Original Article

Formulation and quality evaluation of complementary mixes from foxtail millet, amaranth, spinach, banana, and papaya

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Abstract

Background: Proper nutrition during infancy has a significant effect on a child's future health, immunity and success. Weaning is a transition time for the child during which the consistency and source of its diet shifts.

Objective: This study was carried out to formulate foxtail millet-based composite mixes and to assess the feeding practices among the infants under the age group of 0–12 months.

Materials and Methods: Foxtail millet and other major ingredients such as Bengal gram dhal, green gram dhal, groundnut, and amaranthus, as well as spinach, were procured from local market in Salem, Tamil Nadu. Fruits such as banana and papaya were also procured from the local market in Salem, Tamil Nadu. Four kinds of complementary feeding mixes were formulated at different combinations. The formulated four composite mixes have undergone an assessment of nutritive value, microbial examination, sensory analysis, and shelf-life studies.

Results: The findings showed that the formulated composite mixes compared to Prescribed Dietary Allowances (Recommended Dietary Allowances) were expected to show a significant difference in nutrients such as energy, protein, thiamine, and riboflavin at 0.05% level. Regarding sensory analysis, there was a significant difference between standard and overall acceptability of the formulated mixes at 0.05% level. The shelf-life at the end of 30 days showed no noticeable difference in appearance, consistency, odor, taste and overall acceptability.

Conclusion: From this study, it was concluded that minor millet and multi-nutrient grains, green leafy vegetables, and basic low-cost fruits were good sources of energy, protein, iron, and micronutrients to the targeted infants as a supplementing weaning food. It can be recommended based on the infant's length and weight with the supervision. To improve the infant and young child feeding, access to adequate complementary food is necessary. complementary food is necessary.

Keywords: Complementary foods, microbial examination, proximate composition, sensory properties, supplementation

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INTRODUCTION

Children are the most precious human resource, and this future generation deserves the best possible ingoing. Each year, millions of children in developing countries die from diarrheal disease principally as a major cause of childhood mortality and morbidity. Appropriate nutritional practices play a pivotal role in determining the optimal health and development of children. However, more

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than 90% as the world's children live in low-income countries where infectious disease is the predominant cause of increased rates of childhood mortality and morbidity. The World Health Organization (WHO) estimates that hardly one billion episodes of diarrhea occur annually among children less than 5 years of age in the developing world, resulting in more than three million deaths.[1]

The weaning period is the most critical phase of the infant's life. During this period, mother's milk is not generally adequate to cover the nutritional requirements and support body growth. With increasing the number of working mothers in a developing country, the market for baby foods has been increased tremendously.[2] Breast milk alone cannot support the nutrition and other needs of the growing infant. There comes a time when complementary weaning foods must be introduced into the diet to fill the gap between what is provided by milk and what the infant requires to cover his/her nutritional requirements. In case of baby food products, mothers often try the product first and then decide whether to give it to their children or not.[3]

Millets, small-seeded grasses, are hardly cropping grown on dry zones as rain-fed crops, under marginal conditions of soil fertility and moisture. These are one of the oldest foods known to humans and possibly the first cereal grain to be used for domestic purposes.[4] Millet is a small-seeded annual cereal grain. These are very hardly cropping and can be grown successfully in infertility lands. These crops are less prone to diseases and pests. These are stable cereals such as wheat and rice; some of them are even better with regard to average protein, fat, and mineral contents.[4,5]

Sharma *et al.* (2008) stated that supplementary foods for infants, senior citizens, or vulnerable populations as complementary foods for convalescent and those with poor digestion. Supplementary foods based on commonly consumed, inexpensive locally available ingredients involve no additional burden and possess the protein quality comparable to that of commercial formulae. Being cost-effective and nitrides, these formulations could form a sustainable strategy for combating the widespread malnutrition, especially that of protein and energy.

Poor feeding practices are characterized by poor timing of complementary foods introduction (too early or too late); infrequent feeding; and poor feeding methods, hygiene, and child-care practices. Added to these is the poor dietary quality of the foods served, characterized as too little variety; inappropriate consistency (food is too thin or too thick); too few essential vitamins and minerals, especially Vitamin A, iron, zinc, and calcium; too few essential fatty acids; and too few calories among nonbreastfed infants.[6] The poor quality and lack of diversity in foods adversely affect the children's growth and nutritional status.[7]

Composite mixes often serve as supplementary foods for infants, senior citizens, or vulnerable populations as complementary foods for convalescent and those with poor digestion. Supplementary foods based on commonly consumed, inexpensive locally available ingredients involve no additional burden and possess the protein quality comparable to that of commercial formulae. Being cost-effective and nutria-dense, these formulations could form a sustainable strategy for combating the widespread malnutrition, especially that of protein and energy (Gahlwat and Sehgal, 1994). Based on the above facts, the study was aimed to formulate foxtail millet-based composite mixes and to assess its quality evaluation of complementary mixes.

METHODOLOGY

Procurement of raw materials

Foxtail millet was procured from the local market, cleaned, dried, and stored in a freezer for further use. Major ingredients, viz., Bengal gram dhal, green gram dhal, groundnut, amaranthus, and spinach, were procured from the local market in Tharamangalam. Banana and papaya were procured from Salem Pazhamudhir Cholai in Salem district, Tamil Nadu.

Preparation of complementary mixes powders

The grains foxtail millet, Bengal gram dhal, and green gram dhal were roasted till the development of pleasant aroma mixed in required proportion and powdered. Groundnuts were roasted and de-skinned before blending with other ingredients. Green leafy vegetables such as amaranth and spinach were cleaned, blanched by dipping in boiling water for 2 min, drained and dried in a microwave oven at 100% power for 5.30 min, and then powdered. Bananas were cut into small thick pieces without peels and dip in citric acid for few seconds, drained and dried in a hot air oven at 120°C for 1 h, and then powdered. While another lot of papaya was sorted, washed, cut, and dried, without peels in a hot air oven at 120°C for 1 h and then powdered.

Formulation of complementary mixes

Different kinds of foxtail millet-based complementary mixes were prepared by combining 30% foxtail millet powder, 6% of Bengal gram dhal powder, green gram dhal powder, 4% of roasted groundnut powder, 30% of amaranth leaves powder, spinach leaves powder, banana powder, and papaya powder with a constant of 30% iced sugar [Table 1]. The powders were then made into porridges. The powders were evaluated for their nutrient composition and shelf-life evaluation, while the sensory properties of porridges were also evaluated.

Table 1: Foxtail millet-based complementary mixes

Ingredients	Complementary mixes			
	FMM + A	FMM + S	FMM + B	FMM + P
Foxtail millet (g)	30	30	30	30
Bengal gram dhal powder (g)	3	3	3	3
Green gram dhal powder (g)	3	3	3	3
Roasted groundnut powder (g)	4	4	4	4
Amaranth leaves powder (g)	30	-	-	-
Spinach leaves powder (g)	-	30	-	-
Banana powder (g)	-	-	30	-
Papaya powder (g)	-	-	-	30
Iced sugar (g)	30	30	30	30

FMM + A: Foxtail millet mix with amaranth, FMM + B: Foxtail millet mix with banana, FMM + S: Foxtail millet mix with spinach, FMM + P: Foxtail millet mix with papaya

Proximate analysis

The energy, protein, beta-carotene, thiamin, riboflavin, ascorbic acid, and folic acid contents of the complimentary food samples were determined in triplicate, according to the standard analytical methods.[8]

Microbiological examination

The microbial load (bacteria, fungi, and yeast) of the stored samples was enumerated at regular intervals by the serial dilution techniques using nutrient agar medium for bacteria, respectively. At the initial and final day of the storage period, the microbial population was analyzed in both the packages by serial dilution agar plate technique given by Dubey and Maheshwari (2004) and Ismail (2013).[9,10]

Sensory analysis

Sensory evaluation of the different formulae was carried out by two groups of panelists. The first group included 40 babies (15 girls and 25 boys) in the age of 6–12 months.[11] The test was carried out as recommended by Kroll (1990), who depended on the face reaction of the baby. The nine-point hedonic scale was used which included super good (9), really good (8), good (7), just a little good (6), may be good or bad (5), just a little bad (4), bad (3), really bad (2), and super bad (1). Overall acceptability was calculated from the obtained scores of the evaluated attributes. All the formulations were compared with the standard porridge prepared using NIN values.

Shelf-life evaluation

The formulated powder composite mixes were packed in airtight pouches using a packaging machine for 1 month at ambient temperatures (20.8°C–31.176°C) and relative humidity (RH, 36.83%–80.91%). The samples were drawn fortnightly for the analysis of moisture and sensory evaluation. The samples were assessed initially and after 30 days for moisture content using moisture balance equipment and sensory evaluation using nine-point hedonic scale.

Statistical analysis

The data were compiled and analyzed using statistical methods. The results are represented as descriptive statistics mean, the standard error means, standard deviation, one-way ANOVA, followed by Duncan's multiple comparison tests. A $P < 0.05$ was considered statistically significant. Differences in baseline characteristics were analyzed using *t*-test. Paired comparison tests are computed using statistical software SPPS Statistics (Version 19, 2010) produced by SPSS Inc, IBM, New York.

RESULTS AND DISCUSSION

Proximate analysis of foxtail millet-based complementary mixes

Data relating to the proximate analysis of foxtail millet-based complementary mixes are presented in Table 2. A perusal of data discloses of the energy content ranged from 43.02 to 47.64 kcal. The highest energy content was found in FMM + B (47.64 kcal) followed by FMM + A (44.69 kcal) and the lowest energy content was observed in FMM + S (43.02 kcal). Protein is one of the main necessities in weaning foods. Here, the major sources of protein were barnyard millet solids. From Table 2, it was observed that the highest protein content of 1.77 g was found in FMM + A. The highest thiamine content was found in FMM + B (9.98 μg) due to the fact that banana and foxtail millet combinations enhance the thiamine levels in complementary food mixes. Ranganne (1977) specified in his study that carotenoids are plant pigments that are present in human diets as microcomponents of fruits and vegetables. Ascorbic acid level-rich mix was found in FMM + A (5.14 mg) followed by FMM + P (3.04 mg). They are a group of aliphatic alicyclic, fat-soluble, yellow-to-red compounds responsible for the red, orange, and yellow colors of edible fruits and vegetables and are widely distributed in nature.[12]

Mean sensory and shelf-life evaluation of foxtail millet-based complementary mixes

The sensory analysis of complementary mixes is presented in Table 3. FMM+A has the maximum sensory score of 6.80, 7.50, 7.00, 6.60, and 7.80 for appearance, consistency, taste, and flavour, among the four formulations. The highest overall score was found in FMM + B with a score of 8.00. The results provide a basis for the development of acceptable complementary food that can provide the required protein and energy levels that are essential basic nutrients to enable the accomplishment of a day's work.[13,14] A similar trend was observed by Balasubramanian *et al.* (2014)[14] in the weaning food prepared using different levels of malted pearl millet and barley. The flavor of the complimentary food increased for those formulae prepared using a higher concentration of malted millet powder. The increase in flavor scores in the experimental samples is attributed to the fact that, during germination, there will be an increase in the free sugars increasing the sweetness perception due to increased α-amylase activity and there would be the development of characteristic flavor which plays a role in the flavor profile of malted complimentary food.[15] Duncan's multiple range tests revealed that there was a significant difference between standard and overall acceptability of the complementary feeding mixes at a 0.01% level.

The storage analysis of foxtail millet mixes are showed in Table 3. Among the four formulations, between 0 day and 30 days of storage, FMM+A showed no significant improvement. On 0day, FMM+S showed no significant improvement, while the appearance, consistency, taste, flavour and overall acceptability showed some variations on 30th day. At 0 and 30 days of storage, FMM+B showed no noticeable difference. The FMM+P formulation showed a major difference in flavour, taste and overall acceptability of the mix on the 30th day of storage. More *et al.* (2015)[16] evaluated the shelf-life of soy-based weaning foods using different packaging materials and proved laminated aluminum foil as the best packaging material for 90 days' storage at 30°C with 65% RH. Ranjana *et al.* (2000)[17] reported that blended supplementary food stored in polyethylene bags and laminated pouches displayed satisfactory results.

Microbial examination of foxtail millet-based complementary mixes

Data on the microbiological characteristics of the sample are presented in Table 4. The microbiological analysis was carried out to ascertain the safety of the complementary mixes for consumption. While microorganism was detected in all the samples, the total viable bacterial count increased from 11×10^{-4} to 35×10^{-4} in all the formulated samples. For FMM + A, FMM + S, FMM + B and FMM + P, the MPN index showed 2/ml. The low microbial load

Table 2: Proximate analysis of foxtail millet-based complementary mixes

Nutrients	FMM + A	FMM + S	FMM + B	FMM + P
Energy (kcal)	44.69±39.21^{ab}	43.02±40.80^{a}	47.64±37.34^{b}	43.44±40.36^{ab}
Protein (g)	1.773±1.080^{ac}	1.64±1.178^{ab}	1.60±1.22^{c}	1.57±1.26^{a}
Beta-carotene (μg)	278.90±674.64^{b}	281.90±681.99^{bc}	266.80±8.87^{ab}	335.90±814.26^{b}
Thiamin(μg)	0.98±1.57^{c}	0.98±40.80^{c}	9.98±1.57^{ac}	0.98±1.57^{c}
Riboflavin (μg)	0.23±0.49^{abc}	0.23±0.49^{b}	0.22±0.50^{ab}	0.23±0.49^{ac}
Ascorbic acid (mg)	5.14±12.03^{a}	1.59±3.36^{a}	0.54±0.87^{b}	3.04±6.89^{bc}
Folic acid (μg)	3.10±4.62^{ab}	3.60±5.82^{ac}	1.05±1.17^{c}	1.05±1.17^{a}

Values with different superscripts are significantly different from each other on the application of Duncan's multiple comparison tests. FMM + A: Foxtail millet mix with amaranth, FMM + B: Foxtail millet mix with banana, FMM + S: Foxtail millet mix with spinach, FMM + P: Foxtail millet mix with papaya

Table 3: Mean sensory and shelf-life evaluation of foxtail millet-based complementary mixes

Sensory/shelf life	Sensory parameters	FMM + A	FMM + S	FMM + B	FMM + P
Sensory analysis	Appearance	6.80±0.44^{c}	5.40±0.89^{ab}	6.60±0.54^{c}	5.20±0.83^{a}
	Consistency	7.50±0.57^{a}	7.20±0.83^{d}	5.20±0.44^{ab}	6.80±1.30^{cd}
	Taste	7.00±1.41^{a}	6.60±0.89^{bc}	6.00±1.41^{a}	5.60±1.51^{abc}
	Flavor	6.60±0.89^{bc}	6.40±1.67^{ab}	6.60±0.89^{bc}	4.80±0.83^{a}
	Overall acceptability	7.80±0.83^{b}	7.00±1.00^{ab}	8.00±0.70^{b}	6.02±0.73^{b}
0 day	Appearance	6.00±1.22^{a}	6.00±1.22^{b}	6.25±1.13^{ac}	6.00±0.73^{ab}
	Consistency	6.40±1.51^{ab}	6.40±1.51^{ab}	6.66±0.98^{a}	6.33±1.23^{a}
	Taste	6.80±0.44^{b}	6.80±0.44^{c}	6.58±1.24^{b}	5.58±1.16^{bc}
	Flavor	6.20±1.18^{c}	6.20±1.48^{b}	6.50 ±1.08^{c}	5.58±0.99^{c}
	Overall acceptability	7.40 0.89^{ac}	7.40±0.89^{ac}	7.25±1.05^{a}	6.83±1.11^{d}
30 days	Appearance	6.16 ±0.93^{a}	5.53 ±0.79^{ab}	6.600 ±0.54^{ab}	5.50±1.04^{ab}
	Consistency	6.66 ±1.23^{ab}	6.00 ±1.20^{ac}	7.200 ±1.30^{c}	5.66±1.21^{a}
	Taste	6.50 ±1.08^{b}	5.66 ±1.49^{b}	7.20±1.30^{b}	5.33±1.50^{ac}
	Flavor	6.16 ±1.02^{ac}	5.25 ±0.96^{d}	6.60 ±0.89^{ac}	5.00±0.89^{b}
	Overall acceptability	7.41 ±0.99^{d}	6.58 ±0.90^{b}	7.80± 0.44^{b}	7.00±0.89^{c}

Values with different superscripts are significantly different from each other on the application of Duncan's multiple comparison tests. FMM + A: Foxtail millet mix with amaranth, FMM + B: Foxtail millet mix with banana, FMM + S: Foxtail millet mix with spinach, FMM + P: Foxtail millet mix with papaya

Table 4: Microbiological examination of foxtail millet complementary mixes

Sample	Total bacterial count (CFU/ml)	Yeast and mold test/colonies (CFU/ml)			Coliform test
	10^{-5}	10^{-3}	10^{-4}	10^{-5}	MPN index/ml
FMM + A	11×10^{-4}	**	**	**	2
FMM + S	24×10^{-4}	1	**	**	2
FMM + B	63×10^{-4}	**	**	**	2
FMM + P	35×10^{-4}	**	**	**	<2

**No growth. FMM + A: Foxtail millet mix with amaranth, FMM + B: Foxtail millet mix with banana, FMM + S: Foxtail millet mix with spinach, FMM + P: Foxtail millet mix with papaya, MPN: Most probable number

of the complimentary mixes was due to low water activity and low pH caused by fermentation of the grain.[18] The trend in mold and yeast population was similar. This could be probably due to the antioxidant effect of ginger. The relative presence of bacteria and molds might be due to the processing that sorghum was subjected to. However, the high temperature of cooking is expected to reduce the microorganisms present. Yeasts and coliforms were not detected in the mixes throughout the storage period of 60 days probably because of the acidification of the medium by lactic acid fermenters[19] and storage temperature. Fermentation induced an antimicrobial environment that reduced the risk of microbial contamination as observed by Ayoya *et al.* (2010)[20] in home-made complementary foods. The low microbial load could also be due to roasting of the food samples.

CONCLUSION

The present study concludes from the results that minor and multinutrient grains, green leafy vegetables, and basic low-cost fruits are good sources of energy, protein, iron, and micronutrients to the targeted 0–12 months' infants for supplementing weaning foods. It can be recommended based on the infant's length and weight with the supervision. To improve the infant and young child feeding, access to adequate complementary food is necessary. Locally available staples are commonly used for the manufacture of complementary foods. If we rely solely on such unmodified ingredients, it will be adequate to meet the energy and nutrient needs. By applying simple technologies, we can improve the availability of complementary foods. From the study, it may be concluded that locally available ingredients available in the developing countries have a great potential in developing highly nutritious and acceptable weaning foods. Addition of malt in weaning food improved functional and nutritional qualities. Such a protein and energy-dense weaning food would help in eradicating malnutrition in children. Such products would also promote the utilization of millet which is slowly losing importance to wheat and rice.

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Conflicts of interest

There are no conflicts of interest.

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