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Revitalizing Nutrition: Energy Dense Protein Rich Supplementary Foods From Indigenous Crops For Moderate Acute Malnourished Children

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Abstract
This study aimed to standardize, develop, and characterize energy dense protein rich (EDPR) ready-to-eat supplementary foods, namely paste (P0: control; P1-P8: variants), biscuit (B0: control; B1- B7: variants), and nutribar (N0: control; N1-N5: variants) from indigenous crops (preprocessed) for Moderate Acute Malnourished (MAM) children of age 6-59 months. The final variants P6 [50.4% peanut, 20% germinated soybean flour (GSF), 21% germinated finger millet flour (GFMF), and 8% germinated wheat flour (GWF)], B4 [50% GSF, 30% GWF, and 20% germinated pearl millet flour (GPMF)], and N5 [82% peanut, 9% GWF, and 9% GPMF] were selected based on the highest mean sensory scores (9-point hedonic scale) and their conformity to the technical specifications for supplementary foods by the World Health Organization (WHO). The physico-chemical analysis revealed that the energy content of P6, B4, and N5 variants was 544.23Kcal, 520.34Kcal, and 521.09Kcal, respectively. While the protein content was 13.59%, 13.48%, and 13.75% for P6, B4, and N5 variants, respectively. Furthermore, the micronutrients also fell well within the specified limits. The shelf life (moisture content, water activity, peroxide value, microbial assays, and sensory evaluation) evaluated for 180 days revealed that all the three standardized supplementary foods were shelf stable up to 180 days. Hence, the developed supplementary foods in different forms made from indigenous crops to suit the Indian palate will help addressing the alarming issue of MAM in children.
Keywords: *Supplementary foods; Moderate acute malnutrition; Biscuits; Nutribar; MAM*

I. INTRODUCTION

Malnutrition is a global concern around the world, especially among children, which has adversely affected their cognitive development, growth, and overall well-being. According to the World Health Organization (WHO), 148 million children have been reported to be stunted, 45.0 million were wasted, and
37.0 million were reported to be overweight around the world. As per the National Family Health Survey- 5, 31.7% of children under the age of 5 years are reported to be stunted, 18.7% are wasted, and 2.8% are overweight in India Despite several preventive and curative measures taken by various government and non-government organizations, malnutrition persists, and its prevalence is alarming. The WHO classifies wasting based on weight-for-height (WHZ) scores or mid-upper arm circumference (MUAC) into Moderate Acute Malnutrition [(MAM) WHZ between -3 and -2 or MUAC between 11.5 and 12.5 cm] and Severe Acute Malnutrition [(SAM) WHZ or MUAC less than -3 and 11.5 cm, respectively]. Children who experience MAM are more likely to suffer fatalities from illnesses and are more susceptible to progressing into SAM. Hence, managing malnutrition at this stage is very important. WHO has recommended ready- to-use supplementary food (RUSF) for treating MAM in children between six months and five years. RUSF is an energy-dense protein-rich lipid-based paste that provides 510–560 kcal of energy, 11–16 g of protein, and 26–36 g of fat per 100g.

Supplementing RUSF to children with MAM can effectively improve their nutritional status and break the cycle of malnutrition. Singh *et al.*, 2021 and Rashid *et al.*, 2022 reported recovery rates of 68% (conducted in Sierra Leone for 12 weeks) and 73% (conducted in Eastern Ethiopia for 16 weeks), respectively, for children supplemented with RUSF in the age group of 6 and 59 months. However, there are challenges with the acceptability of RUSF in terms of its palatability due to the product's paste-like consistency. Furthermore, its traits also deviate from the population's usual feeding patterns, which raises the possibility of refusal. Globally, the major limitation in the success of this approach is the lack of acceptability and discontentment in children and caregivers with the sensory aspects of these products. Therefore, a strategic approach to address MAM is through locally produced RUSF with enhanced sensory attributes and acceptability. Moreover, introducing a diversity of products with higher acceptability will open promising avenues to combat malnutrition in children. These measures will further lower the burden of malnutrition and improve the health status of the children. Thus, the present study has been planned to standardize, develop, and characterize energy dense protein rich (EDPR), ready-to-eat supplementary foods in different forms made from indigenous crops in MAM children of 6-59 months. The standardization of the supplementary foods in different forms by keeping the specifications of RUSF intact will help open avenues to manage acute malnutrition via nutritional interventions in a more effective way.

II. MATERIALS AND METHODS

The present study was carried out in the Department of Food Science and Technology, National Institute of Food Technology Entrepreneurship and Management, Kundli (NIFTEM-K), Sonepat, Haryana, India. The trial was reviewed and approved by the institutional ethical review board of the NIFTEM-K with the protocol number vide 5/91/NECHR/22.

Selection and procurement of raw materials

The raw materials [soybean, wheat, pearl millet, finger millet, skim milk powder (SMP), sugar, butter, oil, baking powder, baking soda, and flavor] were procured from the supermarkets in Sonepat, Haryana, India. Vitamin and mineral premixes were customized as per the formulation requirements and technical specifications according to the WHO and procured from Hexagon Nutrition Limited, Mumbai, Maharashtra, India. The commercially available peanut-based RUSF (C0) was provided at gratis by GC Reiber Compact India Private Limited, Manesar, Gurgaon, Haryana, India.

Preprocessing of grains

The cleaned raw materials, namely soybean, wheat, pearl millet, and finger millet were steeped for 24 h in distilled water. The water was replaced after an interval of every 8 hours. The soaked grains were germinated in germinators for 48 h at room temperature (25°C) (Anvarjonovich and Ogli, 2021). Afterward, germinated grains were tray-dried at 50°C for 6 h, then roasted at 180°C for 15 min. The roasted grains (soybean, wheat, pearl millet, finger millet, and peanut) were grounded (Philips mixer grinder HL7778/00), sieved (300 µm), and stored (room temperature) in airtight containers for further use.

Standardization and development of indigenous EDPR ready-to-eat supplementary foods

Three ready-to-eat food products namely paste, biscuit, and nutribar were selected for developing EDPR ready-to-eat supplementary foods. Biscuit and nutribar were chosen due to their popularity among children, while the paste was designed as an indigenous alternative to commercially available peanut-based RUSF pastes. The ingredients for each product were carefully selected to balance availability and nutritional value.

The final variant of each product was chosen based on sensory evaluation scores across various attributes on the 9-point hedonic scale.

Standardization and development of indigenous EDPR ready-to-eat supplementary paste

The recipe was standardized, and eight variants (P1-P8) along with a control (P0) were prepared (Table 1). For the eight variants (P1-P8), peanut and germinated soybean flour (GSF) were varied from 0-35 g, while the other ingredients [SMP, sugar, germinated finger millet flour (GFMF), germinated wheat flour (GWF), micronutrient premix, and oil] were kept constant. For the control (P0), GSF, GFMF, and GWF were replaced with peanut (49.6 g), while other ingredients were kept in the same amount. Furthermore, a commercial control (C0: peanut-based RUSF paste) was also taken as a control; therefore, for the EDPR ready-to-eat supplementary paste, there were two controls (C0: commercial paste and P0: base product without variants) to assess the degree of liking on a nine-point hedonic scale. All the ingredients were accurately weighed and mixed using a planetary mixer (Model PLM-90) at 90 rpm for 8 minutes. The product was aseptically packed (100 g) and coded in aluminum-coated Low Density Polyethylene (LDPE) sachets for the trials.

Table 1. Formulations of EDPR ready-to-eat supplementary paste

Ingredients	P0	P1	P2	P3	P4	P5	P6	P7	P8
Peanuts (g)	49.6	0	5	10	15	20	25	30	35
GSF (g)	0	35	30	25	20	15	10	5	0
SMP (g)	7	7	7	7	7	7	7	7	7
Sugar (g)	21	21	21	21	21	21	21	21	21
GFMF (g)	0	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6
GWF (g)	0	4	4	4	4	4	4	4	4
Micronutrient Premix (g)	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
Oil (g)	17	17	17	17	17	17	17	17	17

Energy dense protein rich ready-to-eat supplementary paste (P0: control; P1-P8: different variants; GSF: germinated soybean flour; SMP: skim milk powder; GFMF: germinated finger millet flour; GWF: germinated wheat flour; *C0: commercially available peanut-based RUSF)

Standardization and development of indigenous EDPR ready-to-eat supplementary biscuit

The recipe was standardized, and seven variants (B1–B7) along with a control (B0) were prepared (Table 2). For the seven variants (B1-B7), a combination of GSF, GWF, and germinated pearl millet flour (GPMF) were taken as variables ranging from 35–65 g, 0–60 g, and 5–35 g, respectively. The other ingredients (SMP, sugar, butter, oil, micronutrient premix, baking powder, baking soda, and flavor) in all the variants were kept constant. The control (B0) was prepared from GWF, keeping other ingredients constant without any variants to assess the degree of liking for the EDPR ready-to-eat supplementary biscuit. For developing the EDPR biscuit, the dry ingredients (flour, SMP, baking powder, baking soda, and flavor) were weighed and sieved together for uniform mixing and good aeration.

Table 2. Formulations of EDPR ready-to-eat supplementary biscuit

Ingredients	B0	B1	B2	B3	B4	B5	B6	B7
GSF (g)	0	35	40	45	50	55	60	65
GWF (g)	100	60	50	40	30	20	10	0
GPMF (g)	0	5	10	15	20	25	30	35
SMP (g)	17	17	17	17	17	17	17	17
Sugar (g)	70	70	70	70	70	70	70	70
Butter (g)	70	70	70	70	70	70	70	70
Oil (ml)	20	20	20	20	20	20	20	20

Micronutrient Premix (g)	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.5
Baking Powder (g)	2	2	2	2	2	2	2	2
Baking Soda (g)	2	2	2	2	2	2	2	2
Flavor (g)	2	2	2	2	2	2	2	2
Water (ml)	8	8	8	8	8	8	8	8

Energy dense protein rich ready-to-eat supplementary biscuits (B0: control; B1-B7: different variants; GSF: germinated soybean flour; GWF: germinated wheat flour; GPMF: germinated pearl millet flour; SMP: skim milk powder)

The butter, sugar, and oil were creamed in a planetary mixer (Model PLM-90) at 45 rpm for 5 minutes. The dry ingredients were gradually added to the creamed mixture to form a firm dough. The dough was rolled out to a thickness of 2.0 mm, cut for a diameter of 3.5 cm with the help of a cutter, placed on pre-greased trays, and baked in a preheated deck oven at 180°C for 12 minutes. The biscuits were cooled for one hour at room temperature and packed (100 g) in LDPE pouches (primary packaging) and boxes (secondary packaging) for the trials.

Standardization and development of indigenous EDPR ready-to-eat supplementary nutribar

The recipe was standardized, and five variants (N1–N5) along with a control (N0) were prepared (Table 3) based on the feedback received by the sensory panel. For the N1 variant, 65% germinated soybean (GS) was taken in a 1:1 ratio of finely to coarsely ground. In the N2 variant, 54% of GS was replaced with peanuts (finely ground), further in the N3 variant according to the feedback of the sensory panel GS was eliminated and 100% peanut was used in finely ground form. In the N4 variant peanut was incorporated in the ratio 1:1 of finely and coarsely ground, to improve the texture. In the N5 variant, GFMF was replaced with GWF, and 50% of the sugar was replaced with jaggery powder to impart a desirable golden color.

Table 3. Formulations of EDPR ready-to-eat supplementary nutribar

Ingredients	**N0**	**N1**	**N2**	**N3**	**N4**	**N5**
Peanuts (g)	79	0	35	65	65	65
GS (g)	0	65	30	0	0	0
Sugar (g)	15	30	30	30	30	15
Jaggery Powder (g)	15	0	0	0	0	15
GFMF (g)	0	7	7	7	7	0
GWF (g)	0	0	0	0	0	7
GPMF (g)	0	7	7	7	7	7
Micronutrient Premix (g)	6.5	6.5	6.5	6.5	6.5	6.5
Maltodextrin (g)	8	8	8	8	8	8
Water (ml)	12.5	12.5	12.5	12.5	12.5	12.5

Energy dense protein rich ready-to-eat supplementary nutribar (N0: nutribar; N1-N5: different variants; GS: germinated soybean; GFMF; germinated finger millet flour; GWF: germinated wheat flour; GPMF: germinated pearl millet flour)

The other ingredients (micronutrient premix, maltodextrin, and water) in all the variants were kept constant. Control (N0) was developed using peanuts while keeping the other ingredients constant (without variations) to assess the degree of liking for EDPR ready-to-eat supplementary nutribar. For developing EDPR nutribar, the sugar syrup was prepared by weighing, mixing, and boiling the ingredients (sugar, jaggery powder, maltodextrin, and water) to one thread consistency. The other ingredients (peanuts, GS, GFMF, GWF, and GPMF) were weighed and mixed in the syrup with the help of a planetary mixer (Model PLM-90) at 90 rpm for 2 min. The tray was pre-greased with oil and the nutribar mixture was transferred and rolled with the help of a rolling pin to a uniform thickness of 1 cm. The tray was set in the refrigerator (7 °C) for 30 minutes and then cut to the desired weight (100 g), packed in aluminum foil (primary packaging) and LDPE pouches (secondary packaging) for the trials.

Physico-chemical and microbial analysis

The proximate composition (moisture, ash, protein, and fat) for each product was determined using the standard AACC 2000 method. Carbohydrate content was determined by the difference method (equation 1), and energy was estimated using the bomb calorimeter (Parr Instrument Company, PARR 6200).

The percent carbohydrate was calculated using the following equation:

$$Carbohydrate\ (\%) = [100 - (Moisture + Fat + Protein + Ash)] \quad \text{(Eq. 1)}$$

The water activity was determined by water activity meter (Aqualab 4TE; Decagon Devices, Inc., Pullman, WA, United States) and peroxide value (PV) using the standard AOAC 2010 method. The total plate count (TPC), yeast (TYC) and mold count were determined according to AACC 2000 method. *Salmonella* count was determined using the ISO 6579 method, *Enterobacteriaceae* count was determined using the ISO 21528-2 method and total aflatoxin was determined using the ISO 16050 method. The analysis was done in triplicates and results are represented as mean±standard deviation (SD).

Shelf-life evaluation

For the shelf life studies, the EDPR ready-to-eat supplementary paste was packaged in aluminum coated multi layered packaging material chiefly made with low density polyethylene (LDPE) (primary packaging) and stored in cardboard boxes (secondary packaging), while the EDPR ready-to-eat supplementary biscuits were packed in LDPE as a primary packaging, followed by plastic boxes (secondary packaging), and then stored in cardboard boxes (tertiary packaging), furthermore, the EDPR ready-to-eat supplementary nutribar was packed in aluminium foil (primary packaging), LDPE pouches (secondary packaging), and stored in cardboard boxes (tertiary packaging) at room temperature (25°C). The standardized samples along with their respective controls were periodically evaluated for moisture content water activity (aw), peroxdise value (PV), TPC, yeast and mold count, and sensory analysis at an interval of 30 days starting from the 0th day for a period of 180 days. Furthermore, *Salmonella, Enterobacteriaceae*, and total aflatoxin were also tested on the 0^{th}, 90^{th} day, and 180^{th} day and of the storage period.

Sensory analysis

The selection of the standardized variant of all the EDPR ready-to-eat supplementary products comprised sensory analysis of all the variants of the developed indigenous EDPR ready-to-eat supplementary foods [paste (P1-P8), biscuit (B1-B7), and nutribar (N1-N5)], which were assessed against their respective control counterparts [paste (P0 and C0), biscuit (B0), and nutribar (N0)] for various sensory attributes (color, aroma, texture, taste, and overall acceptability) using a 9-point hedonic scale by a panel of 30 semi-trained personnel (food scientists and researchers) from the Department of Food Science and Technology, NIFTEM-K, Sonepat, Haryana, India, to avoid any systematic errors or potential bias. The sensory panel was selected after conducting a triangle test (discrimination test used to determine if a perceptible difference exists between two products). The sensory appraisal involved the 9- point hedonic rating scale in which the degree of preference by each semi-trained panelist to determine the level of like and dislike, ranging from liked extremely with a score of 9 to disliked extremely with a score of 1. The highest mean sensory scores for various sensory attributes and overall acceptability were taken as criteria for the selection of the final variant.

Statistical analysis

Results are represented as Mean±SD, the analysis was carried out in triplicates for physico-chemical and microbial parameters of EDPR ready-to-eat supplementary foods. The statistical inference was drawn based on a One-Way Analysis of Variance (ANOVA) and the means were separated using Tukey's Honest Significant Difference post hoc test at a significance level of $p \leq 0.05$ using IBM SPSS software (version 20.0).

III. RESULTS AND DISCUSSION

Standardization and development of indigenous EDPR ready-to-eat supplementary foods

In this study, three indigenous EDPR ready-to-eat supplementary foods (paste, biscuit, and nutribar) were standardized and developed. The variants (P1-P8, B1-B7, and N1-N5) along with their respective control (P0, B0, and N0) and positive control (C0; commercial RUSF paste) were subjected to sensory appraisal on a nine-point hedonic scale by a semi-trained panel (n=30) of the NIFTEM-K, Sonepat, Haryana, India to select the final test variant. In this study, EDPR ready-to-eat supplementary paste was developed, as RUSF paste offers a structure to food that can accommodate many nutrients due to its strong taste (Reggi *et al.*, 2024). The results of sensory appraisal (Table 4) indicated a minimum value of all the sensory attributes for P0, owing to its oily texture, which further affected its taste and overall acceptability). Furthermore, an increasing trend was observed for all the sensory attributes from P0 to P6 (maximum sensory scores), which further showed a decreasing trend from P6 to P8 as it was noted that any more incorporation of peanuts, further beyond 25% decreased the sensory attributes because of increased oil (Ferdaus *et al.*, 2022) in the product, thereby affecting the sensory attributes. Therefore, among the variants (P1-P8) of the EDPR ready-to-eat paste, the P6 variant (50.4% peanut, 20% GSF, 21% GFMF, and 8% GWF) in comparison to the control (P0; 100% peanut) (Table 5) received the highest mean sensory scores as proportion of peanuts and GSF imparted the desired sensory attributes to the EDPR ready-to-eat supplementary paste and hence it was the final standardized variant.

Table 4. Sensory scores of controls and variants for Indigenous EDPR ready-to-eat supplementary foods

EDPR ready-to-eat supplementary paste	Color	Aroma	Texture	Taste	Overall Acceptability
C0	8.1±0.73^{a}	7.3±0.82^{a}	6.9±0.74^{ab}	6.7±1.06^{ab}	7.1±0.88^{a}
P0	7.3±0.51^{c}	6.4±0.51^{d}	6.3±0.48^{c}	5.4±0.51^{e}	5.7±0.48^{e}
P1	7.7±0.48^{ab}	6.4±0.51^{d}	6.8±0.48^{ab}	6.2±0.42^{cd}	6.2±0.42^{cd}
P2	7.6±0.51^{ab}	6.4±0.51^{d}	6.8±0.42^{ab}	6.3±0.43^{c}	6.4±0.51^{bc}
P3	7.7±0.48^{ab}	6.6±0.51^{d}	6.9±0.31^{ab}	6.6±0.51^{c}	6.9±0.31^{b}
P4	7.7±0.48^{ab}	7.0±0.00^{c}	7.0±0.47^{a}	7.3±0.48^{a}	7.3±0.48^{a}
P5	7.7±0.48^{ab}	7.4±0.51^{a}	7.0±0.47^{a}	7.6±0.51^{a}	7.5±0.52^{a}
P6	7.8±0.63^{a}	7.5±0.52^{a}	7.2±0.42^{a}	7.7±0.48^{a}	7.6±0.51^{a}
P7	7.3±0.48^{c}	7.3±0.48^{a}	6.8±0.42^{ab}	7.3±0.48^{a}	7.3±0.48^{a}
P8	7.2±0.42^{d}	7.1±0.31^{ab}	6.6±0.51^{c}	7.2±0.42^{ab}	6.9±0.31^{b}
EDPR ready-to-eat supplementary biscuit					
B0	8.2±0.42^{a}	8.1±0.56^{a}	7.9±0.56^{a}	8.2±0.42^{a}	8.4±0.51^{a}
B1	7.8±0.42^{ab}	7.9±0.56^{a}	7.6±0.51^{a}	7.9±0.31^{a}	7.9±0.31^{ab}
B2	7.8±0.42^{ab}	7.9±0.56^{a}	7.6±0.51^{a}	7.9±0.31^{a}	7.8±0.42^{ab}
B3	7.8±0.63^{ab}	7.9±0.56^{a}	7.8±0.42^{a}	7.9±0.31^{a}	8.1±0.31^{a}
B4	8.0±0.47^{ab}	8.0±0.31^{a}	8.0±0.56^{a}	8.1±0.31^{a}	8.3±0.48^{a}
B5	7.8±0.42^{ab}	8.0±0.47^{a}	7.9±0.47^{a}	7.9±0.31^{a}	8.3±0.48^{a}
B6	7.8±0.42^{ab}	7.9±0.31^{a}	7.4±0.51^{ab}	7.2±0.63^{b}	7.1±0.56^{c}
B7	7.4±0.51^{c}	7.2±0.63^{ab}	6.0±0.66^{c}	6.5±0.70^{c}	6.2±0.42^{d}
EDPR ready-to-eat supplementary nutribar					
N0	8.4±0.51^{a}	8.2±0.42^{a}	8.3±0.48^{a}	8.3±0.48^{a}	8.2±0.42^{a}
N1	6.4±0.51^{d}	6.2±0.42^{d}	6.2±0.42^{d}	5.4±0.51^{d}	5.8±0.42^{de}
N2	6.4±0.51^{d}	6.2±0.32^{d}	6.6±0.51^{d}	5.8±0.42^{d}	6.0±0.00^{d}

N3	6.6±0.51^{d}	6.9±0.31^{bc}	7.2±0.78^{c}	7.0±0.66^{c}	7.0±0.66^{bc}
N4	7.1±0.63^{bc}	7.2±0.78^{ab}	7.3±0.82^{b}	7.2±0.63^{c}	7.3±0.82^{b}
N5	7.6±0.51^{b}	7.8±0.63^{a}	7.7±0.48^{b}	7.9±0.56^{a}	8.1±0.56^{a}

C0: Commercially available RUSF; P0: EDPR Paste control; P1-P8: EDPR Paste variants; B0: EDPR Biscuit control; B1-B7: EDPR Biscuit variants; N0: EDPR Nutribar control; N1-N5: EDPR Nutribar variants Means with different superscripts letters in a category of sensory test differ significantly ($p < 0.05$)]; n=30

Likewise, another product, EDPR ready-to-eat supplementary biscuits, was developed which is commonly consumed by children across different age groups (Borooah *et al.*, 2024). The results for sensory appraisal (Table 4) revealed that for the color attribute in comparison to the control, the B4 variant received the highest mean sensory scores and was non-significantly different, further the scores were observed to be non-significant for B1-B3, B5 and B6, with a minimum scoring for B7. For the aroma attribute, in comparison to the control, B4 and B5 received the highest and comparable scores (non-significantly different), while a decreasing trend was seen from B5 to B7. For the texture attribute, there was no significant difference between the control and B1-B6 variants. In comparison to the control, the B4 variant showed highest mean sensory scores, which further showed a decreasing trend from B4 to B7. For the taste attribute, there was no significant difference between the control and B1-B5 variants, while B6 and B7 different significantly. The variant B1-B3 received similar scoring and the maximum scores were observed for the B4 variant after which from B4-B7 a decreasing trend was noticed. A similar trend as that of taste was observed for the overall acceptability. Therefore, in comparison to the control counterpart (B0: 100% GWF), the B4 variant (50% GSF, 30% GWF, and 20% GPMF) (Table 5) received the highest mean scores as the proportion of ingredients namely, GSF, GWF, and GPMF in the B4 variant imparted the desirable

ensory attributes, further any increase in the percent of GSF and GPMF decreased the sensory attributes. Therefore, B4 was selected as the standardized variant. Similarly, Wang *et al.*, 2021 developed soybean- based biscuits and observed that addition (greater than 20%) of soybean dreg powder imparted a darker color and made the biscuits harder. Due to the likability of biscuits among children, researchers have developed supplementary biscuits for children to manage malnutrition as they provide accessible and affordable nutrient-dense products. Reggi *et al.*, 2024 developed indigenous RUSF biscuits with different proportions of ingredients namely raw soy flour, peanut flour, rice flour, and wheat flour. Likewise, Fetriyuna *et al.*, 2021 and Grover *et al.*, 2020 developed RUSF biscuits from different indigenous crops to meet the nutritional requirements of MAM children.

Table 5. Composition (100 g) of the standardized EDPR ready-to-eat supplementary foods (paste, biscuit, and nutribar)

Ingredients (g/100g)	**Paste**	**Biscuit**	**Nutribar**
Peanuts (g)	25	-	56.52
GSF (g)	10	17.85	-
GWF (g)	4	10.7	6.08
GPMF (g)	-	7.10	6.08
GFMF (g)	10.60	-	-
SMP (g)	7	6.07	-
Sugar (g)	21	25	13
Jaggery (g)	-	-	13
Maltodextrin (g)	-	-	8
Butter (g)	-	25	-
Oil (g)	17	7.14	-
Micronutrient Premix (g)	5.40	5.17	5.65
Leavening agents (g)	-	1.42	-

Flavor (g)	-	0.71	-
Water (ml)	-	2.85	10.86

GSF: germinated soybean flour; GWF: germinated wheat flour; GPMF: germinated pearl millet flour; GFMF: germinated finger millet flour; SMP: skim milk powder

The third product developed was EDPR ready-to-eat supplementary nutribar, an increasing trend in all the sensory attributes (Table 4) was seen from N1 to N5. In comparison to the control, all the variants differed significantly for color attribute, while for aroma, texture, taste, and overall acceptability attributes there was no-significant difference between the control and B5 variant, Among all the variants (N1-N5), in comparison to the control (N0;100% peanut) the N5 variant (82% peanut, 9% GWF, and 9% GPMF) (Table 5) received the highest mean sensory scores for all the sensory attributes due to its composition which constituted peanuts and jaggery, which imparted the desirable taste and color (Singh *et al.*, 2023) respectively. Henceforth, P6, B4, and N5 variants were selected for paste, biscuit, and nutribar, respectively for further analysis.

Physico-chemical and microbial analysis

The selected variants (P6, B4, and N5) of each product (paste, biscuit, and nutribar), their respective controls (P0, B0, and N0), and commercial RUSF (C0) were subjected to physicochemical and microbial analysis (Table 6). A significant difference ($p \leq 0.05$) was observed in the energy, carbohydrate, fat, and protein content of the respective variant to its control counterpart. The products exhibited varied nutritive value with the highest content of energy, carbohydrates, fats, and protein content in the P0, B4, P6, and N5 variants, respectively owing to the combination of ingredients in the formulations. Interestingly the ash content was maximum in the B4 variant and minimum in the N5 variant. The N5 variant exhibited highest moisture content, followed by B4, and P6. The water activity showed a similar trend varying between 0.401±0.000 to 0.541±0.002. The test variants (P6, B4, and N5) showed significant differences ($p \leq 0.05$) in the nutritional index in comparison to the commercial RUSF (C0). The peroxide value for all the variants, their respective controls, and positive control varied between 3.76±0.02 meq O_2/kg (N0) to 1.12±0.03 meq O_2/kg (C0). Further, the microbial assay showed that the total plate count, yeast and mold count, total aflatoxin, and *Salmonella* were absent while the *Enterobacteriaceae* were <10 CFU/g in all the variants which conform to the technical specifications.

The results of all the variants for the mineral contents for calcium (mg), phosphorus (mg), potassium (mg), magnesium (mg), manganese (mg), zinc (mg), copper (mg), iron (mg), iodine (mcg), selenium (mcg), and sodium (mcg) ranged from 654.12 (P6) - 698.12 (B0), 513.14 (N0) - 593.16 (B0), 1210.12 (C0) - 1345.13
(B0), 185.11 (P6) – 202.02 (N5), 1.31 (P0 and B0) – 1.41 (B4), 12.02 (C0) – 13.10 (B4), 1.51 (P6) – 1.61 (B0), 10.13 (N0) – 10.48 (B4), 108.21 (N5) – 113.13 (N0), 22.02 (C0) – 23.18 (N0), and 132.21 (B0) 141.12 (P0), respectively. The physico-chemical analysis of the selected variants (P6, B4, and N5) conferred to the technical specifications of WHO for supplementary foods providing 510–560 kcal of energy, 11–16 g of protein, 26–36 g of fat, and the specified micronutrients per 100g.

Table 6. Physicochemical and microbial analysis of control and test variants for indigenous EDPR ready-to-eat supplementary foods

Paramete rs	Positiv e Contr ol	Paste		Biscuit		Nutribar	
	C0	P0	P6	B0	B4	N0	N5
Energy (kcal)	530.03 ±0.07[c]	580.10 ±0.07[a]	544.23 ±0.06[b]	501.09 ±0.06[g]	520.34 ±0.02[f]	529.36±0.05[d]	521.09±0.02[e]
Carbohyd rate (%)	45.04± 0.02[f]	41.20± 0.20[g]	49.70± 0.03[d]	62.76± 0.28[a]	52.30± 0.01[b]	47.50±0.02[e]	51.39±0.43[c]

Fat (%)	34.18±0.11^{b}	39.40±0.20^{a}	32.19±0.03^{c}	24.39±0.51^{f}	28.24±0.03^{e}	30.56±0.39^{d}	28.79±0.15^{e}
Protein (%)	12.04±0.06^{e}	15.13±0.02^{b}	13.59±0.04^{d}	6.97±0.04f	13.48 ± 0.04^{d}	15.63±0.03^{a}	13.75±0.05^{c}
Moisture (%)	2.92±0.01^{c}	2.73±0.02^{d}	2.79±0.00^{d}	2.98±0.03c	3.13±0.01b	4.44±0.02a	4.62±0.04a
Ash (%)	1.77±0.01^{b}	1.54±0.03^{c}	1.73±0.02^{b}	2.90±0.01a	2.85±0.01a	1.55±0.09c	1.43±0.02d
Water activity	0.410±0.00^{c}	0.398±0.002^{d}	0.401±0.00^{cd}	0.397±0.002^{d}	0.435±0.003^{b}	0.530±0.003^{a}	0.541±0.002^{a}
Peroxide value (meq O2/kg)	1.12±0.03^{f}	2.16±0.03^{c}	1.74±0.06^{e}	1.99±0.01d	2.46±0.32c	3.76±0.02a	3.43±0.13b
TPC (CFU/g)	Absent	Absent	Absent	Absent	Absent	Absent	Absent
YMC (CFU/g)	Absent	Absent	Absent	Absent	Absent	Absent	Absent

Salmonella (per 25 g)	Absent	Absent	Absent	Absent	Absent	Absent	Absent
Enterobacteriaceae (CFU/g)	<10	<10	<10	<10	<10	<10	<10
Total aflatoxin (µg/kg)	ND	ND	ND	ND	ND	ND	ND
Calcium (mg)	672.12 ±0.03	689.01 ±0.06	654.12 ±0.02	698.21 ±0.10	663.53 ±0.02	679.42 ±0.07	692.44 ±0.03
Phosphorus (mg)	589.16 ±0.06	584.15 ±0.10	572.22 ±0.07	593.16 ±0.06	581.32 ±0.19	513.14 ±0.01	574.32 ±0.04
Potassium (mg)	1210.12±0.10	1258.17±0.19	1249.17±0.04	1345.13±0.02	1276.12±0.10	1313.23±0.03	1213.27±0.04
Magnesium (mg)	189.23 ±0.03	194.12 ±0.04	185.11 ±0.01	198.21 ±0.19	201.14 ±0.04	195.38 ±0.07	202.02 ±0.06
Manganese (mg)	1.32±0.07	1.31±0.06	1.40±0.03	1.31±0.06	1.41±0.02	1.32±0.03	1.43±0.19
Zinc (mg)	12.02±0.06	12.14±0.07	12.03±0.02	12.07±0.07	13.10±0.03	12.91±0.02	12.80±0.10
Copper (mg)	1.60±0.02	1.54.01±0.19	1.51±0.02	1.61±0.07	1.52±0.06	1.53±0.04	1.55±0.02
Iron (mg)	10.31±0.04	10.40±0.06	10.21±0.03	10.22±0.03	10.48±0.04	10.13±0.06	10.23±0.05
Iodine (mcg)	110.21 ±0.06	110.34 ±0.04	110.42 ±0.10	110.24 ±0.07	110.12 ±0.04	113.13 ±0.05	108.21 ±0.03
Selenium (mcg)	22.02±0.02	23.10±0.10	22.34±0.07	22.21±0.10	22.32±0.02	23.18±0.05	22.14±0.07
Sodium (mcg)	138.12 ±0.10	141.12 ±0.07	135.10 ±0.02	132.21 ±0.07	137.02 ±0.10	136.81 ±0.07	140.02 ±0.05

Mean±SD (n=3), different superscripts in a row are considered statistically significant at a P ≤0.05. Where, C0: commercially available RUSF; P0: EDPR paste control; P6: EDPR paste Test Variant; B0: EDPR biscuit control; B4: EDPR biscuit Test Variant; N0: EDPR nutribar control; N5: EDPR nutribar Test Variant, TPC: Total plate count; YMC: yeast and mold count; CFU: colony forming units; ND: not detectable

Shelf-life evaluation

The shelf-life study of the EDPR ready-to-eat supplementary foods (paste, biscuit, and nutribar) were periodically evaluated for various physico-chemical and microbial parameters (moisture content, PV, TPC, yeast and mold count, and sensory analysis) at an interval of 30 days starting from the 0th day for a period of 180 days (data shown in supplementary Table 7, 8, and 9). The moisture content and water activity of both the variants (P0 and P6) showed a slow increasing trend during storage (Table 7). The percent increase in moisture content of P0 from 0th to 180th day was 1.83%, while the P6 variant was 1.7%. Furthermore, the increase in the aw for P0 and P6 was 1.2%. The percent increase in the PV for P0 and P6 variants was 22.8% and 21.8%, respectively. The moisture content and water activity of both the variants (B0 and B4) showed an increasing trend during storage (Table 8). The percent increase in moisture content of the B0 from 0th to 180th day was 42.2%, while the B4 variant was 43.1%. Furthermore, the increase in the aw for B0 and B4 was 48.3% and 37.1%, respectively. The PV of both variants showed an increasing trend during storage, with a higher PV for the B4 variant owing to the fat content. The moisture content and water activity of both the variants (N0 and

N5) showed an increasing trend during storage (Table 9). The percent increase in moisture content of N0 from 0th to 180th day was 16.4%, while the N5 variant was 29%. Furthermore, the increase in the aw for N0 and N5 was 7.1% and 9.7%, respectively. The PV of both variants showed an increasing trend during storage, with a higher PV for the N0 variant.
The results of shelf-life evaluation for all the products (P0, P6, B0, B4, N0, and N5) revealed that the products were shelf stable for 180 days as, it was studied that the aw of all the products remained less than
0.6 after the storage period, thereby inhibiting microbial growth (Duta *et al.,* 2019). Furthermore, results for *Salmonella, Enterobacteriaceae,* and total aflatoxin, tested on the 0th, 90th day, and 180th day were not detectable. The results illustrate that the supplementary foods were stable in terms of all sensory attributes and overall acceptability during the storage period.

Table 7. Physico-chemical properties of EDPR ready-to-eat supplementary paste during storage

Storage period (days)	Moisture content (%)		Water activity (a_W)		Peroxide value (meq O_2/kg)	
	P0	P6	P0	P6	P0	P6
0	2.73±0.02 a	2.79±0.00 a	0.398±0.002 b	0.401±0.001 a	2.16±0.03 e	1.74±0.06 c
30	2.75±0.01 a	2.80±0.00 a	0.398±0.002 b	0.401±0.001 a	2.16±0.03 e	1.76±0.02 c
60	2.75±0.01 a	2.79±0.00 a	0.399±0.001 b	0.401±0.001 a	2.24±0.03 d	1.75±0.01 c
90	2.78±0.01 a	2.79±0.01 a	0.410±0.002 a	0.403±0.001 a	2.34±0.04 c	1.79±0.02 c
120	2.78±0.03 a	2.80±0.02 a	0.410±0.002 a	0.404±0.001 a	2.41±0.05 c	1.81±0.02 c
150	2.78±0.01 a	2.80±0.01 a	0.409±0.001 a	0.404±0.000 a	2.54±0.01 b	1.93±0.12 b
180	2.78±0.04a	2.84±0.00 a	0.410±0.002 a	0.406±0.001 a	2.64±0.01 a	2.12±0.02 a

Mean±S.D. (n=3), Where; ND = Not detected, P0 = Control, P6 = EDPR ready-to-eat supplementary paste

Table 8. Physico-chemical properties of EDPR ready to eat supplementary biscuits during storage

Storage period (days)	Moisture content (%)		Water activity (a_W)		Peroxide value (meq O_2/kg)	
	B0	B4	B0	B4	B0	B4
0	2.98±0.03 de	3.13±0.01d	0.397±0.002c	0.435±0.003e	1.99±0.01d	2.46±0.32g
30	2.99±0.03 de	3.15±0.01d	0.397±0.002c	0.435±0.001e	1.99±0.02d	2.66±0.32f
60	3.02±0.08 d	3.15±0.00d	0.399±0.002c	0.437±0.002e	2.03±0.04d	2.85±0.35e
90	3.06±0.07 d	3.15±0.00 d	0.400±0.002c	0.459±0.001d	2.11±0.02c	3.06±0.07d

120	3.65±0.03 ^{c}	3.77±0.00^{c}	0.420±0.002^{c}	0.496±0.002^{c}	2.18±0.01^{c}	3.27±0.10^{c}
150	4.13±0.04 ^{b}	4.36±0.03^{b}	0.562±0.001^{b}	0.583±0.002^{b}	2.34±0.03^{b}	3.61±0.19^{b}
180	4.24±0.02 ^{a}	4.48±0.01^{a}	0.589±0.001^{a}	0.596±0.001^{a}	2.60±0.07^{a}	3.99±0.02^{a}

Mean±S.D. (n=3), Where; ND = Not detected, B0 = Control, B4 = Standardized EDPR ready-to-eat supplementary biscuits

Table 9. Physico-chemical properties of EDPR ready-to-eat supplementary nutribars during storage

Storage period (days)	Moisture content (%)		Water activity (a_W)		Peroxide value (meq O_2/kg)	
	N0	N5	N0	N5	N0	N5
0	4.44±0.02^{f}	4.62±0.04^{d}	0.530±0.003^{d}	0.541±0.002^{cd}	3.76±0.02^{e}	3.43±0.13^{de}
30	4.49±0.02^{f}	4.65±0.07^{d}	0.529±0.002^{d}	0.541±0.001^{cd}	3.76±0.09^{e}	3.44±0.08^{de}
60	4.54±0.02^{e}	4.65±0.04^{d}	0.530±0.003^{d}	0.541±0.002^{cd}	3.76±0.02^{e}	3.47±0.13^{d}
90	4.61±0.02^{d}	4.67±0.01^{d}	0.547±0.001^{c}	0.543±0.002^{c}	3.84±0.04^{d}	3.53±0.09^{d}
120	4.69±0.01^{c}	4.73±0.04^{c}	0.552±0.003^{b}	0.549±0.003^{c}	3.93±0.02^{c}	3.68±0.03^{c}
150	4.76±0.02^{b}	4.85±0.02^{b}	0.559±0.001^{b}	0.583±0.001^{b}	4.36±0.03^{b}	3.84±0.04^{b}
180	5.17±0.01^{a}	4.91±0.07^{a}	0.568±0.003^{a}	0.594±0.003^{a}	4.87±0.07 ^{a}	4.24±0.05^{a}

Mean±S.D. (n=3), Where; ND = Not detected, N0 = Control, N5 = EDPR ready-to-eat supplementary nutribar

IV. CONCLUSION

The study focused on the development and evaluation of the acceptability of indigenous EDPR ready-to- eat supplementary foods. The products were developed (paste, biscuit, and nutribar) according to the specifications of the WHO for supplementary foods. The development of supplementary food using indigenous crops will increase the acceptability and compliance of the nutritional interventions and hence lower the prevalence of acute malnutrition in children.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article.

Author contributions

Vanya Pareek: Conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resources, software, validation, visualization, writing – original draft, writing – review, and editing. **Komal Chauhan:** Conceptualization, supervision, project administration, visualization, writing - review and editing. **Neetu Taneja**: Resources. **Harinder Singh Oberoi**: Resources. Nishant Kumar: visualization, writing - review and editing.

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