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Evaluation of physical and functional properties of weaning food blended with banana, sweet potato and drumstick leaves powder

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Abstract
The weaning period is a crucial period in an infant's life. At the age of 5–6 months, most infants begin to eat supplementary semisolid foods. At this stage homogenized infant foods play a major role in their nutrition. In developing country like India hidden hunger is one of the main problem due to deficiency of micronutrients like vitamins and minerals especially vitamin A, iron and zinc. Cereal gruel is the common complementary foods in developing countries, and it is usually low in energy and protein, thus increase in protein-energy malnutrition among underprivileged weaning aged children. In this context present experiment was conducted to formulate weaning food (7 treatments) for infants from malted wheat flour, malted ragi flour, malted green gram flour, roasted flax seed powder blended with banana, sweet potato and drumstick leaves powder. Functional and physical properties of the formulated samples were analyzed. The maximum L*(80.69) a* (1.70) and b* (12.63) values were recorded in T_7. Treatment T_1 [MWF (10%) +MRF (10%) +MGF (10%) + BP (50%) + SPP (10%) + DLP (5%) +RFP (5%) had low bulk density(0.52 g/cc), water absorption capacity (43.88%) and cooking time(2.54 min). This implies that it forms low viscous and high caloric density food per unit volume rather than a high viscosity or high volume density.

Keywords: Weaning food, banana, sweet potato, drumstick leaves, functional properties

Introduction
Weaning is defined as the process starting when breast milk alone is no longer sufficient to meet the nutritional requirements of infants, and therefore other foods and liquids are needed, along with breast milk (Onis *et al.*, 1993) [1]. It is also called 'complementary feeding' as these food complemented with breastfeeding. During the critical period of an infant's growth and development which is the weaning stage in infancy (6 and 24 months), a transition in administration of diet occurs from a diet based on mother's milk to another diet which is usually semi-solid to a more solid diet. The mothers' milk or any other form of milk is sufficient for a newborn baby and starts getting insufficient for some essential elements of nutrition beyond six months of age. At this stage, it becomes necessary to introduce other foods into the infant diets to meet the nutritional requirement of the child, especially for energy and micronutrients, notably iron, zinc, calcium, vitamins (A, C, B group etc.)

Banana (*Musa paradisiaca* L.) belongs to the family Musaceae. It is grown in an area of 858.1 thousand ha, with a production of 29162.6 MT and productivity of 34 MT/ha (Anon, 2016) [2]. The primary product of banana in market is "fried chips and candy" which constitute around (31%), rest as banana puree (9%), banana pulp (3%), banana beer (3%), banana wafers (3%), banana powder (6%) and others (Rashmi and Jyothsna, 2011) [3]. Banana is a highly perishable fruit thus it is necessary to develop shelf stable products such as banana powder, dried slices, jam, baby food etc. (Patel *et al.*, 1999) [4].

Bananas are one of the best sources of potassium, an essential mineral for maintaining normal blood pressure and heart function and act as a energy booster. It is used as a remedy for constipation in children. It forms the part of diets of children suffering from malnutrition. A mashed ripe banana is an extremely simple and healthy baby food. It contains high amount of potassium, fiber, calcium, magnesium, phosphorus, selenium, iron, Vitamins A, B_2, B_6, C, E, niacin, folate, and pantothenic acid. Furthermore, bananas are very easy to digest and rarely cause allergic reactions (Kumar *et al.*, 2013) [5].

Sweet potato (*Ipomoea batatas* L.) belongs to the family *Convolvulaceae*. In India, it is grown in an area of 134.9 thousand hectares with a production of 1638.8 MT and 12.2 MT/ha (Anon, 2016). It is a valuable medicinal plant having anti-cancer, anti-diabetic, and anti-inflammatory activities (Mohanraj and Sivasankar, 2014) [6].

Protein contents of sweet potato leaves and roots range from 4.0 to 27.0 per cent and 1.0 to 9.0 per cent, respectively. The sweet potato could be considered as an excellent novel source of natural health-promoting compounds, such as β-carotene and anthocyanins (Adelia *et al.* 2007) [7].

Drumstick is widely cultivated in tropical and subtropical areas where its young seed pods and leaves are used as vegetables. It is grown for its nutrient rich tender, but full grown pods, leaves and flowers which are used for culinary preparations. Extracts from the leaves are used to treat malnutrition, augment breast milk in lactating mothers. It is used as potential antioxidant, anticancer, anti-inflammatory, antidiabetic and antimicrobial agent (Gopalakrishnan *et al.*, 2016) [8]. Drumstick leaves are reported to contain substantial amounts of vitamin A, C and E. The leaves of drumstick also contain appreciable amounts of total phenols, proteins, calcium, potassium, magnesium, iron, manganese and copper (Hekmat *et al.,* 2015) [9]. The powder will also find suitable application in preparation of weaning food, ready to eat foods, instant *Sambhar* mix, soup powder, juice, chutney and pickle.

Traditionally weaning food has been based on local staple food, usually a cereal and it is either made into a thick porridge or liquid gruel, which is not only unpalatable but also more viscous and difficult for child to swallow. On the other hand, addition of more liquid results in dilution of nutrients. This along with low feeding frequency leads to low food intake and subsequently lead to the malnutrition (Mehta and Shah, 2001) [10]. Formulation of low-cost and highly nutritious food supplement for weaning infants is a constant challenge. This is particularly important in developing countries where malnutrition problems are still common particularly during weaning (Temesgen, 2013) [12].

A study was therefore designed to develop nutrient-dense, safe, low cost weaning food from the combination of wheat, ragi, greengram, flax seed and incorporated with banana, sweet potato and drumstick leaves powder in order to evaluate its physic-chemical and organoleptic properties.

Material and methods

Procurement and processing of raw materials

Unripe but mature bananas of cultivar ‘Grand Naine’ were procured from the local market, Bagalkot in batches to avoid ripening. Sweet potato powder from the cultivar ‘Sri Hari’, a released variety from AICRP on tuber crops, RHREC, Kumbapur Farm, Dharwad, Karnataka and the leaves of KDM-01 (Bhagya) a newly released drumstick variety of University of Horticultural Sciences, Bagalkot were used for the study. Other ingredients such as wheat, ragi, greengram and flax seeds were purchased from the grocery shop local market, Bagalkot.

Preparation of banana powder

Mature green bananas were selected, washed and the fruits were peeled to obtain pulp. After separation from the peel, the pulp was cut into slices and fumigated with sulfur @ 2g/kg for 10 minutes. After pretreatment, the slices were placed in a tray drier at 60^0 C for 6 hours to obtain dried slices. The dried banana slices were crushed by food grinder into powder form to completely pass through 60 mm size sieve. Unripe banana powder was packed in aluminum foil pouches for incorporating it into weaning mix.

Preparation of drumstick leaves powder

Fresh drumstick leaves were procured from the trees of drumstick variety KDM-01 (Bhagya) plantation maintained by Main Horticulture Research and Extension Centre, UHS, Bagalkot at Sector No.1. Bagalkot, Karnataka. The leaves were separated from twigs, washed thoroughly in clean running water, drained and spread on the clean stainless steel tray to remove surface moisture. After removal of surface moisture leaves were weighed and dried under electrical tray drier at 60 ˚C until they were crisp. Dried drumstick leaf powder was packed separately in LDPE bags (200 gauze) for further use.

Preparation of malted wheat flour

The whole malted wheat flour was prepared as per the procedure of Taragopal *et al.* (1982) [13]. Good quality wheat was cleaned and soaked in clean water for 12 h. Then water was drained out and kept for germination for 36 h at room temperature covered with wet cloth, followed by shade drying till the grain becomes dry completely. Dried wheat was devegetated to remove rootlets and roasted for 15 min. The germinated dried wheat was ground to obtain malted wheat flour. The flour thus obtained was sieved using 60 mm mesh sieve and stored in LDPE bags until used.

Preparation of malted ragi flour

Ragi malt flour was prepared as per the procedure described by Swamy (2003) [14] with slight modification. A good quality ragi was cleaned and soaked in clean water for 16 h followed by draining out the water. Further, it was held for germination for 36 h in wet cloth and sprinkling with water at regular interval. After germination, it was shade dried until they become crisp. Devegetation was done to remove rootlets. Further, it was roasted for 15 min to improve the flavor followed by grinding to fine powder. The powdered ragi malt was sieved using 60 mm mesh sieve and stored in LDPE bags until used.

Preparation of malted green gram flour

The green gram malt was prepared as per the procedure outlined by Malleshi (1995) [15]. A good quality green gram procured from the local market was cleaned and soaked in clean water for 12 h. Further, water was drained and kept for germination for 24 h at room temperature covering with wet cloth, followed by shade drying till the grains become crisp. Sprouted dried green gram was devegetated and dehusked to obtain malted dhal. The dhal was roasted for 15 min followed by grinding to get fine powder. The flour thus obtained was sieved using 60 mm mesh sieve and stored in LDPE bags for further use.

Preparation of roasted flax seed powder

Roasted flax seed powder is prepared by using good quality flax seeds which are cleaned and roasted for three minutes at low heat by stirring gently every few seconds. As the flax seeds tends to pop and release characteristic aroma, heating is stopped. The seeds are cooled and and ground to obtain powder, packed in LDPE bags and sealed for further usage in the investigation.

Formulation of weaning mix

The unripe banana, sweet potato, drumstick leaves powder, malted wheat, ragi and green gram flours and roasted flax seed powder were used for preparation of weaning mix. Only the malted wheat flour was replaced by different levels of unripe banana powder *i.e.,* 25, 30, 35, 40, 45 and 50 per cent.

Treatment details

Treatments	: 7
Design	: Completely randomized design
Replications	:3
Raw material	: Unripe banana, sweet potato powder drumstick leaves, wheat, ragi and green gram and flax seed
Sample size	: 100 g per treatment

Table 1: Recipe of different treatments for weaning mix incorporated with banana, sweet potato, drumstick leaves powder

Ingredients	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Malted wheat flour (g)	10	15	20	25	30	35	35
Malted ragi flour (g)	10	10	10	10	10	10	30
Malted green gram flour (g)	10	10	10	10	10	10	30
Roasted flax seed powder (g)	5	5	5	5	5	5	5
Banana powder (g)	50	45	40	35	30	25	0
Sweet potato powder (g)	10	10	10	10	10	10	0
Drumstick leaf powder (g)	5	5	5	5	5	5	0

Bulk density (g/cc)

The procedure of Okaka and Potter (1979) [16] was used to determine the bulk density. A 100 ml graduated cylinder was weighed and recorded as W_1, 15g of sample was put into cylinder tapped hermetically to eliminate air space between the flour, the volume was noted and new mass was recorded as W_2. Bulk density was computed as follows.

$$\text{Bulk density (g/cc)} = \frac{\text{Mass of the sample } (W_2\text{-}W_1) \text{ (g)}}{\text{Volume of the cylinder (cc)}} \times 100$$

Water absorption capacity (%)

The water absorption capacity of the powders was determined by the method of (Sosulski *et al.*, 1976) [17]. One gram of sample mixed with 10 ml distilled water and allowed to stand at ambient temperature (30 ± 2 °C) for 30 min and centrifuged for 30 min. at 3,000 rpm. Water absorption was examined as per cent water bound per gram flour.

Cooking time (min)

Determination of optimum cooking time was achieved by taking 10 g sample from each treatment cooked in 100 ml of water (in which 25 ml water was used to make paste, rest 75 ml is used for boiling). The paste is poured to 75 ml water along with 10 g jaggery and it was cooked until semi-solid paste is obtained. This is the optimum cooking time and is recorded in minutes.

Chroma (*L, *a**, *b**)**

Powders colour was measured with a ColorFlex (Model CFEZ 1919, Hunter Associates Laboratory, Inc., Reston) with a 45 mm (diameter) measuring tube using a white tile background. *L* a** and *b** values denote lightness (white-black), red-green and yellow-blue scales, respectively. There were three replicate powder samples for each treatment.

Statistical analysis

The data on the physical parameters and recorded in the experiment were subjected to completely randomised block design analysis using Web Agri Stat Package (WASP) software. The level of significance used in t test was at one per cent level of significance.

Results and Discussion

Bulk density (g/cc)

The results bulk density, water absorption capacity and cooking time are shown in Table 2 Incorporation of banana, sweet potato and drumstick leaf powder had significant effect on bulk density of weaning food. The bulk density of weaning food ranged from 0.52 g/cc to 0.69 g/cc. Among the different treatments the significant minimum bulk density of weaning food was recorded in T_1 [MWF (10%) +MRF (10%) +MGF (10%) + BP (50%) + SPP (10%) + DLP (5%) +RFP (5%) : 0.52 g/cc] which was on par with T_2 [MWF (15%) +MRF (10%) +MGF (10%) + BP (45%) + SPP (10%) + DLP (5%) +RFP (5%) : 0.52 g/cc] (0.53 g/cc) and maximum bulk density was observed in Treatment T_7 [MWF (35%) +MRF (30%) +MGF (30%) +RFP (5%) : 0.69g/cc]. The lower bulk density recorded in treatment T_1 and T_2 could be due to the incorporation of banana, sweet potato and drumstick leaves powder which have the coarse nature or higher porosity compared to control. It is evident that high bulk density limits the calorie and nutrient intake per feed of a child, because of the small capacity of the child's stomach that would not be able to accommodate large volume of food to satisfy their energy and nutrient requirements (Omueti *et al.*, 2009) [18]. So, diets of lower bulk density are required in weaning food for the easy swallowing without any suffocation by the child. The results are in agreement with Victor *et al.* (2013) [19] where incorporation of defatted fluted pumpkin flour to complementary food resulted in significant reduction of bulk density.

Water absorption capacity (%)

Water absorption capacity of weaning food was influenced by incorporation of banana, sweet potato and drumstick leaves powder. The water absorption capacity of weaning food was ranged from 43.88 to 106.47 per cent. Among the different treatments the lowest water absorption capacity was recorded in T_1 (43.88%) which was statistically different from all other treatments. The maximum water absorption capacity was recorded in T_7 (106.47%) and it was significantly higher when compared to other treatments. Water absorption capacity (WAC) gives an indication of the amount of water available for gelatinization. Lower absorption capacity is desirable for making thinner gruels (Ghavidel and Prakash, 2010) [20]. Variation in water absorption capacity of different treatments may be due to variation in the level of ingredients. Water absorption represents the ability of the product to associate with water under conditions where water is limiting (Omueti *et al.*, 2009) [18]. The lower water absorption capacity of formulated diet could be attributed to the relatively low amount of carbohydrates compared to control. The difference in the properties of polysaccharides is related to their monosaccharide composition, type of chemical linkages among sugar units, hydrogen bonding and ionic interaction between and among polymers (Manay and Shadaksharaswamy, 2008) [21]. The more polysaccharide constituents, the more water is likely to be absorbed and bind by the diets (Otegbayo *et al.*, 2000) [22]. The significance of having lower water absorption capacity in the formulated diets is that it is helpful in making thinner gruels(less viscous) with high calorie density per unit volume. The results of water absorption capacity are in accordance with Adepeju *et al.* (2014) [23] in breadfruit incorporated weaning food.

Cooking time (minutes)

Cooking time of weaning food ranged from 2.54 to 4.28 min. Significantly minimum cooking time was recorded in T_1 (2.54 min) which was significantly different from all other treatments. Maximum cooking time was recorded in T_7 (4.28 min). Gluten is responsible for formation of starch protein structure. Relatively high amount of carbohydrates present in control might be the reason for higher cooking time whereas cooking time gradually decreased with the incorporation of banana, sweet potato and drumstick leaves powder as they are low in carbohydrate content. Cereal starches under normal conditions usually have a moisture content of 12-14 per cent. If water is added and the mixture is heated the intra molecular hydrogen bonding is broken, the starch absorb more water and swell. The temperature at which the granules begin to swell rapidly and lose birefringence is called gelatinization temperature. As the temperature of the starch suspension is increased above gelatinization range, the granules continue to swell if sufficient water is present and finally cooking takes place (Manay and Shadaksharaswamy, 2008) [21]. Hence, in the present study T_7 and T_6 containing more cereal flours compared to other treatments required more cooking time. Pasting is the result of a combination of processes that follows gelatinization from granule rupture to subsequent polymer alignment due to mechanical shear during the heating and cooling of starches. The low peak viscosity and final viscosity of the diets implies that the complementary diets will form a low viscous paste rather than a thick gel on cooking and cooling (Omueti *et al.*, 2009) [18]. It thus indicates that the gruel will be a high caloric density food per unit volume (Otegbayo *et al.*, 2006) [22] rather than a dietary bulk (high volume viscosity) (Ikujenlola and Fasakin, 2005) [24]. The relatively high cooking time might be related to the proportion of starch in the diet, the ratio of amylose to amylopectin and the resistance of the starch granules to swelling.

Table 2: Effect of new weaning food formulation on bulk density, water absorption capacity and cooking time of weaning food

Treatment	Bulk density (g/cc)	Water absorption capacity (%)	Cooking time (minutes)
T_1: MWF (10%) + MRF (10%) + MGF (10%) + BP (50%) + SPP (10%) + DLP (5%) + RFP (5%)	0.52	43.88	2.54
T_2: MWF (15%) + MRF (10%) + MGF (10%) + BP (45%) + SPP (10%) + DLP (5%) + RFP (5%)	0.53	46.55	3.13
T_3: MWF (20%) + MRF (10%) + MGF (10%) + BP (40%) + SPP (10%) + DLP (5%) + RFP (5%)	0.56	47.28	3.23
T_4: MWF (25%) + MRF (10%) + MGF (10%) + BP (35%) + SPP (10%) + DLP (5%) + RFP (5%)	0.57	47.98	3.57
T_5: MWF (30%) + MRF (10%) + MGF (10%) + BP (30%) + SPP (10%) + DLP (5%) + RFP (5%)	0.60	48.88	4.04
T_6: MWF (35%) + MRF (10%) + MGF (10%) + BP (25%) + SPP (10%) + DLP (5%) + RFP (5%)	0.62	50.47	4.14
T_7: MWF (35%) + MRF (30%) + MGF (30%) + RFP (5%)	0.69	106.47	4.28
Mean	0.58	55.93	3.56
SEm±	0.87	0.39	0.03
CD at 1%	2.48	1.63	0.04

MWF: Malted wheat flour **MRF**: Malted ragi flour **MGF:** Malted greengram flour
BP: Banana powder **SPP:** Sweet potato powder **DLP:** Drumstick leaf powder
RFP: Roasted flax seed powder

L* a* b* **values**

The *L** (Table 3) value influenced by the incorporation of banana, sweet potato and drumstick leaves powder and it was ranged from 75.57 to 80.69. Among the treatments, the maximum *L** value was recorded in control T_7 (80.69) and it was statistically significant from all other treatments. The minimum *L** value was recorded in T_1 (75.57). Decrease in *L** value could be attributed to compositional changes. Ingredients other than wheat such as ragi flour, green gram flour, banana, sweet potato and drumstick leaf powder having colour pigments result in lower *L** value. Similar results were recorded by Bazaz, (2016) [25] in rice based weaning food supplemented with green gram.

The highest *a** value (1.70) was recorded in control or T_7 and it was statistically differed from all other treatments except T_5 (1.16) and T_6 (1.25). The minimum *a** value was recorded in T_1 (0.53). Incorporation of drumstick leaf powder which imparted greenness to the weaning food might be the reason for decreasing trend in *a** value. As the proportion of banana powder increased in the treatments *L** and *a** values decreases accordingly. The *b** value of weaning food was ranged from 11.48 to 12.63.

The highest *b** value was recorded in T_7 [MWF (35%) +MRF (30%) +MGF (30%) +RFP (5%): 12.63) and it statistically differed from all other treatments. The minimum *b** value was recorded in T_1 (11.48). Higher proportion of wheat flour in T_7 could be the reason for highest *b** value. Whereas, replacement of wheat flour significantly reduced the *b** value. Similar results were recorded by Bazaz (2016) [25] in rice based weaning food supplemented with green gram who reported a decrease in *b** value due to sprouting.

Table 3: Effect of new weaning food formulation on colour values of weaning food

Treatment	*L**	*a**	*b**
T1: MWF (10%) + MRF (10%) + MGF (10%) + BP (50%) + SPP (10%) + DLP (5%) + RFP (5%)	75.57	0.53	11.48
T2: MWF (15%) + MRF (10%) + MGF (10%) + BP (45%) + SPP (10%) + DLP (5%) + RFP (5%)	75.97	0.93	11.51
T3: MWF (20%) + MRF (10%) + MGF (10%) + BP (40%) + SPP (10%) + DLP (5%) + RFP (5%)	76.64	1.09	11.55
T4: MWF (25%) + MRF (10%) + MGF (10%) + BP (35%) + SPP (10%) + DLP (5%) + RFP (5%)	76.81	1.14	11.92
T5: MWF (30%) + MRF (10%) + MGF (10%) + BP (30%) + SPP (10%) + DLP (5%) + RFP (5%)	76.85	1.16	12.27
T6: MWF (35%) + MRF (10%) + MGF (10%) + BP (25%) + SPP (10%) + DLP (5%) + RFP (5%)	77.86	1.25	12.28
T7: MWF (35%) + MRF (30%) + MGF (30%) + RFP (5%)	80.69	1.70	12.63
Mean	77.20	1.11	11.90
SEm±	0.05	0.14	0.04
CD at 1%	0.18	0.55	0.05

MWF: Malted wheat flour **MRF**: Malted ragi flour **MGF:** Malted greengram flour
BP: Banana powder **SPP:** Sweet potato powder **DLP:** Drumstick leaf powder
RFP: Roasted flax seed powder

Conclusion

The results of the study showed incorporation of banana, sweet potato, drumstick leaf powder to weaning food are advantageous as they caused reduction in bulk density, water absorption capacity and cooking time. Knowledge of solubilities will assist in the preparation of gruels with low viscosity and high calorie density per unit volume that can be easily swallowed by babies and it also saves the preparation time.

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