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Comparison between low-cost locally produced complementary foods with high-cost imported complementary foods available in Bangladesh by Rat Bioassay

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Abstract

Highly nutritive value contained complementary foods are very important for the children 6-23 months to meet the increasing demands for body requirement as well as fight against high malnutrition. Malnutrition is a persistent health problem among children in Bangladesh, especially under 2 year's children due to the lack of proper complementary foods both diverse and balanced. Highly nutritive locally produced Complementary foods were prepared by using locally available food resources to ensure the availability of low-cost Complementary food in Bangladesh. The developed foods were evaluated for their nutritional characteristics and microbiological quality. The food (L-1) contained the major nutrients like moisture, ash, fat, protein, fiber, carbohydrate, and energy respectively 2.96%, 3.13%, 9.45%, 15.56%, 0.07%, 59.12%, and 394.1 kcal/ 100 g, and (L-2) 2.08%, 3.09%, 9.3%, 16.09%, 0.08%, 59.74%, and 397.5 kcal/ 100 g, respectively which were comparable to those of the two good quality imported commercial Complementary foods F-1 & F-2. The vitamin A, iron, and calcium contents were significantly different ($p<0.05$) than the commercial foods. The overall bacteriological status of the prepared and imported commercial Complementary foods was observed to be satisfactory. In rat bioassay, the highest PER and FER were shown in the rats feed on the locally produced instant complementary foods which indicates that it would favorable for the children and good option for the mothers. The costs of the locally prepared Complementary foods are considerably cheaper than the two imported commercial Complementary foods of the same quality and suitable for low-income people of Bangladesh.

Keywords: Complementary Food; Low Cost; locally produced; Rice; Rat bioassay; Microbial

1 Introduction

Complementary feeding – defined as the process of providing foods when breast milk or milk formula alone are no longer adequate to meet nutritional requirements – generally starts at age 6 months and continues until age 23 months, although breastfeeding may continue beyond this period [1]. This is a developmental period when it is critical for children to learn to accept healthy foods and beverages and establish long-term dietary patterns [2]. It also coincides with the peak period for the risk of growth faltering and nutrient deficiencies [3].

The low nutrient density of complementary foods further accounts for under-nutrition resulting in Protein Energy Malnutrition (PEM) as well as micro-nutrient deficiencies [4, 5].

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In the long term, early childhood undernutrition leads to reduced work capacity and earnings and, among girls, reduced reproductive capacity [3]. Inappropriate complementary feeding can result in overweight, type 2 diabetes, and disability in adulthood [13]. The first 2 years of life are also a critical period for brain development, the acquisition of language and sensory pathways for vision and hearing, and the development of higher cognitive [6].

According to the Bangladesh Demographic and Health Survey (BDHS 2011 [7], almost one-third of children under five years are underweight (36%), and 41% are stunted. Only 64% of infants aged less than six months are exclusively breastfed and almost one-third (29%) of children aged 6 to 23 months received a minimum acceptable diet (BDHS 2011 [7]. The most common complementary foods include khichuri, bhaat/rice, dal/pulse, suji/semolina, and muri (puffed rice) [8].

In most developing countries, commercial complementary foods of excellent quality either imported or locally produced are generally 10 to 15 times higher than the cost of the common staple foods due to sophisticated processing, expensive packing, extensive promotion, and solid profit margins [9].

Therefore, the development of supplementary foods based on locally available cereals and legumes has been suggested by the Integrated Child Development Scheme (ICDS) and Food and Agriculture Organization (FAO) to combat malnutrition among mothers and children of low socio-economic groups [10].

A highly nutritive complementary food prepared from rice and milk in Cereal Technology section, IFST, BCSIR, Dhaka and safety aspects of it was compared to imported commercial complementary foods [11] which formula is using by local producer for complementary food. Thus, in this study, cereal-based complementary food is collected from local markets to ensure the quality of the products available of low-cost complementary food that is microbiologically safe to reduce infant malnutrition and mortality rates. We also compare the locally produced complementary food's nutritional value with the imported commercial complementary foods in Bangladesh.

The locally available complementary foods have been compared with two imported foreign complementary foods available in Bangladesh by analyzing their essential nutrients and Rat bioassay to assess the nutritional quality of the complementary feeding.

2 Material and methods

2.1 Collection of imported commercial Complementary foods and locally produced Complementary food

The two imported commercial Complementary foods (Wheat-milk-based Complementary food as F-1, and rice-milk-banana based Complementary food as F-2) were selected based on their popularity and market availability. These two commercial Complementary foods are recommended for children aged 6 months and above. These Complementary foods were purchased from supermarkets in Bangladesh.

Locally produced Complementary foods are prepared of rice, Wheat, sugar, skim milk powder, butter, etc (Rice-milk-based Complementary food as L-1 and Wheat-milk-based Complementary food as L-2).

For control group consumption, I collect casein. The casein diet was containing of 75% starch, 10% oil, 4% salt, 1% vitamin mix and 10% casein protein also purchased to run the rat bioassay test, named as CG.

2.2 Chemical analysis of Complementary foods

2.2.1 Nutrient analysis

The nutrient compositions of the imported commercial Complementary foods and as well as the locally produced Complementary foods were carried out as follows:

Determination of moisture content

Moisture content was determined by oven-dry method as the loss in weight due to evaporation from the sample at a temperature of 105°C. The weight loss in each case represented the amount of moisture present in the sample:

$$\text{Moisture (\%)} = \text{(Weight of the original sample- weight of the dried sample) / weight of the original sample} \times 100$$

Determination of crude protein

The crude protein content was determined by the following micro Kjeldahl method [12]. The percentage of nitrogen (N) was calculated using the following equation:

$$Nitrogen\ (\%) = (S - B) \times N \times 0.014 \times 100\ /W$$

Where S= Titration reading for sample, B= Titration reading for blank, V = titration volume = (S-B), N= Strength of N/70 H_2SO_4, W = Weight of the sample, 0.014 = Constant value.

Crude protein was obtained by multiplying the corresponding total nitrogen content by a conventional factor of 6.25. Thus, crude protein (%) = % of N × 6.25.

Determination of crude fat

Crude fat was determined by the Soxhlet extraction technique followed by AOAC (2005). The fat content of the dried samples was easily extracted into an organic solvent (petroleum ether) at 60 to 80°C and followed to reflux for 6 h. The percentage of fat content was calculated using the following formula:

$$Crude\ Fat\ (\%) = Weight\ of\ the\ fat\ in\ the\ sample/\ Weight\ of\ the\ dried\ sample \times 100$$

Determination of ash

Ash content was determined by combusting the samples in a muffle furnace at 600°C for 8 h according to the method of [12]:

$$Ash\ Content\ (\%) = Weight\ of\ ash\ /\ Weight\ of\ sample \times 100$$

Determination of crude fiber

The bulk of roughage in food is referred to as the fiber and is called crude fiber. The milled sample was dried, defatted with ethanol ethanol-acetone mixture, and then the experiment was carried out using the standard method as described in AOAC [12]:

$$Crude\ Fiber\ (\%) = (Weight\ of\ the\ residue - Weight\ of\ the\ Ash)/\ Weight\ of\ the\ sample \times 100$$

Determination of carbohydrate

The carbohydrate content was estimated by the difference method. It was calculated by subtracting the sum of the percentage of moisture, fat, protein, and ash contents from 100% according to AOAC [12]:

$$Carbohydrate\ (\%) = 100 - (moisture\% + fat\% + protein\% + ash\ \%)$$

Determination of total energy

The total energy value of the food formulation was calculated according to the method of Mahgoub (1999) using the formula as shown in the following equation:

$$Total\ energy\ (kcal/100\ g) = [(\%\ available\ carbohydrates \times 4.1) + (\%\ protein \times 4.1) + (\%\ fat \times 9.3)]$$

Determination of vitamin A

About 10 g of the sample was homogenized, weighed, and transferred into a ground bottom flask, 30 ml of extraction solution, 0.1% antioxidant, and a few drops of KOH was added and refluxed for 30 min at 70°C. The sample was cooled down, vitamin A was extracted into hexane, and the combined hexane extract was washed with water and then dried the hexane layer to about 2 ml on a water bath or rotary evaporator. The final volume was made up to 50 ml with the mobile phase. The mobile phase, standard and sample were filtered through a 0.45 μ membrane filter and were degassed before injection. Calibration curve was made by a standard in the mobile phase with five point calibrations and analyzed independently by HPLC. A standard curve was plotted between the concentration of vitamin A and peak area obtained. For HPLC analysis, an Eelipse × BD – C18 column (4.6 × 250 mm 5 μm) was used with a linear gradient of methanol: water (95:5) at a constant flow rate of 1 ml /min by using a binary pump with column temperature 40°C.

A multiple-wavelength detector was employed for the detection of pecks using a wavelength of 325 nm and a bandwidth of 8 nm.

Determination of minerals

The mineral contents were determined after the ash content determination. The ash residue of each formulation was digested with perchloric acid and nitric acid (1:4) solution. The samples were left to cool and contents were filtered through Whatman filter paper 42. Each sample solution was made up to a final volume of 25 ml with distilled water. The aliquot was used separately to determine the mineral contents of Fe and Ca by using an Atomic Absorption Spectrometer (Spectra AA 220, USA Varian).

2.3 Determination of microorganisms

A microbiological examination of the Complementary foods was performed to assess bacterial, fungal, and yeast load under laboratory conditions. Standard Plate Count (SPC), fungal and yeast count, and enumeration of total coliform and Salmonella of the Complementary foods were examined according to BAM [13]. The plate count method was employed for the examination of the total number of viable microbes present in the sample. Standard plate count (SPC) was estimated by decimal dilution technique followed by pour plate method and spread method for fungus and yeast. The streak plate method was used to isolate the specific micro-organism. Isolation and enumeration of total coliform were performed by the most probable number (MPN) method using MacConkey broth [14].

2.4 Rat Bioassay

To do the assessment of the nutritional quality of four complementary baby foods or infant formulas, a standard rat bioassay procedure was done. To determine the growth of those rats, they were fed with four infant formulas and one casein diet. For this study fifteen (15) healthy Long-Evan rats of 28 to 30 day maturity (0-21 day old rats are breast feed rats) were divided into five groups in five separate cages. First seven days, they were kept for the acclimatization period and the individual groups were given the same amount of commercial laboratory chow diet. After 7 days, each rat group acclimatized on average 55 g of different complementary foods and was fed water ad *labitum* for 4 weeks. The control group was fed on a casein diet containing 75% starch, 10% oil, 4% salt, 1% vitamin mix, and 10% casein protein. Food consumption, spoilage, and weight gain were recorded every 4 days. Protein efficiency ratio (PER) and feed efficiency ratio (FER) were calculated using the following formula;

PER= Weight gain of the test group (g)/ Total protein consumed (g)

FER= Gain in body weight (g) / Food consumed (g)

2.5 Statistical analysis

The data were analyzed using SPSS version 17.0. The mean and standard deviations of the triplicate analyses were calculated. The analysis of variance (ANOVA) was performed to determine significant differences between the means using Dunnett's T3 tests.

3 Results and discussion

3.1 Nutritional composition

The nutritional compositions (g/100 g dry weight) of the locally produced Complementary food and imported commercial Complementary foods were summarized in Table 1. The energy content of the locally produced Complementary food was 394.1 & 397.54 kcal/100 g. For the imported commercial Complementary foods, the energy content ranged from 395.18 to 485.72 kcal/100 g. For all the Complementary foods both locally produced and commercial, the energy density per 100 g of the dry food was lower than the minimum energy (483.9 kcal/100 g) recommended in the Codex Alimentarius Standards for Complementary/follow-up foods [15].

Protein is one of the most important nutrients required in Complementary foods. The locally produced Complementary foods had a protein content of 15.56% and 16.09 which are the same as specified in Codex Alimentarius standards. The protein levels of commercial Complementary foods ranged from 14.67 to 16.59% (one lower than the RDA and another two is slightly higher than RDA) which almost the same as locally produced Complementary foods. According to FAO/WHO Codex Alimentarius Standards for follow–up/ Complementary foods, the protein content should range from 14.52 to 37.70 g/100 g [15].

Table 1 Nutritive Value of the Locally Produced Complementary Food as compared with Imported Commercial Complementary Foods

Baby food sample	L-1	L-2	F-1	F-2
Moisture (%)	2.961	2.084	2.349	4.011
Ash (%)	3.132	3.086	1.869	2.578
Fat (%)	9.45	9.297	7.63	6.548
Protein (%)	15.56	16.088	14.67	16.593
CHO (%)	59.127	59.738	68.764	64.94
Fiber (%)	0.074	0.086	0.307	0.573
Energy (K.Cal)	394.1	397.54	413.04	395.18
Vitamin-A (µg/100 g)	944.66	892	888.66	1398
Vitamin-B1 (mg/100 g)	0.56	0.37	0.35	0.07
Iron(mg/100 g)	7.44	7.36	7.26	1.44
Calcium (mg/100 g)	439.26	443.63	325.29	450.86

The locally produced Complementary food contained 9.45% and 9.39% fat which was significantly higher ($p<0.05$) than the commercial Complementary foods of F-1 and F-2 but lower than F-3; ranging from 6.55 to 11.17% but lower than the specified amount in the Codex Alimentarius Standards (range 14.52- to 41.13%). The lower fat content contributed to the lower energy value of the locally produced Complementary food. The lower fat content may also have contributed to the increase in the shelf-life of the formulation by decreasing the chances of rancidity [16]. Ash content is an important nutritional indicator of mineral content and an important quality parameter for contamination, particularly with foreign matter (for example, pebbles

The ash content of the locally produced Complementary foods was 3.13% & 3.09% for L-1 and L-2 accordingly; this result was significantly higher than the commercial Complementary foods (F-1: 1.87%, F-2: 2.58& and F-3: 1.72%). No standard for ash concentration has been specified for Complementary/follow–up foods in the Codex Alimentarius Standards [15].

The moisture content of the locally produced Complementary food for L-1 and L-2 were 2.96% and 2.08% respectively. These results were significantly different from the commercial Complementary foods F-2 (4.01%) and within the range of F-1 and F-3 (F-1: 2.35% and F-3: 2.57%) (Table 1).

The percent crude fiber of the locally produced Complementary food was 0.074% and 0.086% (Table 1). These values were significantly higher than the value of commercial Complementary foods which ranged from 0.00 to 0.573%. Fiber is an important dietary component in preventing overweight, constipation, cardiovascular disease, diabetes, and colon cancer [17].

The carbohydrate content in the locally produced Complementary foods was 59.13% and 59.74% for L-1 and L-2 (Table 1). This result was significantly ($p<0.05$) lower than the commercial Complementary foods which ranged from 64.94 to 77.4%. The carbohydrate levels of the locally produced Complementary food and all the imported commercial Complementary foods were within the standard limit (41.13 to 73.79 g/100 g) of the Codex Alimentarius Standards [15]. Vitamins are substances that are indispensable for the growth and maintenance of good health.

According to Food and Nutrition, Institute of Medicine [18], the recommended daily allowances (RDA) for energy, carbohydrate, protein, fat, vitamin A, vitamin B1, Ca, and Fe for 7 to 12 months old infants are 743 kcal, 95 g, 11 g, 30 g, 500 µg, 0.3 mg, 270 mg, and 11 mg, respectively.

Table 2 Comparison of Recommended Daily Allowance (RDA) meet by the Complementary foods

Nutrient Name	RDA	L-1	L-2	F-1	F-2
Calorie	743 Kcal	53.0%	53.5%	55.6%	53.2%
CHO	95g	62.2%	62.9%	72.4%	68.4%
Protein	11g	141.5%	146.3%	133.4%	150.8%
Fat	30g	31.5%	31.0%	25.4%	21.8%
Vitamin-A	500 µg	188.8%	178.4%	177.7%	279.6%
Vitamin-B	0.3 mg	186.7%	123.3%	116.7%	23.3%
Calcium	270 mg	162.7%	156.9%	120.5%	167.0%
Iron	11 mg	67.6%	66.9%	66.0%	13.1%

These findings suggest that both locally produced and commercial Complementary foods have the potential to provide the recommended daily requirements for energy and other nutrients for infants and young children. These foods, however, may be unable to meet the RDAs for energy and macro/micronutrients as the children grow older due to increased demand for nutrients to support growth.

3.2 Microbiological quality of Complementary foods

The overall bacteriological status of the locally produced and the imported commercial Complementary foods was observed to be satisfactory (Table 7). The obtained results revealed that the total viable bacterial count, total yeast and mold count, total coliform count, and presence of Salmonella per gram were absolutely nil/g in all Complementary foods analyzed; when packets were opened. The low counts of the examined foods indicated adequate thermal process, good quality of raw materials, and as a result of the good. Different processing conditions under which the production of foods was carried out.

Table 3 Comparative Microbiological Load of Complementary Foods

Baby food sample	Total viable count (CFU/g)	Yeast and mold count (CFU/g)	Total Coliform count (CFU/g)	Salmonella/g
L-1	Less than 10	Less than 10	Nil	Nil
L-2	Less than 10	Less than 10	Nil	Nil
F-1:	Nil	Nil	Nil	Nil
F-2:	Nil	Nil	Nil	Nil

3.3 Result of Rat Growth Study

From the below figure 1, at first 7 days weight increase was very low in case of all complementary foods, because of their food habit changes. Locally produced complementary food had highest growth of 205 and 209.9 gm in 28 days compared to the imported complementary food (F-1: 155.8gm and F-2: 178.7 gm).

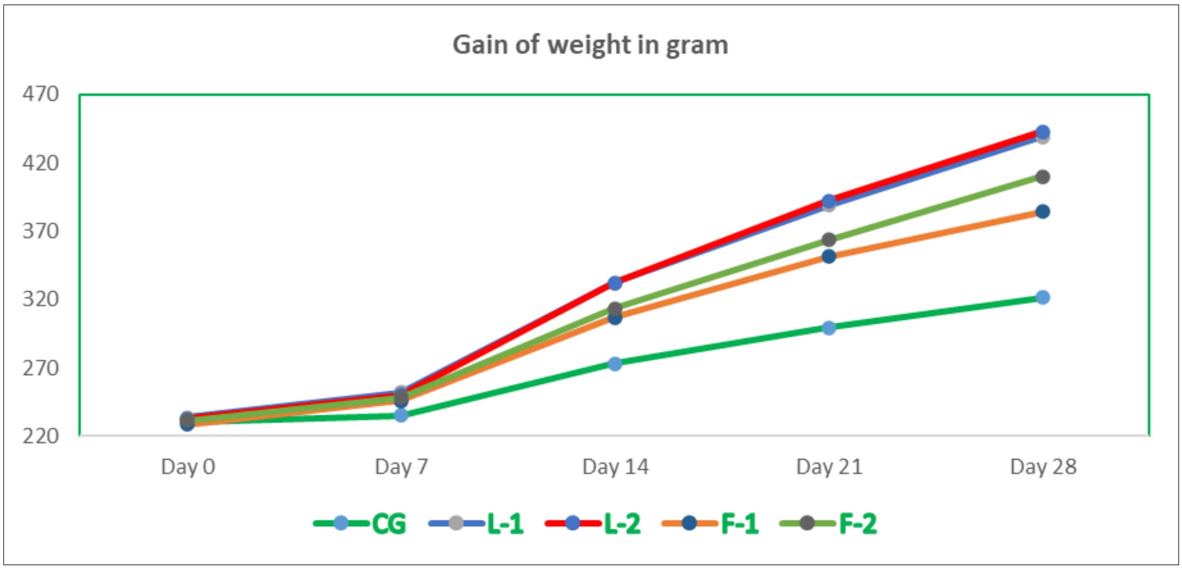

Figure 1 Total Gain of weight (GoW) in 7 days interval after feeding for 28 days

In a 21-days study of complementary food intake, the locally produced complementary foods had the highest value (596.8g and 609.9 g per rat for L-1 and L-2 respectively) and it differed from other foods where food intake ranged from 538.8 to 576.0 g per rat (Table 4). Group of rats feed on the locally prepared complementary food gained the highest body weight (L-1: 205.0 g and L-2: 209.9 g per rat) than the other groups of rats feed on the three imported commercial complementary foods where body weight gain ranged from 91.1 to 178.7 g per rat. Also, protein intake was high in the rats feed on of the prepared complementary food. PER and FER were the highest for those rats feed on the locally prepared complementary foods (2.21 and 0.34 for L-1 and 2.14 and 0.34 for L-2). The PER of commercial complementary foods were ranged from 1.87 and 1.97 which were higher than casein diet but up to the mark. The imported commercial complementary foods F-, and F-2 had 0.29, & 0.39, respectively; and were lower than the prepared complementary food. PER was high in the locally prepared complementary food than the other imported commercial complementary foods (Table 4). So the growth rate was also higher of those rats feed on the prepared complementary food than those rats feed on the commercial foods. Based on earlier studies, it has been recommended that the PER of the complementary foods should not be less than 2.1 and preferably 2.3 (PAG, 1971). Thus, the locally prepared complementary foods would meet the required standards for PER and adequately satisfy the recommended nutritional quality

Table 4 Food intake, protein intake and body weight gain of rats, for assessment of PER and FER

Complementary foods	Food intake (g)	Protein intake (g)	Weight gain up (g)	PER	FER
Casein diet	553.6	53.83	91.1	1.69	0.165
L-1	596.8	92.86	205	2.21	0.343
L-2	609.9	98.12	209.9	2.14	0.344
F-1	538.8	79.04	155.8	1.97	0.289
F-2	576.0	95.58	178.7	1.87	0.310

4 Conclusion

Highly nutritive value contained complementary foods are very important for the children 6-23 months to meet the increasing demands for body requirement as well as fight against high malnutrition. So locally produced complementary food prepared from rice, wheat, and milk which are available in the local market with low-price, and their safety aspects were compared to imported commercial Complementary foods. From the nutritional analysis of various constituents like moisture, protein, fat, ash, carbohydrate, crude fiber, and energy among four (two locally produced and two commercial) complementary foods; the locally produced complementary food has shown the most satisfactory result. The protein (an essential nutrient for rapid growth in infants) was higher in the locally produced complementary food than in imported commercial complementary foods. From the vitamins (vitamin A and B1) and minerals (iron and calcium) analysis of those complementary foods, locally produced complementary food has also given the most satisfactory result. From the microbial point of view, the locally produced complementary food showed satisfactory results concerning microbial food safety. In rat bioassay, the highest PER and FER were shown in the rats feed on the locally produced instant complementary foods. Thus, the highly nutritive low-cost locally produced complementary foods in our country are satisfactory to meet food safety requirements, ensure the rapid growth of infants, and finally, help to reduce the malnutrition situation and give extra support to nourishment for the children of Bangladesh.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of ethical approval

"This study was approved by the ethics committee of Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka, Bangladesh. Animals were not captured, restrained, sedated, or anesthetized, solely for this study."

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