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Nutritional Quality and Organoleptic Acceptability of Sorghum Based Complementary Food Mix for Infants and Children

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Abstract: The study focused on developing a complementary food mix using sorghum through malting, and various analyses were conducted to assess its qualities. The nutritional composition of the mix includes 2.21% moisture, 2.26% total ash, 14.0% crude protein, 3.74% crude fat, 0.35% crude fiber, 77.99% carbohydrate, and 401.03 kcal energy content. Physico-chemical properties were determined, indicating a water absorption capacity of 166.26%, a bulk density of 0.64 gcm^{-3}, water solubility index of 46.66, swelling index of 1.38, and viscosity of 9.82 cps. Microbiological analysis confirmed the safety of the complementary food mix for consumption by young children. Organoleptic evaluation by a panel of judges revealed that the formulated mix was highly appreciated, being described as "liked very much." In conclusion, the study suggests that the formulated complementary food mix is nutritionally sound and recommended for use as a complementary food for young children aged 6-24 months.

Key words: Sorghum, complementary food mix, nutritional evaluation, formulation, organoleptic acceptability, storage.

In the recent years, there has been an increasing recognition of the importance of millets as partial substitute of major cereals due to their higher protein, energy, vitamins and minerals content. In addition, millets are also rich source of dietary fibre, phytochemicals and micronutrients and hence, they are rightly termed as "nutri-cereals". Sorghum (*Sorghum bicolor,* L. Moench) is one of the most important crops in the world and is one of the four major food grains of our country after wheat, rice and maize. It is a staple food for millions of poor rural people in Asia and Africa. Sorghum is rich in mineral content but its nutritional quality is dictated mainly by its chemical composition. Presence of considerable amounts of anti-nutritional factors such as tannin, phytic acid, polyphenol and trypsin inhibitors in it is considered undesirable. Hence, elimination or inactivation of such anti-nutritional compounds is absolutely necessary to improve the nutritional quality of sorghum, and effectively utilize its full potential as human food, by using simple household technologies like fermentation or germination (Gilani *et al*., 2005).

India faces a significant challenge with one of the highest prevalence rates of undernutrition globally, despite improvements in food availability and poverty alleviation efforts (Upadhyay and Palanivel, 2011). Various determinants contribute to this issue, making it complex to pinpoint a single key factor. The interplay of factors includes female illiteracy, lack of awareness about the nutritional needs of infants and young children, and inadequate access to healthcare. These elements collectively exacerbate the problem of malnutrition in children.

Infancy is the most critical and vulnerable period. Protein-energy malnutrition is essentially a syndrome that occurs during the crucial transitional phase of child's life from breast milk to other types of foods. During this period, children need nutritionally balanced, calorie-dense complementary foods in addition to mother's milk because of the increasing nutritional demands of the growing body (Umeta *et al.,* 2003).

According to National Family Health Survey-3 data (2009), about 20 million children are not able to receive exclusive breast feeding for the first six months of life and about 13 million do not get good, timely and appropriate complementary feeding after six months along with continued breast feeding. The fourth round of National Family Health Survey, conducted in 2015-2016, found that the prevalence of underweight, stunted and wasted children under- five was at 35.7, 38.4 and 21 percent, respectively. However, according to the data from the fifth round of National Family Health Survey (2019-2021) from the 22 states surveyed so far, only nine showed a decline in the number of stunted children, 10 in wasted children and six in underweight children. The percentage of stunted, wasted and underweight children increased or remained unchanged in the remaining states.

Despite decades of investment to tackle malnutrition, India's rates are still one of the most alarming in the world. The Global Hunger Index (2020) places India at 94th spot among 107 countries. The bane of child and maternal malnutrition is responsible for 15% of India's total disease burden.

Although breast feeding is the best choice for feeding the infants, it meets nutritional requirements of growing infant only up to six months. Thereafter, complementary feeding becomes a necessity for the optimum development of an infant. However, the capacity of a complementary diet to meet the protein and energy requirements of infants depends on its nutritional quality as well as its dietary bulk. This can be achieved through legume supplementation of cereal-based complementary foods. Complementary feeding, i.e. introduction of foods other than milk to an infant's diet, is a major step in the development of food behaviour, it represents a critical stage from both nutritional and behavioural standpoints, likely to affect the infant's growth and health (Sloan *et al.*, 2008).

Most of the requirement of complementary foods is met through commercially produced complementary foods prepared by various processes which are either complicated or too expensive as drum drying and extrusion cooking. Complementary foods, thus prepared are excellent and meet the maximum requirements of the infant. However, these marketed products are too expensive for the target groups who need such a product in developing countries. Therefore, it is need of the society to develop ways and means of developing economic but nutritionally excellent products within the reach of wider population using locally available staple grains. The process or technology of production should suitable for home or community kitchens and it should also be highly adaptable.

Till now sorghum has been used in the food preparations for the adults, animal fodder, alcoholic beverages, industrial applications, etc. There is a need to popularize its use for infant foods by applying several processing techniques and improving its nutritive value and thus formulating a home-based complementary food mix. The present study was planned with the objective to formulate and evaluate complementary food mix based on sorghum in combination with legumes and other ingredients to obtain optimum nutritional and organoleptic attributes.

Material and Methods

The present study was conducted in the Department of Food Science and Nutrition, College of Community and Applied Sciences, MPUAT, Udaipur. Sorghum variety CSV-23 was procured and malted (Fig. 1). Complementary food mix was prepared by mixing malted sorghum flour with other ingredients including

Sorghum
↓
Sorting
↓
Washing
↓
Draining
↓
Soaking
(24 hrs)
↓
Excess water was drained and grains left for germination (72 hrs)
↓
Water was sprinkled after every 4 hrs
↓
Oven drying (50°C for 24 hrs)
↓
Roots and shoots removed manually
↓
Grinding
↓
Sieving
↓
Making flour
↓
Packed in air tight container

Fig. 1. Preparation of Malted and Dried Sorghum flour.

malted chick pea flour, roasted rice flakes flour, whole milk powder and powdered sugar in different proportions given in Table 1.

The formulated complementary food was analysed for its chemical, physico-chemical, organoleptic and microbiological qualities (total bacterial count and yeast and mould count) using standard methods as detailed below.

Proximate composition

Moisture: Electronic moisture analyzer, (Sartorius, Germany, Model-MA 100) was used to determine moisture content of the flour (AOAC, 2012). Instrument was allowed to heat up for one hour. One gram of sample was placed in the instrument. Temperature was adjusted at 105°C for drying the sample. Automatic computation of the moisture per cent was displayed after completion of drying of the sample.

Crude protein: Crude protein was estimated in powdered moisture free samples using micro-kjeldahl method (Kel Plus nitrogen estimation unit, Make: Pelican) (NIN, 2003). The method involves digestion of 100 mg of sample in triplicate in a micro-kjeldahl flask with 2 mL conc. H_2SO_4 and 0.5 g digestion mixture (98 parts K_2SO_4+2 parts CuSO4) on a digestion rack till a clear solution is obtained. A reagent blank was run simultaneously. Next step is distillation by adding 10 mL of 40 per cent NaOH to the digested samples, which were then boiled. The steam liberated ammonia is collected in a conical flask containing 25 mL of boric acid (4%) with two drops of mixed indicator, till the distillate collected is about 15 mL. Last step is titration in which the content of the conical flask is titrated with 0.1 N HCl till an end point of pink color is reached. The amount of HCl used is noted as titer value and calculation is done as follows:

Nitrogen N% = *[14×0.1×(Titer value – Blank value)×100]/Weight of sample × 1000*

Crude Protein % = *Total nitrogen % × general factor 6.25*

Crude fat: Fat content of the sample was estimated by SOCS PLUS fat extraction unit (Make: Pelican). The crude fat was estimated by standard procedures (NIN, 2003).

Fat (g/100 g) = *[Weight of flask with extracted fat (g) – Weight of empty flask (g)] / [Weight of sample (g)] ×100*

Crude fiber: Crude fiber was determined after digesting a known weight of fat-free sample in refluxing 1.25% sulfuric acid and 1.25% sodium hydroxide.

Crude Fibre (g/100 g) = [Weight of residue(g)– Weight of ash (g)] / [Weight of sample (g)] ×100

Ash: Ash was determined by incineration (550°C) of known weights of the samples in a muffle furnace.

Ash (g/100 g) = [Weight of ash (g)] / [Weight of sample (g)] × 100

Carbohydrate: Carbohydrate content of sample can be determined by difference method i.e. sum of moisture, protein, crude fiber, fat and ash, subtracted from 100 (Gopalan *et al.*, 2004).

Carbohydrate content (g/100 g) = [100 - (moisture + crude protein + crude fiber + crude fat + total ash)]

Energy: The energy content of the food sample was determined by multiplying protein, fat and carbohydrate contents with their physiological fuel value as follows:

Energy content (kcal/100 g) = (%crude protein×4)+(%carbohydrate ×4) + (%crude fat × 9)

Organoleptic evaluation: The organoleptic qualities such as color, flavor, taste, appearance and overall acceptability were evaluated by panel of judges for assessing the acceptability of the product (Ranganna, 1986).

Physico-chemical properties

Bulk density: The bulk density of the flour samples was determined by using the method given by Singh *et al.* (2005). Sample is filled in a 100 mL graduated cylinder with gentle tapping. Cylinder is filled to the mark and weight of the mix is measured. Bulk density is expressed as mass by volume in gram per cm^3.

Water absorption capacity (WAC): Water absorption capacity of flour gives an indication of the amount of water available for gelatinization (Edema *et al*., 2005; Ghavidel and Prakash, 2010). It was determined using the method suggested by Sathe *et al*. (1982). Ten mL of water was added to 1.0 g (W_1) of each flour samples, kept at ambient temperature for 30 min and centrifuged at 3,500 rpm for 30 min. Excess water was decanted and each sample was allowed to drain by inverting the tube over absorbent water (W_2). The water absorbed was calculated as per cent water absorbed per gram of the flour.

Water absorption capacity (%) $=(W_2\text{-}W_1) / W_1 \times 100$

Water Solubility index: It determines the amount of free polysaccharide or polysaccharide released from the granule on addition of excess water (Anderson, 1969). One gram of sample was weighed into a centrifuge tube and 10 mL distilled water was added. The sample was then stirred gently with a stirring rod for 30 minutes. The tube containing the paste is centrifuged at 4000 rpm for 15 minutes. After completion, the supernatant was decanted into crucibles and dried in oven. The residue remaining in the tubes and crucible after drying were weighed. WSI is calculated as:

WSI = (weight of crucible after drying-weight of empty crucible) / (weight of sample) × 100

Swelling index: Swelling index is an important parameter since it determines the consistency of the diet. It refers to the expansion accompanying spontaneous uptake of solvent. Swelling index was carried out by weighing three gram of flour sample into clean, dry graduated 50 mL measuring cylinders. The flour sample was gently levelled and the volume was noted, before the addition of 30 mL distilled water. The cylinder was swirled manually and allowed to stand for 60 minutes while the change in volume (swelling) was recorded. The swelling index of sample flour was calculated as the final volume of sample in cylinder divided by the initial volume of sample in cylinder (Iwuoha, 2004).

Viscosity: Cold water slurries containing 20% sample solids were heated in a boiling water bath with constant stirring until boiling which was continued for three more minutes. They were cooled to room temperature and viscosity was measured with a Brookfield Synchro-electric Viscometer, using RVT Spindle number-one at a constant speed of 60 rpm. Conversion into centipoises (cps) units was done using the specific factor for spindle no. 1 (Quinn and Beauchat, 1988).

Wettability: The method given by Okezie and Bello (1988) was used to determine wettability of the flour samples. One gram of each sample was measured into a 10 cm^3 measuring cylinder. The cylinder was inverted at 10 cm above the water contained in a 600 mL beaker. Finger was used to close the cylinder disallowing the flour sample from falling. By removing the finger and giving the cylinder a gentle tap, the flour sample was discharged into the water surface.

The time taken by the sample to get completely wet was recorded as the time of wettability.

Microbiological examination: Complementary food mixes were examined for the presence of micro-organisms like total bacterial count (IS: 5402-2012) and yeast and mould (IS: 5403-1999) using standard procedure at zero to ninety days of storage period.

*Composition of agars***:** Plate Count Agar (PCA) media consisted of enzymatic digestion of Casein (5 g), yeast extract (2.5 g), D-Glucose (1 g), Agar (9-18 g) mixed in 1 litre of distilled water. For yeast and mould count, yeast extract (5 g), Dextrose (20 g), Chloramphenicol (0.1 g) and Agar (12-15 g) (YDCA) media was prepared in 1 litre distilled water.

Preparation of media: Both agar were weighed (1.2 to1.8 g- PCA and YDCA- 3.9 g) and dissolved in 100 mL distilled water by boiling. Media was transferred to screw capped media bottles and autoclaved at 121°C for 15 minutes.

Sterilization procedure: Cleaned, heat resistant glass wares like petri plates, pipettes, conical flasks, test tubes were sterilized in an oven at the temperature of 160-180°C for a period of 2 hours.

Counting of colonies: After the specified incubation period (Bacterial count-72 hours at 30°C and Yeast and mould count-70 to 90 hours at 25°C), the colonies on the plates are counted, using the colony counting equipment and colony forming unit (cfu) was calculated by using formula:

No. of colonies × dilution factor × 10 = cfu per gram of sample

Results and Discussion

The amount per serving of the formulated complementary food mix was calculated such that each gram of the mix provides one kcal as per the guidelines provided by Government of India regarding complementary feeding (Guidelines for Enhancing Optimal Infant and Young Child Feeding Practices, Govt. of India, 2013). One serving (35 g) of the formulated complementary food mix consisted of malted sorghum flour (10.5 g), malted chick pea flour (7 g), roasted rice flakes flour (3.5 g), powdered sugar (3.5 g) and whole milk powder (10.5 g) reconstituted with 30 mL water.

Organoleptic evaluation

Formulated complementary food mix were subjected to organoleptic evaluation on 9-point hedonic rating scale by panel of ten trained adult members, as they could give an accurate and objective judgement regarding the organoleptic characteristics. Regarding color, scores obtained by complementary food mix was 8.83±0.12. The formulated mix scored 8.83±0.11 in terms of taste attribute. The texture of formulated mix scored 8.60±0.01 i.e. "liked very much" by the panel members. Flavor of formulated mix was "liked very much" and the score was 8.73±0.12. The appearance of the formulated complementary food mix was "liked very much" by the panel members and was acceptable with overall acceptability scores of 8.71±0.05. The scores revealed that the formulated complementary food mix was "liked very much" by the judges.

Proximate composition

The proximate composition of the formulated complementary food mix including moisture, crude protein, crude fat, total ash, crude fibre, carbohydrate and energy were found to be 2.21±0.55g, 14.0± 0.01g, 3.74± 0.15 g, 2.26± 0.08 g, 0.35 ± 0.03 g 77.99±1.64g 401.03±0.06 kcal per 100 g on dry weight basis, respectively.

The results of the present study were comparable to the study by Parvin *et al.* (2014) on cereal based supplementary food for young children which had low ash contents (1.88g/100g), 0.58% crude fiber, 11.91 g/100g protein, 8.61g/100g fat, 74.39g/100 g carbohydrates and provided 433.9 kcal of energy per 100g on dry weight basis. In a study by Satter *et al.* (2013), developed instant weaning food contained the major nutrients like moisture, ash, fat, protein, fiber, carbohydrate and energy 2.43%, 2.26%, 11.32%, 15.98%, 1.06%, 75.35% and 456.6 kcal per 100 g, respectively.

The bulk density of the formulated mix was recorded to be 0.64±0.04gcm^{-3}. The low value for bulk density is attributed to the effect of malting on the grains. This finding is line with the study by Bhatia and Mogra (2013) on weaning mixes prepared from pearl millet and wheat, with the bulk density of the mixes ranging from 0.62 to 0.71 gcm^{-3}. High bulk density limits the caloric and nutrient intake per feed of a child which can result in growth faltering. In contrast, however, low bulk density would be an advantage in the formulation of complementary foods (Ugwu and Ukpabi, 2002). The low bulk density value (0.64 gcm^{-3}) recorded in this study could therefore be advantageous in complementary feeding.

Water absorption capacity is the ability of flour to absorb water and swell for improved consistency in food (Adepeju *et al*., 2014). Lower water absorption capacity is desirable for making thinner gruels. In the present study, the water absorption capacity of the formulated complementary food mix was 166.26±0.77%.

Water solubility index is related to the amount of soluble solids, which is often used as an indication of degradation of starch molecules and dextrinization (Dogan and Karwe, 2003). When water solubility is high it will make a fine paste and improve the mouth feel. Sugar and milk powder are added to increase the water solubility index (Griffith *et al*., 1998). The water solubility index of the formulated complementary mixes was 46.66±0.20.

Swelling index of the formulated complementary food mix was recorded as 1.38±0.01. Swelling causes changes in hydrodynamic properties of the food, thus impacting characteristics such as body, thickening and increase in viscosity to foods. Swelling index is an important parameter since it determines the consistency of the diet. According to WHO (2003), appropriate complementary diet is one which produce a gruel or porridge that is neither too thick for the infant to consume nor so thin that energy and nutrient density are reduced.

Thus, it can be concluded that formulated complementary food mix has lower swelling index and thus would deliver comparatively more energy and nutrients and may be more desirable for a complementary diet. Similar trend have been reported by earlier workers (Ikpeme -Emmanuel *et al*., 2012).

Microbiological parameters

Formulated mix was assessed for total bacterial count ($cfug^{-1}$) of surviving microbes for ninety days period. The total bacterial count at zero day was recorded as 45×10^1 $cfug^{-1}$. An increase was observed in the total bacterial count during thirty days storage from 45×10^1 to 48×10^2 $cfug^{-1}$. The presence of total bacterial count due the presence of viable organisms, which may be the contaminants from malted sorghum or malted legume flour, sugar and whole milk powder. These enumerated values are much lower than the ISI specification of maximum permissible level of total bacterial count of 1,00000 $cfug^{-1}$ for flour items (Indian Standards: 5402, 2012).

The yeast and mould count of the formulated mix was found to be <10 $cfug^{-1}$ during the entire storage period of 90 days. These enumerated values are much lower than the ISI specification of maximum permissible level of yeast and mould count of 1000 $cfug^{-1}$ for flour items (Indian Standards: 5403, 1999) up to three months of storage.

Conclusion

Thus, on the basis of above results, it can be concluded that the complementary food mix formulated in the present study, using malted sorghum flour was nutritionally sound for consumption by young children of weaning age to fulfill his/her nutritional requirements. The formulated complementary food mix, thus formulated, has superior nutritional and physico-chemical values and is well accepted organoleptically. Also it is microbiologically safe for consumption up to three months of storage. The complementary food mix is recommended as complementary food for young children from 6-24 months age, increasing the frequency of feed depending on the age.

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