Industrial Collaborative Project
Corporate Partner: Nutricircle

On

Utilization of Protein Powders for Product Development

Project Report

By

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1. Introduction

The global food industry is witnessing a paradigm shift towards plant-based nutrition, driven by consumer awareness regarding sustainability, health, and ethical concerns. Protein fortification remains a critical area of innovation, particularly in converting standard staple foods into functional products. Consumer preferences are consistently shifting toward plant-based alternatives. This Project represents collaborative effort between Nutricircle and NIFTEM-Kundli (NIFTEM-K).

NIFTEM-K possesses a formidable infrastructure that positions it as a national leader in food research and technological advancement within India. The core of its technical capacity lies in its 14 advanced laboratories, specifically designed to facilitate comprehensive, interdisciplinary research across critical domains, including food engineering, processing, safety, packaging, and nutrition. These facilities support both foundational academic studies and highly applied research, and feature pilot-scale demonstration units that enable real-world simulation of complex industrial food processing operations.

A key strategic focus for NIFTEM-K is its commitment to public health and functional food systems, exemplified by the establishment of the Centre of Excellence for Food Fortification (CEFF). The institute's authoritative standing is further validated by its recognition by the Food Safety and Standards Authority of India (FSSAI) as a National Reference Laboratory (NRL) for fortified foods, empowering it to conduct advanced analytical testing, meticulous method validation, and compliance assessment in strict accordance with national food safety standards.

Beyond its physical labs, NIFTEM supports academic excellence through the NIFTEM Knowledge Centre, a multi-storey digital library that offers seamless engagement through extensive access to e-journals, databases, and automated systems. Crucially, the institute maintains strong industry linkages, formalized through Memoranda of Understanding (MoUs) with leading food corporations and global institutions. These collaborations actively drive collaborative Research and Development (R&D), facilitate internship programs, and ensure efficient technology transfer. Collectively, this integrated infrastructure not only ensures a foundation for high-calibre academic work but also actively fosters entrepreneurship and the development of scalable solutions necessary to meet contemporary food industry challenges.

The project, "Utilization of Protein Powders for Product Development: Functional and Nutritional Assessment of Horsegram, Foxtail Millet Protein, Rajma Protein, Amaranth Protein, Rice Protein, Chickpea Protein, is strategically positioned to address the rapidly

expanding global demand for healthy, sustainable, and non-animal protein sources. Leveraging specialized raw materials provided by Nutricircle company to NIFTEM, including proteins derived from Horsegram, Foxtail Millet, Rajma (Red Kidney Bean), Amaranth, and Chickpea, Rice Protein, this research focuses on developing high-value, novel food matrices across critical consumer segments

2. Materials & methodology:

The present investigation was designed to evaluate the application potential of plant-based protein ingredients supplied by Nutricircle Pvt. Ltd. for the development of nutritionally enhanced food products. The protein materials—including foxtail millet, horsegram, rajma, amaranth, chickpea, and rice proteins—were received as fine protein fractions in powdered form, produced through proprietary separation processes. The powders were free-flowing, with color ranging from off-white to light brown and exhibiting typical cereal–legume sensory notes.

The present project, titled "**Utilization of Protein Powders for Product Development**," aims to systematically explore the functional potential of protein ingredients derived from Horse gram, Foxtail millet, Rajma, Amaranth, and Finger millet. The specific objectives are:

1. Proximate and Functional Characterization of Protein powders.
2. Product Development and Optimization
3. Sensory and textural evaluation
4. Shelf Life study

Phase I

1. Characterization of Protein Sources

To analyze and characterize the physicochemical, functional, and nutritional properties of proteins extracted from Horse gram, Foxtail millet, Rajma, Amaranth, and Finger millet for their suitability in food product applications.

2. Product Development and Standardization

To develop, formulate, and standardize a diverse range of value-added products utilizing the selected protein sources, including:

- Horse gram: Atta fortification, weaning mixes, and ready-to-cook porridge mixes
- foxtail millet: Atta fortification, weaning mixes, cookies, and health mix composites
- Rajma: Cookies
- Amaranth: Bread, muffins, pasta, spaghetti, and extruded breakfast cereal
- Finger millet: Cookies, Pasta, Noodles

Nutritional and Functional Evaluation

To conduct comprehensive analytical testing of the developed products, including proximate composition, nutritional profiling, total phenolics, antioxidant activity, tannin and phytate content, total dietary fiber, and microbial quality.

Sensory and Textural Assessment

To evaluate sensory attributes, consumer acceptability, and instrumental texture parameters, along with cooking characteristics for products such as noodles, pasta, and spaghetti.

Shelf Life Study

To assess the stability and shelf life of the optimized products under defined storage conditions by monitoring physicochemical, microbiological, and sensory changes over time.

Phase II:

1) Plant protein blends with balanced amino acids profile and application in novel product development
2) Flour blend with high protein and balanced amino acid profile and their applications in development of different food products
3) Texturized vegetable protein
4) Protein rich ready to eat extruded products

2.1 Proximate analysis:

The protein content of samples were analyzed using the automated Kjeldahl method. 0.2 - 0.5g sample was taken and digested using 98% pure sulphuric acid, catalyst cupric sulfate, and potassium sulfate in a 1:10 ratio at 420° C for 120 minutes. The digested samples were subjected to distillation, using 4% boric acid and 40% NaOH solution. The distillate was titrated against 0.1N sulphuric acid.

The moisture content of Protein Powders and optimised products was estimated using SHIMADZU's Uni Bloc MOC63u rapid moisture analyzer. 1 g of the sample was taken for moisture analysis at 27±2°C. The moisture content obtained was on a wet basis and was expressed as % moisture in the sample. Fat estimation of optimized products were done using the Soxhlet method as prescribed by AOAC 922.06. 1- 3 g of the sample was taken in a porous thimble. The thimble was placed in the Soxhlet apparatus. The solvent used for fat extraction was petroleum ether, and the heating cycle was continued for 6 hours. After the heating cycle, the solvent was recovered, and the extracted fat was dried in the oven at 100°C for 3 hours. Crude fiber was estimated using the protocol of AOAC 962.09 and AOAC 978.10. 2g of the sample was taken to assess Fiber in FP. It was first digested with 1.25% sulphuric acid at 420°C for 40 minutes and 1.25% NaOH at 420°C for 40 minutes. After digestion, the samples were dried at 105°C for 3 hours or until a constant weight was observed and were incinerated in a muffle furnace at 550°C for 3 hours. Ash analysis was

performed as per the guidelines of AOAC 942.05. The 5g sample was taken in a dry crucible and was charred. The crucibles were kept in a muffle furnace for 3 hours at 550°C.

2.2 Water and oil holding capacity

WHC and OHC were determined following the method described by (Shin, 2022); with slight modifications. 0.5 g of protein powder was dispersed in 10 mL of distilled water and vortexed for 1 min. The suspension was allowed to stand for 60 min and then centrifuged at 4000 × g for 10 min. The supernatant was discarded, and the residue was weighed. WHC or OHC was expressed as grams of water or oil retained per gram of protein.

For FP, WHC and OHC were evaluated using the procedure reported by Rivas et al. (2021). In this case, 0.2 g of FP was mixed separately with 10 mL of water and 10 mL of oil and allowed to stand for 24 h. The samples were centrifuged at 2000 × g for 25 min, the supernatant discarded, and the sediment weighed. WHC and OHC were Emulsion stability studies for proteins and functional powder (FP) were carried out following the method of Padial-Domínguez et al. (2020) with minor modifications. Briefly, 1 g of protein was dissolved in 100 mL of phosphate buffer (pH 7.0) and stirred for 1 h. Sunflower oil (10 mL) was then mixed with 10 mL of the protein suspension, and the mixture was homogenized at 12,000 rpm for 2 min. From the resulting emulsion, a 50 μL aliquot was diluted in 5 mL of 0.1% freshly prepared SDS solution, and the absorbance (A_0) was measured immediately. After 10 min, the absorbance (A_{10}) was measured again to calculate the Emulsion Stability Index (ESI). The same procedure was followed for FP.

The Emulsion Activity Index (EAI) and Emulsion Stability Index (ESI) were calculated using the following equations, where D is the dilution factor, φ is the oil volume fraction, and C is the protein concentration (g/mL):

$$EAI = \frac{2 \times 2.303 \times Ao \times D}{C \times \phi \times 10000} \qquad (1)$$

$$ESI = \frac{A10}{Ao \times A10} \times 10 \qquad (2)$$

2.3 Foaming capacity and foam stability

The method described by (Hassan, 2019) was used for the determination of foam capacity (FC) and foam stability (FS). Two grams of the Protein Powder sample was added to 50 mL of distilled water at 30 ± 2C in a 100-mL measuring cylinder. The suspension was mixed and properly shaken by whipping for 3 min in a homogenizer to form foam. The content was transferred into the measuring cylinder, and the volume of the foam after 30 s was recorded. The FC was expressed as a percentage increase in volume:

$$\text{Foam capacity (\%)} = \frac{\text{Volume after whipping} - \text{Volume before whipping}}{\text{Volumebeforewhipping}} \times 100 \quad \ldots. \ (3)$$

The foam volume was recorded 1 hr after whipping to determine the FS as a percentage of the initial foam volume:

$$\text{Foam stability (\%)} = \frac{\text{Foam volume after standing time } (60\ min)}{\text{Initial foam volume}} \times 100 \quad \ldots. (4)$$

2.4 Bulk Density

Bulk density was measured (Wani, 2013) as a ratio of mass to volume. A graduated cylinder, previously tarred, was gently filled upto 10 ml mark with flour. The sample was then packed by gently tapping the cylinder on the bench top from a height of five cm until there was no further diminution of the sample level and noted the volume. The weight of the filled cylinder was taken and the bulk density was calculated as the weight of sample per unit volume (kg/L).

2.5 Swelling power (SP)

Swelling power was determined by the method outlined by Shafi et al. (2016). Samples weighing 0.5 g each were dispersed in 50 ml distilled water. The mixture was heated for 30 min at 90°C. Centrifugation of the homogenate was performed at 3,000 rpm for 15 min. Thereafter, the supernatant was decanted and oven-dried (Memmert) at 100 ± 5°C till constant weight. Results for SP were represented in g/g of the dried sample. (Muhammad Waseem1, 2020)

2.6 Particle Size

Particle size for the protein was analysed using Anton Paar's particle size analyser. The particle size distribution of the protein sample was determined using Anton Paar's particle size analyser based on dynamic light scattering (DLS) technology. Prior to analysis, the sample was dispersed in distilled water and sonicated to ensure uniform suspension. Measurements were conducted at room temperature, and average particle size was calculated using the instrument's integrated software.

3. Results & Discussion

PHASE 1

Table 1 Characterization of Protein Sources

Protein Type	Foxtail Protein	Horsegram protein	Rajma	Amaranth	Quinoa
Protein Content (g/100g)	17%	24.9%	40.51%	26.03	
WAC (g water/g protein)	2.27 ± 0.053	2.49 ± 0.011	4.28 ± 0.34	1.98 ± 0.005	2.26 ± 0.022
OAC (g oil /g protein)	2.23 ±0.06	2.21 ± 0.020	2.47 ± 0.11	2.67 ± 0.05	2.6 ± 0.241
Foaming Capacity (%)	3.06 ± 0.750	27.65 ± 3.00	61 ±1.14	14.58 ± 0	27.08 ± 0
Foaming Stability (%)	100%	100%	99.38%	100%	100%
Emulsion Activity (m^2/g)	46.62 ± 1.29	47.82 ± 1.4	58.81 ± 1.67	52.41 ± 0.45	25.73 ± 1.5
Emulsion Stability (min)	56.89 ± 0.95	50 ± 0.41	50 ± 0.93	46.96 ± 0.48	46.96 ± 1.28
Bulk Density(g/ml)	0.625	0.532	0.526	0.500	0.510
Swelling power (g/g)	8.22 ± 0.24	5.92 ± 0.57	9.94 ± 1.70	6.06 ± 0.07	7.73 ± 0.31
Particle size (µm)	14.341 ± 0.512	51.780 ± 5.611	35.618 ± 0.855		

The functional evaluation of Foxtail, Horsegram, Rajma, Amaranth, and Quinoa proteins revealed distinct properties relevant for product development. Foxtail protein, although lower in protein content (17%), exhibited a high bulk density (0.625 g/ml) and good swelling power (8.22 g/g), supporting its suitability for extruded and structure-dependent products. Amaranth protein showed balanced protein content (26.03%) and the highest oil absorption capacity (2.67 g/g), indicating strong lipid-binding behavior useful in flavor-rich, high-fat food matrices. Rajma protein demonstrated high water absorption (4.28 g/g), swelling (9.94 g/g), and foaming capacity (61%), but its sensory limitations reduce its applicability in taste-sensitive products.

Horsegram and Quinoa provided moderate hydration and foaming properties with excellent stability, making them suitable for composite flours and nutritional blends. Overall, Foxtail and Amaranth show strong potential for high-quality product development, while each protein source contributes unique functionalities for targeted applications.

4. Product Development and Standardization

4.1. Cookies

Raw materials :

Refined Wheat Flour:

Acts as the primary structural component, forming gluten networks that hold the dough together. It determines cookie spread, crumb structure, and overall mechanical strength

Breakfast Sugar:

Functions as a sweetener and controls cookie spread by delaying gluten development. It promotes caramelization and Maillard browning, contributing to color, crispness, and flavor.

Butter:

Serves as the main fat source, creating tenderness by coating flour particles and limiting gluten formation. It enhances mouthfeel, flavor release, and helps achieve the characteristic cookie spread.

Milk Powder:

Contributes lactose and proteins that improve browning reactions and enhance flavor. It also adds body, increases nutrient density, and supports better dough consistency.

Ammonium Bicarbonate:

Used as a high-temperature leavening agent suitable for low-moisture products. It releases gases rapidly, producing a porous, light internal structure without leaving alkaline residues.

Baking Powder:

Provides controlled secondary leavening to balance texture, prevent excessive hardness, and contribute to uniform cookie expansion.

Cashew Pieces:

Added for a desirable crunchy texture and improved sensory richness. cashew fats add flavor depth and contribute to overall consumer acceptability.

Vanilla Essence: Used to enhance aroma and provide a uniform flavor profile. It masks any cereal or beany notes from foxtail protein, improving taste perception.

Water: Hydrates flour, proteins, and dry ingredients to form a cohesive dough. It activates leavening agents and helps achieve the desired dough rheology for cookie shaping.

4.1.1. Foxtail Protein Enriched Butter Cookies

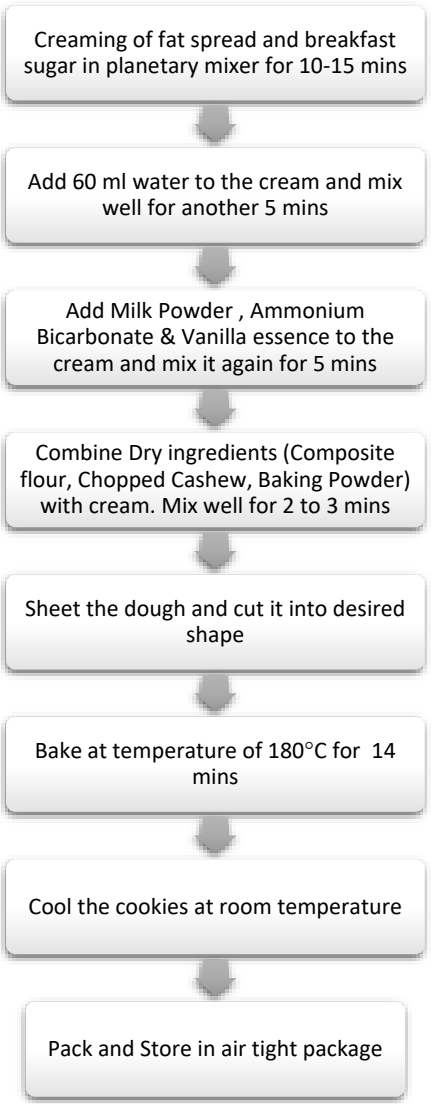
Ingredients: Refined wheat flour + Foxtail protein powder (30% of replacement of flour), Refined wheat flour, Breakfast Sugar, Fat spread, Cashew, Milk powder, Baking powder, Ammonia Bicarbonate, Vanilla essence

Table 2 Composition Table of foxtail enrich butter cookies

Sl.no.	Ingredients	Brand	(g) for 250 g of composite Flour	Amount (%)
1.	Refined wheat flour	Pansari	175	26.19
2.	Foxtail Protein	BB Royal	75	11.22
4.	Fat Spread	Delicious	125	18.7
5.	Breakfast Sugar	Trust	125	18.7
6.	Cashew	BB Royal	50	7.48
7.	Milk powder	Nestle Everyday	50	7.48
8.	Baking powder	Weikfield	4	0.5
9.	Ammonium bicarbonate	Baking	4	0.5
10.	Vanilla	Puramate	10 drops	10 drops
11.	Water	-	60 ml	8.98

The cookie dough was prepared using a standardized multistage process. In the first step, fat spread and breakfast sugar were creamed in a planetary mixer for 15 minutes to achieve uniform aeration and homogenization. Water (≈60 mL) was incorporated gradually to obtain a consistent emulsion. In the next stage, milk powder, ammonium bicarbonate, and vanilla essence were added and mixed for 5 minutes to ensure proper dispersion. The composite flour blend (refined wheat flour, and Foxtail millet protein), chopped cashew, and baking powder were then incorporated at low speed for 2–3 minutes to develop a cohesive dough. The dough was sheeted, cut into uniform shapes, and baked at 180 °C for 14 minutes. After baking, the cookies were cooled to ambient temperature and packed in airtight containers. A 250 g batch of composite flour yielded approximately 45 cookies.

Process Flow Chart





Nutritional Profile

The nutritional profile indicates the balance of essential nutrients—carbohydrates, proteins, fats, vitamins, and minerals—relative to consumer dietary requirements. It reflects both the quantitative nutrient composition and the qualitative contribution of each nutrient to daily intake. Nutritional analysis of the product was conducted at the CFRA, NABL-accredited laboratory, NIFTEM. The evaluated parameters and corresponding results are presented in the following table.

Table 3 Nutritional information for foxtail protein enriched butter cookies

Sl.no	Parameters	Result (per 100g) (%)
1.	Energy (Kcal)	479.29
2.	Carbohydrates	67.30
3.	Protein	9.00
4.	Total fat	19.37
5.	Saturated fat	12.43
6.	Total trans-fat	BLQ
7.	Dietary fibre	2.86
8.	Total sugar	21.42
9.	Sodium (mg)	2649.53
10.	Antioxidant Activity By DPPH	70.27
11.	Total Polyphenol content (TPC) By Gallic acid	83.41

BLQ: (Below Limit of Quantification)

Storage Studies

The freshly prepared cookies were packed in aluminised laminated pouches and stored at ambient conditions (28°C). The sealed samples were placed in a

desiccator for the duration of the storage study. At 15-day intervals, individual packets were withdrawn and analyzed for key quality parameters, including moisture content, water activity, free fatty acid level, sensory attributes, and microbial load (TPC and YMC).

***N.D – Not Detected**

Table 4 Shelf Life study of foxtail protein enriched butter cookies

Days	Water activity	Moisture (%)	FFA (%)	TPC	YMC	Sensory score (O.A)
0th Day	0.3589	3.24	0.539	N.D	N.D	8.9
15th Day	0.3595	3.36	0.698	N.D	N.D	8.6
30th Day	0.3556	3.43	0.864	N.D	N.D	8.5
45th Day	0.3563	3.49	0.989	N.D	N.D	8.3
65th Day	0.3773	4.53	1.242	N.D	N.D	8.2

4.1.2. Foxtail Protein Enriched Choco-Chip Cookies

Ingredients

Refined wheat flour + Foxtail millet protein powder (30% replacement of refined wheat flour), butter, breakfast sugar, milk powder, baking powder, ammonium bicarbonate, cocoa powder, dark chocolate, choco chips, chocolate essence, and water.

Table 5 Composition of Foxtail Protein Enriched Choco-Chip Cookies

Sl.no.	**Ingredients**	**Brand**	**(g) for 250 g of composite Flour**	**Amount (%)**
1.	Refined wheat flour	Pansari	175	25.43
2.	Foxtail Protein	BB Royal	75	10.90
4.	Fat Spread	Delicious	125	18.16
5.	Breakfast Sugar	Trust	125	18.16
7.	Milk powder	Nestle Everyday	50	7.26
6.	Choco chips	-	35	5.08
8.	Dark Chocolate	Amul	25g	3.63
9	Coco powder	Weikfield	10	1.45
8.	Baking powder	Weikfield	4	0.58
10.	Ammonium bicarbonate	Baking	4	0.58
11.	Chocolate essence	Puramate	10 drops	10 drops
12.	Water	-	60 ml	8.72

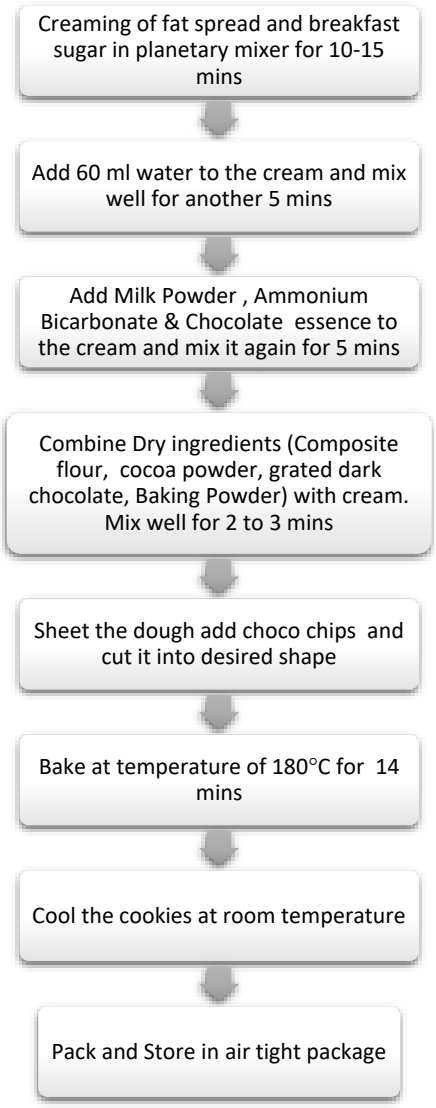
Method of Preparation

The cookie dough was prepared using a standardized multistage process. Initially, butter and breakfast sugar were creamed in a planetary mixer for approximately 15 minutes to achieve uniform aeration and proper homogenization. Water (≈60 mL) was gradually incorporated to form a smooth emulsion. Subsequently, milk powder, ammonium bicarbonate, cocoa powder, and chocolate essence were added and mixed for 5 minutes to ensure uniform dispersion.

The composite flour blend (refined wheat flour and foxtail millet protein powder), baking powder, dark chocolate pieces were then incorporated at low speed for 2–3 minutes to obtain a cohesive dough. The dough was sheeted uniformly add choco chips on sheet cut into

desired shapes, and baked at 180 °C for 14 minutes. After baking, the cookies were cooled to ambient temperature and packed in airtight containers. A 250 g batch of composite flour yielded approximately 45 cookies.

Process Flow Chart





Nutritional Profile

The nutritional profile indicates the balance of essential nutrients—carbohydrates, proteins, fats. —relative to consumer dietary requirements. Nutritional analysis of the product was conducted at the labs of NIFTEM. The evaluated parameters and corresponding results are presented in the following table.

Table 6 Nutritional information for foxtail protein enriched butter cookies

Sl.no	Parameters	Result (per 100g) (%)

1.	Energy (Kcal)	492.6
2.	Carbohydrates	66.85
3.	Protein	9.35
4.	Total fat	20.85

4.1.3. Rajma protein enriched Butter cookies:

Ingredients : Refined wheat flour + Rajma protein powder (15 % of replacement of flour) , Refined wheat flour, Breakfast Sugar, Fat spread, Cashew , Milk powder, Baking powder, Ammonia Bicarbonate, Vanilla essence

Table 7 Rajma Protein enriched butter cookies composition table

Sl.no.	**Ingredients**	**Brand**	**(g) for 250 g of composite Flour**	**Amount (%)**
1.	Refined wheat flour	Pansari	212.5	31.11
2.	Rajma Protein	BB Royal	37.5	6.0
4.	Fat Spread	Delicious	150	21.96
5.	Breakfast Sugar	Trust	125	18.30
6.	Cashew	BB Royal	50	7.32
7.	Milk powder	Nestle Everyday	50	7.32
8.	Baking powder	Weikfield	4	0.5
9.	Ammonium bicarbonate	Baking	4	0.5
10.	Vanilla	Puramate	10 drops	10 drops
11.	Water	-	50 ml	7.32

Cookie dough preparation began with creaming fat spread and sugar for 15 minutes in a planetary mixer. Ammonium bicarbonate and skimmed milk powder were then added and mixed for 5 minutes, followed by gradual incorporation of vanilla essence and ~60 mL water

to form a uniform emulsion. A composite flour blend containing refined wheat flour and 15% rajma protein, along with baking powder, was added to the wet mixture and mixed at low speed for 2–3 minutes to develop a cohesive dough. The dough was sheeted to an 8 mm thickness, topped with chopped cashew pieces during sheeting, and cut into uniform shapes. Cookies were baked at 180°C for 15 minutes (8 + 7 minutes), cooled, and packed, yielding about 45 cookies from 250 g composite flour.

Process Flow Chart

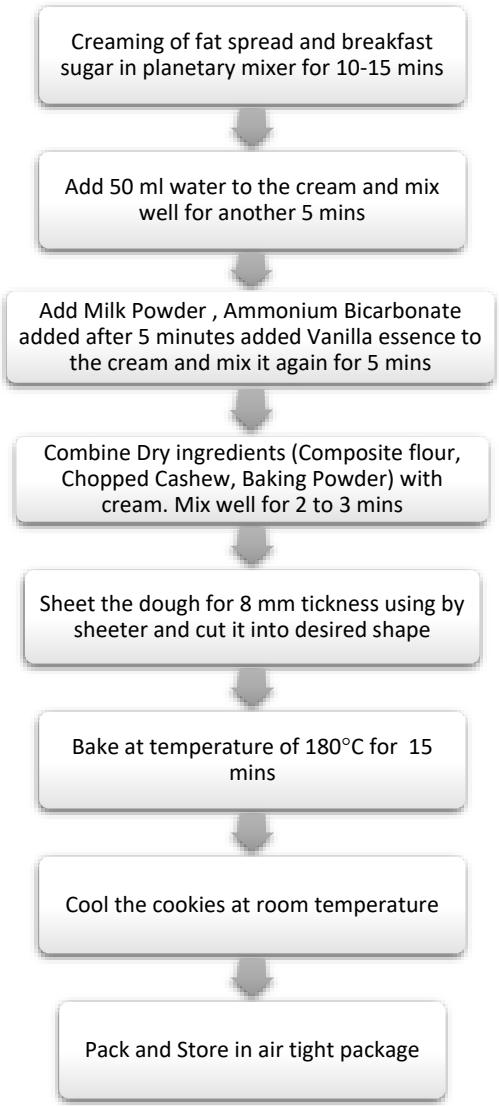




Figure 1 Rajma protein enriched butter cookies

Nutritional Profile

Nutritional analysis of the product was conducted at the CFRA, NABL-accredited laboratory, NIFTEM. The evaluated parameters and corresponding results are presented in the following table

Table 8 Nutritional Information of Rajma protein enriched butter cookies

Sl.No.	Parameters	Result (per 100g) (%)
1.	Energy (Kcal)	439
2.	Carbohydrates	60.5
3.	Protein	8.5
4.	Total fat	20.2
5.	Dietary fibre	2.0
6.	Ash	1.8

Storage Studies

The freshly prepared cookies were packed in aluminised laminated pouches and stored at ambient conditions (28°C). The sealed samples were placed in a desiccator for the duration of the storage study. At 15-day intervals, individual packets were withdrawn and analyzed for key quality parameters, including moisture content, water activity, free fatty acid level, sensory attributes, and microbial load (TPC and YMC).

Table 9 Shelf Life study of Rajma protein enriched butter cookies.

Days	Water activity	Moisture (%)	FFA (%)	TPC	YMC	Sensory score (O.A)
0th Day	0.3591	3.31	0.539	N.D	N.D	8.8
15th Day	0.3596	3.39	0.598	N.D	N.D	8.6
30th Day	0.3602	3.42	0.747	N.D	N.D	8.5
45th Day	0.3612	3.87	0.892	N.D	N.D	8.3
65th Day	0.3775	4.14	1.256	N.D	N.D	8.1

***N.D – Not Detected**

4.2. Bread

Refined Wheat Flour

Refined wheat flour provides the primary gluten network responsible for dough elasticity and gas retention. It balances the reduced gluten functionality caused by amaranth protein incorporation. Its starch fraction assists in crumb softness and moisture retention during baking.

Active Dry Yeast

Yeast initiates fermentation, producing carbon dioxide that contributes to dough rise and crumb aeration. It improves bread volume and texture even in reduced-gluten systems. Fermentation enhances flavor development and overall palatability.

Water

Water hydrates flour proteins and starches, enabling gluten development and dough formation. It regulates dough consistency, mixing behavior, and gas-holding capacity. Adequate hydration is essential for the uniform dispersion of amaranth protein.

Sugar

Sugar acts as a substrate for yeast fermentation, supporting gas production and dough expansion. It contributes to crust browning through caramelization and Maillard reactions. It improves bread softness and overall sensory quality.

Salt

Salt strengthens the gluten network and improves dough stability during fermentation. It regulates yeast activity to prevent excessive gas production. Salt enhances the overall flavor profile of the bread.

Oil

Oil improves dough extensibility and handling by lubricating the gluten network. It contributes to a softer crumb structure and delayed staling. Oil enhances mouthfeel and increases shelf life through moisture retention.

Bread Improver

Bread improver enhances gas retention and dough strength, compensating for reduced gluten content due to amaranth substitution. It improves loaf volume and crumb uniformity. Enzymes and oxidizing agents within the improver enhance dough stability and baking performance.

4.2.1. Amaranth Protein Enriched Bread

Ingredients: Refined wheat flour, Rajma protein (25% Replacement of Flour), water, salt, sugar, yeast, oil, bread improver, cling paper, Muslin Cloths, Moulds, Oven, planetary mixers

Table 10 Composition Table for Amaranth Protein enriched Bread.

Sl.no.	**Ingredients**	**Brand**	**(g) for 500 g of composite Flour**	**Amount (%)**
1.	Refined wheat flour	Pansari	375	43
2.	Amaranth Protein	-	125	14
4.	Water	-	300	34
5.	Sugar	Refined	30	3.4
6.	Yeast	Urban Platter	15	1.7
7.	Salt	TATA	7.5	0.8
8.	Oil	Refined	7.5	0.8
9.	Bread Improver	Urban Platter	3	0.3

Process Flow Chart

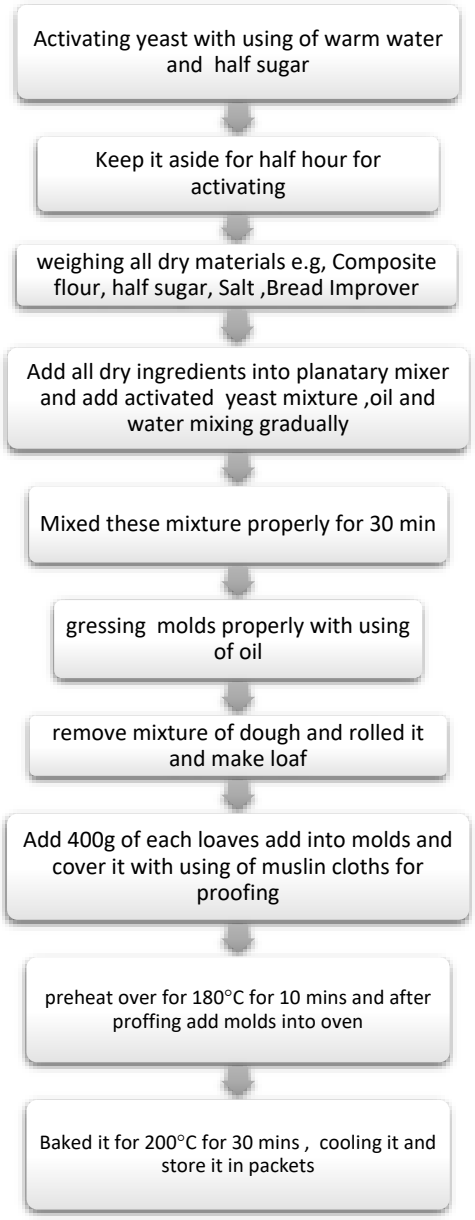




Figure 2 Amaranth Protein Enriched Bread

Bread preparation followed the flowchart sequence, beginning with yeast activation in warm water and sugar to initiate fermentation. After resting, all dry ingredients—including the 25% amaranth–wheat composite flour, remaining sugar, salt, and bread improver—were weighed and added to the planetary mixer. The activated yeast, oil, and water were incorporated gradually, and the dough was mixed for 30 minutes to develop structure despite reduced gluten. The dough was shaped, placed into greased molds in 400 g portions, covered for proofing, then baked in a preheated oven at 200°C for 30 minutes. The baked loaves were cooled and packed.

Nutritional Profile

Nutritional analysis of the product was conducted at the CFRA, NABL-accredited laboratory, NIFTEM. The evaluated parameters and corresponding results are presented in the following table.

Table 11 Nutritional information of Amaranth protein enriched Bread

Sl.no	Parameters	Result (per 100g) (%)
1.	Energy (Kcal)	279.48
2.	Carbohydrates	53.31
3.	Protein	9.36
4.	Total fat	3.20
5.	Saturated fat	0.84
6.	Total trans-fat	0.01
7.	Dietary fibre	6.34
8.	Total sugar	9.77
9.	Sodium (mg)	3614.12
10	Cholesterol	ND

ND*: Not Detected

4.3. Muffins

Refined Wheat Flour

Acts as the primary structural matrix, developing a gluten network that stabilizes air cells incorporated during mixing and leavening. Its starch fraction gelatinizes during baking, contributing to crumb set, volume retention, and overall muffin architecture.

Breakfast Sugar

Regulates batter viscosity by competing with proteins and starch for water, enabling a finer crumb structure. Promotes maillard browning and enhances moisture retention, both critical for soft texture and extended freshness in enriched muffins.

Butter

Incorporates air during creaming, creating initial aeration that amplifies muffin volume and contributes to a light crumb. coats flour particles, preventing excessive gluten development and maintaining tenderness in a protein-enhanced formula.

Baking Powder

Acts as the primary chemical leavening system, releasing CO_2 in both mixing and baking phases to achieve uniform rise. Stabilizes aerated batter through controlled gas expansion, delivering a soft, well-domed muffin.

Eggs

Serve as multifunctional ingredients providing emulsification, foaming, structure, and moisture binding—all critical in protein-enriched bakery products. Egg proteins coagulate during baking, creating a strong, cohesive internal framework that supports the added protein load.

Vanilla Essence

Masks any grainy or earthy notes that may arise from added protein sources, ensuring a clean and appealing flavor profile. enhances overall aroma perception, increasing consumer acceptability in a nutritionally fortified product.

Custard Powder

Provides starch that helps stabilize batter viscosity, improving volume and preventing collapse during baking.

contributes color and mild flavor notes while enhancing crumb tenderness and moisture retention.

4.3.1. Amaranth Protein Enriched Muffins

Ingredients: Refined wheat flour, Amaranth Protein (30% Replacement of Flour) Breakfast Sugar, Fat Spread, Baking powder, Eggs, Vanilla essence, Custard powder

Table 12 Composition table for Amaranth Protein enriched muffins.

Sl.no.	**Ingredients**	**Brand**	**(g) for 100 g of composite Flour**	**Amount (%)**
4.	Fat Spread	Delicious	125	29.27
5.	Breakfast Sugar	Trust	125	29.27
6.	Eggs	BB Royal	2.5 eggs	17.56
1.	Refined wheat flour	Pansari	70	16.39
2.	Amaranth Protein	BB Royal	30	7.02
7.	Baking powder	Nestle Everyday	1	0.23
8.	Vanilla Essence	Weikfield	20 drops	20 drops
9.	Custard Powder	Baking	1	0.23

Process Flow Chart

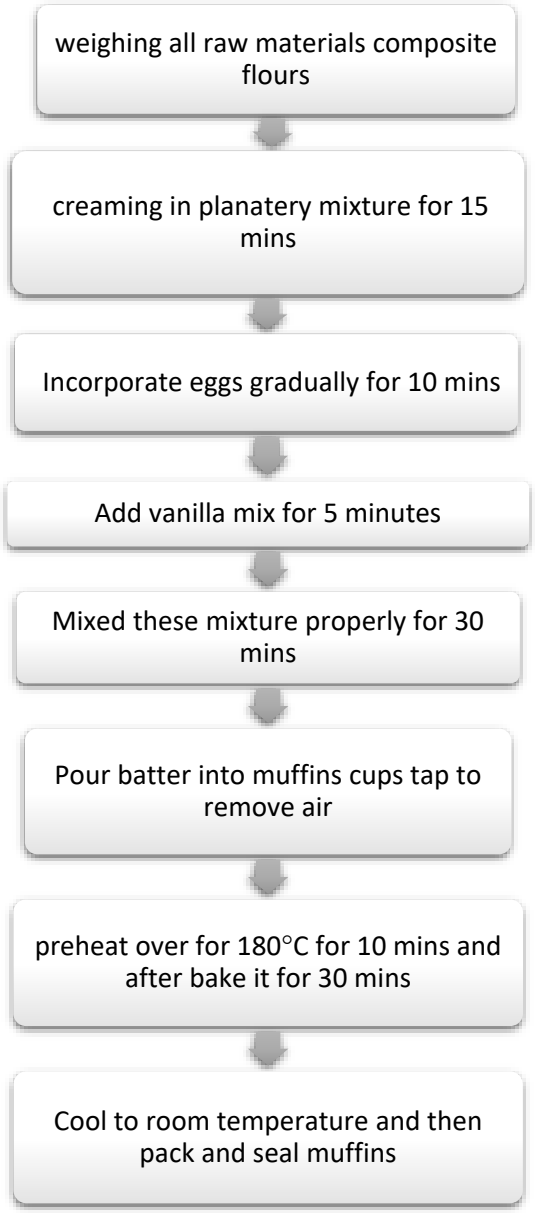




Figure 3 Amaranth Protein Enriched Muffins

The preparation of Amaranth Protein Enriched Muffins begins with accurately weighing all dry ingredients to ensure formulation consistency. Fat spread and breakfast sugar are creamed in a planetary mixer for about 15 minutes to incorporate air and develop a light structure. Eggs are then added gradually, and mixing continues for ten minutes to form a stable emulsion, followed by the slow addition of vanilla essence and further mixing for five minutes. The dry ingredients are incorporated next and gently mixed to form a homogeneous batter without overdeveloping gluten. The batter is portioned into muffin cups, tapped to remove air bubbles, and baked for approximately thirty minutes. After baking, the muffins are cooled to stabilize their structure before being packaged and sealed to maintain quality

Nutritional Profile

Nutritional analysis of the product was conducted at the CFRA, NABL-accredited laboratory, NIFTEM. The evaluated parameters and corresponding results are presented in the following table.

Table 13 Nutritional information of Amaranth protein enriched Muffins.

Sl.no	Parameters	Result (per 100g) (%)
1.	Energy (Kcal)	463.42
2.	Carbohydrates	43.53
3.	Protein	7.03
4.	Total fat	29.02
5.	Saturated fat	45.16
6.	Total trans-fat	BLQ
7.	Dietary fibre	3.33
8.	Total sugar	26.94
9.	Total Polyphenol content	48.15
10	Sodium (Na)	2844.39
11	Antioxidant	32.97

4.4. Foxtail protein enriched Atta Fortification

Protein deficiency is a growing nutritional concern, and fortification of staple foods such as wheat atta is an effective strategy to enhance dietary protein intake without altering food habits. Foxtail millet protein concentrate containing 26% protein was used to fortify whole wheat flour with the objective of developing a high-protein atta suitable for chapati preparation. Four formulations were prepared by replacing whole wheat flour with foxtail millet protein at different levels: 85:15, 80:20, 70:30, and 65:35 (Whole wheat flour: Foxtail millet protein)

All formulations were evaluated for dough handling, chapati preparation, sensory attributes, and selected quality parameters. Based on preliminary observations and sensory acceptability, the 70:30 formulation was identified as the most suitable and hence selected as the optimized formulation.



Figure 4 Foxtail protein enriched Atta Fortification

Material used

- Whole wheat flour (atta)
- Foxtail millet protein concentrate (17% protein)

Sensory Evaluation of Chapati

Chapatis prepared from all formulations were subjected to sensory evaluation for appearance, colour, texture, taste, mouthfeel, and overall acceptability. Among the tested samples, chapatis prepared from the 70:30 formulation exhibited the highest overall acceptability, showing a desirable balance between improved protein content and acceptable sensory quality.

At higher fortification levels (65:35), a decline in texture and eating quality was observed, whereas lower fortification levels (85:15 and 80:20) showed comparatively less nutritional enhancement. Therefore, the 70:30 formulation was selected as the optimum formulation for further analysis.

Colour Characteristics of Fortified Atta

Colour analysis of the optimized foxtail millet protein–fortified atta and control whole wheat flour was carried out using the CIELAB colour system (L*, a*, b*). The results are presented in Table 2

The *L value** of the fortified sample (**90.37 ± 0.14**) was higher than that of the control (**88.63 ± 0.08**), indicating increased lightness. The *a value** decreased in the fortified sample, suggesting reduced redness, while a slight decrease in *b value** indicated lower yellowness compared to the control.

The overall colour difference (ΔE) for the fortified sample (**7.44 ± 0.23**) was lower than that of the control (**9.43 ± 0.02**), suggesting that the colour variation due to fortification remained within an acceptable range and did not negatively affect product appearance.

Table 14 Colour values of control and foxtail protein enriched fortified atta.

Sample	L*	a*	b*	ΔE	Water Activity
Control (Whole wheat flour)	88.63 ± 0.08	1.65 ± 0.03	12.75 ± 0.02	9.43 ± 0.02	0.34
Fortified atta (70:30)	90.37 ± 0.14	1.10 ± 0.03	11.41 ± 0.27	7.44 ± 0.23	0.356

Table 15 Optimization Trials for Foxtail Millet Protein–Enriched Atta for Chapati Preparation

Sample Code	**Raw Materials (Composition)**	**Replacement Level (%)**	**Remarks / Observations**
T0 (Control)	100% Whole Wheat Flour (Atta)	0%	Good dough handling and chapati puffing; typical wheat colour, taste, and aroma; served as control for comparison.
T1	85% Whole Wheat Flour + 15% Foxtail Millet Protein Concentrate	15%	chapatis showed good texture and acceptability but limited nutritional& protein enhancement.

T2	80% Whole Wheat Flour + 20% Foxtail Millet Protein Concentrate	20%	Minor improvement in protein content; acceptable dough handling and sensory quality; slight changes in colour and texture observed.
T3 (Optimized)	70% Whole Wheat Flour + 30% Foxtail Millet Protein Concentrate	30%	**Optimized formulation**; best balance between enhanced protein content and sensory acceptability. Chapatis exhibited desirable texture, taste, mouthfeel, and overall acceptability.
T4	65% Whole Wheat Flour + 35% Foxtail Millet Protein Concentrate	35%	Excessive fortification led to reduced dough extensibility, harder texture, and decline in eating quality; overall acceptability decreased.

Nutritional Profile

Nutritional analysis of the product was conducted at the CFRA, NABL-accredited laboratory, NIFTEM. The evaluated parameters and corresponding results are presented in the following table.

Table 16 Nutritional Information of foxtail protein enriched fortified atta.

Sl.no	Parameters	Result (per 100g) (%)
1.	Energy (Kcal)	
2.	Carbohydrates	
3.	Protein	
4.	Total fat	
5.	Saturated fat	
6.	Total trans-fat	
7.	Dietary fibre	
8.	Total sugar	
9.	Total Polyphenol content	

4.4.1. Horse gram protein enriched Atta Fortification

Atta is a staple food in the Indian sub-continent, typically consumed at least twice a day. Supplementing wheat with legumes like horsegram is an effective strategy to increase the protein and mineral density of chapatis. The objective of this trial was to evaluate various replacement levels (10%, 15%, 20%, and 30%) to find a balance between nutritional fortification and sensory acceptability

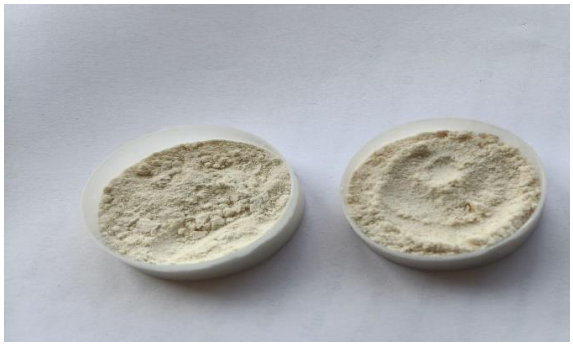




Figure 5 Horse gram protein enriched Atta Fortification

Materials and Methods

• **Formulation Selection:** Based on preliminary trials, the **15% replacement** (85% Whole Wheat Flour : 15% Horsegram Protein) was selected as the optimized ratio.

Chapati Preparation: The dough was rested, sheeted to a 15 cm diameter, and baked on an electric hot plate followed by a tandoor grill to ensure proper "puffing"

Physical and Color Characterization The laboratory data indicates a distinct shift in the physical profile of the fortified flour compared to the control.

Table 17 Colour and water acticity of Control Atta &Horsegram protein enriched Atta.

Parameter	**Control Atta (100% WWF)**	**Fortified Atta (15% Horsegram)**
Lightness (*L*∗)	88.63 ± 0.08	85.81 ± 0.14
Redness (*a*∗)	1.65 ± 0.03	2.21 ± 0.03
Yellowness (*b*∗)	12.75 ± 0.02	15.31 ± 0.05
Total Colour Diff (Δ*E*)	9.43 ± 0.02	13.0 ± 0.08
Water Activity (*aw*)	0.3496	0.3981

the incorporation of non-wheat grains typically results in a **reduction in brightness (*L*∗)** and an **increase in yellowness (*b*∗)**. The fortified sample follows this trend, appearing slightly

darker and more yellow. The total color difference (ΔE) increased from 9.43 to 13.0, suggesting a visible but acceptable change in the flour's appearance

Sensory Evaluation and Optimization Trials at 20% and 30% replacement levels showed a decline in **pliability** and a shift away from the desirable "wheaty" aroma. The **15% formulation** was optimized because it retained. Maintaining softness comparable to pure wheat chapatis

Overall acceptability Found to be most acceptable at lower replacement levels, as high legume inclusion can lead to a "bland" taste

Table 18 Trails, Control and Optimised Formulations of chapati

Samples Code	Raw materials (Composition)	Replacement Level (%)	Remarks /Observations
Trial 1 (Control)	100% Whole wheat flour	0 %	Standard wheat aroma and color; high lightness (L*); good puffing, softness, and overall acceptability. Used as control.
T1	90% WWF + 10% Horsegram Protein	10%	Slight increase in protein content with minimal change in color and aroma; chapatis retained good pliability and sensory acceptability.
T2 (Optimized)	85% WWF + 15% Horsegram Protein	15%	**Optimized formulation**; balanced nutritional enhancement and sensory quality. Slightly darker and more yellow appearance (higher ΔE) but acceptable. Maintained softness, puffing, and wheaty aroma similar to control.
T3	80% WWF + 20% Horsegram Protein	20%	Noticeable reduction in pliability; chapatis showed darker color, reduced wheaty aroma, and moderate decline in sensory acceptability.
T4	70% WWF + 30% Horsegram Protein	30%	Significant loss of softness and puffing; bland taste and strong legume notes observed. Overall acceptability decreased due to textural and sensory changes.

4.5. Amaranth Protein enriched Instant Noodles:

Traditional instant noodles, primarily composed of refined wheat flour, are often deficient in essential nutrients such as dietary fiber and the amino acid **lysine**. This industrial project successfully optimized a high-protein noodle variant by substituting **30%** of whole wheat flour with **Amaranth protein (25% protein content)**. The resulting product balances high nutritional density with the structural integrity required for commercial cold extrusion.

Ingredients: Refined wheat flour, water, amaranth protein (30% of Flour Replacement), guar gum, salt



Figure 6 Amaranth Protein enriched Instant Noodles

Table 19 Composition Table of Amaranth Protein enriched Instant Noodle.

Sl.no.	**Ingredients**	**Brand**	**(g) for 100 g of composite Flour**	**Amount (%)**
1.	Refined wheat flour	Fortune	70g	46.57
2.	Amaranth Protein	-	30g	19.96
4.	Water	-	47.5ml	31.60
5.	Guar Gum	Urban platter	0.3g	0.199
6.	Salt	TATA	2.5g	1.66

Optimized Formulation & Trial Strategy: To identify the optimal substitution level, trials were conducted at **10%, 15%, 20%, 30%, and 35%** replacement levels. While nutritional value increases linearly with substitution, sensory acceptance and texture often decline at very high levels

• **Whole Wheat Flour (70g):** Provides the core gluten network

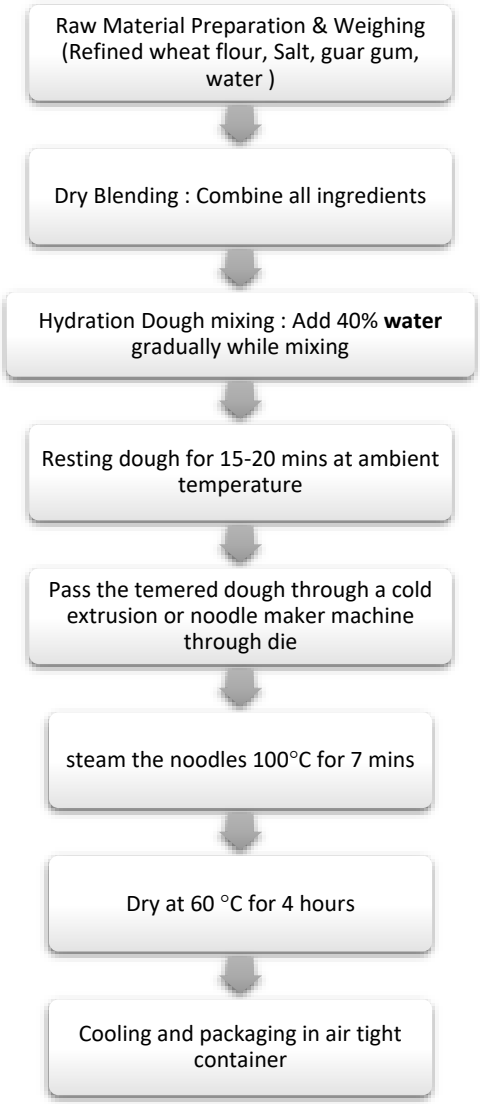
Amaranth Protein Fractionate (30g): Fortificant containing 25% protein to balance the amino acid profile

Salt (2g): Acts as a flavoring agent and structural modifier

Guar Gum (0.3g): Functions as a stabilizer to improve viscosity, texture, and minimize cooking loss

Water (47.5 ml): Added to achieve the necessary dough consistency for extrusion

Process flow chart



The production of amaranth-fortified noodles begins with the precise weighing and uniform dry blending of **70g of wheat flour** (refined or whole wheat), **30g of amaranth protein fractionate**, **2g of salt**, and **0.3g of guar gum** to ensure consistent nutrient and stabilizer distribution. Once blended, **47.5 ml water** is gradually incorporated to achieve the necessary

dough consistency and viscosity, followed by a critical resting period of **15 minutes** at ambient temperature to allow for proper hydration and structural development. The tempered dough is then processed through a **cold extruder** or pasta machine to form uniform noodle threads. To "instantize" the product and improve rehydration quality, the noodle strands are typically steamed at 100°C for 7 minutes before undergoing the final dehydration phase in a tray dryer set at **60°C for 4 hours**. This drying process is essential to reduce the moisture content to a target range of **5%–7%**, ensuring the product meets microbial safety standards and maintains a stable shelf life for up to six months.

Table 20 Nutritional Information of Amaranth protein enriched Instant Noodles.

Sl.no	Parameters	Result (per 100g) (%)
1.	Energy (Kcal)	405 Kcal
2.	Carbohydrates	75.4%
3.	Protein	15.1%
4.	Fiber	2.2%
5.	Fat	1.80%

Table 21 *Shelf Life data ofr Amaranth protein enriched Instant Noodles*

Stored final product in airtight polyethylene bags at 22-25 °C

Storage Interval	**Moisture Content (%)**	**Water Activity (*aw*)**	**Total Plate Count (TPC)**	**Overall Acceptability**
Day 0 (Initial)	6.61%	**0.44**	Nil	8.9
Day 15	6.62%	**0.45**	Nil	8.9
Day 30 (Month 1)	6.65%	**0.45**	Nil	8.8
Day 45	6.68%	**0.46**	Nil	8.7
Day 60 (Month 2)	6.72%	**0.46**	Nil	8

Day 75	6.75%	**0.46**	Nil	8
Day 90 (Month 3)				

4.6. Amaranth Protein enriched Pasta

the formulation of a high-protein pasta where **30% of durum semolina** is replaced with **Amaranth Protein (26.03% protein content)**. To ensure structural integrity without the use of stabilizers like guar gum or the "instantization" (steaming) process, the formulation utilizes an increased hydration level of **45%** and a traditional slow-drying method. This creates a "raw" dried pasta

Optimized Formulation
This blend relies on the natural gluten network of the durum semolina and the water-binding capacity of the amaranth protein

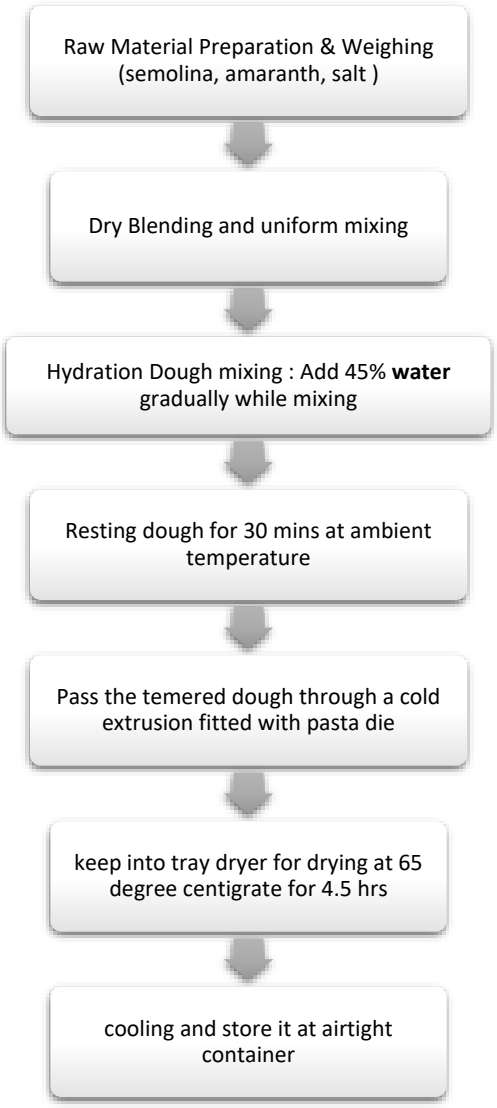
Table 22 Composition Table for Amaranth protein enriched Pasta.

Ingredients	Brand	Amount (per 100g dry mix)	Percentage %
Durum Wheat Semolina	Selezione Casillo	70	47.46%
Amaranth Protein (26.03% Protein)	-	30	20.34%
Water	-	45	30.51%
Salt	TATA	2.5	1.69%



Figure 7 Amaranth Protein enriched Pasta

Process flow chart



Dry Blending: Mix semolina, amaranth protein, and salt until uniform.
2. **Hydration:** Gradually incorporate 45% water to achieve a stiff, homogenous dough [3, history].
3. **Tempering:** Rest the dough for 15–30 minutes at ambient temperature for complete moisture penetration.
4. **Cold Extrusion:** Process through a single-screw extruder with a pasta die at ambient temperature.
5. **Dehydration:** Dry in a tray dryer at 45–60°C for 5–8 hours until moisture reaches 5%–8%

Table 23 Nutritional Information of Amaranth protein enriched Pasta

Nutritional information	**Per 100 g**
Energy	395 KCal

Protein	15.8 %
Carbohydrates	63 %
Crude Fiber	2.5 %
Ash	1.8 %

Table 24 Shelf Life study of Amaranth Protein enriched Pasta.

Stored final product in airtight polyethylene bags at 22-25 °C

Storage Interval	**Moisture Content (%)**	**Water Activity (*aw*)**	**Total Plate Count (TPC)**	**Overall Acceptability**
Day 0 (Initial)	6.5	**0.44**	Nil	8.7
Day 15	6.8	0.46	Nil	8.5
Day 30 (Month 1)	7.1	0.49	Nil	8.1
Day 45	7.23	0.51	Nil	8.0
Day 60 (Month 2)	7.87	0.52	Nil	8.0

4.7. Nutri Chick Puffs

Nutri Chick Puffs are developed as a **plant protein-powered snack** utilizing advanced twin-screw extrusion technology. This product is designed to meet the growing consumer demand for **nutritious, gluten-free, and non-fried** snacking options. By blending wholesome grains with high-quality legume proteins, the product achieves a superior nutritional profile without compromising the "crispy" sensory attributes expected in a puffed snack

Various ratios of cereal flours (Rice and Corn) were blended with different levels of Red Lentil flour and Chickpea protein.

Final Optimized Composition: The formulation was finalized to balance high protein delivery with the desired "puffy" texture. The chosen blend ensures the snack remains lightweight while providing significant satiety.

Table 25 Composition table for Nutri Chick puffs

Ingredients	Amount (per 100g dry mix)	Percentage %
Rice flour	40	37.55
Corn flour	35	32.86
Red Lentil flour	15	14.08
Chickpea protein	10	9.38
Salt	2.5	2.34
water	4 ml	3.75

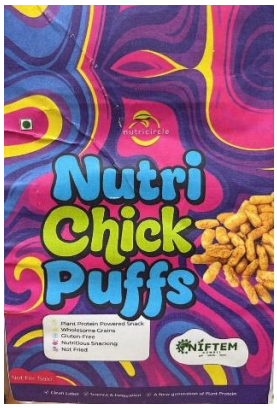
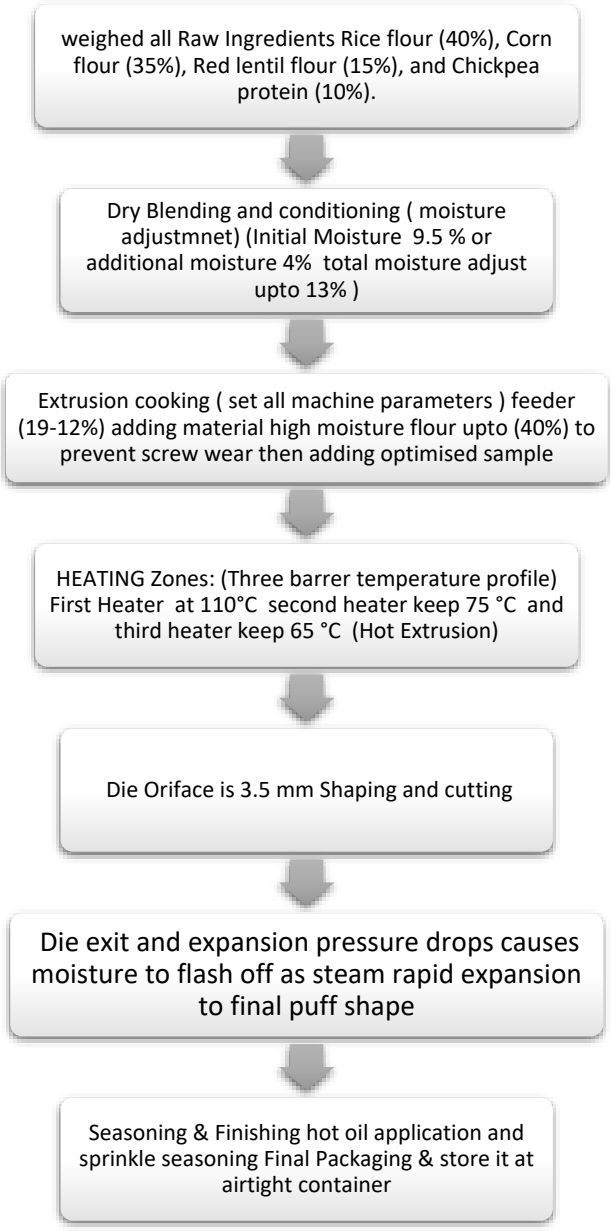


Figure 8 Nutri Chick Puffs Pack

Process flow chart



Preparation Method

1. **Raw Material Preparation:** Clean and grind the raw materials (Rice, Corn, and Red Lentils) using a grinder mill to achieve the required particle size. The flour must be passed through a **sieve (ASTM No. 20)** to ensure a fine, uniform texture.
2. Start extruder with high-moisture flour (40%) to prevent screw wear
3. **Dry Blending & Composition:** In a mixer, blend the flours according to the optimized ratio: **Rice flour (40%), Corn flour (35%), Red lentil flour (15%), and Chickpea protein (10%)**. Add salt as per the recipe requirements. (purity of chickpea protein is 70%)
4. **Moisture Optimization (Pre-Conditioning):** With an initial moisture content of approximately **9.5%**, add **4% additional water** to reach a final feed moisture of **13-**

14%. It is recommended to use a planetary mixer and allow the dough to sit/equilibrate to ensure uniform moisture distribution before feeding.

5. **Extrusion Process:**

Twin Screw Extruder (HTST) Heating: First Heater at 110°C(Hot Extrusion) second heater kept 72°C, Third Heater 65°C

Zones: Feeding - Kneading - High Pressure/Metering **Action**: Shearing, Starch Gelatinization, & Protein Denaturation

a. **Feeding:** Load the sieved composite flour into the feeder. Set the **feeder speed between 10-14 RPM** to maintain a consistent mass flow rate, and screw speed kept 180 RPM
b. **Texturization:** The material is subjected to high temperature and shear forces, causing it to cook and expand as it is forced through the **interchangeable die**. Used 3mm die

6. **Shaping and Cutting:** The shape and size are determined by the specific die used. The **cutter RPM** should be adjusted according to the desired length and shape of the individual puffs.
7. **Post-Processing (Seasoning):** Once the expanded puffs exit the die, they are immediately treated with a **jet spray of oil**. This serves as an adhesive for the **masala**, which is then sprinkled over the puffs to ensure even coating
8. **Cooling and Packaging:** After seasoning, the puffs are cooled and packaged in **laminated pouches** to maintain crispiness and a shelf life of **6 months**.



Figure 9 Twin screw extruder machine



Figure 10 Nutri Chick Puffs

Table 26 Nutritional Information of Nutri Chick Puffs.

Nutritional information	**Per 100 g**
Energy	368 KCal
Carbohydrates	60.67 %
Protein	16.67 %
Fat	6.45%
Dietary Fibre	5.4%
Ash	1.8%

Stored final product in airtight polyethylene bags at 22-25 °C

Table 27 Shelf Life Study for Nutri Chick Puffs

Storage Interval	**Moisture Content (%)**	**Water Activity (*aw*)**	**Total Plate Count (TPC)**	**Overall Acceptability**
Day 0 (Initial)				
Day 15				
Day 30 (Month 1)				
Day 45				
Day 60 (Month 2)				
Day 75				
Day 90 (Month 3)				

4.8. Nutri Rice Puffs

This optimized formulation utilizes a multi-grain and legume strategy to create a high-quality, gluten-free (GF) product. By combining cereals (Rice and Corn) with a high concentration of legumes (Chickpea and Lentil) and a high-purity rice protein isolate (94%).

Ingredients: Rice flour, Corn flour, Lentil flour, Chickpea flour, Rice protein isolate

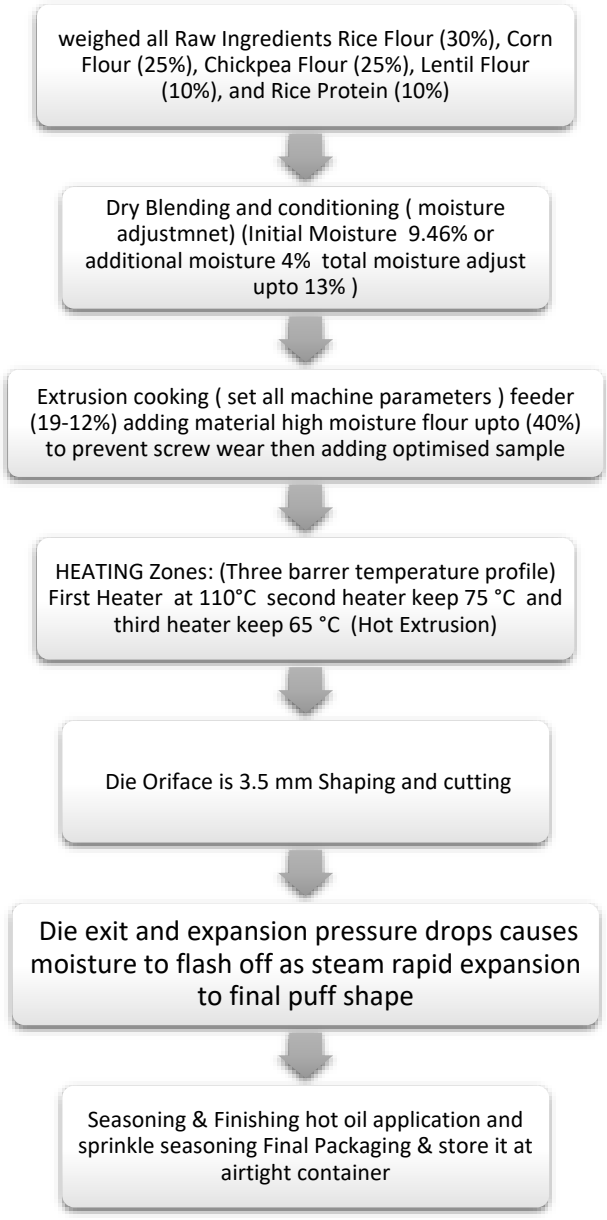
Table 28 Composition Table for Nutri Rice Puffs.

Ingredients	**Amount (per 100g dry mix)**	**Percentage %**
Rice flour	30	28.16
Corn flour	25	23.47
Chickpea flour	25	23.47
Red Lentil flour	10	9.38
Rice protein	10	9.38
water	4 ml	3.75
Salt	2.5	2.34



Figure 11 Nutri Rice Puffs pack

Process flow chart



Preparation Method: Nutri Rice Protein Puffs (Twin-Screw Hot Extrusion)
The production of these puffs follows a high-temperature, short-time (HTST) process to create a "Plant Protein Powered" snack that is "not fried"

Pre-Conditioning and Blending
• **Ingredient Homogenization**: The optimized blend—**Rice Flour (30%)**, **Corn Flour (25%)**, **Chickpea Flour (25%)**, **Lentil Flour (10%)**, and **Rice Protein (10%) (rice protein present 94% of protein content)**—is dry-mixed. This multi-legume and cereal strategy ensures a balanced amino acid profile, compensating for the lysine deficiency typical in cereal-based food,

Particle Standardization: All raw materials are sieved through a **0.4 mm 60 BSS mesh** to ensure uniform particle size, which is critical for consistent hydration and starch gelatinization during hot extrusion

Moisture Adjustment: Start extruder with high-moisture flour (40%) to prevent screw wear Initial moisture upto 9.46% so add in that 30% of moisture, total final moisture 40%. The blend is conditioned with water to reach a specific moisture level (typically 12%–14%) optimised 13%. required for effective expansion during the puffing process.

2. Twin-Screw Hot Extrusion (Puffing)

• **Feeding**: The conditioned mix is fed into the twin-screw extruder. The dual screws provide superior mixing and shearing compared to single-screw systems, which is essential for incorporating high levels of **Rice Protein (94% purity)** without clumping. feeder speed kept **9-14 RPM**

Thermomechanical Processing (Hot Extrusion): The barrel is heated across multiple zones, first zone optimised temperature 110 **°C**, Second zone 75 **°C** and Third zone of heater 65**°C,** often reaching temperatures between **110 °C**. on heater 1 , keep screw speed **150-180 RPM** Under high pressure and shear the starch from the rice and corn flours undergoes **complete gelatinization**, and the plant proteins are restructured into a cohesive matrix

Flash Expansion (The "Puff"): As the molten dough is forced through the die at the end of the extruder, the sudden drop to atmospheric pressure causes the internal moisture to instantly turn into steam. This creates the expanded, porous, and "puffed" structure of the snack.

3. Post-Extrusion Stabilization

• **Drying**: The puffs are immediately transferred to a continuous hot-air dryer. They are dried to a very low moisture content (typically **3%–5%**) to ensure a crisp texture and a **6-month shelf life**. This low moisture is critical for inhibiting microbial growth.

• **Seasoning**: Since the product is "not fried," any seasonings are applied using a coating drum, often utilizing a fine mist of oil help spices adhere without significantly increasing the fat content.

• **Packaging**: The final puffs are cooled and packed in **aluminium laminated pouches**. This packaging is essential for protecting the high-protein matrix and unsaturated fats from oxidation and moisture ingress, ensuring the product remains shelf-stable for 6 months




Figure 12 Nutri Rice Puffs developed from Twin Screw Extruder

Table 29 Nutritional information for Nutri Rice puffs.

Nutritional information	**Per 100 g**
Energy	376.5 KCal
Carbohydrates	60.06 %
Protein	17.65 %
Fat	7.3 %
Dietary Fibre	5.07 %
Ash	1.78 %

Stored final product in airtight polyethylene bags at 22-25 °C

Table 30 Storage Study of Nutri Rice Puffs.

Storage Interval	**Moisture Content (%)**	**Water Activity (*aw*)**	**Total Plate Count (TPC)**	**Overall Acceptability**
Day 0 (Initial)				
Day 15				
Day 30 (Month 1)				
Day 45				
Day 60 (Month 2)				
Day 75				
Day 90 (Month 3)				

4.9. Protein millet Energy bar

In the modern lifestyle, consumers require convenient, nutritious, and ready-to-eat foods that can provide instant as well as sustained energy.

The **Protein Millet Energy Bar** is a functional snack developed using millets, natural sweeteners, plant protein, nuts, and dry fruits. The product is gluten-free, free from refined sugar, and does not contain any artificial preservatives or flavors. It is designed to deliver high protein, dietary fiber, and essential micronutrients while maintaining good sensory acceptability.

Ingredients

Millet Pops and Flakes: Millet pops and flakes form the base of the bar and act as primary sources of complex carbohydrates and dietary fiber. Millets are gluten-free grains rich in minerals such as iron, magnesium, and phosphorus. Their inclusion improves the nutritional density of the bar and provides a crispy texture and better mouthfeel.

Plant Protein: Plant-based protein is added to enhance the protein content of the bar
Jaggery: Jaggery is used as a natural sweetener and binding agent. It provides iron and minerals and offers a slow release of energy compared to refined sugar
Honey: Honey contributes natural sweetness and acts as a humectant and binder.
Dates: Dates are rich in natural sugars, dietary fiber, potassium, and antioxidants
Dark Chocolate and Cocoa Powder: These ingredients enhance flavor, color, and consumer acceptability
Nuts and dryfruits: Almonds, cashews, and flaxseeds supply healthy fats, high-quality protein, omega-3 fatty acids, and micronutrients.
Guar Gum (INS 412): Used as a thickener and stabilizer to improve binding, texture, and moisture retention.
Soy Lecithin (E322): Acts as an emulsifier to ensure uniform mixing of fats and syrups and prevents oil separation.

Table 31 Composition Table of Protein Millet energy bar.

Sl.No	Ingredients	Brand	for 100 g Total weight	Percent (%)
1.	Date Paste	Lion	24	22.32
2.	Jaggery	Pro nature	22	20.46
3.	Kodo Flakes (Unsalted)	Tradifo IARI	13	12.09
4.	Jowar Pops (Salted)	Jain Pickle Wala	13	12.09
5.	Chocolate (Dark compound)	Amul (18% Cocoa)	14	12.09
6.	Chickpea Protein	-	10	9.30
7.	Cashew	BB Royal	2	1.86
8.	Almonds	BB Royal	2	1.86
9.	Butter	Delicious	2	1.86
10.	Dried Cranberries	Nutty gritties	2	1.86
11.	Cocoa Powder	Hersheys cocoa	2	1.86
12.	Emulsifier E322 (Soy Lecithin)	Urban platter	1	0.93
13.	Thickener INS 412 (Guar gum)	Urban platter	0.5	0.46

Process Flow Chart:

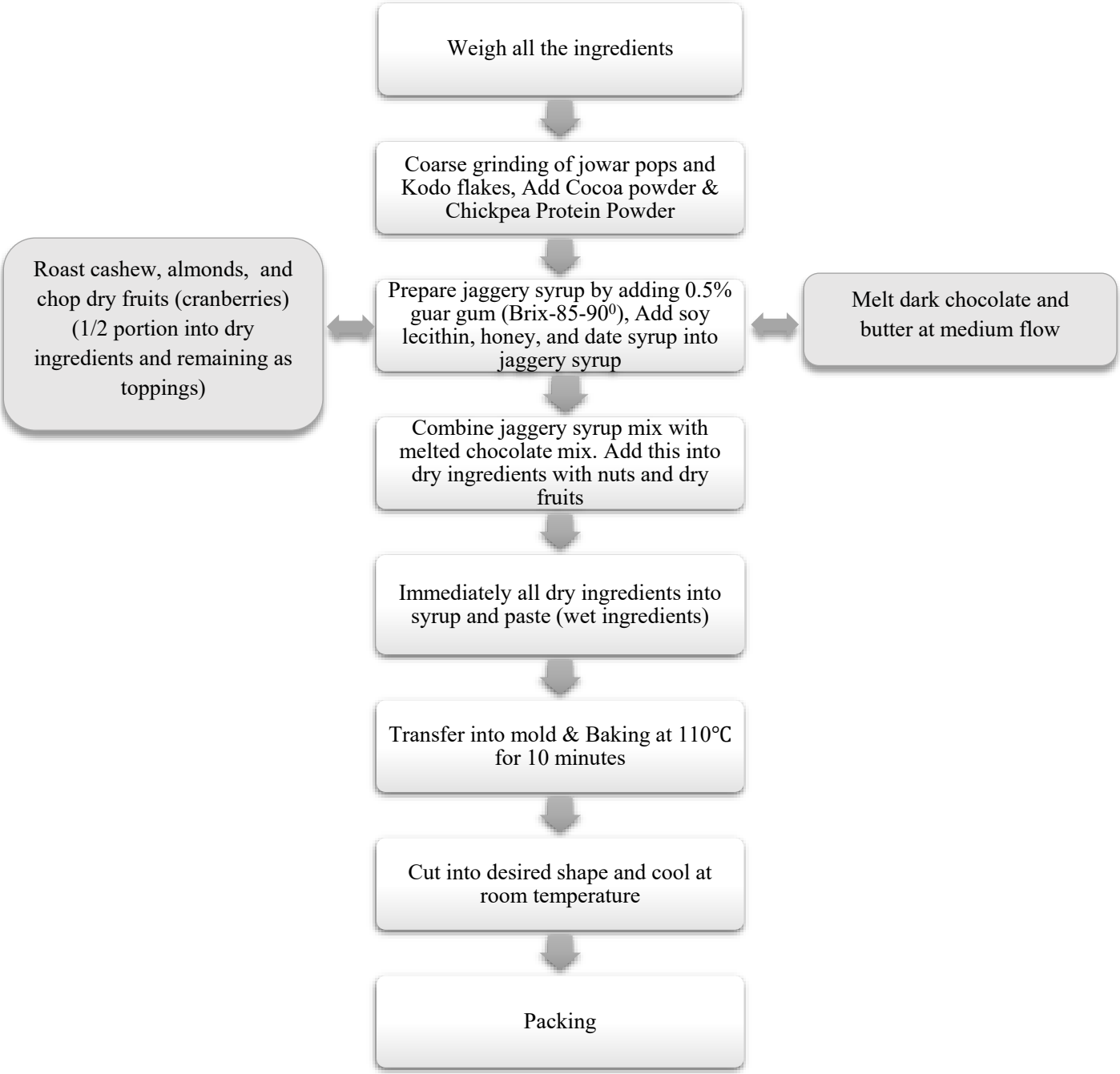




Figure 13 Pro millet Energy bar



Table 32 Nutritional information for Protein Millet energy bar.

Nutritional information	**Per 100 g**
Energy	396 KCal
Carbohydrates	68.64 %
Protein	14.5 %
Fat	7.81%
Dietary Fibre	3.7 %
Ash	2.08 %

Table 33 Shelf Life study of protein Millet Energy Bar

Days	Water activity	Moisture (%)	FFA (%)	TPC	YMC	Sensory score
0^{th} Day	0.4291	5.71	0.841	N.D	N.D	9
15^{th} Day	0.4379	5.72	0.981	N.D	N.D	8.9
30^{th} Day	0.4459	5.79	1.122	N.D	N.D	8.8
45^{th} Day	0.4491	5.81	1.122	N.D	N.D	8.7

***N.D – Not Detected**

The millet energy bar were stored at 28℃ at ambient temperature in aluminised laminated pouches. The sealed pouches were stored in desiccator and kept for storage study. Each packet was removed at the duration of 15 days and evaluated for changes in quality attributes like free fatty acid, moisture content, water activity, sensory score and microbial load (TPC and YMC) up-to 3 months.

4.10. GMP & HACCP Guidelines

- Procurement of certified raw materials
- Hygienic handling and segregation
- Controlled baking and cooling
- Metal and physical hazard control
- Allergen labelling
- Batch traceability
- Regular microbial testing
- Personnel hygiene and sanitation

4.11. Product Display and Sensory Evaluation at AAHAR 2024



Figure 14 Product Display at AAHAR 2024

During **AAHAR 2024**, the developed products were successfully displayed to a wide range of visitors, including industry professionals, researchers, and consumers. The showcased products included **foxtail millet protein-enriched butter cookies with choco chips, rajma protein-enriched butter cookies, and amaranth protein-enriched bread**. Samples of these

products were distributed for sensory evaluation, and the overall response was highly encouraging.

Sensory evaluation was carried out using a **9-point hedonic scale**, focusing on overall acceptability. The **foxtail millet protein-enriched butter cookies** received an overall acceptability score of **8.5 out of 9**, indicating very high consumer liking. The **amaranth protein-enriched bread** achieved an overall acceptability score of **8 out of 9**, reflecting good acceptance in terms of taste, texture, and overall quality. The **rajma protein-enriched butter cookies** were also well appreciated by visitors, contributing positively to the compiled sensory results for cookies.

4.12. WORLD FOOD INDIA 2025

During World Food Day 2025 at Pragati Maidan, NIFTEM-developed NutriCircle products, including Nutri Chick Puffs and Nutri Rice Puffs, were showcased and distributed to industry professionals. The products received a highly positive response, reflecting strong acceptance of their nutritional quality, sensory attributes, and commercial potential



Figure 15 Showcasing food products at the NutriCircle stall during World Food India 2025.



Figure 16 NutriCircle stall showcasing developed products at World Food India (WFI 2026)

(5-Point Hedonic Scale: 1 = Dislike Very Much, 5 = Like Very Much)

Table 34 Sensory Evaluation Score of Nutricircle Products at WFI 2025

Product Name	**Color**	**Taste**	**Texture**	**Overall Acceptability**	**Remarks**
Nutri Rice Puffs	**4.5**	**4.5**	**4.0**	**4.0**	Savory and pleasant flavor; light and crunchy texture; preferred over chick puffs; minor adjustments suggested for salt balance and moisture stability
Nutri Chick Puffs	**4.0**	**4.0**	**4.0**	**4.0**	Acceptable savory taste; slightly reduced crispness due to environmental moisture exposure during the event

Pro-Millet Bar	**5**	**5**	**5**	**5**	Naturally sweet with date flavor; crunchy and cohesive texture; highest consumer acceptance among all products

Product 2 : Nutri Rice and Chick Puffs

The puff samples received an **overall acceptability score of 4/5**, reflecting a good level of consumer liking. Among the two varieties offered, **rice puffs were preferred over chick puffs**, primarily due to their balanced flavor and lighter texture.

Taste:
Both puff variants were described as **savory and pleasant**, with the rice puffs receiving a **score of 4.5/5** and chick puffs **4/5**. A few participants suggested **adjusting the salt content slightly**, as some found it either mildly low or uneven.

Texture:
In terms of texture, the puffs were appreciated for being **light and crunchy**, though a few participants noted that they could be **made slightly crispier**. The chick puffs, in particular, had **lost some of their crunch** due to environmental moisture exposure during the event, which may have influenced perception.

Suggestions from consumers:

- Ensure **better packaging or moisture control** to maintain crunchiness.
- **Enhance crispness** slightly for a more satisfying texture.
- **Fine-tune the salt balance** for improved flavor uniformity.

Overall Observation:
The puffs were well-received for their savory taste and light texture, especially the rice variant. Minor improvements in moisture stability and seasoning could further enhance consumer acceptability and shelf appeal.

Product 3 : Pro-Millet Bar

The **Pro Millet Bar** achieved an **overall acceptability score of 5/5**, making it the most highly rated product among all samples. Consumers showed a very positive response toward its flavor, texture, and overall concept.

Taste:
The bar was described as **naturally sweet and flavorful**, with the **sweetness of dates being distinctly noticeable and well appreciated**. Tasters found the balance of sweetness and nuttiness appealing, reflecting a wholesome, energy-rich snack suitable for health-conscious consumers.

Texture:
The **crunchy and cohesive texture** was highly favored, also receiving a **perfect score of 5/5**. Participants particularly enjoyed the **crisp bite and chewiness**, which contributed to the product's sensory appeal.

Suggestions from consumers:

- Many visitors expressed interest in **understanding how millets were incorporated** into the product and requested **clearer labeling or ingredient details**.
- A few suggested introducing a **"chikki-style" version** of the bar, positioning it as a **winter snack**, which could appeal to traditional tastes while retaining its nutritional value.

Overall Observation:
The Pro Millet Bar stood out for its excellent taste, ideal sweetness, and crunchy texture. The concept successfully combined health and indulgence, resonating strongly with consumers. Providing more detailed ingredient information and exploring regional adaptations like a chikki variant could further strengthen its market appeal.

Appendix 1

Table 35 Phase-I Summary of Product Development Using Industry-Provided Protein Sources

Protein Source	Raw Material Availability	Products Planned	Products Developed (Phase-I)	Replacement / Fortification Level	Status / Remarks
Foxtail Millet Protein	Available	Atta fortification Cookies	• Foxtail Protein enriched Atta Fortification • Foxtail protein enriched Cashew butter cookies • Foxtail protein enriched Choco Chip Cookies	• 30% Replacement of flour • 30% replaced of flour • 30% replacement of flour	Done • Done • Done
Horse Gram Protein	Available	Atta fortification	Horse gram protein enriched Fortification Atta	Optimised at 15%	Successfully developed; higher replacement levels adversely affected texture and sensory quality.
Rajma Protein	Available	Cookies	Rajma protein enriched butter cookies	Optimised at 15%	Product successfully standardized; acceptable sensory profile observed.
Amaranth Protein	Available	Bread, muffins, pasta, spaghetti,	• Amaranth protein enriched bread	• Optimised at 25%	The Product successfully standardized formulations resulted in

			• Amaranth protein enriched Muffins • Amaranth Protein Enriched Instant Noodles • Amaranth Protein Enriched Pasta	• 30% of Flour Replacement • 30% of Replacement of Flour • 30% of Replacement of Flour	acceptable sensory quality with appropriate texture and mouthfeel.
Finger Millet Protein / Flour	**Not available**	Cookies, pasta, noodles	Not developed	-	Product development could not be carried out due to non-availability of finger millet raw material from industry.
Chickpea protein	Available	Energy Bar	Protein Millet Energy Bar	• 9.30 % Protein Powder added • 24.18% of millets used	The product was successfully formulated with chickpea protein, Kodo flakes, and jowar Pops, demonstrating desirable sensory attributes and favourable acceptance at WFI

Appendix 2

Table 36: Phase-II Product Development Summary – Nutri Chick Puffs & Nutri Rice Protein Puffs

Product Name	Raw Materials Used	Replacement / Fortification Level	Processing Technology	Key Nutritional / Structural Outcome	Status / Remarks
Nutri Chick Puffs	Rice flour, Corn flour, Red lentil flour, Chickpea protein (70% purity), Salt, Water	• Cereals (Rice + Corn flour): **75%** of dry mix • Legumes (Red lentil flour): **15%** • Chickpea protein: **10%**	Twin-screw hot extrusion (HTST); optimized barrel temperatures **110–72–65 °C**, screw speed **180 RPM**, feeder speed **10–14 RPM**, die size **3 mm**, feed moisture **13–14%**	Achieved good expansion and porous structure with crisp texture; high plant-protein incorporation while maintaining light, puffy characteristics.	Successfully developed gluten-free, non-fried puffs with good sensory acceptability, uniform expansion, and stable structure.
Nutri Rice Protein Puffs	Rice flour, Corn flour, Chickpea flour, Red lentil flour, Rice protein isolate (94% purity), Salt, Water	• Legumes (Chickpea + Lentil): **35%** of dry mix • Rice protein isolate: **10%** • Cereals (Rice + Corn): **55%**	Twin-screw hot extrusion (HTST); barrel temperature optimized at **110–75–65 °C**, screw speed **150–180 RPM**, feed rate **9–14 RPM**, final moisture	Achieved uniform expansion with a porous, crisp structure; high protein incorporation without collapse of puff structure; balanced starch–protein matrix providing light texture and improved satiety	Successfully developed gluten-free, non-fried, protein-rich puffs with good expansion, crisp texture, and balanced sensory acceptability; product demonstrated stable structure and enhanced nutritional profile.

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