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Formulation and Evaluation of Weaning Foods Prepared from Multigrain Flour and Powdered Milk

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Children after 6 months need to shift from breast milk to weaning food. The present study aims to develop low cost nutritious weaning foods to fulfil the increased nutritional requirements during this phase of growth.

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Study Design: The present study involved development of three different samples of low cost weaning foods prepared with multigrain flour (combination of rice flour, wheat flour and gram flour in the ratio of 2:1:0.5) mixed with milk powder (5%, 7.5% and 10% of the total flour mixture). Sensory, physicochemical and cost analyses were performed for the samples.
Place and Duration of Study: University Polytechnic (Boys), Aligarh Muslim University, Aligarh, Uttar Pradesh, between January 2016 and July 2016.
Methodology: Sensory evaluation was done on a 9 point hedonic scale after preparing the samples for consumption by adding either water or milk. Physicochemical properties of the developed samples such as moisture content, ash content and protein content were assessed during storage at room temperature (25-32˚C) for 2 months in airtight laminated aluminium film packing material.
Results: In sensory of samples prepared with water, sample 3 was found to be the most preferred sample while in case of samples prepared with milk, sample 1 was found to be the best in sensory quality. All the developed weaning food samples were found to be stable during 50 days of storage. Moisture content, Protein content and Ash content of the samples ranged from 4.84 to 10.38%, 13.23 and 16.29% and 1.22 to 1.54% respectively. Samples with more milk powder showed higher protein content and fat content.
Conclusion: The prepared weaning food samples had comparable physicochemical and sensory characteristics and lower cost than the commercially available weaning foods. They will be helpful in fulfilling the nutritional requirement of the vulnerable sections of society including middle-income groups (MIG) and low-income groups (LIG) consumers and overcoming malnutrition.

Keywords: Weaning food; sensory quality; physicochemical characteristics; baby food.

1. INTRODUCTION

As per WHO 2021 reports, an estimated 2.7 million children die each year (45% of all child fatalities) as a result of under-nutrition. Moreover, according to WCD Ministry India has over 3.3 million underweight children, with Maharashtra, Bihar, and Gujarat at the top of the list for severely malnourished children (The Hindu, 2021, World Health Organization, 2021).

The high frequency of malnutrition in children below the age of five around the world is mostly a result of the period when malnutrition begins in many infants, especially from 5 to 6 months of age because they find it difficult to accept other foods apart from milk. According to the findings of UNICEF, low-income nations have 2 out of 5 children who are stunted. In 2017, nearly 51 million children below the age of 5 were found to be wasted and 16 million were found to be severely wasted (UNICEF, 2018).

The most important factor in improving child survival and fostering healthy growth and development is infant and young child nutrition. The first two years of a child's life are particularly significant since good nutrition during this period promotes better overall development, lowers morbidity and mortality, and lowers the chance of chronic disease.

The process of gradually introducing other meals in addition to breast milk is known as complementary feeding. So-called complementary foods are those that are introduced. By the age of six months, these can be introduced (NCERT, 2009).

There are foods made from cereal and/or legume, soybean, millets, edible oil seeds, nuts and, processed to low moisture content and fragmented so as to permit dilution with water, milk, or other suitable medium. These are referred to as processed cereal-based complementary food, also known as weaning food or supplementary food. These foods are designed to supplement infants' diets starting at six months of age and continuing through age two (Commercial Law Publishers India Pvt. Ltd., 2013).

In fact, after six months, a baby's nutritional and energy requirements start to outpace those of breast milk, necessitating the consumption of supplemental foods. In order to achieve optimal growth in the first year, a weaning diet that is nutritionally appropriate is necessary. At 6 months age, a baby is also developmentally prepared to eat other foods. The growth of an infant may stall if complementary foods are not offered at the age of 6 months or if they are introduced improperly. The first year of development has an impact on the person's health as a child as well in the long-term as an adult. The liquid foods with fine solids given at infant stage can be replaced by less finely

comminuted foods as the infant's digestive system matures, before making a final transition to table foods (Sajilata et al., 2002, World Health Organization, 2021).

All infants should begin ingesting solids in addition to breast milk at the appropriate time, which is about six months. Complementary feeding, which is often known as the switch from exclusively breastfeeding to solid foods, typically occurs between the ages of 6 and 18 to 24 months and is a particularly vulnerable time. While continuing nursing, weaning food given to the child should be sufficient in terms of quantity, regularity, consistency, and use of a range of foods to meet the developing child's nutritional demands. According to WHO recommendations, infants should be provided complementary foods to supplement the breast milk at 6 months of age. These complementary foods should be given initially 2-3 times per day at 6 to 8 months age, increasing to 3-4 times per day at 9 to 11 months age, and then 1-2 times per day as desired (World Health Organization. (n.d.), UNICEF, 2018).

They should be made and administered in a safe manner, which entails taking precautions to reduce the possibility of pathogen contamination. In order to prevent infection to the baby throughout the supplemental feeding process, appropriate hygiene conditions must be maintained when using feeding bottles and utensils. Moreover, these foods ought to be of appropriate texture according to the age of the child and fed by responsive feeding according to the principles of psycho-social care (World Health Organization. (n.d.), NCERT, 2009).

For these weaning foods, at least 75% of it must be made up of milled cereal and legumes. Protein content must be at least 15% of the dry weight of the product when it is intended to be mixed with water before consumption, and the PER (Protein Efficiency Ratio) must be at least 70% of casein. The products' salt concentration cannot be more than 100 mg/100 g of the product. Hydrogenated fats containing trans-fatty acids must not be added to the products. Protein concentrates, essential amino acids (only in natural L form), and milk, eggs, iodized salt, edible fats and oils, fruits and vegetables, carbohydrates like sucrose, maltose, lactose, dextrose, dextrin, malt, honey, potatoes, corn syrup are other ingredients that may be present.

It must be homogeneous in appearance, having any of the forms including powder, tiny granules, or flakes, and it must preferably be free of lumps. All ingredients, even those that are optional, must be good quality, acceptable, and clean. It must be free of added flavor, color, and preservatives (Commercial Law Publishers India Pvt. Ltd., 2013).

The Protein Advisory Group recommends that weaning meals have a minimum protein level of 20% (on a dry weight basis), a minimum fat content of 10%, a minimum moisture content of 5% to 10%, and a maximum total ash content of 5% (Sajilata et al., 2002).

The main requirements for a high-quality weaning food are a high proportion of balanced proteins, a high caloric value per unit of food volume, a soft texture with little fiber, a sufficient amount of vitamins and minerals, and the absence of antinutritional elements (Wu and Xu, 2019).

The qualities listed below are necessary in a weaning food.

- It should be rich in energy and it should contain all nutrients in sufficient amounts.
- It should be processed in such a way that it needs minimum preparation before consumption.
- It should have good digestibility when given to children with minimum presence of antinutritional factors and indigestible fiber.
- On addition of water it should easily convert to semi-solid form which can be easily ingested by children.
- It should have less dietary bulk.
- It is preferable to avoid artificial flavouring and coloring agents to weaning foods.
- The composition of the weaning food should conform to the standards recommended by competent authorities (Sajilata et al., 2002).

Following are the guiding principles for proper complementary feeding:

- sustain regular nursing whenever demanded until the child turns 2 years old or more;
- practice responsive feeding (feed new-borns directly and help older children); establish eye contact with the child, talk to him or her and feed gently and attentively;
- practice good cleanliness and proper food handling;

- begin feeding the infant in modest portions at the age of 6 months and progressively increase as the child becomes older;
- progressively improve the variety and consistency of the food offered to the child;
- increase the frequency of feedings: 2 to 3 meals per day for infants in the age group of 6 to 8 months, and 3 to 4 meals per day for infants aged 9 to 23 months, plus 1-2 extra snacks as needed;
- where necessary, utilise fortified supplementary foods or vitamin-mineral supplements;
- when the child is ill, increase fluid intake, including more breastfeeding, and offer soft, favourite foods (World Health Organization, 2021).

The aim was to develop a weaning food with nutrient content and energy value comparable to that of commercially available weaning foods.

2. MATERIALS AND METHODS

2.1 Preparation of Sample

This study focuses on development of weaning food from multigrain flour mixture and milk powder in various combinations using methods proposed by Sajilata et.al, 2002, with slight modifications (Sajilata et al., 2002). Proximate and sensory analysis were analysed and stability of the developed samples was also checked during 50 days storage period.

Physical features, chemical properties, nutrient content, and sensory evaluation were all considered to be significant elements in the study of weaning food formulation. Table 1 lists the nutrients found in the raw ingredients used to make the weaning food samples.

Table 2 shows the amounts of ingredients taken for preparing the weaning food samples. Rice flour, wheat flour, gram flour and milk powder were procured from the local market. After sieving rice flour, wheat flour and gram flour they were mixed in the ratio 2:1:0.5 Milk powder was added in different proportions i.e. 5%, 7.5% and 10% of the flour mixture in the three different weaning food samples. The proportion of different flours and milk powder was decided based on optimizing their nutrient content and cost of the final product. Also, the ingredients in these ratio provided shelf-stable products with good shelf lives.

The unit operations used in the production of weaning food samples included mixing, diluting/ blending (addition of water to form batter like substance), autoclave cooking at 121˚C at 15 psi for 20 minutes, oven drying, grinding in grinder, sieving in 60 mm mesh size and packaging in laminated film. The details of treatment combination are provided in the flow chart given in Fig. 1.

2.2 Physicochemical Analysis of Weaning Food Samples

Moisture content: A known amount of sample was weighed into a dish and this initial weight of sample with dish was recorded as W_0. Then it was dried in a hot air oven for 3 hours or until a constant weight was reached. It was cooled in the desiccator and the final weight of the sample with the dish after drying was recorded as W_1. Finally, the tare weight of the empty dish was noted as W_2.

$$Moisture\ content = [(W_0 - W_1)/(W_1 - W_2)] \times 100$$

Table 1. Chemical Composition of Ingredient per 100 g (on Raw Basis) (Gopalan et al., 2012)

Ingredient	Moisture (g)	Carbohydrate (g)	Protein (g)	Fat (g)	Minerals (mg)	Energy (kcal)
Rice flour	13.7	78.2	6	0.5	0.6	345
Wheat flour	12.2	72.57	12.1	1.7	2.1	341
Gram flour	9.9	59.8	20.8	5.6	2.7	331
Skim Milk powder	4.1	38	38.0	0.1	6.8	357

Table 2. Raw materials used for processing

Name	Sample 1	Sample 2	Sample 3
Rice flour (g)	200	200	200
Wheat flour (g)	100	100	100
Gram flour (g)	50	50	50
Milk powder (g)	17.5	26.25	35
Water (ml)	450	460	470

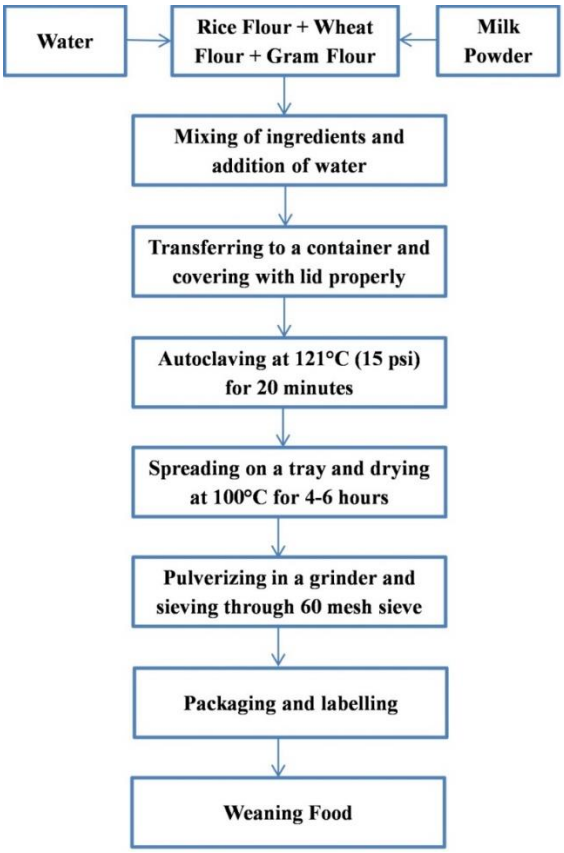

Fig. 1. Process of preparation of weaning food samples

Protein content: Around 2 g sample was weighed and added to a Kjeldahl flask with catalyst mixture (6 to 8 g) and concentrated sulfuric acid. Then it was allowed to digest by heating at 60 to 80°C. This was continued until the color of the digest is pale blue. Then the digest was transferred to a volumetric flask and its volume was made up to 100ml. Again it was transferred to a distillation flask. 50 ml boric acid and few drops of mixed indicator were added to it. Kjeldahl distillation set-up was assembled properly (by placing the receiving flask with boric acid below the condenser and ensuring that the delivery tube dips into the boric acid solution). The tap of the funnel was opened and 10 ml 50% NaOH was allowed to drop into the distillation flask. Heating was done till all the contents of distillation flask are transferred to the receiving flask. Finally, the distillate was titrated against 0.05N HCl until a faint pink end-point. A blank digestion and distillation was carried out in the same way. Protein content was calculated using the following expression:

$$Nitrogen\ \% = \frac{(A-B) \times Normality\ of\ HCl \times 14 \times 100}{W_1\ or\ V_1 \times 100}$$

$$Protein = Nitrogen\% \times 6.25$$

Ash content: Tare weight of a silica crucible is noted as W_1. A known amount of sample was weighed into the silica crucible and the weight was recorded again as W_2. Then the sample was kept for ashing in a muffle furnace at 550°C for 4 to 6 hours or overnight if needed. Then the crucible was kept in a desiccator to cool and its weight was recorded as W_3.

$$Ash\ content\ \% = \frac{(W_2 - W_1) \times 100}{(W_3 - W_1)}$$

Proximate parameters namely, moisture, ash and protein were analyzed for the formulated weaning food samples and all observations were made in triplicate (A.O.A.C., 2005, Achidi et al., 2016, Fathelrahman et al., 2015, Imtiaz et al. ,2011, Mishra et al., 2014, Nkeudem et al., 2018, Rim et al., 2021, Satter et al., 2013).

2.3 Sensory Analysis

The developed weaning food samples were prepared for consumption by mixing the product with warm water in the ratio of 1: 3.5 and sugar was added according to the taste and stirred slowly and served hot. The developed weaning food samples were also prepared for

consumption by using milk for getting better results as the addition of milk significantly increases taste, flavor and nutritive value of the weaning food.

Organoleptic assessment was carried out on the weaning food samples by semi-trained panelists and trained panelist comprising the students and research scholars of AMU. The panelists were provided with the same quantities of the samples simultaneously in white disposable bowls and water was also provided to clean and rinse their mouths between the evaluations.

2.4 Statistical Analysis

Statistical analyses were done for these parameters by SPSS.20 and Microsoft Excel 2010. Duncan's multiple range test was used and the significance of parameters was tested at 5% levels.

3. RESULTS AND DISCUSSION

3.1 Effect of Storage on Physicochemical Characteristics

The quality parameters of weaning food samples were studied for approximately 2 months at ambient conditions. All the samples were packed properly in the laminated films. Fig. 2 shows that on storage average moisture, protein, ash contents in sample 1, sample 2 & sample 3 remained well within the levels recommended by FAO/WHO (Nkeudem et al., 2018) for at least 50 days and the samples were perfectly safe for consumption for this period.

Moisture contents of the samples ranged from 4.84 to 10.38%. Low moisture contents are desirable for longer shelf lives and for convenient packaging and transportation. Moisture also affects the sensory qualities and yield of the product (Rim et al., 2021). Moisture content causes lumping and reduces its keeping quality. When moisture is removed by drying the weight of the final product decreases, thus, decreasing the yield. Sample 1 showed highest moisture content while sample 2 and 3 showed lower values. This might be due to the presence of milk powder in sample 2 and sample 3. This indicates that milk solids have a binding effect on the moisture present in the sample. There was a slight increase in moisture contents of all the samples with storage because of the permeation of moisture through the package.

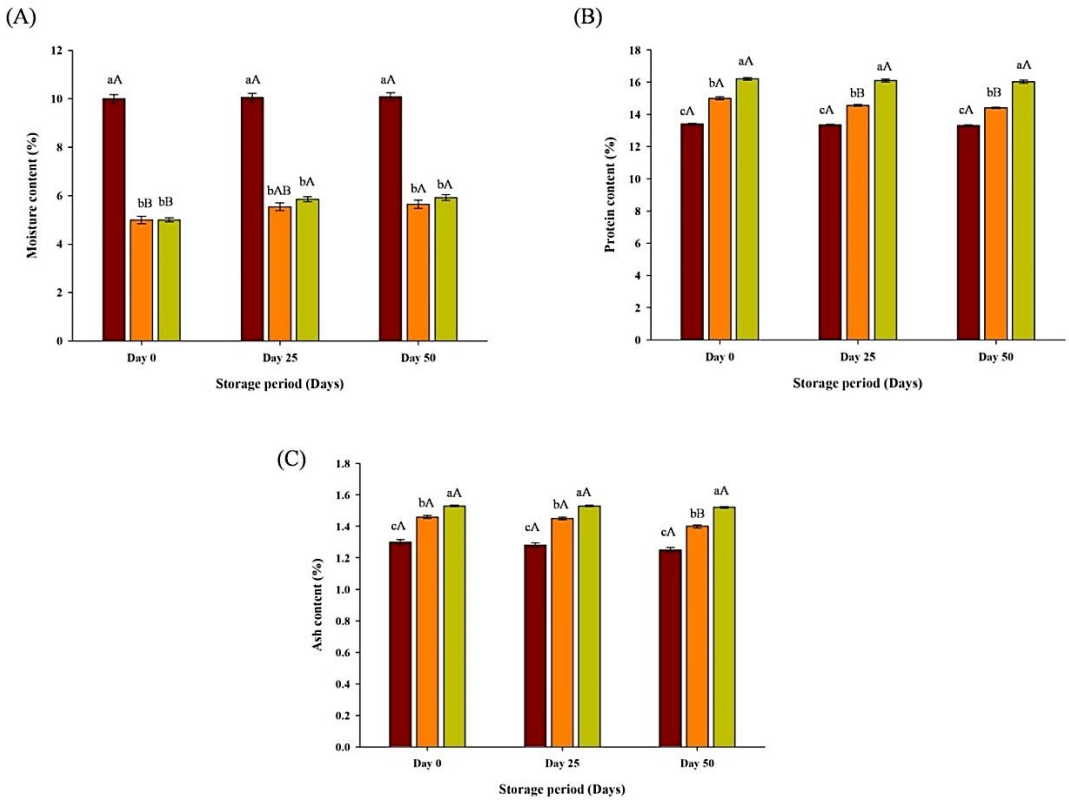

Fig. 2. Effect of storage on (A) Moisture content, (B) Protein content and (C) Ash content on weaning food Sample 1 ; Sample 2 and Sample 3

Proteins are the most important constituent of weaning food because of their role in growth of babies. Protein contents of the samples were between 13.23 and 16.29%. Samples containing milk powder were found to have protein contents higher than the values recommended by FAO. Protein content of the samples increased on increasing the concentration of milk powder. Sample 3 had the highest protein content while Sample 1 had lowest protein content. The protein contents of the samples decreased slightly with time which is also in agreement with the results obtained by other researchers (Mishra et al., 2014, Naeem et al., 2022, Rim et al., 2021). Because of the increase in moisture content, the fraction of protein present in the samples decreased.

Ash content indicates the amount of minerals and foreign matter in a product. Ash contents of developed samples of weaning foods fell in the range of 1.22 to 1.54% with samples containing milk powder showing higher ash contents. Addition of milk powder increased the total minerals in the samples, thus increasing their ash contents. Ash contents of the samples decreased slightly with storage remaining within recommended levels after 50 days of storage. Similar results were shown in the studies conducted by other researchers (Mishra et al., 2014, Rim et al., 2021). With increase in the fraction of moisture with time there was bound to be a corresponding decrease in the fraction of ash present in the samples. Many more properties of the formulated weaning foods remain to be analyzed such as bulk density, swelling power, wettability, water absorption capacity, dispersibility, in-vitro starch digestibility, pasting properties, etc. (Onuoha et al., 2014). These days mainly the researchers are focused on determining the safety of the weaning foods (Pasecnaja et al., 2024, TatahMentan et al., 2024, Sarmiento-Santos et al., 2023, Tang et al., 2023, Mikolajczyk et al., 2023).

3.1.1 Statistical analysis of physicochemical parameters

All the statistical analyses were made at significance levels of 5% (*P* =.05). Fig. 2 also shows the results of the statistical analysis of the physicochemical parameter of the samples. Significant difference was observed between the moisture contents of samples 1, 2 and 3 ($p = 6.06 \times 10^{-6}$). It was observed that moisture contents of sample 1 and 2 as well as that of sample 1 and 3 were significantly different to each other ($p = 2.12 \times 10^{-5}$ and $p = 0.000115$ *respectively*). However, moisture contents of sample 2 and 3 were not significantly different to each other at a significance level of 5% ($p = 0.617321$). The moisture content of sample 1 did not change significantly with time ($p = 0.947474$) while the moisture contents of sample 2 and sample 3 changed significantly with time at significance levels of 5% ($p = 0.05$ and $p = 0.001107$ *respectively*).

Protein and ash contents of the samples 1, 2 and 3 were also found to be significantly different to each other ($p = 6.27 \times 10^{-6}$ and $p = 3.98 \times 10^{-5}$ *respectively*). Except for sample 2, the protein and ash contents of samples did not change significantly with time at significant levels of 5%. The p-values for change in protein content of samples with time were 0.302183, 0.001169 and 0.425741 respectively. The p-values for change in ash content of samples with time were 0.144703, 0.011391 and 0.421875 respectively.

3.2 Sensory Characteristics

The samples were evaluated for color, flavor, taste, aroma, consistency, mouth-coating, granularity and palatability on a 9-point Hedonic scale where 1 and 9 represented 'dislike extremely' and 'like extremely' respectively (Jahan et al., 2021).

The developed weaning food was also sensory evaluated separately with milk preparation by the panelists for the above characteristics.

The results obtained from the sensory evaluation of the three weaning food samples are shown in Fig. 3 and Fig. 4. The average sensory scores of taste, aroma, granularity and palatability for weaning food samples show that sample 3 had the highest score followed by sample 2 and sample 1 when they were prepared with warm water. Figures indicate that by increasing the amount of milk powder, sensory attributes of the weaning food gradually increased. This was because of the fact that milk powder provided richness and creaminess to the final product. The product was also prepared with milk and then the average scores of sample 1 were found to be high, as compared to sample 2 and 3. It may be due to the fact that when the concentration of milk powder was increased in the samples and milk was also used to prepare the sample before consumption, then the excess use of milk affected the scores of the samples adversely. In samples containing higher amount of milk

powder, we do not need to add milk for preparation of samples for consumption. Sample 1 was found to contain optimum amount of milk in powdered form and liquid form.

When comparing the samples prepared in water and in milk, all the samples prepared in milk had higher scores for all attributes except color. This is depicted in Fig. 4.

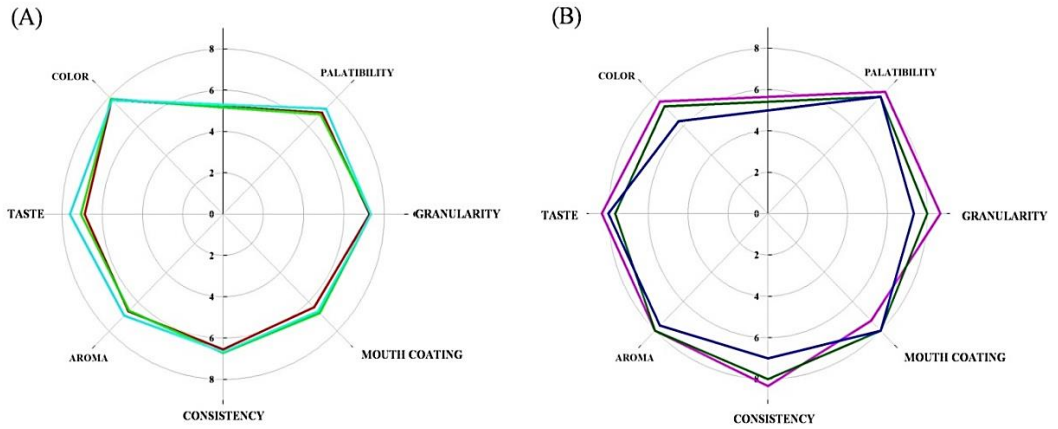

Fig. 3. Comparison of sensory properties of (A) Sample 1; Sample 2; and Sample 3 prepared in water and (B) Sample 1; Sample 2 and Sample 3 prepared in milk

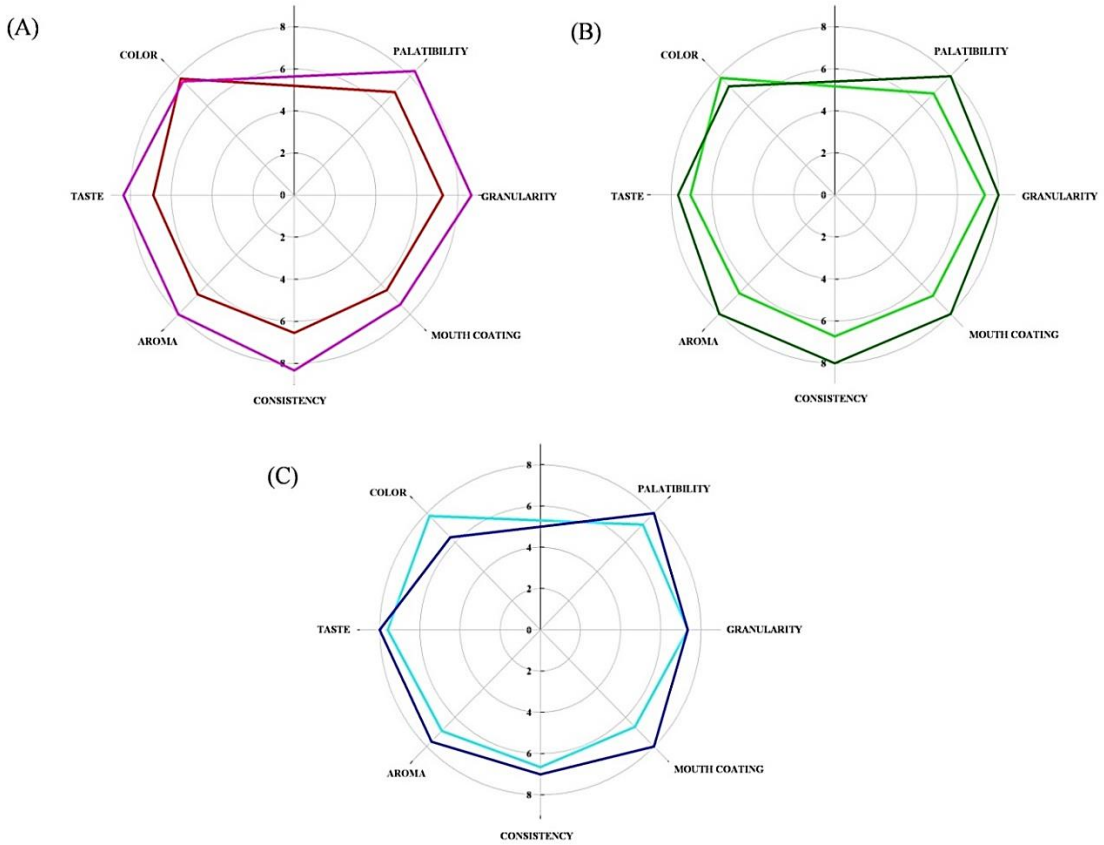

Fig. 4. Sensory properties of (A) Sample 1 with water; with milk; (B) Sample 2 with water; with milk; (C) Sample 3 with water; with milk.

Table 3. Estimation of cost of developed weaning food

Ingredient	Price in Rs./kg ($/kg)	Sample 1		Sample 2		Sample 3	
		Weight in g	Price in Rs. ($)	Weight in g	Price in Rs. ($)	Weight in g	Price in Rs. ($)
Rice flour	50 (0.61)	200	10 (0.12)	200	10 (0.12)	200	10 (0.12)
Wheat flour	35 (0.42)	100	5 (0.061)	100	5 (0.061)	100	5 (0.061)
Gram flour	120 (1.45)	50	6 (0.073)	50	6 (0.073)	50	6 (0.073)
Milk powder	570 (6.91)	17.5	10 (0.12)	26.25	15 (0.18)	35	20 (0.24)
Total cost		**367.5**	**31(0.38)**	**376.25**	**36 (0.44)**	**385**	**41(0.50)**
Total cost Rs./kg of Weaning food		**1000**	**135(1.64)**	**1000**	**146 (1.77)**	**1000**	**157(1.90)**

Table 4. Comparative test performance score of infant (baby) foods (World Health Organization. (n.d.))

Chemical composition	Milk-Cereal Based Complementary Foods Cerelac	Processed Cereal Based Complementary Foods Nestum	Developed weaning food Sample 1	Developed weaning food Sample 2	Developed weaning food Sample 3
Moisture (%)	1.75	1.29	10	5.4	5.8
Total carbohydrates (%)	5.6	15	-	-	-
Total Protein (%)	9.57	4.6	13.4	15	16.2
Total Ash (%)	1.67	1.91	1.3	1.46	1.53
Fat (%)	5.96	-	-	-	-
Price/kg (Rs.)	600	540	135	146	157

3.2.1 Statistical analysis of sensory characteristics

All the statistical analyses were made at significance levels of 5% (*P* =.05). In statistical analysis of sensory parameters it was found that there was no significant difference in the color, taste, aroma, consistency, mouth-coating, granularity and palatability of samples 1, 2 and 3 for both water and milk preparations. However, difference was observed between water and milk preparation of the samples. Taste, aroma, consistency, mouth-coating and palatability of water and milk preparations were significantly different from each other but their color and granularity did not show significant difference at a significance level of 5%.

3.3 Cost Analysis of Prepared Weaning Foods

The cost of developed weaning food samples were determined according to the price of all the ingredients used in preparing them (shown in Table 3), gas, electricity, water and others. The cost of the prepared food was compared with the cost of the two commercial baby foods. The determination of cost of preparation of Sample 1 is shown below as an example:

Price of 368 g of weaning food product = Rs. 31 ($ 0.38)

Price of 1g of weaning product = Rs. 31⁄368 ($ 0.38/368)

Price of 1000 g of weaning food product is Rs ((31×1000)⁄368 = Rs. 84.239 ($ 1.02)

Assuming the other charges such as gas, electricity, packaging material etc. as Rs. 50 per kg of weaning food produced ($ 0.61 per kg of weaning food produced). Thus total cost of weaning food, Sample 1 was estimated to be approximately around Rs. 135 per kg ($ 1.64 per kg). The costs of other samples were analyzed in the same way and they have been shown in Table 4.

The prepared samples were compared with the other commercial weaning foods (Cerelac & Nestum). As shown in Table 4, it was found that the prepared weaning food samples were nutrient rich, high in calories and cost effective. The rising costs of commercial weaning foods have necessitated the development of cost effective alternative options.

4. CONCLUSION

In the present study it was tried to develop such a weaning food which should be nutritive as well as economical. When the cost was estimated, it was found that the developed weaning food samples were more economical as compared to the other commercial weaning foods. The formulated weaning food can be produced at small and large-scale industrial levels and used locally to eliminate malnutrition in children particularly in developing and underdeveloped countries. There was no significant change in the composition of weaning food samples on storage indicating the increased shelf life of the product because of the use of proper processing technology and because of appropriate packaging that was done with the laminated aluminium film. Depending upon the requirements, operating capacity and corresponding degree of mechanization, the scale of production can be modified according to the local needs and conditions. To produce weaning food at commercial level, further addition with appropriate quality and quantity of micronutrients (premix) should be done.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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