Mysore J. Agric. Sci., 59 (4) : 203-212 (2025)

Formulation and Nutrient Analysis of an Infant Food Based on Barnyard Millet and *Amaranthus viridis* leaves

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Received : July 2025
Accepted : September 2025

ABSTRACT

Micronutrient enriched weaning foods are vital in addressing infant malnutrition by supplying essential nutrients for healthy growth and development. Barnyard millet, being a rich source of protein, iron and flavonoids with a gluten free nature, along with *Amaranthus viridis* leaves, abundant in calcium, iron and β carotene, were incorporated to develop value added weaning mixes. Formulations containing 1-5 per cent *A. viridis* leaf powder were prepared using barnyard millet, rice flakes, green gram and skim milk powder (40:25:20:15) along with a control. Among the formulations, the B4 sample with 3 per cent leaf powder and 40 per cent barnyard millet was most acceptable in sensory attributes. The B4 formulation provided 17.04 g protein, 1.95 g crude fiber, 66.93 g carbohydrate, 352.70 kcal energy, 6.78 mg iron, 288.56 mg calcium, 216.28 mg phosphorus, 2.52 mg zinc and 209.56 µg β carotene per 100 g. Phytochemical analysis showed improved total phenolic (242.74 mg FAE/100 g) and flavonoid content (186.11 mg CE/100 g), contributing to enhanced antioxidant potential. Microbial counts were negligible up to 120 days and within safe limits at 180 days, confirming storage stability. The findings demonstrate that *A. viridis* leaf fortified barnyard millet weaning foods are nutritionally enriched, functionally promising, sensorially acceptable and cost effective, making them suitable as complementary foods to combat malnutrition.

Keywords : Weaning food, Barnyard millet, *Amaranthus viridis*, β- carotene

WEANING foods are introduced to infants after six months in addition to breast milk to meet an infant's nutritional requirements (Dewey *et al*., 2003). According to the World Health Organization, weaning food should be timely, sufficient, appropriate and nutritionally adequate (WHO 2003). Most weaning foods commonly include wheat, which is associated with food allergies, celiac disease and stomach cramps. This highlights the need to develop alternative weaning foods by replacing wheat with easily digestible, fiber-rich ingredients. The introduction of millets can diversify an infant's diet and potentially reduce the risk of food allergies by exposing them to a range of grains and setting the stage for healthy eating habits, which support growth, immunity and development. Millets are light on the stomach and easy to digest when cooked properly, making them ideal for a baby's delicate digestive system. Millets offer a significant opportunity to enhance food and nutrition security while also creating avenues for product development, value addition, improved marketing and overall economic growth in millet production (Banu *et al.,* 2022). Millets are gluten-free and it has low glycemic index (Sukanya *et al.,* 2023).

Barnyard millet (*Echinochloa frumentacea*), a member of the Poaceae family, is cultivated in the semiarid tropics of Asia and Africa (Clayton *et al*., 2006). It is a great source of protein, dietary fiber and non-starchy polysaccharides and its low glycemic index and gluten-free nature make it a healthy choice for the sensitive digestive system of infants (Lorenz, 1983; Watanabe, 1999; Monteiro *et al*., 1987 and Krishna Kumari *et al*., 1998). *Amaranthus viridis* is a green leafy vegetable belonging to the Amaranthaceae family (Haider *et al*., 2023). It is known as slender amaranth or green amaranth in English and is referred to as *Tanduliya* or *Vishaghna* in Sanskrit and *Kilkeerae* in Kannada. The plant is a good source of calcium, phytosterols, polyphenols and β-carotene (Ahmed *et al*., 2013; Jayanetti *et al*., 2024 and Sarker *et al*., 2019). Mung dal is commonly referred to as a green gram dal and is a staple diet in many parts of the world for 3500 years (Kole, 2007). Nutritionally, it is a rich source of protein (20-25%) (Khattak *et al*., 2007). Owing to its low-cost protein, it is referred to as 'poor man's meat' (Potter *et al*., 1997). As green gram dal does not cause flatulence, it is recommended for incorporation in weaning foods. Rice flakes, locally known by various names such as aval, avalakki, poha, chivda and beaten rice, are derived from paddy (*Oryza sativa*) and serve as staple foods in India (Pollitt *et al*., 1978). They are rich in iron, vitamins and minerals (Sivakami *et al*., 2013). Skim milk powder (SMP), also known as nonfat dry milk (NDM) or dried skim milk (DSM), is a low-fat product containing 0.8 g of fat per 100 g. SMP is highly nutritious and serves as an excellent source of high-quality protein, providing 36 g per 100 g with a well-balanced profile of essential amino acids (Hoffman *et al*., 2004).

The present study was conducted to develop weaning food from Barnyard Millet enriched with *Amaranthus viridis (*Kilkeerae) and to analyze the sensory attributes, functional properties, nutritional and anti-nutritional characteristics and storage studies of the developed weaning food.

Material and Methods

Barnyard millet, green gram dal, rice flakes, skim milk powder and *Amaranthus viridis* leaves were purchased from a local market in Mysuru. A series of weaning food formulations using barnyard millet as a partial substitute for rice flakes were formulated. The control formulation (RF- Rice flakes) was based solely on rice flakes, whereas six experimental formulations (B1 to B6) were developed by partially replacing the rice flakes with barnyard millet flour (Table 1). Barnyard millet was soaked for 30 min, pressure cooked for 12 min, dehydrated in a hot air oven at 110°C for 6-7 h, milled to flour and sieved through a 200-mesh size (Fig. 1). In these formulations, the concentration *Amaranthus viridis* leaf powder was varied from 1 to 5 per cent (Fig. 2). Each formulation also contained roasted green gram dal flour and skim milk powder. To prepare the weaning food, organic jaggery was added and the mixture was cooked with water (150 mL of water per 25 g of weaning food) for 10 minutes on medium flame.

Sensory Analysis : The sensory evaluation of the weaning food was conducted using the nine-point hedonic scale to measure preference levels (Amerine *et al*., 1965). The semi trained panelist (M.Sc.students) and nursing mothers of

Table 1

Weaning food formulations by incorporating Barnyard millet and *Amaranthus viridis* leaf powder

Ingredients (g)	Control	B1	B2	B3	B4	B5	B6
Barnyard Millet flour	00	40	40	40	40	40	40
Rice flakes flour	65	25	25	25	25	25	25
Green Gram Dal flour	20	20	20	20	20	20	20
Skim Milk Powder	15	15	15	15	15	15	15
Amaranthus viridis leaf powder	0	0	1	2	3	4	5

Control- Rice flakes weaning food; B1- 0%; B2- 1%; B3- 2%; B4- 3%; B5- 4%; B6- 5%

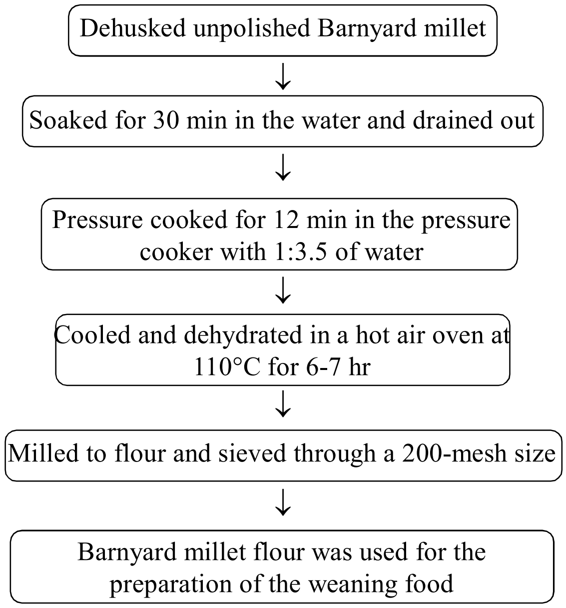

Fig. 1 : Method of preparation of Barnyard millet flour

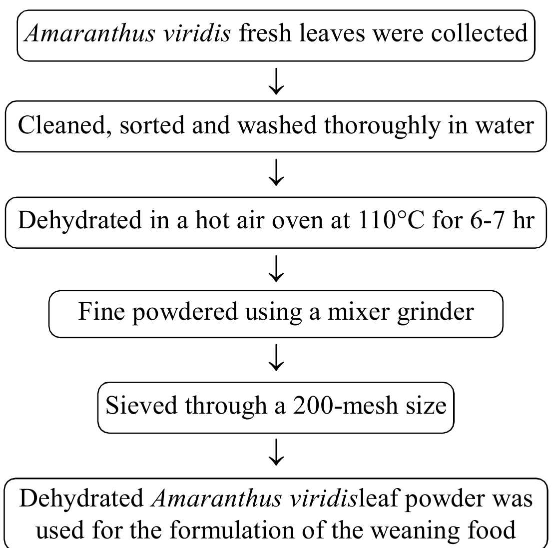

Fig. 2 : Method of preparation of *Amaranthus viridis* leaf powder

15 members each carried out the sensory analysis for the prepared Barnyard millet-based weaning food and scores were given keeping the rice flakes-based weaning food as a control.

Functional Properties : The Oil absorption capacity (OAC) and water absorption capacities (WAC) of the samples were measured using the centrifugation method outlined by Lin *et al.,* (1974) and Thilagavathi *et al.* (2015) respectively. Bulk density was determined by the method given by Pritham (2021).

Nutrients Analysis : Moisture, crude fiber, fat and protein contents were quantified *via.,* standard AOAC methods. Carbohydrates were computed by difference. The samples were incinerated in a muffle furnace to obtain dry ash, from which an ash solution was prepared and the minerals were analyzed by AOAC methods. Beta-carotene was also determined by standard AOAC methods (AOAC, 2005).

Anti-nutritional and Phytochemical Analysis : Phytates was analyzed as phytate phosphorous by the method of Gao *et al*. (2007). Oxalates were determined by titrimetric method explained by Day and Underwood (1986). Tannins, TPC, TFC were analyzed by standard AOAC methods (AOAC, 2005).

Microbial Studies : The samples were stored in the laboratory for 180 days in sealed aluminium foil packaging material and the microbial load of the stored samples were enumerated once in 60 days for Total bacterial count (TBC) and Total yeast and mold count (TYM) by the method of Thambekar *et al.* (2009).

Statistical Analysis : All determinations were conducted in three replicates. The results were expressed as mean values along with their standard deviations. Data analysis was performed using one-way analysis of variance (ANOVA), followed by Duncan's Multiple Range Test (Duncan, 1955) for multiple comparisons of treatment means. Differences were considered statistically significant at $P< 0.05$.

Results and Discussion

Nutritional Composition of Processed Barnyard Flour and Amaranthus viridis Leaf Powder : The nutrient comparison between processed barnyard millet flour and *A. viridis* leaf powder highlights their complementary nutritional profiles. Barnyard millet flour contains moderate moisture (10.98 g), fat (3.05 g) and protein (9.52 g), with substantial carbohydrate (61.40 g) and energy (311.13 kcal), along with notable levels of iron (10.25 mg),

TABLE 2

Nutrient content of processed Barnyard millet flour and *Amaranthus viridis* leaf powder*

Nutrients	Processed Barnyard millet flour	*Amaranthus viridis* leaf powder
Moisture (g)	10.98 ± 0.13 [a]	5.43 ± 0.09 [b]
Fat (g)	3.05 ± 0.04 [b]	5.26 ± 0.05 [a]
Protein (g)	9.52 ± 0.20 [b]	24.11 ± 0.03 [a]
Crude fiber (g)	2.46 ± 0.25 [b]	5.83 ± 0.10 [a]
Ash (g)	3.35 ± 0.16 [b]	5.60 ± 0.09 [a]
Carb (g)	61.40 ± 0.05 [a]	51.03 ± 0.08 [b]
Energy (Kcal)	311.13 ± 0.11 [b]	347.63 ± 0.04 [a]
Iron (mg)	10.25 ± 0.09 [b]	23.00 ± 0.08 [a]
Calcium (mg)	19.28 ± 0.10 [b]	2195.06 ± 0.12 [a]
Phosphorous (mg)	212.05 ± 0.08 [a]	57.01 ± 0.15 [b]
Magnesium (mg)	17.06 ± 0.05 [b]	493.18 ± 0.03 [a]
Zinc (mg)	4.21 ± 0.10 [a]	1.54 ± 0.12 [b]
Copper (mg)	0.46 ± 0.13 [b]	1.38 ± 0.09 [a]
Beta-carotene (µg)	-	6185.26 ± 0.22 [a]

*Values are expressed as mean ± standard deviation (n=3). All mean scores bearing different superscripts in rows are significantly different on application of Duncan's Multiple Range Test ($P < 0.05$)

phosphorus (212.05 mg) and zinc (4.21 mg). In contrast, *A. viridis* leaf powder is richer in protein (24.11 g), fat (5.2 g), crude fiber (5.83 g), ash (5.60 g) and energy (347.63 kcal) but has lower carbohydrate content (51.03 g). It is also exceptionally high in calcium (2195.06 mg) and magnesium (493.18 mg) and contains abundant beta-carotene (6185.26 µg). The elevated beta-carotene, calcium and protein content in *A. viridis* suggests it is a potent source of micronutrients and antioxidants, complementing barnyard millet's carbohydrate and mineral contributions, thereby enhancing the nutritional density of combined formulations. These differences align with reported literature that barnyard millet offers good macro and mineral nutrition while *A. viridis* serves as an exceptional source of calcium, beta-carotene and protein.

Sensory Analysis : The sensory evaluation of the weaning food formulations showed a gradual decrease in scores across all attributes with increasing levels of *A. viridis* leaf powder (Table 3). The control formulation exhibited the highest scores for appearance (8.51), color (8.40), consistency (8.32), taste (8.61), flavor (8.36), mouth feel (8.42) and overall acceptability (8.53). Formulations with low to moderate leaf powder supplementation (B1 to B4) maintained relatively high sensory scores, with B1 showing scores close to the control (overall acceptability 8.16) and B4 still exhibiting acceptable levels (7.67). However, at higher inclusion levels (B5 and B6), a marked decline was observed in all sensory attributes, with overall acceptability dropping to 6.87 and 6.45, respectively. This indicates that while small amounts of *A. viridis* leaf powder do not adversely affect sensory quality, higher concentrations negatively influence consumer perception, particularly in taste, flavor and mouth feel, emphasizing that formulations up to 3 per cent leaf powder strike an optimal balance between nutrition and sensory appeal.

Functional Properties of Weaning Food : Functional properties was carried out for the control (RF) and

TABLE 3

Sensory scores of weaning food formulations by incorporating Barnyard millet and *Amaranthus viridis* leaf powder*

Attributes	Control	B1	B2	B3	B4	B5	B6
Appearance	8.51 ± 0.11 [a]	8.22 ± 0.12 [a]	7.89 ± 0.11 [a]	7.63 ± 0.11 [ab]	7.54 ± 0.14 [b]	6.84 ± 0.19 [b]	6.32 ± 0.19 [b]
Colour	8.40 ± 0.13 [a]	8.13 ± 0.13 [a]	7.94 ± 0.12 [a]	7.88 ± 0.13 [ab]	7.76 ± 0.19 [b]	6.86 ± 0.12 [b]	6.61 ± 0.14 [b]
Consistency	8.32 ± 0.12 [a]	8.14 ± 0.15 [a]	7.99 ± 0.15 [a]	7.80 ± 0.15 [ab]	7.72 ± 0.13 [b]	6.82 ± 0.14 [b]	6.50 ± 0.12 [b]
Taste	8.61 ± 0.13 [a]	8.03 ± 0.12 [a]	7.80 ± 0.12 [a]	7.77 ± 0.14 [ab]	7.68 ± 0.11 [b]	6.98 ± 0.13 [b]	6.01 ± 0.19 [b]
Flavour	8.36 ± 0.15 [a]	8.08 ± 0.14 [a]	7.92 ± 0.12 [a]	7.86 ± 0.13 [ab]	7.79 ± 0.15 [b]	6.79 ± 0.15 [b]	6.90 ± 0.15 [b]
Mouth Feel	8.42 ± 0.15 [a]	8.11 ± 0.15 [a]	7.89 ± 0.14 [a]	7.71 ± 0.19 [ab]	7.66 ± 0.11 [b]	6.76 ± 0.14 [b]	6.39 ± 0.13 [b]
Overall Acceptability	8.53 ± 0.17 [a]	8.16 ± 0.18 [a]	7.89 ± 0.16 [a]	7.72 ± 0.14 [ab]	7.67 ± 0.13 [b]	6.87 ± 0.11 [b]	6.45 ± 0.14 [b]

*Values are expressed as mean ± standard deviation (n=3). All mean scores bearing different superscripts in rows are significantly different on application of Duncan's Multiple Range Test ($P < 0.05$). Control- Rice flakes weaning food; B1- 0%; B2- 1%; B3- 2%; B4- 3%; B5- 4%; B6- 5%

TABLE 4

Functional properties of the best accepted weaning food formulated with Barnyard millet and *Amaranthus viridis* leaf powder *

Weaning food formulations	Control	B1	B4
WAC (g/ml)	1.09 ± 0.02 [c]	1.43 ± 0.01 [b]	1.60 ± 0.05 [a]
OAC (g/ml)	0.95 ± 0.02 [b]	1.19 ± 0.03 [a]	1.20 ± 0.02 [a]
Bulk density (g/ml)	0.63 ± 0.02 [a]	0.60 ± 0.02 [a]	0.54 ± 0.01 [b]

* Values are expressed as mean ± standard deviation (n=3); Control- Rice flakes weaning food; B1 - 0%; B2 - 1%; B3- 2%; B4- 3%; B5- 4%; B6- 5%; WAC- Water absorption capacity, OAC- Oil absorption capacity. All mean scores bearing different superscripts in rows are significantly different on application of Duncan's Multiple Range Test ($P < 0.05$)

the selected variations B1 (0%) and B4 (3%) (Table 2). Water absorption capacity (WAC) of the weaning food formulations ranged from 1.09 to 1.60 g/ml. Higher WAC values in B1 and B4 may be attributed to the presence of dietary fiber and starch degradation during processing, enhancing the water-binding capacity of the flour. Oil absorption capacity (OAC) varied from 0.95 to 1.20 g/ml. B4 exhibited the highest OAC. The improved oil absorption in the formulations may enhance mouth feel and flavor retention in the final product. Bulk density ranged from 0.54 to 0.63 g/ml. Lower bulk density in B4 indicate better suitability for infant feeding and it can be more nutrient-dense formulations with reduced volume per serving. These values are similar to values reported by Bala and Nazni (2018) for barnyard millet-based weaning food.

Proximate Composition : Proximate analysis was carried out for the control (RF) and the best accepted variations B1 (0%) and B4 (3%) (Table 5).

The proximate composition of the weaning food formulations showed variation among Control, B1 (0%) and B4 (3%) samples. Moisture content was highest in the control (3.40 g) and slightly lower in B1 (3.20 g) and B4 (3.23 g). Fat content increased with leaf powder addition, from 0.94 g in control to 1.87 g in B4. Protein content similarly increased from

TABLE 5

Proximate composition of the best accepted weaning food formulated with Barnyard millet and *Amaranthus viridis* leaf powder (per 100g on dry weight basis) *

Weaning food formulations	Control	B1	B4
Moisture (g)	3.40 ± 0.03 [a]	3.20 ± 0.05 [b]	3.23 ± 0.02 [b]
Fat (g)	0.94 ± 0.12 [c]	1.73 ± 0.10 [b]	1.87 ± 0.10 [a]
Protein (g)	14.32 ± 0.05 [c]	16.11 ± 0.09 [b]	17.04 ± 0.05 [a]
Crude fiber (g)	1.51 ± 0.24 [c]	1.82 ± 0.15 [b]	1.95 ± 0.21 [a]
Ash (g)	2.09 ± 0.05 [c]	3.10 ± 0.06 [b]	3.26 ± 0.10 [a]
Carbohydrate (g)	75.12 ± 0.18 [a]	68.44 ± 0.12 [b]	66.93 ± 0.09 [c]
Energy (Kcal)	366.20 ± 0.04 [a]	353.80 ± 0.03 [b]	352.70 ± 0.02 [b]

*Values are expressed as mean ± standard deviation (n=3). Control- Rice flakes weaning food; B1- 0%; B4- 3%. All mean scores bearing different superscripts in rows are significantly different on application of Duncan's Multiple Range Test ($P < 0.05$)

14.32 g in control to 17.04 g in B4, reflecting the contribution of protein-rich *A. viridis*. Crude fiber and ash content also showed an increasing trend, with B4 having the highest values (1.95 g and 3.26 g, respectively). Carbohydrate content decreased from 75.12 g in control to 66.93 g in B4, while energy content was slightly lower in B1 (353.80 Kcal) and B4 (352.70 Kcal) compared to the control (366.20 Kcal). These results demonstrate that supplementation with 3 per cent *A. viridis* leaf powder improves protein, fat, crude fiber and ash content, contributing to enhanced nutritional quality of the weaning food formulation.

Bala and Nazni (2018) formulated a weaning food using barnyard millet and soybean flour and reported proximate composition values comparable to those observed in the present study. Similarly, Prasanna *et al.* (2020) developed millet-based weaning food and recorded similar results in proximate analysis. Ghavidel *et al.* (2010) also formulated complementary food using a combination of cereals and legumes, reporting moisture and protein contents in line with the present findings, although their formulations showed comparatively lower fat and dietary fiber levels.

Micronutrient Composition : The micronutrient content of the best accepted weaning food formulated with Barnyard millet and *Amaranthus viridis* leaf powder is given in Table 6.

The mineral and beta-carotene analysis revealed significant improvements in nutrient content in the weaning food formulation supplemented with 3 per cent *A. viridis* leaf powder (B4) compared with the control and B1. Iron content increased significantly from 3.71 mg in the control to 6.78 mg in B4, potentially enhancing the formulation's ability to combat iron-deficiency anemia. Calcium showed a marked rise from 218.55 mg to 288.56 mg, reflecting the rich mineral profile of *A. viridis*, which is known for its exceptional calcium content. Phosphorus content also increased modestly with supplementation. Magnesium was highest in B4 but showed a decrease in B1 compared to control, indicating variability in mineral retention. Zinc and copper levels were significantly elevated in B4, suggesting enhanced trace mineral nutrition important for immune function and growth. Notably, beta-carotene content showed a dramatic increase in B4 (209.56 µg) compared to negligible values in control and B1, highlighting the formulation's improved pro-vitamin A potential. These enhancements demonstrate that *Amaranthus viridis* leaf powder fortification effectively augments the mineral and antioxidant quality of weaning foods, contributing to improved nutritional adequacy crucial

TABLE 6

Micronutrient composition of the best accepted weaning food formulated with Barnyard millet and *Amaranthus viridis* leaf powder (per 100g) *

Weaning food formulations	Control	B1	B4
Iron (mg)	3.71 ± 0.02 [c]	6.09 ± 0.04 [b]	6.78 ± 0.06 [a]
Calcium (mg)	218.55 ± 0.01 [c]	222.71 ± 0.05 [b]	288.56 ± 0.09 [a]
Phosphorus (mg)	206.16 ± 0.20 [c]	214.57 ± 0.18 [b]	216.28 ± 0.13 [a]
Magnesium (mg)	77.53 ± 0.03 [b]	55.08 ± 0.16 [c]	69.88 ± 0.08 [a]
Zinc (mg)	1.33 ± 0.01 [c]	2.47 ± 0.02 [b]	2.52 ± 0.02 [a]
Copper (mg)	0.32 ± 0.25 [c]	0.42 ± 0.18 [b]	0.46 ± 0.21 [a]
Beta-carotene (µg)	24.01 ± 0.03 [b]	24.01 ± 0.01 [b]	209.56 ± 0.06 [a]

*Values are expressed as mean ± standard deviation (n=3). Control- Rice flakes weaning food; B1- 0%; B4- 3%. All mean scores bearing different superscripts in rows are significantly different on application of Duncan's Multiple Range Test ($P < 0.05$)

for infant and toddler health. Bala and Nazni (2018) reported a mineral composition which aligns with the present study in weaning food formulated with barnyard millet and soybean flour.

Anti-Nutritional and Phytochemical Profile of Weaning Food Formulations : The Anti-Nutritional and Phytochemical Profile of the best accepted weaning food is given in Table 7.

For phytates, the control (0.09 mg/100g) showed significantly lower levels than B4 (0.14 mg/100g), while B1 (0.12 mg/100g) was intermediate. Similarly, oxalates were lowest in the control (0.65 mg/100g), followed by B1 (0.73 mg/100g), with B4 recording the highest value (0.82 mg/100g). A marked increase in tannin content was observed in the formulations compared to the control. The control (0.10 mg/100g) was significantly lower, whereas B1 (1.24 mg/100g) and B4 (1.39 mg/100g) exhibited higher concentrations. For total phenolic content (TPC) and total flavonoid content (TFC), the formulations (B1 and B4) recorded significantly higher values than the control. Among the treatments, B4 (246.08 mg FAE/100g TPC; 187.98 mg CE/100g TFC) showed the maximum concentration, followed by B1, while the control had negligible levels. Bala

TABLE 7

Anti-Nutritional and Phytochemical Profile of the best accepted weaning food formulated with Barnyard millet and *Amaranthus viridis* leaf powder *

Weaning food formulations	Control	B1	B4
Phytates (mg/100g)	0.09 ± 0.14 [c]	0.12 ± 0.09 [b]	0.14 ± 0.08 [b]
Oxalates (mg/100g)	0.65 ± 0.02 [c]	0.73 ± 0.01 [b]	0.82 ± 0.03 [a]
Tannins (mg/100g)	0.10 ± 0.21 [c]	1.24 ± 0.18 [b]	1.39 ± 0.19 [b]
TPC (mg FAE/100g)	4.79 ± 0.02 [c]	238.71 ± 0.01 [b]	246.08 ± 0.02 [a]
TFC (mg CE/100g)	3.26 ± 0.09 [c]	181.10 ± 0.07 [b]	187.98 ± 0.09 [a]

*Values are expressed as mean ± standard deviation (n=3). Control- Rice flakes weaning food; B1- 0%; B4- 3%; TPC- Total phenolic content; TFC- Total flavonoid content.All mean scores bearing different superscripts in rows are significantly different on application of Duncan's Multiple Range Test ($P < 0.05$)

and Nazni (2018) formulated a weaning food using barnyard millet and soybean flour and reported anti-nutrient values that contrast with the present study. Tesby *et al.* (2019) developed a rice-based weaning food and noted a low phytic acid content.

Microbial Studies of the Best Accepted Barnyard Millet-based Weaning Food Formulation : The microbial analysis of the stored samples is presented in Table 8. In all samples (Control, B1 and B4), the initial microbial load (0 and 60 days) was negligible, with total bacterial counts (TBC) remaining below detectable levels (<10 cfu/g) and no growth observed for yeast and mold (TYM). By 120 days of storage, there was a slight increase in bacterial counts, ranging from 2.91×10^2 to 3.24×10^2 cfu/g, while yeast and mold counts remained undetectable across all treatments. At 180 days of storage, TBC showed further increases, recording 6.50×10^2 cfu/g in the control, 6.86×10^2 cfu/g in B1 and 6.92×10^2 cfu/g in B4. In contrast, yeast and mold growth was first detected at this stage, with values of 1.50×10^2, 1.56×10^2, and 1.63×10^2 cfu/g in the control, B1 and B4 samples, respectively.

Overall, bacterial growth was minimal up to 120 days, while both bacterial and fungal populations increased moderately by 180 days. The microbial loads, however, remained within generally acceptable limits for stored cereal based products. The present study meets the Food Safety and Standard Regulations (FSSR, 2010) for the permissible microbial load for the weaning food.

Cost Analysis of the Best Accepted Barnyard Millet-based Weaning Food Formulation (B4) : The estimated cost of barnyard millet-based weaning food with the incorporation of 3 per cent *A. viridis* leaf powder (B4) is approximately Rs.35/100g (Table 6). The present cost of commercially available cereal-based weaning food in the Indian market is Rs.88/100g. Hence, weaning food prepared from barnyard millet with 3 per cent incorporation of *A. viridis* leaf (B4) powder is economically viable compared with the commercially available one offering a nutrient-dense infant food at a reasonable cost. Rushikesh *et al.* (2022) developed a weaning food using ragi, green gram and rice, reporting higher cost economics compared to the present study. Similarly, Prasanna *et al.* (2020) formulated millet-based weaning food with cost values also exceeding those observed in the current formulation.

The development of micronutrient-enriched weaning food incorporating Barnyard millet and *Amaranthus viridis* leaf powder proved effective in enhancing the nutritional quality essential for infant growth and development. The optimized formulation with 3 per cent *A. viridis* leaf powder (B4) demonstrated superior protein, mineral and antioxidant content, particularly in iron, calcium, zinc and β carotene, while maintaining acceptable sensory characteristics and

TABLE 8

Microbial studies of the best accepted weaning food formulated with Barnyard millet and *Amaranthus viridis* leaf powder

Storage days	Control		B1		B4	
	TBC	TYM	TBC	TYM	TBC	TYM
00	<10	Nil	<10	Nil	<10	Nil
60	<10	Nil	<10	Nil	<10	Nil
120	2.91×10^2	Nil	3.21×10^2	Nil	3.24×10^2	Nil
180	6.50×10^2	1.50×10^2	6.86×10^2	1.56×10^2	6.92×10^2	1.63×10^2

Control- Rice flakes weaning food; B1- 0%; B4- 3%; TBC- Total Bacterial count; TYM- Total Yeast and mold count. All the values are expressed in cfu/g microbial stability during storage. These attributes, combined with cost-effectiveness, highlight the potential of *A. viridis* leaf-fortified barnyard millet formulations as a promising complementary food option to alleviate malnutrition in infants.

References

Ahmed, S. A., Hanif, S. and Iftkhar, T., 2013, Phytochemical profiling with antioxidant and antimicrobial screening of *Amaranthus viridis* L. leaf and seed extracts. *Open Journal of Medical Microbiology,* **3** (3) : 164 - 171. https://doi.org/10.4236/OJMM.2013.33025.

Amerine, M. A., Pangborn, R. M. and Roessler, E. B., 1965, *Principles of sensory evaluation of food.* Academic Press.

AOAC., 2005, Official methods of analysis, Association of official analytical chemists, 8thed. Washington, D. C., USA, 2 - 38.

Bala, I. and Nazni, P., 2018, Physical, chemical, nutritional evaluation and sensory acceptability of barnyard millet and soybean based weaning food mixes. *International Journal of Food Science and Nutrition*, **3** (4) : 123 - 129. ISSN/ 2455 4898.

Banu, A., Ganapathy, M. S., Gowda, V. G., Siddayya, Girish, M. R., Begum, S. and Mohan Kumar, T. L., 2022, Value chain analysis of minor millets for improving economic status of farmers in Tumakuru District of Karnataka. *Mysore J. Agric. Sci.*, **56** (4) : 51 - 60.

Clayton, W. D. and Renvoize, S. A., 2006, *Genera Graminum: Grasses of the world.* Royal Botanic Gardens, Kew.

Day, R.A. and Underwood A. L., 1986, Quantitive analysis 5th ed. *Prentice. Hall publication,* pp. : 701.

Dewey, K. G. and Brown, K. H., 2003, Update on technical issues concerning complementary feeding of young children in developing countries and implications for intervention programmes. *Food and Nutrition Bulletin,* **24** (1) : 5 - 28.

Duncan, D. B., 1955, Multiple range and multiple F-test. *Biometrics*, **11** : 1 - 42.

FSSR., 2010, Processed cereal based complementary food. Food Safety and Standard Regulations. 5.1.9 (4)

Gao, Y., Shang, C., Maroof, M. S., Biyashev, R. M., Grabau, E. A., Kwanyuen, P. and Buss, G. R., 2007, A modified colorimetric method for phytic acid analysis in soybean. *Crop science*, **47** (5) : 1797 - 1803.

Ghavidel, R. A. and Prakash, J., 2010, Composite weaning mixes: formulation and quality characteristics. *Food science and technology research*, **16** (1) : 65 - 70.

Haider, A., Ikram, M., Fatima, U. and Javed, A., 2023, Pharmaceutical activity of medicinal plant *Amaranthus viridis* Linn. due to its chemical constituents: A review. *Bioeduscience,* **7** (2) : 143 - 148. https://doi.org/10.22236/JBES/12089

Hoffman, J. R. and Falvo, M. J., 2004, Protein: Which is best? *Journal of Sports Science and Medicine,* **3** : 118 - 130.

Jayanetti, M., Arampath, P. C. and Thambiliyagodage, C. J., 2024, Determination of nutritional composition, enzyme inhibitory activity and antioxidant activity of pretreated, dehydrated *Amaranthus viridis* L. leaves. *Journal of Science of the University of Kelaniya,* **17** (1).

Khattak, A. and Bibi, N., 2007, Quality assessment and consumer acceptability studies of newly evolved mungbean genotypes (*Vigna radiata* L.) [Report].

Kole, C., 2007, *Pulses, sugar and tuber crops* (Vol. 3). Springer Science & Business Media.

Krishna Kumari, S. and Thayumanavan, B., 1998, Characterization of starches of proso, foxtail, barnyard, kodo and little millets. *Plant Foods for Human Nutrition,* **53** : 47 - 56.

Lin, J. Y. and E. S. Humbert., 1974, Certain functional properties of sun flower meal products. *Journal of Food Science,* **39** (2) : 368 - 370.

Lorenz, K., 1983, Tannin and phytate content of proso millets (*Panicum miliaceum*). *Cereal Chemistry,* **60** : 424 - 426.

MONTEIRO, P. V., SUDHARSHANA, L. AND RAMACHANDRA, G., 1987, Japanese barnyard millet (*Echinochloa frumentacea*): Protein content, quality and SDS PAGE of protein fractions. *Journal of the Science of Food and Agriculture,* **43** : 17 - 25.

POLLITT, E., GERSOVITZ, M. AND GARGIULO, M., 1978, Educational benefits of the United States school feeding program: A critical review of the literature. *American Journal of Public Health,* **68** : 477 - 481.

POTTER, N. N. AND HOTCHKISS, J. H., 1997, *Food science.* CBS Publishers.

PRASANNA, M. S., SOWJANYA, V. S., JAYA, E. AND RAJENDER, G., 2020, Development of millet based instant weaning mix. *Journal of Pharmacognosy and Phytochemistry*, **9** (4) : 1908 - 1913.

PRITHAM, S. M., 2021, Processing and value addition of quinoa (*Chenopodium quinoa* wild) *Ph.D. Thesis* (Unpub.), Univ. Agric. Sci., Bangalore.

RUSHIKESH S. JADHAVAR., SWAPNIL G. JAISWAL. AND DEEPAK T. BORNARE., 2022, Development of weaning food premixes for infants based on ragi, green gram and rice. *Int J. Food Nutr. Sci.,* **11** : 96 - 104.

SARKER, U. AND OBA, S., 2019, Nutraceuticals, antioxidant pigments and phytochemicals in the leaves of *Amaranthus spinosus* and *Amaranthus viridis* weedy species. *Scientific Reports,* **9** (1) : 1 - 10. https://doi.org/10.1038/s41598-019-50977-5

SIVAKAMI, P. L. S. AND SAROJINI, K. S., 2013, Formulation of value-added biscuits using defatted coconut flour. *American Journal of Food Technology,* **8** : 207 - 212.

SUKANYA, T. S., KUMAR, A., SATHYA, K., CHAITHRA, C., NARAYANAN, A. L., ANAND, M. R. AND NAG, N. K., 2023, Nutricereals Role in Indian Agriculture, Food and Nutritional Security: A Review. *Mysore J. Agric. Sci.*, **57** (2).

TAMBEKAR, D. H., MURHEKAR, S. M., DHANORKAR, D. V., GULHANE, P. B. AND DUDHANE, M. N., 2009, Quality and safety of street vended fruit juices: a case study of Amravati city, India. *Journal of Applied Biosciences*, **14** (1997 - 5902), 782 - 7.

TESBY MOHAMED, R. L., ASTEER VICTOR, A. E., ZAKI MAHFOUZ, M. AND KHALED SHAFIK, A., 2019, Preparation and evaluation of some weaning foods made from rice and legumes. *Alexandria Journal of Agricultural Sciences*, **64** (1) : 1 - 9.

THILAGAVATHI, T., KANCHANA, S., BANUMATHI, P., HEMALATHA, G., VANNIARAJAN, C., SUNDAR, M. AND ILAMARAN, M., 2015, Physico-chemical and functional characteristics of selected millets and pulses. *Indian Journal of Science and Technology*, **8** (S7) : 147 - 155.

WATANABE, M., 1999, Antioxidative phenolic compounds from Japanese barnyard millet (*Echinochloa utilis*) grains. *Journal of Agricultural and Food Chemistry,* **47** : 4500 - 4505.

WORLD HEALTH ORGANIZATION. (2003). *Diet, nutrition and the prevention of chronic diseases: Report of a joint WHO/FAO expert consultation.* World Health Organization.