Reduction in phytic acid content and enhancement of antioxidant properties of nutricereals by processing for developing a fermented baby food

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Abstract Cereal blends containing pearl millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*) and oat (*Avena sativa*) in different ratios were processed (roasted and germinated) and also used as unprocessed flours followed by fermentation with *Lactobacillus* sp. (*Lactobacillus casei* and *Lactobacillus plantarum*). They were screened for total phenolic content (TPC), phytic acid content (PAC) and free radical scavenging activity (FRSA). A formulation with the highest TPC, FRSA and the lowest PAC was selected to optimize a nutricereal based fermented baby food containing selected fermented cereal blends (FCB), rice-corn cooked flour (RCF), whole milk powder (WMP), whey protein concentrate (WPC) and sugar. The optimized baby food formulation contained 37.41 g 100 g⁻¹ FCB, 9.75 g 100 g⁻¹ RCF, 27.84 g 100 g⁻¹ WMP, 5 g 100 g⁻¹ WPC and 20 g 100 g⁻¹ sugar. It had high protein, vitamin, minerals, as well as good quantity of carbohydrates and fat, to fulfil the nutritional needs of preschool children of age 1–3 years. The nutricereal based fermented baby food showed high water absorption capacity, dispersibility, wettability and flowability indicating good reconstitution properties.

Keywords Cereal blends · Free radical scavenging activity · Functional properties · Phytic acid content · Total phenolic content

Introduction

The period from 4 to 6 months to 3 years is considered as weaning period, believed to be the most critical in the life of infants and preschool children (Egounlety 2002). During this phase, breast milk, which is considered as an ideal baby food, no longer meets the increasing needs of the growing child. Thus, complementary foods are usually given to the infants to fulfil the paucity of nutrition. It essentially needs to supply sufficient energy and nutrients to support the rapid growth of the infants. Inadequacy of energy and nutrient intake adversely affects the organ development and cellular function of the infant later in life (SCF 2003).

In developing countries, complementary foods are often based on local staple foods, usually cereals that are processed into porridges (Egounlety 2002). Coarse cereals, more appropriately called ‘nutricereals’ are regarded as one of the most significant sources of dietary proteins, carbohydrates, vitamins, minerals and fibre. However, the nutritional quality of these cereals and the organoleptic properties of their products are inferior in comparison with milk and milk products. This may be due to their lower protein content, the deficiency of certain essential amino acids, low starch availability, the presence of antinutrients, such as phytic acids (myo-inositol 1,2,3,4,5,6 hexakis [dihydrogen phosphate]), and the coarseness of the grains (Blandino et al. 2003). The antinutrient components are limiting factors for utilization of these nutrient rich cereals in the human diet. Phytic acid strongly binds minerals such as iron and zinc, making them unavailable for absorption in the body (Lopez et al. 2002; Beevi et al. 2010; Sanz-Penella et al. 2012). These minerals are needed in large amounts during the accelerated growth phase of life and thus bioavailability of these nutrients needs to be ensured. It is established that processing of raw grains, seeds and legumes with techniques such as soaking, cooking, germination and fermentation, help reduce the antinutrient factors in the foods (Sinha and Kawatra 2003).

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Germination and fermentation are considered as superior options (Rasha Mohamed et al. 2011). During germination, the phytase activity in grains increases, leading to a decrease in the content of phytic acid (Abdelrahman et al. 2007). Fermentation is known to improve the nutritional and sanitary quality of the food (Nout 2009). Lactic acid fermentation of different cereals such as maize, sorghum and pearl millet effectively reduces the amount of antinutrients such as phytic acid by activating phytase enzymes (Greiner and Konietzny 2006) and thus improve protein and minerals availability.

In the present work, attempt was made to develop a nutriceal based fermented baby food, utilizing three nutriceals viz. pearl millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*) and oat (*Avena sativa*), formulated into a blend along with incorporation of whole milk powder (WMP) and whey protein concentrate (WPC). In this study, processing techniques such as roasting, germination and fermentation have been used to reduce the phytic acid content of the cereals. Lactic acid fermentation by *Lactobacillus casei* and *Lactobacillus plantarum* has been employed along with germination to improve the digestibility and palatability, ensuring proper nutritional qualities such as reduced phytic acid content and fair levels of phenolic acids, in the baby food.

Materials and methods

The cereals viz. pearl millet (*P. glaucum*) variety: kalyanpur, sorghum (*S. bicolor*) variety: mainpuri and oat (*A. sativa*) variety: kent, used for preparation of the baby food were procured from the local market of Varanasi, India. The processed cereal blends were then fermented with two bacteria viz. *L. casei* (NCDC 19) and *L. plantarum* (NCDC 20), separately. The organisms were procured from National Dairy Research Institute (NDRI), Karnal, India and were propagated in MRS broth and maintained in Lactobacillus selection broth at pH 5.8. The whole milk powder (WMP) and whey protein concentrate (WPC) were procured from Modern Dairy, Karnal, India. Figure 1 shows the method of preparation of the optimized baby food. The cereal blends (Table 1) used for optimization of the baby food were processed with 2 processes viz. roasting and germination, separately and also used as unprocessed (raw) flours.

Roasting

The cereal mixes (Table 1) were roasted in an oven at 120 °C for 20 min and then cooled to room temperature (25 °C) prior to sterilization for fermentation.

Germination

The grains were washed with 1.5 % formaldehyde solution to avoid fungal contamination, then were washed with sterile distilled water thrice to ensure no residual formaldehyde; tested using ferric chloride method described by VICH Steering Committee (2002). The grains (1 Kg) were then soaked in potable water (4 L) for 15 h and were then kept for germination wrapped in wet muslin cloth. The germination time was standardized by preliminary trials (Fig. 2) to 72 h. Sample grains were taken at 12 h intervals and assayed for amylase activity as described by Chrispeels and Varner (1967). The maximum amylase activity was obtained at 72 h.

Fermentation

Cereal blend formulations were sterilized at 121 °C for 15 min at 103.4 kPa pressure (15 psi). Sterile distilled water was added to the formulated blends aseptically so that the total solids (TS) were 20 g 100 mL⁻¹ (w/v). Fermentation was carried out in a shake flask at pH 5.8 for 24 h at 37 °C. The inoculum volume was standardized to 1 mL containing 3 × 10⁶ CFU mL⁻¹ of culture.

Screening of cereal blends

The fermented cereal blends were screened for the maximum total phenolic content (TPC) and free radical scavenging activity (FRSA) and the minimum phytic acid content (PAC). The cereal blends were also analysed for presence of tannins. Finally, one processed fermented cereal blend was selected as optimized blend for development of the baby food.

Total phenolic content (TPC), free radical scavenging activity (FRSA), tannins and phytic acid content (PAC)

TPC and FRSA were analysed by the spectrophotometric process used by Sedej et al. (2011), with slight modification.

Total phenolic content of was determined spectrophotometrically at 750 nm (UV/Vis Spectrophotometer, Shimadzu Corporation, Japan) by using Folin Ciocalteu's reagent. Tannic acid was used as a standard and results were expressed as tannic acid equivalents (TAE) (mg TAE/g of sample on wet mass basis).

The FRSA was analysed by DPPH method. The concentration of the DPPH solution used in the assay was 90 µmol/L (22.5 mL of 0.4 mmol/L DPPH solution (0.01577 g DPPH in 100 mL methanol), diluted with 95 % ethanol to 100 mL). An aliquot (1.0 mL) of the DPPH solution (90 µmol/L) was diluted in 2.9 mL ethanol, and 0.1 mL of the extracts at various

Fig. 1 Process flowchart for manufacture of nutriceals based fermented baby food

concentrations (10.0, 20.0, 30.0 and 40.0 mg/mL) was added. The mixture was shaken vigorously and left to stand for 60 min in the dark, then the absorbance was measured at 517 nm (UV/Vis Spectrophotometer, Shimadzu Corporation, Japan) against the blank (mixture without extract).

The antiradical activity was calculated using the ratio:

$$FRSA(\%inhibition) = \left(\frac{A_{control} - A_{sample}}{A_{control}} \right) \times 100$$

Where, $A_{control}$ is the absorption of the DPPH solution and A_{sample} is the absorption of the DPPH solution after the addition of the sample.

PAC was analysed by the process described by Ledesma et al. (2005). The presence or absence of tannins was determined by the qualitative method, the bleach test, described by Waniska et al. (1992).

Optimization by response surface methodology (RSM)

The optimization of the product was performed using response surface methodology (RSM). The product variables included fermented cereal blends (FCB) (30–40 g 100 g⁻¹), rice-corn cooked flour (RCF) (5–10 g 100 g⁻¹), sugar (10–20 g 100 g⁻¹), whey protein concentrate (WPC) kept constant at 5 g 100 g⁻¹ level and whole milk powder (WMP) was added as to make up for 100 g

Table 1 Ratios of different cereals to prepare the cereal blends

Nutricereals	Mix 1 (g 100 g ⁻¹)	Mix 2 (g 100 g ⁻¹)	Mix 3 (g 100 g ⁻¹)	Mix 4 (g 100 g ⁻¹)	Mix 5 (g 100 g ⁻¹)	Mix 6 (g 100 g ⁻¹)
Pearl millet	10	10	40	40	50	50
Oat	50	40	10	50	10	40
Sorghum	40	50	50	10	40	10

of the total formulation. Twenty trials (Tables 2, 3 and 4) were carried out to optimize the nutriceal based fermented baby food.

Texture profile analysis (TPA)

The nutriceal based fermented baby food formulations were analysed for different textural characteristics viz. consistency, cohesiveness and index of viscosity using a texture profile analyser (Stable Micro Systems, Model TA-XT Plus, Surrey, UK). A 35 mm compression plate was used. The product was subjected to compressive force by probe up to the distance of 5 mm. The conditions set in the texture analyser for measuring textural properties were Pre-test speed 1 mm s⁻¹; Post-test speed 1 mm s⁻¹; Test speed 1 mm s⁻¹; Trigger force 5.0 g; Time 5.0 s. For each evaluation, 45 g of sample was reconstituted in 50 mL of warm (60 °C) potable water. Texture analysis was done at 25 °C.

Sensory evaluation

The nutriceal based fermented baby food formulations were subjected to sensory evaluation using 100 points score card which comprised of colour and appearance (10), body and texture (30), flavour and sweetness (40) and mouthfeel (20). The scores of the judges were then calculated into total sensory score (100). The sensory evaluation was performed by a panel of 50 semi-trained judges (25 male and 25 female, aged

25–35 years) from the Banaras Hindu University, Varanasi (India). All the analyses were conducted in triplicate. The sensory evaluation was carried out at 25 °C and 60 % relative humidity (Tables 2 and 3).

Experimental design and statistical analysis

The data obtained were suitably analysed using Tukeys post hoc test for determination of the optimal ratio and processing parameter. Duncans multiple range test was performed to analyse the significance between the ratios and processing parameters using SPSS 16.0 software (SPSS Italia, Bologna, Italy). RSM was used to optimize the various parameters. ANOVA was performed to validate the RSM optimization. The experimental data obtained from the design were analysed by the response surface regression procedure. The second order polynomial coefficients were calculated using the package design expert version 8.0.3.1 (Stat-Ease Inc., Dulles, Washington, USA) to estimate the responses of the dependent variables. The coefficient estimates for various responses for nutriceal based fermented baby food were determined. The significance of each coefficient was determined using the F-test and *P*-value. Further, the lack of fit values for the model were also determined in order to assess the adequacy of the fitted model.

Functional properties

The loose and packed bulk density, porosity and flowability of the optimized nutriceal based fermented baby food, as the angle of repose (as a static measure for flowability), was determined by the method of Sjollem (1963). The particle density, interstitial and occluded air content was determined by the methods used by Jha et al. (2002). The wettability was determined by the method given by Muers and House (1962). The dispersibility of the optimized baby food was determined by the method described by the American Dry Milk Institute (ADMI 1965). The insolubility index was determined by the modified ADMI method described by Jha et al. (2002). The water absorption capacity and swelling capacity of the product were determined by the method described by Sodipo and Fashakin (2011). The gelation capacity of the optimized baby food was determined by the method described by Adeleke and Odedeji (2010).

Fig. 2 Activity curve of α-amylase activity during germination

Table 2 Sensory attributes of the powdered baby food as affected by different constituents

Run	FCB (g 100 g ⁻¹)	RCF (g 100 g ⁻¹)	Sugar (g 100 g ⁻¹)	WMP (g 100 g ⁻¹)	C & A (powder)	B & T (powder)	F & S (powder)	Mouthfeel (powder)	Total sensory score (powder)
1	40.00	5.00	20.00	30.00	7.67	24.99	31.93	14.82	85.98
2	35.00	7.50	15.00	37.50	7.82	27.20	33.01	16.27	83.12
3	35.00	7.50	6.59	45.91	8.45	28.56	32.97	15.14	84.02
4	35.00	3.30	15.00	41.70	7.78	21.71	35.64	16.43	80.04
5	35.00	7.50	23.41	29.09	7.97	29.25	34.88	16.34	91.01
6	26.59	7.50	15.00	45.91	6.76	26.87	37.83	18.61	89.03
7	35.00	7.50	15.00	37.50	8.34	26.21	36.11	15.40	82.07
8	30.00	10.00	20.00	35.00	7.75	24.01	37.84	19.15	81.99
9	35.00	7.50	15.00	37.50	7.65	26.76	33.02	15.28	87.94
10	35.00	11.70	15.00	33.30	7.95	20.94	37.84	18.42	80.10
11	35.00	7.50	15.00	37.50	8.05	28.03	34.91	15.40	87.99
12	30.00	10.00	10.00	45.00	7.76	24.10	35.18	17.20	81.96
13	30.00	5.00	10.00	50.00	7.58	25.41	36.41	18.50	83.04
14	35.00	7.50	15.00	37.50	8.45	27.16	31.91	14.74	83.02
15	43.41	7.50	15.00	29.09	7.32	27.03	31.74	13.15	81.99
16	40.00	10.00	20.00	25.00	7.75	24.11	34.99	16.20	84.02
17	40.00	5.00	10.00	40.00	7.65	25.70	31.69	13.30	78.01
18	40.00	10.00	10.00	35.00	7.76	24.00	31.84	13.01	80.97
19	35.00	7.50	15.00	37.50	8.20	29.20	37.01	17.34	87.95
20	30.00	5.00	20.00	40.00	7.57	24.90	35.83	17.14	89.97

FCB Fermented cereals blend, RCF Rice-corn cooked flour, WMP Whole milk powder, C & A Colour and appearance, B & T Body and texture, F & S Flavour and sweetness

Data represents the mean score of 50 panellists ($n=50$)

The values in columns against sensory attributes represent corresponding sensory scores; higher value designates higher score

The 100 point scale for total sensory score is divided into attributes as colour and appearance (max. 10), body and texture (max. 30), flavour and sweetness (max. 40) and mouthfeel (max. 20)

Nutritional composition

The proximate composition of the optimized nutriceal based fermented baby food was determined by the official methods of AOAC (2000). The total energy value was determined by the method used by Adebayo-Oyetoro et al. (2012). The calcium, iron and phosphorus content was determined by the atomic absorption spectrophotometric method (SOLAAR, Unicon 969, America). The zinc content was determined by the method used by Polycarpe-Kayode et al. (2006). The riboflavin, ascorbic acid, thiamine and niacin content was determined by the method of AOAC (1980).

Results and discussion

Screening of cereal blends

The cereal blends formulations (Table 1) were processed as raw cereal flour, roasted and germinated blends and fermented with *Lactobacillus sp* (*L. casei* and *L. plantarum*). These

processed formulations were screened for TPC, PAC and FRSA. Table 5 depicts the effect of processing on TPC, PAC and FRSA activity of the formulated cereal blends.

Effect of processing and fermentation on TPC and FRSA of cereal blend formulations

It is evident from Table 5 that the TPC of cereal blends varied significantly ($p<0.05$) with difference in the processing of the cereals and the species of the bacteria used for fermentation. The general trend in the increase in the TPC and FRSA was non-fermented (NF) germinated cereal blends < NF raw cereal blends < NF roasted cereal blends < *L. casei* fermented germinated cereal blends < *L. casei* fermented raw cereal blends < *L. casei* fermented roasted cereal blends < *L. plantarum* fermented raw cereal blends < *L. plantarum* fermented roasted cereal blends < *L. plantarum* fermented germinated cereal blends.

Craft et al. (2010) and Dewanto et al. (2002) reported that thermal processing may release bound phenolics from cellular constituents. This could be responsible for the increase in TPC

Table 3 Sensory attributes of the reconstituted baby food as affected by different constituents

Run	FCB (g 100 g ⁻¹)	RCF (g 100 g ⁻¹)	Sugar (g 100 g ⁻¹)	WMP (g 100 g ⁻¹)	C & A (reconstituted)	B & T (reconstituted)	F & S (reconstituted)	Mouthfeel (reconstituted)	Total sensory score (reconstituted)
1	40.00	5.00	20.00	30.00	7.66	24.14	32.13	14.22	80.18
2	35.00	7.50	15.00	37.50	7.29	26.23	34.21	17.11	86.12
3	35.00	7.50	6.59	45.91	7.98	24.17	33.67	14.87	81.19
4	35.00	3.30	15.00	41.70	8.31	26.54	35.54	16.53	87.29
5	35.00	7.50	23.41	29.09	8.88	25.13	35.38	16.21	83.25
6	26.59	7.50	15.00	45.91	8.23	28.41	38.63	17.99	94.80
7	35.00	7.50	15.00	37.50	7.93	26.29	35.21	16.10	83.45
8	30.00	10.00	20.00	35.00	8.65	27.51	38.24	20.00	91.80
9	35.00	7.50	15.00	37.50	7.92	25.46	34.22	14.18	83.14
10	35.00	11.70	15.00	33.30	8.25	26.83	37.44	17.92	90.15
11	35.00	7.50	15.00	37.50	7.99	26.14	35.21	15.43	82.35
12	30.00	10.00	10.00	45.00	8.33	26.20	36.18	17.22	86.98
13	30.00	5.00	10.00	50.00	8.76	27.30	37.41	18.51	91.07
14	35.00	7.50	15.00	37.50	7.75	24.51	33.31	13.99	78.73
15	43.41	7.50	15.00	29.09	7.13	24.14	32.65	12.95	75.99
16	40.00	10.00	20.00	25.00	8.92	25.51	35.11	15.97	83.98
17	40.00	5.00	10.00	40.00	7.36	22.90	33.16	13.31	77.28
18	40.00	10.00	10.00	35.00	7.31	23.15	31.89	13.61	74.03
19	35.00	7.50	15.00	37.50	8.09	26.90	36.72	17.87	88.76
20	30.00	5.00	20.00	40.00	8.19	26.82	36.43	16.89	88.31

FCB Fermented cereals blend, RCF Rice-corn cooked flour, WMP Whole milk powder, C & A Colour and appearance, B & T Body and texture, F & S Flavour and sweetness

Data represents the mean score of 50 panellists ($n=50$)

The values in columns against sensory attributes represent corresponding sensory scores; higher value designates higher score

The 100 point scale for total sensory score is divided into attributes as colour and appearance (max. 10), body and texture (max. 30), flavour and sweetness (max. 40) and mouthfeel (max. 20)

in the roasted formulation. It can also be observed from Table 5, that the TPC of the germinated cereal blends decreased significantly ($p<0.05$) as compared to the raw cereal blends. Similar decrease in TPC was reported by Bvochora et al. (1999). Dordevic et al. (2010) reported an increase in total phenolic content of cereals by lactic acid fermentation. Thus, additional increase in TPC of cereal blends may be observed due to fermentation. The cereal blends formulation fermented with *L. casei* and *L. plantarum* showed significant difference ($p<0.05$) in TPC of the processed cereal blends formulations. However, the increase in TPC was greater in cereal blends fermented with *L. plantarum* than that for *L. casei*.

The FRSA is positively related to the TPC of the cereal blends. The improvement in FRSA may be due to the increase in TPC and to release of the free phenolics from bound form during germination and fermentation and the products of Maillard reactions during roasting. The FRSA of the germinated cereal blends showed an overall increase as compared to raw unprocessed cereal blends. The FRSA did not show any particular trend among the fermented cereal

blends. Nonetheless, a significant ($p<0.05$) increase in FRSA was observed with fermentation in cereal blends as compared to non-fermented cereal blends.

Phytic acid, though anti-nutritional, also acts as antioxidants. Thus decrease in PAC should decrease the FRSA of the formulations. However, in the present study, no such change in the FRSA was observed. This may be due to increase in TPC during processing of the formulations.

Effect of processing and fermentation on PAC and tannins of cereal blend formulations

We observed in Table 5, that the PAC was significantly ($p<0.05$) affected by the processing parameters and also the species of fermentation. There was also a significant ($p<0.05$) change in PAC due to the compositional changes in the cereal blends formulations. Formulations with higher sorghum content had higher phytic acid. This may be due to higher initial phytic acid content of the sorghum.

The general trend of PAC was NF raw cereal blends > NF roasted cereal blends > NF germinated cereal blends > *L. casei*

Table 4 Textural properties, total phenolic content (TPC) and free radical scavenging activity (FRSA) of the baby food as affected by different constituents

Run	FCB (g 100 g ⁻¹)	RCF (g 100 g ⁻¹)	Sugar (g 100 g ⁻¹)	WMP (g 100 g ⁻¹)	Consistency (g. s)	Cohesiveness (g)	Index of viscosity (g. s)	Total phenolic content (mg TAE 100 g ⁻¹ of sample)	FRSA (% Inhibition)
1	40.00	05.00	20.00	30.00	789.33	34.71	62.71	421.75	52.17
2	35.00	07.50	15.00	37.50	917.92	31.16	62.54	476.21	66.33
3	35.00	07.50	06.59	45.91	871.94	35.78	58.76	411.11	48.31
4	35.00	03.30	15.00	41.70	801.63	31.42	51.24	389.36	37.23
5	35.00	07.50	23.41	29.09	839.91	31.47	61.34	426.15	53.24
6	26.59	07.50	15.00	45.91	627.99	21.71	39.37	387.18	33.22
7	35.00	07.50	15.00	37.50	881.21	32.75	63.39	488.21	49.14
8	30.00	10.00	20.00	35.00	793.45	30.02	53.86	411.04	29.29
9	35.00	07.50	15.00	37.50	705.00	30.47	58.53	471.11	56.11
10	35.00	11.70	15.00	33.30	836.91	33.92	61.49	446.18	63.17
11	35.00	07.50	15.00	37.50	842.81	32.44	63.47	462.75	49.14
12	30.00	10.00	10.00	45.00	822.95	31.41	54.42	353.18	40.26
13	30.00	05.00	10.00	50.00	700.41	24.71	45.01	403.02	25.17
14	35.00	07.50	15.00	37.50	890.91	37.94	61.92	464.22	44.19
15	43.41	07.50	15.00	29.09	681.00	31.17	76.48	511.19	78.16
16	40.00	10.00	20.00	25.00	717.62	36.71	70.91	523.34	73.17
17	40.00	05.00	10.00	40.00	711.31	33.55	63.15	489.17	49.05
18	40.00	10.00	10.00	35.00	822.67	33.45	62.64	519.36	69.24
19	35.00	07.50	15.00	37.50	884.72	33.00	61.69	439.18	63.03
20	30.00	05.00	20.00	40.00	706.06	21.13	41.12	382.18	27.16

TAE Tannic acid equivalent, FRSA Free radical scavenging activity, FCB Fermented cereals blends, RCF Rice-corn cooked flour, WMP Whole milk powder

Data represents the mean of three replications ($n=3$)

The values in the rows against corresponding 20 experiments represents corresponding values obtained for textural parameters (Consistency, Cohesiveness and Index of viscosity), TPC and FRSA

fermented raw cereal blends > *L. casei* fermented roasted cereal blends > *L. casei* fermented germinated cereal blends > *L. plantarum* fermented raw cereal blends > *L. plantarum* fermented roasted cereal blends > *L. plantarum* fermented germinated cereal blends. It is shown in Table 5, that about 7–8 times decrease in PAC was observed in the cereal formulations with combined effect of fermentation and germination as compared to NF raw cereal blends.

During germination phytate phosphorus is hydrolysed to inositol monophosphate due to hydrolytic activity of phytase enzyme thus, reducing the phytic acid content of cereal grains (Hussain et al. 2011). There are also reports of the association of α -amylase activity in degradation of phytate as both α -amylase and phytase activity increases during germination (Hotz and Gibson 2001). In the present study, the α -amylase activity of sorghum, oat and pearl millet increased from 0 to 2.80 ± 0.07 , 0 to 3.73 ± 0.08 and 0 to 3.13 ± 0.08 maltose unit, respectively (Fig. 2). The α -amylase activity of the germinated seeds reached optimum after 72 h and further change was not significant ($p > 0.05$). Therefore, the reduction in PAC

observed in the current study could be due to combined effect of phytase and α -amylase activity in the germinated grains.

Although the presence of coloured kernels, normal indication of presence of tannins, in sorghum and pearl millet, the bleach test performed on the cereal blends showed no presence of tannins. Therefore, quantitative analysis of tannins in cereal blends was not conducted. N'Dri et al. (2013) reported similar observations in some African cereals.

Selection of cereal blend formulation for development of nutriceal based fermented baby food

The screening of cereal blends for maximum TPC and FRSA and minimal PAC was performed for cereal blends formulations. Based on the data presented in Table 5, it is evident that germinated cereal blends formulation fermented with *L. plantarum* showed the most significant ($p < 0.05$) effect, with maximum increase in TPC and FRSA as well as decrease in PAC. It is also evident that cereal blend containing pearl millet (PM) (40 g 100 g⁻¹), oat (O) (50 g 100 g⁻¹) and sorghum (S)

Table 5 Phenolic content, phytic acid content and free radical scavenging activity of cereals blends

Ratios			Non-fermented cereals blends				Fermented cereals blends					
Pearl millet blends	Oat	Sorghum	Raw cereals blends		Roasted cereals	Germinated cereals blends	<i>L. casei</i> raw cereals blends	<i>L. casei</i> roasted blends	<i>L. casei</i> germinated grains blends	<i>L. plantarum</i> raw cereal blends	<i>L. plantarum</i> roasted blends	<i>L. plantarum</i> germinated grain blends
Total phenolic content (mg TAE 100 g ⁻¹)												
10	50	40	100.75±6.48 ^a	105.21±3.75 ^b	96.47±2.74 ^c	404.90±4.17 ^d	408.32±2.66 ^d	349.83±1.45 ^e	475.49±2.88 ^f	475.58±4.84 ^f	503.86±3.78 ^g	
10	40	50	102.47±2.74 ^c	105.95±4.92 ^b	98.95±1.96 ^g	449.91±5.09 ^b	454.34±3.88 ^{ef}	404.36±6.20 ^f	494.60±7.06 ^a	501.03±1.03 ^a	506.92±2.65 ^{bc}	
40	10	50	104.68±3.59 ^e	108.35±1.24 ^a	100.57±5.58 ^b	408.93±7.89 ^{bc}	409.37±8.12 ^b	351.53±4.16 ^d	496.15±4.00 ^e	506.14±5.70 ^{ic}	506.20±3.86 ^f	
40	50	10	89.25±6.95 ^b	97.35±2.68 ^c	72.48±2.39 ^a	445.35±0.51 ^b	467.73±4.50 ^d	403.14±3.06 ^f	496.00±3.09 ^e	506.92±5.99 ^f	527.60±5.02 ^{ab}	
50	10	40	99.71±3.68 ^b	106.48±7.95 ^a	86.75±1.28 ^d	460.09±0.59 ^c	463.45±4.63 ^{de}	402.69±3.55 ^f	490.49±1.51 ^b	501.54±1.57 ^{ab}	466.36±4.01 ^{ca}	
50	40	10	82.48±1.27 ^d	95.48±6.48 ^c	70.54±2.77 ^a	451.47±1.18 ^b	452.42±2.21 ^{ef}	401.69±1.34 ^f	450.03±1.82 ^{ef}	506.80±5.92 ^{ic}	506.97±3.88 ^{ic}	
Phytic acid (mg g ⁻¹)												
10	50	40	8.07±0.18 ^b	8.12±0.10 ^a	7.45±0.23 ^{ab}	5.43±0.25 ^{bc}	5.09±0.19 ^d	4.45±0.23 ^c	3.16±0.14 ^{cd}	3.08±0.18 ^f	2.12±0.12 ^g	
10	40	50	8.08±0.24 ^b	8.23±0.23 ^c	7.70±0.27 ^a	5.54±0.36 ^{cd}	5.38±0.24 ^{ab}	4.64±0.37 ^{abc}	3.48±0.19 ^{cb}	3.33±0.23 ^e	2.34±0.31 ^f	
40	10	50	8.19±0.17 ^a	8.12±0.12 ^a	7.34±0.20 ^b	5.47±0.20 ^{bc}	5.09±0.15 ^d	4.53±0.27 ^c	3.41±0.21 ^{ef}	3.18±0.17 ^{ab}	2.30±0.34 ^f	
40	50	10	7.46±0.12 ^c	7.15±0.13 ^{bc}	7.18±0.13 ^{bc}	4.93±0.11 ^a	4.91±0.09 ^a	4.42±0.11 ^{ab}	3.08±0.14 ^{ac}	3.15±0.12 ^b	1.70±0.06 ^d	
50	10	40	8.03±0.27 ^b	8.17±0.16 ^d	7.93±0.19 ^c	5.49±0.25 ^{bc}	5.38±0.27 ^{ab}	4.66±0.11 ^{abc}	3.74±0.21 ^a	3.20±0.14 ^{ab}	2.41±0.10 ^{cb}	
50	40	10	7.41±0.19 ^{ab}	7.41±0.20 ^{ab}	7.26±0.25 ^c	5.07±0.12 ^{bd}	5.04±0.17 ^{bc}	4.60±0.14 ^f	3.28±0.18 ^b	3.17±0.13 ^{ab}	2.02±0.17 ^{de}	
FRSA (% inhibition)												
10	50	40	39.12±1.12 ^a	47.40±1.30 ^{ab}	42.46±0.86 ^a	55.09±6.43 ^b	60.85±8.76 ^c	60.05±1.91 ^c	52.99±2.58 ^{bc}	61.12±16.21 ^c	65.01±12.14 ^f	
10	40	50	37.02±1.42 ^a	48.37±1.67 ^{ab}	40.46±0.61 ^b	57.30±13.34 ^b	64.60±12.82 ^{bc}	68.66±11.79 ^{ab}	73.13±12.25 ^c	63.10±13.31 ^c	56.44±1.00 ^b	
40	10	50	35.92±2.51 ^a	40.36±1.34 ^b	43.85±2.46 ^a	55.28±9.57 ^b	59.21±11.23 ^c	54.17±10.15 ^b	57.79±4.95 ^b	54.57±6.68 ^b	52.30±9.64 ^c	
40	50	10	40.38±0.73 ^a	48.37±1.86 ^{ab}	41.63±1.73 ^b	60.28±0.99 ^c	52.92±18.18 ^d	66.41±17.15 ^{bc}	69.16±9.89 ^c	61.21±6.01 ^c	69.84±8.10 ^c	
50	10	40	33.95±2.22 ^b	41.38±0.16 ^b	38.98±2.57 ^a	62.96±3.79 ^c	56.95±17.33 ^{ab}	59.35±1.06 ^{cd}	60.52±11.08 ^{cd}	71.81±11.36 ^d	64.81±15.54 ^f	
50	40	10	38.30±1.88 ^a	40.72±0.68 ^b	41.30±2.10 ^b	60.63±9.99 ^c	50.95±2.55 ^d	62.58±16.84 ^c	59.47±0.69 ^{ef}	69.45±9.24 ^{ab}	66.85±4.10 ^g	

TAE Tannic acid equivalent, FRSA Free radical scavenging activity

Data represents mean of three replicates ($n=3$) and expressed as Mean ± standard deviationThe values denoted with different superscripts in each column and row for each test differ significantly at $p<0.05$

Table 6 Coefficient estimates of sensory properties for different levels of ingredients in the nutriceals based fermented baby food

Factors	C & A (powder)	B & T (powder)	F & S (powder)	Mouthfeel (powder)	Total sensory score (powder)	C & A (reconstituted)	B & T (reconstituted)	F & S (reconstituted)	Mouthfeel (reconstituted)	Total sensory score (reconstituted)
Intercepts	8.08	27.46	34.35	15.75	85.38	7.83	25.94	34.83	15.78	83.80
A	0.081*	0.048	-1.83*	-1.75*	-1.45*	-0.33*	-1.41*	-1.91*	-1.77*	-5.45*
B	0.061	-0.44*	0.56	0.38	-0.58	0.083	0.12	0.40	0.47	0.36
C	-0.060	-2.897E-003	0.64	0.54*	2.18*	0.23*	0.44*	0.45	0.50	1.36
AB	-0.021	-0.047	0.30	0.048	1.26	0.15	0.25	0.14	0.010	0.13
AC	3.750E-003	0	0.16	0.52	0.51	0.27*	0.35	0.14	0.25	1.33
BC	-3.750E-003	0.16	0.77	0.62*	-1.48	0.28*	0.36	0.91*	0.75	1.85
A ²	-0.37*	-0.37	6.123E-003	3.591E-003	-0.17	-0.053	0.035	0.18	-0.080	0.30
B ²	-0.077	-2.36	0.70	0.55*	-2.09*	0.16*	0.18	0.48	0.54	1.47
C ²	0.045	0.32	-0.30	-0.046	0.54	0.21*	-0.54*	-0.21	0.056	0.82
Model	Significant	Significant	Significant	Significant	Significant	Significant	Significant	Significant	Significant	Significant

A Fermented cereals blend, B Rice-corn cooked flour, C Sugar, AB Interactive term of fermented cereal blend and rice corn cooked flour, AC Interactive term of fermented cereal blend and sugar, BC Interactive term of rice corn cooked flour and sugar, A² Quadratic terms of fermented cereal blend, B² Quadratic terms of rice-corn cooked flour, C² Quadratic terms of sugar, TAE Tannic acid equivalent, FRSA Free radical scavenging activity

The values within the column of each attribute denoted with * are significant at $p < 0.01$

(10 g 100 g⁻¹) showed the most desirable features and significant attributes on the basis of post hoc test ($p < 0.05$). Thus, the process with germinated cereal blend ratio 40 (PM): 50 (O): 10 (S), fermented with *L. plantarum* was selected to develop nutriceal based fermented baby food. The formulation had TPC of 527.60 ± 5.02 mg TAE 100 g⁻¹, FRSA of 69.84 ± 8.10 % inhibition and PAC of 1.70 ± 0.06 mg g⁻¹.

Optimization of nutriceal based fermented baby food

A central composite rotatable design (CCRD) was employed to select the optimum levels of variables viz. FCB, RCF and sugar through 20 experiments. The sensory scores for powdered product as well as reconstituted product along with textural (consistency, cohesiveness and index of viscosity)

Fig. 3 Response surface plot showing effect of variables on the sensory, textural and chemical properties of the nutriceals based fermented baby food. **a** total sensory score (powder) **b** total sensory score (reconstituted) **c**

consistency **d** index of viscosity **e** total phenolic content and **f** free radical scavenging activity

and biochemical characteristics (TPC and FRSA) were analysed in response to the variables.

Effect of variables on the sensory characteristics of nutriceal based fermented baby food

Table 6 (sensory properties) shows that FCB had a significant ($p<0.05$) positive effect on the colour and appearance of the powdered product, while, it shows significant ($p<0.01$) negative effect on the flavour and sweetness, mouthfeel and total sensory score of the powdered (Fig. 3a) as well as the reconstituted (Fig. 3b) product. Table 6 shows that the RCF and sugar had a significant ($p<0.01$) positive interactive effect on colour and appearance score of the reconstituted formulations. The FCB and RCF had a significant positive interactive effect on the mouthfeel score of the powdered formulations, colour and appearance and flavour and sweetness of the reconstituted formulations.

The level of WMP in the formulations ranged from 25.00 to 50.00 g 100 g⁻¹. Leland (1997) reported that fat contributes to the appearance, body and texture, mouthfeel and 'flavour development and stabilization' of the foods. The WMP contributed milk fat to the baby food formulations, giving a shiny appearance to the product and also a better flavour to the product.

Effect of variables on the textural properties of nutriceal based fermented baby food

The response values for the experimental design for the textural properties are shown in Table 4. It is evident from Fig. 3c (consistency), Fig. 3d (Index of viscosity) and the coefficient

estimates (Table 7) that FCB and RCF had a significant ($p<0.01$) positive effect on the consistency, cohesiveness and index of viscosity of the reconstituted formulations. However, sugar had a non-significant ($p>0.01$) effect (Table 7) on the textural characteristics of the product.

Effect of variables on the TPC and FRSA of nutriceal based fermented baby food

As can be observed in Fig. 3e (TPC) and Fig. 3f (FRSA), the level of FCB and RCF are positively related to the TPC and FRSA of the formulations. It is also evident from Table 7, that FCB and RCF individually and interactively had a significant positive effect on the TPC and FRSA of the formulations. WMP and sugar, being an insignificant source of polyphenols, had no significant ($p>0.01$) effect on TPC and FRSA of the formulations.

Optimum levels of ingredient for the manufacture of the nutriceal based fermented baby food

Based on the sensory scores of the powdered and reconstituted formula, textural characteristics and antioxidant properties, the optimum formulation for the development of nutriceals fermented baby food was selected using RSM. Out of the suggested formulations, the formulation containing 37.41 g 100 g⁻¹ of FCB, 9.75 g 100 g⁻¹ of RCF, 20 g 100 g⁻¹ of sugar, 5 g 100 g⁻¹ of WPC and 27.84 g 100 g⁻¹ of WMP was selected as optimum formulation (Tables 8 and 9). The selected optimum formula had total sensory score of 84.61 out of 100 constituting of 8.01 for colour and appearance, 25.52 for body and texture, 35.78 for flavour and sweetness and 17.01

Table 7 Coefficient estimates of textural and biochemical properties for different levels of ingredients in the nutriceals based fermented baby food

Factors	Consistency (g. s)	Cohesiveness (g)	Index of viscosity (g. s)	Total phenolic content (mgTAE g ⁻¹ of sample)	FRSA (% Inhibition)
Intercepts	854.21	32.96	61.96	466.57	54.86
A	7.85*	3.45*	9.33*	44.87*	14.45*
B	22.62	1.59*	3.45*	15.11*	7.47*
C	-7.67	-0.57	0.57	-0.082	0.47
AB	-21.28	-1.71	-1.81	19.10*	3.00
AC	-0.40	1.17	1.54	-12.56	2.00
BC	-27.28	0.54	1.51	18.76*	-1.52
A ²	-73.039*	-2.32*	-1.66*	-3.81	-0.98
B ²	-15.13	-0.12	-2.21*	-14.92*	-2.92
C ²	-2.17	0.22	-0.91	14.92*	-2.72
Model	Significant	Significant	Significant	Significant	Significant

A Fermented cereals blend, B Rice-corn cooked flour, C Sugar, AB Interactive term of fermented cereal blend and rice corn cooked flour, AC Interactive term of fermented cereal blend and sugar, BC Interactive term of rice corn cooked flour and sugar, A² Quadratic terms of fermented cereal blend, B² Quadratic terms of rice-corn cooked flour, C² Quadratic terms of sugar, TAE Tannic acid equivalent, FRSA Free radical scavenging activity

The values within the column of each attribute denoted with * are significant at $p<0.01$

Table 8 Predicted optimization solutions (sensory attributes) for nutriceals based fermented baby food optimized using design expert software 8.0.4

Number	FCB (g 100 g ⁻¹)	RCF (g 100 g ⁻¹)	Sugar (g 100 g ⁻¹)	WMP (g 100 g ⁻¹)	C & A (powder)	B & T (powder)	F & S (powder)	Mouthfeel (powder)	Total sensory score (powder)	C & A (reconstituted)	B & T (reconstituted)	F & S (reconstituted)	Mouthfeel (reconstituted)	Total sensory score (reconstituted)
1	37.42	9.75	20	27.83	8.00	25.51	35.78	17.01	84.60	8.75	26.03	35.89	17.00	85.65
2	37.49	9.79	20	27.72	8.00	25.44	35.80	17.02	84.53	8.76	26.03	35.90	17.01	85.67
3	37.38	9.81	20	27.81	8.01	25.41	35.85	17.06	84.48	8.76	26.05	35.95	17.07	85.79
4	37.26	9.74	20	28	8.01	25.55	35.81	17.04	84.63	8.74	26.05	35.93	17.04	85.74
5	37.49	9.86	20	27.65	8.00	25.31	35.88	17.08	84.38	8.78	26.05	35.96	17.07	85.80
6	37.15	9.65	19.81	28.39	8.02	25.68	35.72	16.95	84.72	8.68	26.04	35.85	16.96	85.58
7	34.46	7.3	20	33.24	8.05	27.77	34.77	16.29	88.36	8.25	25.92	35.16	16.29	84.62

FCB Fermented cereals blend, RCF Rice-corn cooked flour, WMP Whole milk powder, C & A Colour and appearance, B & T Body and texture, F & S Flavour and sweetness

Data represents the mean score of 50 panellists ($n=50$)

The values in corresponding columns against sensory attributes represent sensory scores for the predicted formulations

The 100 point scale for sensory evaluation was divided into attributes as colour and appearance (max. 10), body and texture (max. 30), flavour and sweetness (max. 40) and mouthfeel (max. 20)

for mouthfeel, for the powdered product. The colour and appearance, body and texture, flavour and appearance, mouthfeel and the total sensory scores for the reconstituted product were 8.75, 26.03, 35.89, 17.00 and 85.65, respectively and the consistency, cohesiveness, index of viscosity, TPC and FRSA of the optimum product were 805.24 g. s, 35.40 g, 68.36 g. s, 493.245 mg TAE 100 g⁻¹ of sample and 64.61 % inhibition, respectively. The desirability of the selected formulation was 0.847 (Table 9).

Functional properties of the optimized nutriceal based fermented baby food

The functional properties of the optimized nutriceal based fermented baby food are shown in Table 10. The loose and packed bulk density of the nutriceal based fermented baby food powder was higher than that of WMP (0.41–0.43) (Hols and van Mil 1991) and WPC (0.6–0.7) (Renner 1988). The bulk density of a powder is the function of particle density, interstitial and occluded air and porosity of the powder. Thus, the high bulk density of the powdered baby food formulation may be attributed to the high particle density and low interstitial air and occluded air content observed in it. The particle density of the powdered baby food formulation was higher than that reported in WMP and rice based instant *kheer* mix (Jha et al. 2002); whereas the interstitial and occluded air content was relatively lower. The porosity of the powdered baby food formulation was in range with that of WMP (42–70 %) (Buma 1972; Mettler 1980).

The dispersibility of a mixture in water indicates its degree of reconstitution. The higher the dispersibility, better is the reconstitution. The dispersibility of the optimized baby food formulation was 75.61 %. This showed a good reconstitutability of the powdered baby food formulation. However, it was found to have less dispersibility than that of WMP (95–98 %) and SMP (90–98 %) (Masters 1979), which could be attributed to the compositional characteristics of the optimized baby food formulation containing cereal solids. Good solubility of a powder will mean good reconstitution characteristic. The insolubility index of the optimized baby food formulation was 4.2 mL. It was higher than that for WMP and SMP, may be due to the presence of rice flour in the formulation. The results were in accordance with the findings of Jha et al. (2002).

The swelling capacity of a food powder is a factor responsible in deciding the net amount of powder consumed by the baby. Lower swelling capacity is better as the baby can consume adequate amount of food to meet its requirements for nutrients. The swelling capacity of the optimized baby food was found to be 3.02 mL g⁻¹. The low swelling capacity of the powdered baby food formulation may be attributed to the germination process used in the manufacture, as germination reduces the swelling capacity of the cereal flours (Sodipo and Fashakin 2011). The wettability of the food powder is the

Table 9 Predicted optimization solutions for nutricereals based fermented baby food optimized using design expert software 8.0.4

Number	FCB (g 100 g ⁻¹)	RCF (g 100 g ⁻¹)	Sugar (g 100 g ⁻¹)	WMP (g 100 g ⁻¹)	Consistency (g. s)	Cohesiveness (g)	Index of viscosity (g. s)	Total phenolic content (mg TAE 100 g ⁻¹ of sample)	FRSA (% Inhibition)	Desirability
1	37.42	9.75	20	27.83	804.93	35.38	68.38	493.40	64.65	0.847 Selected
2	37.49	9.79	20	27.72	803.33	35.40	68.47	494.18	64.91	0.846
3	37.38	9.81	20	27.81	804.83	35.39	68.30	493.28	64.52	0.846
4	37.26	9.74	20	28	807.88	35.34	68.12	491.76	64.03	0.846
5	37.49	9.86	20	27.65	802.11	35.43	68.47	494.63	64.97	0.846
6	37.15	9.65	19.81	28.39	812.26	35.24	67.91	490.92	63.77	0.845
7	34.46	7.3	20	33.24	842.80	31.90	60.01	445.73	50.36	0.816

FCB Fermented cereals blend, RCF Rice-corn cooked flour, WMP Whole milk powder, C & A Colour and appearance, B & T Body and texture, F & S Flavour and sweetness

Data represents the mean of three replications ($n=3$)

The values in corresponding columns against textural and chemical parameter represent the values obtained for the parameters for the respective predicted formulations

measure of its hydrophilic property. The wettability of the optimized baby food was 58 s. The wettability of instant powders and ‘SMP and WMP’ are reported in range of 26–119 s (Sweetsur 1976) and 15–60 s (Kelly et al. 2003), respectively. Thus, fairly good wettability was observed in the baby food formulation. The water absorption capacity of a powder gives the indication of the amount of water available for gelatinization. Higher water absorption capacity is desirable to make thicker gruel after reconstitution. The gelation capacity of the optimized baby food was 6 %. The flowability of the optimized baby food powder measured in terms of angle of repose (60.13°) was higher than that of instant *kheer* mix developed by Jha et al. (2002). The cotangent of the angle of repose (0.57) was slightly higher than that of WMP (0.45),

which meant that the optimized baby food formulation was more flowable than WMP.

Nutritional composition of the optimized nutricereal based fermented baby food

The nutritional composition of the optimized nutricereal based fermented baby food is shown in Table 11. Energy content is a parameter used to determine the quality of food (Adebayo-Oyetoro et al. 2012). The energy value of nutricereal based fermented baby food was approximately 1/4th (435.04 Kcal day⁻¹) of the recommended dietary allowance (RDA) (ICMR 2008) of 1,240 Kcal day⁻¹. Thus, the baby food can be supplemented in infant diet, 3–4 times a day. The energy value of the optimized baby food formula was significantly ($p<0.05$) lower than that of the control formulations. However, most amount of it came from the protein content; which is superior to the control formulations.

The low moisture observed for the freshly prepared optimized and control baby foods is a good indicator of its potential to have longer shelf life. However, when the product is allowed to equilibrate for periods of more than 1 week at 60 % relative humidity and at room temperature (25–27 °C), the moisture content might increase. The carbohydrate content of the nutricereal based baby food was lower than that of the wheat and rice based baby food developed by Ghavidel and Davoodi (2011). This can be attributed to the lower carbohydrate content of nutricereals as compared to wheat and rice. The carbohydrate content of control and optimized formulation did not vary significantly ($p>0.05$). The high protein content of the nutricereal based fermented baby food was highly contributed by WMP, WPC and FCB. El Khalifa et al. (2007) reported that fermentation increases the protein content of millets. Similar finding was observed in Table 11.

Table 10 Functional properties of nutricereals based fermented baby food

Sr. No.	Property	Value
1	Loose bulk density (g cm ⁻³)	0.62±0.03
2	Packed bulk density (g cm ⁻³)	0.80±0.05
3	Particle density (g cm ⁻³)	1.29±0.06
4	Porosity (% volume)	51.94±0.12
5	Interstitial air content (cm ³ 100 g ⁻¹)	48.00±1.00
6	Occluded air content (cm ³ 100 g ⁻¹)	7.12±0.09
7	Water absorption capacity (ml g ⁻¹)	1.20±0.56
8	Dispersibility (%)	75.61±0.13
9	Insolubility index (ml)	4.00±0.10
10	Swelling capacity (ml g ⁻¹)	3.02±0.08
11	Wettability (s)	58.00±1.00
12	Gelation (%)	6.00±0.14
13	Flowability (θ)	60.13±0.09

Values are mean of three replications ($n=3$) and expressed as mean ± standard deviation

Table 11 Nutritional composition of nutriceals based fermented baby food

Nutrients	UPNF	GNF	GFOF	RDA
Energy (Kcal 100 g ⁻¹)	455.21 ^a	453.26 ^a	435.04 ^b	1,240 (Kcal day ⁻¹)
Protein calories (Kcal 100 g ⁻¹)	75 ^a	72.64 ^a	92.34 ^b	–
Moisture (g 100 g ⁻¹)	3.29±0.17 ^a	3.95±0.23 ^a	3.64±0.06 ^a	–
Carbohydrate (g 100 g ⁻¹)	58.58±0.27 ^a	58.26±0.79 ^a	58.68±0.13 ^a	124–155** (g day ⁻¹)
Protein (g 100 g ⁻¹)	18.75±0.59 ^a	18.16±1.24 ^a	23.08±0.08 ^b	17–22 (g day ⁻¹)
Fat (g 100 g ⁻¹)	16.21±1.09 ^a	16.42±1.47 ^a	12.00±1.01 ^b	25–30 (g day ⁻¹)
Ash (g 100 g ⁻¹)	3.17±0.09 ^a	3.21±0.11 ^b	2.60±0.28 ^c	–
Dietary fibre (g 100 g ⁻¹)	6.48±1.48 ^a	6.02±1.26 ^b	4.62±0.67 ^c	–
Vitamins				
Riboflavin (mg 100 g ⁻¹)	0.17±0.01 ^a	0.19±0.02 ^a	0.36±0.11 ^c	0.7 (mg day ⁻¹)
Ascorbic acid (mg 100 g ⁻¹)	0.009±0.001 ^a	0.009±0.001 ^a	0.021±0.008 ^b	40 (mg day ⁻¹)
Niacin (mg 100 g ⁻¹)	3.48±0.11 ^a	3.52±0.09 ^a	6.75±0.17 ^c	9 (mg day ⁻¹)
Thiamine (mg 100 g ⁻¹)	0.26±0.19 ^a	0.27±0.08 ^a	0.46±0.14 ^b	0.6 (mg day ⁻¹)
Minerals				
Calcium (mg 100 g ⁻¹)	64.15±0.24 ^a	60.24±0.17 ^a	55.75±0.20 ^b	400 (mg day ⁻¹)
Phosphorus (mg 100 g ⁻¹)	152.17±1.44 ^a	147.12±2.75 ^b	98.56±1.95 ^c	800 (mg day ⁻¹)
Iron (mg 100 g ⁻¹)	5.12±0.14 ^a	6.79±0.22 ^b	8.47±0.19 ^c	12 (mg day ⁻¹)
Zinc (mg 100 g ⁻¹)	3.48±1.15 ^a	3.78±0.54 ^a	4.99±0.35 ^c	10 (mg day ⁻¹)

UPNF Unprocessed non-fermented baby food formula (Control 1), GNF Germinated non-fermented baby food formula (Control 2), GFOF Germinated fermented optimized baby food formula (nutriceals based fermented baby food), RDA Recommended Dietary Allowance for 1–3 years of infants, Source: ICMR (2008)

**Calculated from total calorie value by RDA of 40–50 % of total calorie per day

Values are mean of three replications ($n=3$) and expressed as mean ± standard deviation

The values denoted with different superscripts in each row differ significantly at $p<0.05$

The optimized baby food had higher protein content than the control non-fermented baby food formulations. The increase in the protein content of the optimized baby food formulation could be caused by the breakdown of nutrients of the nutriceals by the culture organism.

The optimized baby food formulation contained fair quantity of fat, to fulfil the RDA of preschool children of 1–3 years of age, whereas, it was lower as compared to the control formulations. This reduction in fat content in the optimized baby food may be due to oxidation during pre-treatments (storage and germination) before fermentation. The reduction in fat can also be attributed to the activity of the culture microorganism to obtain energy from the fat, as fat yields a considerable amount of energy for microbes when oxidized. However, the low level of fat is desirable to enhance the stability and keeping quality of the baby food during storage.

Table 11 shows that there was a significant ($p<0.05$) increase in the vitamins content of the optimized baby food formulation as compared to the control formulations. This could be caused by the action of the fermentation organism, as most lactic acid bacteria are capable of synthesizing vitamins. The ash content of the optimized baby food was lower as compared to the control formulations. The main constituent of the ash is calcium, phosphorus, iron and zinc. The content of calcium and phosphorus in

the optimized baby food was significantly ($p<0.05$) less than the control formulations. This could be attributed to the fermentation activity of the culture organism and the processing method (leaching during steeping/soaking prior to germination). The iron and zinc content however significantly ($p<0.05$) increased in the optimized baby food formulation. This could be due to the increase in the *in vitro* availability of these minerals due to the decrease in phytic acid in the formulation during germination and fermentation. The ash content of the optimized baby food was higher than that of weaning food developed by Adebayo-Oyetoro et al. (2012) and Egounlety (2002).

The dietary fibre content of the optimized baby food formulation was lower than the control formulations. This can be attributed to the germination and fermentation process used in its manufacture as reports suggest that germination and fermentation reduces the fibre content in vegetables and cereals, as the activity of hydrolytic enzymes increases during germination and fermentation (Sindhu and Khetarpaul 2005).

Conclusions

From the present study, it may be concluded that a combination of germination followed by fermentation with probiotic

organism (*L. plantarum*) of indigenously developed nutriceal based food mixtures is a potential process for developing baby food with improved nutritional qualities. The optimized nutriceal based fermented baby food was organoleptically acceptable as well as nutritionally superior and had significantly higher quantity of phenolic content and reduced phytic acid content. The optimized baby food showed high water absorption capacity, dispersibility, wettability and flowability. This indicated that the powder had good reconstitution properties.

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