2.

Table 2. Proximate nutrient content of raw materials

Parameter/Sample	Pawpaw	Fishmeal	Beans	Maize
Moisture Content (g/100g)	5.50 ± 0.01^{b}	5.60 ± 0.50^{c}	2.22 ± 0.08^{a}	5.70 ± 0.09^{c}
Crude Protein (g/100g)	4.28 ± 0.03^{a}	69.00 ± 0.90^{d}	26.22 ± 0.04^{c}	11.63 ± 1.30^{b}
Crude Fiber (g/100g)	15.61 ± 0.10^{c}	0.00 ± 0.00^{a}	22.43 ± 0.59^{d}	1.42 ± 0.02^{b}
Crude Fat (g/100g)	1.85 ± 0.22^{a}	11.00 ± 3.60^{c}	1.60 ± 0.15^{a}	4.71 ± 0.03^{b}
Ash (g/100g)	12.76 ± 0.03^{d}	7.40 ± 0.60^{c}	3.55 ± 0.18^{a}	4.86 ± 0.05^{b}
Total Carbohydrate (g/100g)	60.05 ± 0.34^{c}	6.00 ± 0.76^{a}	44.01 ± 0.20^{b}	71.67 ± 0.40^{d}
Potassium (mg/100g)	1484.01 ± 0.88^{d}	894.71 ± 0.34^{b}	1222.5 ± 0.66^{c}	201.17 ± 5.00^{a}
Calcium (mg/100g)	173.01 ± 0.93^{c}	0.00 ± 0.00^{a}	141.50 ± 0.35^{b}	419.11 ± 4.60^{d}
Magnesium (mg/100g)	253.74 ± 0.12^{d}	0.00 ± 0.00^{a}	90.47 ± 0.34^{b}	128.88 ± 5.99^{c}
Iron (mg/100g)	3.69 ± 0.31^{b}	0.00 ± 0.00^{a}	7.09 ± 0.05^{c}	31.70 ± 0.80^{d}
Phosphorus (mg/100g)	85.35 ± 0.23^{a}	756.21 ± 1.54^{d}	412.60 ± 1.11^{c}	262.99 ± 6.20^{b}
Manganese (Mn/100g)	0.27 ± 0.20^{a}	0.17 ± 0.12^{a}	1.27 ± 0.10^{b}	7.70 ± 0.90^{c}
Sodium (mg/100g)	43.60 ± 0.98^{b}	230.74 ± 0.01^{c}	492.06 ± 1.04^{d}	31.43 ± 0.08^{a}
Zinc (mg/100g)	0.91 ± 0.67^{a}	2.77 ± 0.45^{d}	2.49 ± 0.01^{c}	1.85 ± 0.002^{b}

[a,b,c,d] Means with the same letter (superscripts) in the same row are not significantly different at p>0.05.

Moisture contents of the four raw materials were significantly different for pawpaw, fishmeal, beans and maize, respectively. The results of the proximate analysis of the raw materials revealed beans to have the least moisture content while maize had the highest moisture content. The high moisture content of the maize could be attributed to the high level of water absorbed by the seeds during soaking and boiling while ripe pawpaw is known for its high moisture content. Employing higher temperatures will have an adverse effect on the sample. Beans naturally have very low moisture content coupled with the high roasting temperature. The ash contents of the raw materials were significantly different as shown in Table 2. The higher ash content of pawpaw compared with fishmeal, beans and maize probably indicates a higher mineral content. Oil contents of pawpaw and beans were not significantly different at p>0.05 and were lower than those of fishmeal and maize. The protein contents of the raw materials were significantly different at p>0.05 with fishmeal having a significantly higher protein content than the other raw materials while pawpaw had the least protein content. The carbohydrate contents were also significantly different for each of the raw materials as shown on Table 2, with maize having the higher carbohydrate content while fishmeal had the least compared with the other food samples. Beans had significantly higher crude fiber content than maize, pawpaw and fish. The high value of crude fiber in bean than maize could be attributed to the dehulling and fermenting of the maize during flour production.

3.1.2. Nutrient Compositions of Formulated Diets

The moisture contents of the formulated diets are as shown on Table 3. The moisture content of the formulated diets were significantly higher Than that of Phosphatine at p>0.05. Nelson reported that moisture content is used as a quality factor for prepared cereals which should have 3-8% moisture content [26]. The low moisture content of weaning foods has a positive effect on its shelf life time. The higher is the moisture content, the shorter the lifespan. Hence, the low moisture contents of diets B and D as well as that of the control sample are recommended for convenient packaging and transport of products [27].

The protein contents of the weaning diets are as shown on Table 3. Protein is one of the most important nutrients required in weaning foods. Diets A, C and E had values of protein content which were not significantly different at p>0.05 and were above minimum amount (14.52%) specified in Codex Alimentarius standards. The high protein contents of the formulations were contributed by the beans and fishmeal. The crude protein of Phosphatine was significantly lower than the prepared weaning food and almost two times below the Codex Alimentarius standards lower limit. According to FAO/WHO Codex Alimentarius Standards for weaning foods, the protein content should range from 14.52 to 37.70 g/100 g for maximum complementation of amino acids in foods and growth [28]. Thus, the formulations satisfy the protein demands of weaning foods for infants.

Table 3. Proximate nutrient content of formulated diets and Phosphatin

Parameters/Sample	Diet A	Diet B	Diet C	Diet D	Diet E	Phosphatine
Moisture Content (%)	5.05±0.17^{e}	3.66±0.17^{b}	4.87±0.17^{d}	4.00±0.17^{c}	4.70±0.17^{d}	1.05±0.01^{a}
Ash Content (%)	5.14±0.16^{b}	4.61±0.24^{a}	5.07±0.17^{b}	4.74±0.22^{a}	5.00±0.18^{b}	8.25±0.03^{c}
Crude Protein (%)	17.88±1.42^{b}	23.71±0.71^{d}	18.61±1.33^{b}	22.25±0.89^{c}	19.34±1.24^{b}	0.07±0.00^{a}
Crude Fat (%)	4.46±0.84^{c}	3.41±0.64^{b}	4.49±0.58^{c}	3.72±0.63^{b}	4.34±0.59^{c}	3.15±0.04^{a}
Crude Fiber (%)	4.02±0.11^{b}	12.42±0.43^{f}	5.07±0.15^{c}	10.32±0.35^{e}	6.12±0.19^{d}	1.59±0.14^{a}
Sugar (%)	5.00±0.00^{a}	5.00±0.00^{a}	5.00±0.00^{a}	5.00±0.00^{a}	5.00±0.00^{a}	*
Carbohydrates (%)	58.04±0.74^{e}	47.11±0.44^{a}	56.79±0.54^{d}	49.87±0.47^{b}	55.41±0.53^{c}	85.89±0.45^{f}
Energy (Kcal)	363.82±22.91^{b}	333.97±14.65^{a}	362.01±17.96^{b}	341.96±15.71^{a}	358.06±17.52^{b}	372.19±3.05
Calcium (mg)	316.18±4.67^{f}	205.13±2.26^{b}	302.30±4.37^{e}	232.89±2.87^{c}	288.42±4.07^{d}	123.00±0.34^{a}
Iron (mg)	23.08±0.82^{d}	13.24±0.40^{a}	21.85±0.77^{c}	15.70±0.50^{b}	20.62±0.71^{c}	50.50±0.38^{e}
Zinc (mg)	1.81±0.20^{a,b}	2.12±0.12^{b}	1.90±0.12^{a}	2.06±0.12^{b}	1.93±0.12^{a}	56.00±0.99^{c}
Magnesium (mg)	111.95±5.99^{c}	96.59±2.79^{b}	110.03±5.59^{c}	100.43±3.59^{b}	108.11±5.19^{b,c}	8.04±0.00^{a}
Manganese (mg)	5.55±0.94^{c}	2.97±0.49^{a}	5.21±0.86^{c}	3.62±0.60^{b}	4.90±0.82^{c}	567.00±1.00^{d}
Potassium (mg)	404.38±36.77^{b}	835.27±2.70^{f}	477.81±4.85^{c}	733.14±3.31^{e}	528.87±4.54^{d}	0.71±0.00^{a}
Sodium (mg)	90.69±8.45^{b}	281.31±0.00^{f}	119.49±0.36^{c}	234.65±0.70^{e}	142.52±0.43^{d}	0.01±0.00^{a}
Phosphorus (mg)	286.37±33.21^{b}	365.08±3.65^{e}	312.72±6.17^{b,c}	350.12±4.37^{d}	320.20±5.81^{c}	2.30±0.06^{a}

^{a,b,c,d,e} Means with the same letter (superscripts) in the same row are not significantly different at p>0.05 **Was not calculated or was not added.*

The fat contents of the weaning diets are as shown on Table 3. The fat contents of diets B and D were not significantly different as well as for diets A, C and E at p>0.05. The fat contents of the formulated diets corresponded to the recommended fat level for weaning foods [29] which should be less than 10%. The fat content of a food sample can affect its shelf stability. This is because fat can undergo oxidative deterioration, which leads to food spoilage. Hence a food sample with high fat content is more liable to spoilage than one with a lower fat content. Furthermore, high intake of fat especially saturated fatty acids has been shown to increase the level of cholesterol in the blood; however, this is not the case with unsaturated fats [27] such as fat found in soybean [30] and cereals [31,32]. Hence the formulated diets are suitable for weaning foods.

The carbohydrate contents are as shown on Table 3. The carbohydrate content in the prepared weaning diets were all significantly different from each other at p>0.05. These results were lower than the commercial weaning food, which was significantly lower. The carbohydrate levels of the prepared weaning food and Phosphatine were higher than the lower limit for carbohydrates (41.13 to 73.79g/100 g) of the Codex Alimentarius Standards [28].

The fiber contents are as shown on Table 3. The crude fiber content of the formulated diets were significantly different for each other at p>0.05. This could be attributed to the dehulling of maize during the production of maize flour, thereby reducing the amount of fiber considerably. Fiber is an important dietary component in preventing overweight, constipation, cardiovascular disease, and diabetes and colon cancer [33]. High dietary fiber content has been reported to impair protein and mineral digestion and absorption in human subjects [34]. Some fiber related fractions such as polyphenols and non-starch polysaccharides, bind minerals such as Calcium, Zinc and Iron, making them unavailable for human nutrition [35]. Hence low-fiber diets are suitable for weaning foods and in this case, diet B would not be a suitable weaning diet due to its high fiber content.

The energy contents are as shown on Table 3. The total caloric contents of diets B and D were not significantly different from each other as well as diets A, C and E at p>0.05. The high caloric contents of diets could be attributed to their high carbohydrate content as well as their high fat content relative to diets B and D. For all the weaning foods both prepared and commercial, the energy density per 100 g of the dry food was lower than the minimum energy (483.9kcal/100g) recommended in the Codex Alimentarius Standards for weaning foods [28]. Dewey stated that energy needs from complementary foods for infants and toddlers who are still breastfed vary from 200kcal/day at 6-8 months, 700kcal/day for 9-11 months and 550kcal/day for 12-23 months [36]. Therefore, the amount of diet A to be consumed by a 6-8 month old infant will be 55g, for a 9-11 month old will be 192.4g and 151g for a 12-23 month old infant per day. The amount of diet B to be consumed will be 60g for 6-8 month old infants, 210g for 9-11 month olds and 165g for 12-23 month old infants per day. The amount of diet C to be consumed will be 55g for 6-8 month old infants, 194g for 9-11 month old infants and 152g for 12-23 month old infants. Diet D will be given as follows: 86g for 6-8 month old infants, 301g for 9-11 month old infants and 236g for 12-23 month old infants. Diet E will be given as follows: 56g for 6-8 month old infants, 196g for 9-11 month old infants and 154g for 12-23 month old infants. Hence it would be recommended that infants take more of the diets to meet up to the recommended caloric content of weaning foods i.e. about 133g for diet A, 145g for diet B, 134g for diet C, 208g for diet D and 135g for diet E. The protein caloric content of the formulated diets were 71.52kcal, 94.84kcal, 74.44kcal, 89.00kcal and 77.36kcal for diets A, B, C, D and E respectively, representing 18.49%, 24.52%, 19.25%, 23.01% and 20.00% of the total energy content of the diets respectively. The fat caloric content of formulations A, B, C, D and E were 40.14kcal, 30.69kcal, 40.41kcal, 33.48kcal and 39.06kcal respectively, representing 10.38%, 7.94%, 10.45%, 8.66% and 10.10% of the total energy content of the diets respectively. The carbohydrate caloric contents were 252.16kcal, 208.44kcal, 247.16kcal, 219.48kcal and 241.64kcal representing 65.20%, 53.90%, 63.91%, 56.75% and 62.48% of the total energy content of the diets. The carbohydrate caloric contents for diets A, C and E were slightly higher than the Protein Advisory Group values of 50-60% [29], whereas the protein and fat contents fall within the recommended ranges of 10-20% although those for diets B and D were slightly higher than the Protein Advisory Group values [29] and fat levels fulfill needed energy to meet infants' growth demands except for diets B and D whose values were slightly less.

The results for ash contents are as shown on Table 3. Ash content were not significantly different between diets B and D as well as between diets A, C and E. The ash content of the products, which gives an idea of the mineral content, increased with the addition of the pawpaw flour. Diets B, D and E had ash contents acceptable by the Protein Advisory Group standard which recommended that the ash content should not exceed 5% [29], whereas the ash contents of diets A and C where slightly above the recommended values by the Protein Advisory Group. No standard for ash content has been specified for weaning foods in the Codex Alimentarius Standards [28]. The high amounts of mineral were contributed by pawpaw which had the highest ash content (Table 2). Minerals are essential in infants and young children for building bones and teeth, functioning of muscles and nerves, blood clotting, synthesis of haemoglobin (an oxygen carrier in the red blood cells), myoglobin (used for muscle contraction) and enzymes/coenzymes (used in various metabolic path-ways) enhancement of the body's immune system thus, reducing infections and fostering proper functioning of other organs of the body and for immune defence [34].

3.2. Functional Properties

The functional properties such as Water and Oil Absorption Capacities (WAC and OAC), Bulk Density (BD), Swelling Index (SI), Foam Capacity (FC), and Dispersibility were analysed and the results are shown in Table 4.

Table 4. Functional properties of weaning food diets A to E and Phosphatine per 100 g dry weight

Functional properties	Diet A	Diet B	Diet C	Diet D	Diet E	Phosphatine
BD (g/ml)	0.80±0.00[a]	0.81±0.00[b]	0.80±0.00[a]	0.83±0.00[c]	0.81±0.00[b]	0.36±0.01[d]
WAC (ml/g)	2.90±0.14[c]	2.40±0.00[b]	2.00±0.00[a]	3.10±0.14[d]	3.30±0.14[e]	4.65±0.21[f]
OAC (ml/g)	2.40±0.00[a]	2.80±0.57[c]	3.00±0.28[c]	2.80±0.00[b]	2.30±0.14[a]	2.90±0.99[c]
Hydrophile-Lipophyle index	0.83±0.06[c]	1.17±0.34[d]	1.50±0.20[e]	0.90±0.06[c]	0.70±0.02[b]	1.79±0.76[e]
Dispersibility (%)	94.0±0.54[a,b]	95.5±0.07[a,b]	95.0±0.14[a,b]	94.5±0.07[a,b]	98.0±0.00 [c]	17.5±1.77[d]
Swelling Index (%)	0.91±0.00[a]	1.02±0.03[c]	1.13±0.44[d]	1.23±0.28[d]	1.25±0.11[d]	1.00±0.00[b]
Foam Capacity	3.74±0.05[b]	3.63±0.32[b]	7.55±0.20[c]	2.83±1.33[a]	7.69±0.00[c]	13.56±2.03[d]

[a,b,c,d,e] Means with the same letter (superscripts) in the same row are not significantly different at p>0.05.

3.2.1. Water Absorption Capacity

Table 4 presents the results of the functional properties of the formulated diets. The water absorption capacities of the Diets ranged between 2.00 and 3.30 with Diet C having the lowest water absorption capacity of 2.00±0.00 and Diet E having the highest water absorption capacity of 3.30±0.14 while the commercial weaning diet had a water absorption capacity of 4.65. All values for water absorption capacity were significantly different from each other at p>0.05. WAC indicates the volume of water required to form gruels with suitable consistency for infant feeding. Carbohydrates have been reported to influence water absorption capacity of foods [37]. The ability of protein to bind water is indicative of its water absorption capacity. The observed variation in water absorption among the flours may be due to different protein concentration, their degree of interaction with water and their conformational characteristics [38]. On the other hand, McWatters *et al.*, reported that lower water absorption capacity is due to less availability of polar amino acids in flours [38]. This effect could be due to the loss of native granules structure of starch association [39]. With respect to water absorption capacity, Giami & Bekeham reported that the microbial activities of food products with low water absorption capacity would be reduced, thereby extending the shelf-life of the product [40]. Mahgoub reported low WAC for Cerelac in comparison to weaning diets formulated with sorghum and legumes [41]. Therefore, lower water absorption capacity diets are desirable for making thinner gruels hence diet C is more suitable for weaning diets.

3.2.2. Oil Absorption Capacity

Table 4 presents the results of the oil absorption capacities of the formulated diets. The oil absorption capacity of the formulated diets ranged between 2.30 for Diet E and 3.00 for Diet C while the commercial weaning diet had an oil absorption capacity of 2.90. The oil absorption capacities of diets A and E were not significantly different at p>0.05 while those for diets B, C and Phosphatine were also not significantly different at p>0.05. Generally the water absorption capacities of the weaning food formulations were systematically higher than their oil absorbance capacity, implying that weaning foods with high WACs tend to have low OACs due to the fact that there are more hydrophilic interactions in the weaning foods with high WACs.

3.2.3. Packed Bulk Density

The results for Packed Bulk Density are as shown in Table 4. The Bulk Density ranged between 0.80 for Diets A and C, and 0.83 for Diet D while the bulk density for the commercial weaning diet was 0.36.There was no significant difference between diets A and C, as well as between B and E. The results of bulk density of the formulated diets were similar to those reported by Amarjeet *et al.* [42] obtained from durum wheat blends which ranged from 0.80 to 0.82g/ml, but were higher than those obtained by Fasasi *et al.* [43] from Tilapia-maize flour blends which ranged from 0.355 to 0.610g/ml. Bulk density gives an indication of the relative volume of packaging material required and high bulk density is a good physical attribute when determining the mixing quality of a particulate matter [44]. The bulk density is a reflection of the load the flour samples can carry, if allowed to rest directly on one another. The density of processed products dictate the characteristics of its container or package product density influences the amount and strength of packaging material, texture or mouth feel [45]. According to Basman & Koksel [46] higher bulk density is desirable for greater ease of dispersibility of flours. Also, high bulk density limits the caloric and nutrient intake per feed of a child which can result in growth faltering. However, low bulk density would be an advantage in the formulation of complementary foods [47]. This is because lower BD values lead to higher amounts of flour particles which can stay together and thus increasing the energy content of such diets [48]. Therefore, more of the samples could be prepared using a small amount of water yet giving the desired energy nutrient density and semi-solid consistency which can easily be fed to an infant [49].

3.2.4. Swelling Index

The results for swelling index are as shown in Table 4. The Swelling Index ranged 0.91 for Diet A and 1.25 for Diet E, while that for Phoshatine was 1.00. The swelling indices for diets C, D and E were not significantly different at p>0.03. The Water Absorption Capacity and Swelling Index are important parameters which ultimately determine the sample consistency (that is solid, semi-solid, or liquid). Flours with both high WAC and SI values hold large amounts of water during their preparation into gruels and thus become voluminous with a low energy and nutrient density [50]. The values obtained in this study were lower than those obtained by Ikpeme *et al.* [51] for formulated diets based on taro and soy bean. Samples with the least Swelling Index value such as diet A would provide more nutrient density food for an infant.

3.2.5. Foaming Capacity

The results for foam capacity are given in Table 4. The values ranged between 2.83 for Diet D and 7.69 for Diet E. The Foam capacity for the commercial weaning food was 13.56, significantly greater than that for the formulated diets, while the foaming capacities of diets A and B were not significantly different as well as diets C and E at p>0.05. These results were lower than those obtained by Kouakou *et al.*, [52] for weaning food formulated from cereals and legumes which ranged from 0.00 to 10.00%. According to Yadahally et al. Heat treatment of ingredients causes proteins denaturation and aggregation leading to foam formation after agitation [53]. Diet E, which had 60% maize with low protein content, provided the proof of relation between foam formation and high protein content. In fact, the foam formed by the flour has no stability over time. This was due to protein denaturation caused by grinding and heating during flour preparation. It has been reported that the native proteins provide high foam stability than denatured proteins [21].

3.2.6. Dispersibility

The results for dispersibility are given in Table 4. The dispersibility was within the range 94.0 for Diet A and 98.0 for Diet E while Phosphatine had a dispersibility value of 171.0, which was significantly greater than those of the formulated diets. There was no significant difference between diets A, B, C and D while diet E had a dispersibility value significantly greater than all the other diets at p>0.05. The results obtained by Kulkarni *et al.* [54] on diets formulated from green gram, sesame and sorghum malt flour ranged from 71% to 75% hence were lower than those of the formulated diets A to E. The dispersibility of a diet in water indicates its reconstitutability. The higher the dispersibility value, the better the diet, hence diet E was more suitable in preparing weaning foods due to its high dispersibility value

3.2.7. Hydrophilic-Lipophilic Index

The results for Lipophilic-Hydrophilic Index are given in Table 4. The Lipophilic-Hydrophilic Index was calculated as a quotient between the Oil and Water Absorption Capacity and it ranged between 0.70 for diet E and 1.50 for diet C. There was no significant difference in the Hydrophilic-Lipophilic indices of diets A and D at p>0.05 while the Hydrophilic-Lipophilic index of Phosphatine was significantly lower than that for diet E at p>0.05. A hydrophilic-lipophilic index equal to one indicates that a diet has a high affinity for both water and oil, while a hydrophile-lipophile index greater than or less than one indicates that a diet either has a high affinity for oil or water respectively. As seen in Table 4, diets with high WAC values had low OAC values, hence Hydrophile-Lipophile indices less than one while diets with high OAC had low WAC values hence Hydrophile-Lipophile indices greater than one. Therefore, for weaning foods, it is recommended that the Hydrophile-lipophile index should be less than one, such that the diet would have a greater affinity for water than oil and the more the Hydropile-lipophile index gets smaller than one, the more its viscosity, implying a greater energy density of the diet, hence, Diet E will be ideal for weaning foods due to its low hydrophle-lipophile index, while diet C will not be suitable due to its higher affinity for oil than water.

3.3. Sensory Analysis

The results of the sensory evaluation performed on the reconstituted diets are as shown on Table 5. The ratings for taste, texture/consistency, colour, flavour and overall acceptability all ranged from approximately Slightly Like to Like Moderately.

3.3.1. Colour

The Colour ratings of the formulated Diets are presented on Table 5 and ranged from (5.96 to 6.96). The control sample (Phosphatine) was rated best, while among the formulated Diets, Diet A was rated best (6.96), followed by Diet C (6.48), and Diet B had the lowest rating for colour (5.96).

Table 5. Sensory evaluation of the formulated diets

Diets	Colour	Taste	Flavour	Texture/ Consistency	Overall Acceptability
A	6.96^{d}	5.67^{b}	5.70^{a}	6.41^{c}	5.56^{b}
B	5.96^{a}	5.77^{c}	5.62^{a}	5.96^{a}	5.50^{a}
C	6.48^{c}	5.54^{a}	5.96^{b}	6.21^{b}	5.82^{c}
D	6.29^{b}	5.63^{b}	6.07^{c}	6.46^{c}	5.82^{c}
E	6.11^{a}	5.79^{c}	5.89^{b}	6.25^{b}	5.79^{c}
Phosphatine	8.43^{e}	8.32^{d}	8.36^{d}	7.86^{d}	8.39^{d}

There was no significant difference in the colour rating of diets B and E at p>0.05, while the rating for Phosphatine was significantly higher than those of the formulated diets. Factors that can affect the colour of the composite diets include the chemical composition of the maize, bean, fishmeal and pawpaw flours, the drying temperature and duration, and the proportions or ratio of ingredients: maize, bean, fish meal and pawpaw flours. Low colour ratings of weaning foods can decrease the acceptability as colour is an important organoleptic attribute which enhances the product acceptability. The colour ratings of the evaluated samples were within acceptable limits and therefore would not be objectionable to the infants, but could be further improved by adjusting processing conditions.

3.3.2. Texture

The Texture ratings of the diets are presented on Table 5 and ranged from 5.96 to 6.46. Phosphatine had the best texture rating (7.86) which was significantly higher than those of the formulated diets. Diet D had the best texture rating among the formulated Diets (6.46) followed by Diet A (6.41), while Diet B received the least texture rating (5.96). The colour ratings of diets C and E were not significantly different as well as diets A and D at p>0.05. The differences in the texture ratings could be as a result of the constitutional variations. The texture is very important, as it would determine the amount of food an infant would consume, because infants can only swallow a smooth gruel and not a coarse product. However, texture ratings of the composite Diets were within acceptable limits.WAC and SI are important parameters which determine the consistency of flour. A very thick consistency would need increased effort to swallow, and therefore may limit the food intake in young children who have not fully developed their swallow ability [55].

3.3.3. Taste

The ratings for Taste are as shown on Table 5 and ranged from 5.54 to 5.79 for the formulated diets. Phosphatine had the best rating for taste, while among the formulated diets, diet E had the highest rating, closely followed by Diet B while Diet C had the least rating for taste. The rating for diets A and D were not significantly different as well as diets B and E at p>0.05. However, the taste ratings of the Diets were within acceptable range. The best score rating of the control sample would be as a result of flavouring addition in the product. Infants are likely to reject unflavoured foods therefore, to further improve the taste ratings, flavor or flavor enhancer might need to be incorporated into the formulated samples.

3.3.4. Flavour

The flavour ratings are as shown on Table 5 and ranged from 6.07 to 5.62 for the formulated diets. Phosphatine was rated best for flavour, while among the formulated diets, diet D had flavour ratings significantly higher than the rest of the formulated diets, while the least rated were diets A and B which were not significantly different at p>0.05. The sample rating scores were within a favourable range (6.07 to 5.62), and thus the ratings compared favourably with each other. The best score rating for the control could be a result of the added flavourings. Adebayo-Oyetoro *et al.*, [56] reported low flavour ratings obtained from weaning diets formulated from sorghum, walnut and ginger ranging from 2.3 to 3.1 using a 9-point hedonic scale. These ratings were lower than those obtained by Onoja and Obizoba [57] from Water-yam, cocoyam, plantain, African yam-bean, cowpea, pigeon pea and maize which ranged from 5.46 to 8.50. Low flavour ratings could reduce the acceptability of the food by an infant, hence diet D was the most suitable for a weaning food due to its high flavour rating.

3.3.5. Acceptability

The Overall Acceptability ratings are as shown on Table 5 and ranged from 5.50 to 5.82 for the formulated diets. Phosphatine received the highest ratings for overall acceptability (8.39), while among the formulated diets, Diets C and D were both the highest rated (5.82 respectively), therefore where not significantly different at p>0.05, while Diet B received the lowest rating for overall acceptability. The results obtained by Oyarekua [58] from diets obtained from co-fermented maize, sorghum and cowpea were higher than those obtained in this study ranging from 5.8 to 8.5. The factors affecting the general acceptability are the flavour, taste, colour and texture of the diets. The high general acceptability ratings of Phosphatine could be attributed to additional flavourings, colourings and sophisticated processing of raw materials.

3.4. Rat Bioassay

Table 6 summarizes the results of the protein quality assessment of the formulated diets as well as the commercial weaning food. The protein quality is related to the increase in body weight designated as PER (Protein Efficiency Ratio). The PERs for diets B and D were within the range recommended by the Protein Advisory Group (2.1) suitable for weaning diets, while the PER for diets A, C and E were higher than the PER recommended by the Protein Advisory Group. The PER of control was lower than the recommended PER for weaning foods, hence not suitable for weaning diets. In general, weaning diets with PER values less than 2.00 are not regarded as suitable for weaning diets.

Table 6. Growth response of experimental rats fed with formulated diets

Diets	Body weight			PER
	Initial (g)	Final (g)	Weight Increase (g)	
A	17.30±0.82	67.33±5.33	50.03±6.38[c]	2.80
B	23.13±7.68	72.00±7.01	48.87±0.95[b]	2.06
C	24.00±1.82	67.20±8.66	43.20±9.67[b,c]	2.32
D	21.63±1.57	67.07±5.31	45.44±5.29[b,c]	2.04
E	22.23±1.79	81.70±9.37	59.47±10.72[d]	3.07
Phosphatine	22.25±3.18	32.05±2.76	9.80±0.59[a]	1.19

Results are Mean±S.D of three independent determinations. [a,b,c,d,e] Means with the same letter (superscripts) in the same column are not significantly different at p>0.05.

Table 7 shows the results of the average weight the organs of the rats fed with the formulated diets and Phosphatine. The weights of the organs of rats fed with diet A were significantly higher than that of the commercial diet. The rats fed with the commercial diets had the least organ weights which could be due to the low PER of the commercial diet, where a low amount of protein is incorporated in body organs. The low PER could be as a result of the low protein content of the commercial diet.

Table 7. Body organ weight of rats fed with the formulated diets and Phosphatine

Diets	Liver (g)	Kidney (g)	Heart (g)
A	4.53±0.45[d]	1.17±0.31[d]	0.50±0.10[c]
B	3.47±1.07[b,c,d]	0.83±0.15[c]	0.37±0.12[b]
C	3.37±0.71[b]	0.77±0.15[b,c]	0.30±0.00[a]
D	3.73±0.25[b,c]	0.67±0.12[b]	0.30±0.00[a]
E	3.90±1.30[d]	0.80±0.10[c]	0.40±0.10[b]
Phosphatine	2.25±0.78[a]	0.50±0.00[a]	0.25±0.07[a]

Values with different superscript in a column are significantly different ($P < 0.05$).

The PER values obtained in this study were higher than those obtained by Mahgoub [41] obtained from diets formulated from sorghum, groundnuts, sesame seeds, chickpeas and commercial grade skimmed milk powder which ranged from 1.10 to 2.07, implying that the proteins of the formulated diets of this study were incorporated into body organs more efficiently than that of the commercial diet, leading to greater body organ weights.

4. Conclusions

This study showed that formulations of weaning food from maize, beans, fishmeal and pawpaw can be produced. Available technology in Cameroon (e.g., boiling, drying, and milling, roasting) was successfully employed in the production of this food. This provides alternatives to the weaning foods in the Cameroonian market as well as other countries in the world. The inclusion of fishmeal and beans furnished the food with the required protein content. The nutrient composition of the product was compared favourably with that of a popular commercial weaning food. From the nutritional analysis, various constituents like moisture, protein, fat, ash, carbohydrate, crude fiber and energy among six weaning foods (five formulated and one commercial); the prepared weaning foods have demonstrated the most satisfactory result. The protein (an essential nutrient for rapid growth in infants) was highest in the formulated weaning food than imported commercial weaning food. From the mineral analysis of those weaning foods, the formulated weaning food showed satisfactory results. The addition of pawpaw could improve the total carotenoids and vitamin C contents of the formulated diets. In the rat bioassay, the highest PER values were shown in the rats fed on the formulated weaning food. The formulations had acceptable sensory ratings, with all formulated weaning foods having ratings above 5 on the 9-point hedonic scale. The flavour, texture and colour of all the porridges were liked by the panelists. Thus, the highly nutritive value of the formulated weaning diets was satisfactory to ensure the rapid growth of rats and therefore, can help to reduce malnutrition in developing countries.

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