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Original Article

Physicochemical properties and nutritional traits of millet-based weaning food suitable for infants of the Kumaon hills, Northern India

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A weaning food based on malted foxtail millet flour (30%), malted barnyard millet flour (30%), roasted soybean flour (25%) and skim milk powder (15%) was prepared. The mix contained 18.37 g protein and 398 kcal energy per 100 g. The nutrient composition of this unfortified weaning (UW) mix met the Prevention of Food Adulteration (PFA) standards, except in total ash. In order to meet the minor constituent requirements, the UW mix was fortified. The fortified weaning (FW) mix met PFA standards for various nutrients. The protein efficiency ratio of the UW mix was 2.25 against a casein control, for which a value of 2.50 was recorded. The nutrient composition, viscosity and sensory quality of the UW mix was compared with the marketed weaning mix, commercial infant formula. The viscosity of UW gruel was much lower (20 centipoise (cps)) than that of marketed weaning mix (7400 cps). The high α-amylase activity of 661 units in the UW mix was responsible for its low viscosity. The sensory quality of UW mix and marketed weaning mix did not differ significantly ($P = 0.05$). Both of the gruels were liked moderately on the Hedonic Scale. The UW gruel met the acceptability criteria for weaning food. It could be stored in plastic airtight containers at room temperature for 4 months without any changes in sensory quality.

Key words: barnyard millet, foxtail millet, India, Kumaon hills, malting, soybean, Uttaranchal, weaning food.

Introduction

In India, around 63% of the children under five years of age are malnourished. This accounts for 75 million malnourished children and is one of the worst levels in the world.[1] Nutritionally inferior diets and improper feeding practices are major contributing factors to the development of childhood malnutrition.[2] Many attempts have been made by government, international organizations and commercial enterprises to manufacture and market a formula that provides a balanced weaning food for the child.[3,4] However, these formulae have proved too expensive to be used by those within the range of very poor.[5]

The people of the Kumaon hills, Northern India, are almost solely dependent on homemade preparations that are nutritionally limited due to the major involvement of women in agricultural activities. Lack of knowledge about simple processing techniques to produce nutritious food is another limitation. The availability of ready-made snacks and baby foods is poor in local markets and whatever items are available are expensive. Moreover, they are not available in remote areas.

Millet and black soybean are commonly grown crops in the Kumaon hills of Northern India. These crops may be used to develop a nutritious weaning food to benefit the community. The present investigation was undertaken to develop an instant, low cost, nutritious weaning food suitable for preparation at household and commercial levels.

Materials and methods

Barnyard millet (*Echinochloa frumentacea*) variety VL-29 was procured from Vivekanand Research Laboratory and local variety foxtail millet (*Setaria italica*) was purchased from the local village of Bisra, Almora district, Uttaranchal, India. Local variety black soybean (*Glycine max*) was purchased from the local market in Haldwani, Nainital district, Uttaranchal, India.

Foxtail millet and barnyard millet were malted as in the method of Thathola.[6] Black soybean was roasted in a medium of common salt at 80–125°C for 10 min. All of the above ingredients were ground to pass through a 100 mesh sieve to obtain a fine powder.

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Preparation of unfortified weaning (UW) mix

The UW mix was made by mixing malted foxtail millet flour (30%), malted barnyard millet flour (30%), roasted soybean flour (25%) and skim milk powder (15%).

Estimation of nutrient composition in UW mix

The proximate composition of the UW mix was analyzed according to the method described by the Association of Official Analytical Chemists (AOAC).[7] Calcium and ascorbic acid were estimated according to AOAC[7] and iron according to Ranganna.[8] Niacin was estimated according to the method of the Association of Vitamin Chemists[9] while the anti-nutrient factor phytic acid was estimated by the method given by Wheeler and Ferrel.[10]

Determination of Protein Efficiency Ratio (PER)

The protein quality of grains was evaluated by measuring PER according to Campbell[11] with slight modifications. The protein level of the diet was adjusted to 10%. Weaning albino mice (ten per group) were housed in individual cages at room temperature (26.5–30°C). The experimental diet was fed to mice ad libitum. Drinking water was supplied by an individual nipple water bottle attached to each cage. The diets were formulated as shown in Table 1.[11,12] A casein diet was used as a control. The weekly weight gain and food intake of the mice were recorded for 4 weeks.

Preparation of fortified weaning (FW) mix

For commercial use, UW mix was fortified with multivitamin mineral mixture to meet PFA standards.[13] The values for minor nutrients of the FW mix were calculated on the basis of the values analyzed and the values reported by Gopalan *et al.*[14]

Preparation of weaning gruel

Weaning gruel was prepared by adding 60 mL lukewarm water (70°C) to 25 g of weaning mix. To this, 10 g of sugar was added and mixed thoroughly.

Estimation of α-amylase activity

Unfortified weaning mix was analysed for α-amylase activity according to the method given by Reddy *et al.*[15] Maltose (1% w/v) was sampled in order to plot the standard curve. The α-amylase activity was defined as μg maltose liberated in 1 min at 22°C by 1 mL enzyme extract.

Table 1. Composition of diet for protein efficiency ratio experiments on mice

Ingredients	Casein diet	Test diet
Casein	309.9	–
UW mix	–	544.36
Corn starch	540.1	305.64
Groundnut oil	90.0	90.0
Salt mixture*	40.0	40.0
Vitaminized starch*	10.0	10.0
Vitaminized oil*	10.0	10.0

* Prepared according to the Indian Standard Institute.[12] UW, unfortified weaning.

Evaluation of gruel for viscosity

The viscosity of marketed weaning mix and UW gruel at 40% slurry concentration was measured in a Brookfield synchroelectric viscometer (RVT model) at a constant speed using appropriate spindles, as in the method of Brandtzaeg *et al.*[16] The temperature of the gruel was maintained at 50°C. The instrument was operated for 1 min and the reading was noted. The viscosity was measured in centipoise (cps).

Evaluation of gruel for sensory quality

The UW gruel was evaluated for sensory quality characteristics. The 'Nine Point Hedonic Scale' was used to test the liking or disliking for gruel while the 'Score Card Method' was used to test which attributes contribute to the acceptability of a product. Evaluation was done by a trained panel of ten members' according to the method given by Amerine *et al.*[17] The sensory qualities of UW gruel were compared with those for the marketed weaning mix.

Evaluation of gruel for storage stability

A 100 g portion of UW mix was kept in an airtight plastic container for exactly 4 months. The temperature and relative humidity of the room were recorded daily. Temperature and relative humidity ranged from 14 to 29°C and from 50 to 63%, respectively. The sensory quality of the stored sample was compared with that of a freshly prepared control, according to the method given by Amerine *et al.*[17]

Evaluation of UW gruel for acceptability

For the acceptability test, an observation schedule was made. Twenty children aged 5 months to 2 years were selected from the community and the gruel was fed to them. The responses of the children were recorded with the help of their mothers. After an interval of 2 days, the mothers were interviewed for any sign of discomfort observed in the children. The responses were evaluated on the basis of the criteria given by the Indian Council of Medical Research (ICMR).[18]

Estimation of cost

The cost of the UW and FW mixes were each calculated on the basis of the cost of raw ingredients from which the mixes were prepared.

Statistical analysis

The data obtained on approximate composition, iron, calcium, ascorbic acid, niacin and phytic acid were processed to get the mean values of three replicates ± their standard deviation. The t-test was applied to see the difference ($P = 0.05$) between the sensory quality characteristics of gruel developed in the present study and gruel made from commercially available infant formula. Significant difference ($P = 0.05$) between fresh and stored products was calculated using the 'paired t-test'as in the method given by Snedecor and Cochran.[19]

Results

Nutritional quality

The moisture content, total ash content, crude protein, crude fibre, crude fat, carbohydrate and physiological energy per 100 g UW mix were found to be 7.33, 4.00, 18.37, 0.41, 9.00, 60.89 g/100 g and 398 kcal/100 g, respectively. The iron and calcium content were 4.90 mg/100 g mix and 253.33 mg/100 g UW mix, respectively. The ascorbic acid and niacin content were 74.66 mg/100 g and 2490 μg/100 g UW mix, respectively. The antinutritional factor phytate phosphorus was found to be 9.65 mg/100 g UW mix (Table 2). After fortification of the UW mix, all the minor nutrients of the mix were in accordance with the standards specified by PFA[13] (Table 2). The essential amino acid composition of unfortified weaning mix is given in Table 5. The protein efficiency ratio (PER) of the UW mix was found to be 2.25 against the casein standard, for which a PER of 2.5 was observed. The FW mix contained all of the nutrients as per PFA standards (Table 2).

Alpha amylase activity

Unfortified weaning mix was analyzed for α-amylase activity. This was found to be 661 units in UW mix.

Viscosity

Values of 20 cps and 7400 cps were obtained for hot paste viscosity (50°C) for UW and marketed weaning mix gruel, respectively.

Sensory quality

The data on sensory quality obtained by a trained panel of ten members showed that both UW and marketed weaning mix gruels were moderately liked. A non-significant difference ($P = 0.05$) was observed between the sensory quality of UW and marketed weaning mix gruel (Table 3).

Storage stability

A comparison of the stored UW mix with the freshly prepared control sample for sensory quality characteristics indicated insignificant differences ($P = 0.05$) between them (Table 4).

Acceptability test

The responses towards acceptability of weaning food of 20 children aged 5 months to 2 years were recorded with the help of their mothers. The weaning gruel was found to be acceptable by infants. The UW gruel met the criteria given by ICMR[18] for acceptability of weaning food. None of the children (0%) refused to eat the gruel and no child showed any discomfort. It was observed in the present study that in one sitting, 66.6% of infants aged 5 months to 1 year were able to consume only half of the quantity of gruel provided to them (12.5 g of mix) and the rest were able to consume the whole quantity (25 g of mix).

Cost

The costs of the UW and FW mixes were each calculated on the basis of the cost of raw ingredients. The cost calculated was Rs. 30/kg for UW mix and Rs. 42/kg for the FW mix.

Discussion

The results show that in UW mix all the values except total ash were in accordance with the standards specified by PFA, 1991.[13] The UW mix was found to be superior in terms of protein, total ash and ascorbic acid on comparison with commercial product, marketed weaning mix (Table 2).

Breast milk alone meets the nutrient requirements of children up to 4–6 months of age. Thereafter, the child's need for energy and protein increases due to growth and the regulation of various body functions. Requirements for vitamins (e.g. vitamins A and C and B-group vitamins) and minerals (e.g. calcium, iron and iodine) also increase with growth in

Table 2. Nutrient composition of weaning food suitable for infants of the Kumaon hills, Northern India

Nutrient	UW mix	FW mix	WG	MW	PFA (1991)
Moisture (%)	7.33 ± 0.47	7.33		2.50	4.5
Crude protein (%)	18.37 ± 0.05	18.31	(0.05)	15.50	10.0–16.0
Total ash (%)	4.00 ± 0.98	4.00	(0.01)	2.70	8.5
Crude fibre (%)	0.41 ± 0.11	0.41		1.40	–
Crude fat (%)	9.00 ± 0.53	9.00	(0.03)	9.00	≥ 9.0
Carbohydrate (g/100 g)	60.89	60.89	(0.17)	68.90	–
Physiological energy (kcal/100 g)	398	398	(1.11)	419	–
Iron (mg/100 g)	4.90	9.90	(0.03)	7.50	5.0
Zinc (mg/100 g)	2.72	5.22	(0.01)	–	2.5
Calcium (mg/100 g)	253.33 ± 7.54	385.50	(1.07)	570.00	230.0
Ascorbic acid (mg/100 g)	74.66 ± 7.54	74.70	(0.20)	35.00	35.0
Riboflavin (μg/100 g)	–	200.00	(0.55)	0.15	275.0
Vitamin B_{12} (μg/100 g)	–	0.10		0.19	0.7
Folic acid (μg/100 g)	–	30.00	(0.08)	5.50	20.0
Niacin (μg/100 g)	2490 ± 8.16	2490	(6.92)	1250.00	1160.0
Vitamin A (IU/100 g)	86.13	1086.13	(3.02)	300.00	1050.0
Vitamin D (IU/100 g)	–	400.00	(1.11)	50.00	350.0
Phytate phosphorus (mg/100 g)	9.65 ± 1.22	9.65	–	–	–

Figures in parentheses indicate nutrient density per gram of weaning gruel. FW, fortified weaning; MW, marketed weaning; PFA, Prevention of Food Adulteration; UW, unfortified weaning; WG, weaning gruel.

Table 3. Sensory quality characteristics of unfortified weaning gruel and marketed weaning gruel, as measured by a trained panel of ten

Quality	UW gruel		Marketed weaning gruel		Significance
	HS	SCM	HS	SCM	
Preference	7.1	Liked moderately	7.5	Liked moderately	NS
Colour	7.0	Good	7.9	Good	NS
Flavour	7.0	Good	7.2	Good	NS
Texture	7.0	Good	7.3	Good	NS
Taste	6.5	Fair to good	7.2	Good	NS
Appearance	6.8	Fair to good	7.5	Good	NS
Consistency	6.7	Fair to good	7.5	Good	NS
Overall acceptability	7.7	Good	8.4	Good to very good	NS

Statistical significance paired *t*-test; * $0.05 > P > 0.01$. HS, Hedonic scale; NS, not significant; SCM, score card method; UW, unfortified weaning.

Table 4. Sensory quality characteristics of stored and freshly prepared unfortified weaning gruel, as measured by a trained panel of ten

Parameter	Stored sample		Fresh sample		Significance
	HS	SCM	HS	SCM	
Preference	7.1	Liked moderately	7.2	Liked moderately	NS
Colour	7.1	Good	7.1	Good	NS
Flavour	7.2	Good	7.1	Good	NS
Texture	7.2	Good	7.2	Good	NS
Taste	7.7	Good	7.7	Good	NS
Appearance	7.2	Good	7.2	Good	NS
Consistency	7.1	Good	7.1	Good	NS
Overall acceptability	7.7	Good	7.8	Good	NS

Statistical significance paired *t*-test: * $0.05 > P$ 70.01. HS, Hedonic scale; NS, not significant; SCM, score card method.

Table 5. Essential amino acid composition of unfortified weaning mix

Essential amino acids	Content (mg/g N)
Arginine	211.5
Histidine	103.5
Lysine	215.5
Tryptophan	51.5
Phenylalanine	247.5
Methionine	99.5
Threonine	159.0
Leucine	526.5
Isoleucine	278.0
Valine	272.0

children. In 1991, the Indian Ministry of Health and Family Welfare amended the PFA rules, redefining infant formula so as to incorporate certain minor nutrients that are considered to be essential for normal physiological functions. So there is a need for a balanced weaning food for infants. Fortifications are the best food-based strategy to combat this 'hidden malnutrition'. The FW mix contained all of the major and minor nutrients specified by PFA.[13] Sachdeva[20] described the desirable qualities of weaning food as being easy to digest, high in energy and semisolid in consistency. The PER of UW mix (2.25) was found to be close to the PER of casein (2.5). This indicates the high biological value of UW mix, in terms of essential amino acid make up (Table 5) and digestibility.

In India, especially in the Kumaon hills, an infant's or toddler's first type of food is usually a gruel made from local staple, which may be rice, wheat, bajra, finger millet or maize. No special processing technique is followed for the preparation of weaning food, and the dietary items of an infant are the same as for an adult. During cooking, the starch granules in the staple flours swell and cause 'bulkiness' or 'dietary bulk' in the gruel, resulting in a low calorie-density per unit volume of food. In Asia and Africa, the energy density of a typical gruel is low and ranges between 0.25–0.40 kcal/g of food.[21] The solution to this problem is malting. Malting is a well-established, simple, traditional technique for the production of amylase-rich food that can be followed at a household level. During the germination step of malting, α-amylase is transported to endosperm for mobilization of starch reserves. The long-chain carbohydrates are broken down into the smaller dextrin molecules. Weaning gruels with high α-amylase activity have low viscosity. Mosha and Svanberg[22] have suggested a semiliquid consistency with measured viscosity of 1000–3000 cps as most suitable for infant feeding. This remarkable amylase-rich property of UW gruel makes it possible to offer the weaning child a less viscous yet energy-dense preparation using ingredients that are normally used for feeding young children, even in the poorer homes of the Kumaon hills. The results show that UW gruel is more nutrient-dense and much less viscous in comparison to marketed weaning mix. The result on acceptability shows that the majority of children (66.6%) consumed only half of the quantity of gruel (12.5 g of mix) in one sitting. If the consumption frequency of this UW gruel is four sittings each day, then half the quantity (12.5 g of mix) of the gruel will provide 280 kcal energy and 9.16 g of protein per day. Similarly, the whole quantity (25 g of mix) will provide 560 kcal energy and 18.36 g of protein per day. The energy and protein contents of weaning food for infants recommended by ICMR[16] are 300 kcal and 8 g per day, respectively. The UW gruel can ensure adequate nourishment to infants during the process of weaning.

The results on storage stability show that the UW mix can be prepared in bulk and easily stored for 4 months in airtight containers at room temperature. It indicates that no special storing conditions are required at a household level. Preparation of UW gruel will be much more economical and within the reach of the poorer segments of the Kumaon hills that buy marketed weaning mix at the rate of Rs. 190/kg. Also, FW mix can be produced at cottage level and could be made available to families of the Kumaon hills.

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