RESEARCH & DEVELOPMENT (R&D) REPORT

Collaborative R&D Work Undertaken for

Nutricircle Pvt. Ltd. Nampally, Hyderabad

Collaborating Laboratory

MFPI – Quality Control Laboratory
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Reporting Period
2023 - 2025

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Executive Summary

R&D Collaboration Report (Three-Year Period)
Nutricircle Pvt. Ltd. & MFPI – Quality Control Laboratory

Background

Over the past three years, a structured Research & Development (R&D) collaboration was undertaken between Nutricircle Pvt. Ltd. and the Aghub, PJTAU. As part of the mentorship programme of the university, MFPI – Quality Control Laboratory, under the mentorship of Dr. Aparna Kuna, Principal Scientist & Head.

The collaboration focused on the development of indigenous plant protein ingredients from Indian millets, legumes, and grain sources, with the objective of creating scientifically validated, commercially viable, and sustainable alternatives to imported protein isolates.

Scope of Work

The R&D programme encompassed:

- Screening of protein-rich millets, legumes, and defatted oilseed cakes
- Evaluation of alkaline extraction and air classification methodologies
- Nutritional and functional characterization of protein and starch fractions
- Assessment of batch variability and enrichment efficiency
- Product formulation and sensory validation
- Development of funding proposals and collaborative research initiatives
- Patent-oriented advanced research
- Scientific article preparation and technical advisory support

Key Scientific Outcomes

1. **Material Screening and Technology Evaluation**
    - Alkaline extraction yielded high protein recovery (>70%) but presented scalability, chemical residue, and functional property limitations.
    - Air classification emerged as a clean-label and sustainable method for protein enrichment, particularly for millets and pseudocereals.
    - Raw material suitability was found to be highly dependent on baseline protein content and fat levels.
2. **Process Variability Insight**
    - Protein enrichment levels varied significantly due to lack of direct control over external air classification processing parameters.
    - Ingredient consistency was identified as a critical requirement for commercialization.
3. **Rice Protein Concentrate (RPC) – Major Success**
    - Rice protein concentrate demonstrated stable protein content across batches.
    - Functional and sensory evaluation results were positive.
    - RPC was recommended for market introduction as a viable plant protein ingredient.
    - Application versatility was demonstrated through product development and cooking competitions.

4. **Advanced Research and Patent Orientation**
    - Ongoing Ph.D.-linked research initiated on air-classified protein and starch fractions of millets and grain amaranth.
    - Focus on enhancing nutritional quality, functional performance, and anti-nutritional factor reduction.
    - Work positioned for collaborative patent submission between Nutricircle and PJTAU.
5. **Strategic Proposal Development**
    - Multiple proposals prepared for CCMB, CFTRI, BCIL (DBT), BIRAC, and international collaborators.
    - Themes included allergenicity profiling, fermented protein development, therapeutic bioactivities, and gluten-free protein innovation.
6. **Scientific and Technical Advisory Support**
    - Preparation of technical articles for dissemination.
    - Support for product formulation, exhibition participation, brochure content, labeling guidance, and panel discussions.
    - Continuous scientific inputs to strengthen Nutricircle's plant protein innovation ecosystem.

Key Challenges Identified

- Dependence on third-party air classification limited process optimization and batch reproducibility.
- Variability in raw material composition affected enrichment potential.
- Absence of in-house fractionation infrastructure constrained systematic parameter optimization.

Critical Recommendation

Installation of a laboratory-scale air classification unit is strongly recommended to:

- Standardize processing conditions
- Minimize product variability
- Enable reproducible, validated protein enrichment
- Support patent filing and commercialization
- Facilitate structured scale-up

Such infrastructure will significantly enhance scientific precision and ingredient consistency.

Strategic Significance

Nutricircle's focus on:

- Indian millets
- Underutilized legumes
- Indigenous plant protein sources

is aligned with:

- National millet promotion initiatives
- Nutrition security goals
- Sustainable food systems
- Import substitution strategies

The work contributes meaningfully toward the vision of Atmanirbhar Bharat, reducing dependency on imported protein ingredients while strengthening domestic value chains.

Conclusion

The three-year R&D programme has:

- Established proof of concept for indigenous plant protein fractionation
- Identified commercially promising ingredient streams
- Generated technical knowledge for scale-up and validation
- Initiated intellectual property development
- Strengthened industry–academia collaboration

With targeted infrastructure strengthening and continued optimization, Nutricircle Pvt. Ltd. is well-positioned to emerge as a scientifically credible and innovation-driven contributor to India’s plant protein ingredient

1. INTRODUCTION

1.1 Background of Nutricircle Pvt. Ltd.: Nutricircle Pvt. Ltd. is a science-based nutrition and health company focused on advancing plant-derived protein ingredients to support healthier and more sustainable food systems. The company's vision is anchored in redefining nutrition and health through innovation in plant protein technologies, with a strong emphasis on sustainability, food safety, and conscious consumption.

Nutricircle specializes in the isolation of plant proteins from indigenous pulses and millets using innovative technological approaches, and provides protein isolate ingredients for use in food, beverage, and nutraceutical applications. The company's work is positioned against a backdrop of rising lifestyle disorders, increasing consumer awareness regarding nutrition, and a growing demand for plant-based, dairy-free, soy-free, and allergen-friendly protein sources.

Driven by global and national market trends, government initiatives supporting millets and plant-based foods, and increasing interest in sustainable nutrition, Nutricircle Pvt. Ltd. aims to contribute to the transition towards food systems that are less reliant on animal agriculture and more aligned with environmental and human health goals.

1.2 Purpose of the R&D Collaboration: Nutricircle Pvt. Ltd. was onboarded under the AgHub mentoring program of Professor Jayashankar Telangana State Agricultural University (PJTAU) in 2022, with the objective of strengthening its research and innovation capabilities in the area of plant-based protein sources and ingredients.

As part of this initiative, Dr. Aparna Kuna, Principal Scientist & Head, MFPI–Quality Control Laboratory, was allotted as a technical mentor to guide the company in identifying appropriate plant protein raw materials, understanding scientifically validated extraction, separation, and isolation methodologies, and evaluating the functional and analytical characteristics of plant protein ingredients.

The mentoring program was designed to support Nutricircle Pvt. Ltd. in progressing from conceptual understanding to evidence-based laboratory validation, thereby enabling informed decision-making for product and process development in the plant protein domain.

- Understanding scientifically sound approaches for plant protein extraction, separation, and isolation
- Identifying suitable plant-based raw materials, particularly indigenous pulses and millets
- Building a structured R&D pathway for ingredient development based on laboratory evidence

The collaboration was intended to provide scientific mentoring and laboratory validation support, enabling Nutricircle Pvt. Ltd. to take informed decisions in developing plant protein ingredients aligned with market needs, nutritional relevance, and technological feasibility.

1.3 Scope of Laboratory Work Undertaken: As part of the AgHub–PJTAU mentoring program, a series of laboratory-based R&D activities were undertaken at the MFPI–Quality Control Laboratory over a reporting period of three years. The scope of work was exploratory and developmental in nature and included:

- Screening and identification of suitable plant materials with potential for protein ingredient development
- Evaluation of different laboratory-scale extraction, separation, and isolation procedures for plant proteins
- Comparative assessment of processing approaches to understand yield, feasibility, and suitability of methods
- Preliminary characterization and study of derived protein ingredients to generate technical insights
- Providing scientific guidance and interpretation of results to support Nutricircle Pvt. Ltd.'s R&D decision-making process

The laboratory work was exploratory and developmental in nature, aimed at establishing a scientific foundation for plant protein ingredient development aligned with Nutricircle Pvt. Ltd.'s innovation goals.

2. OBJECTIVES OF THE R&D WORK

The R&D activities undertaken as part of the AgHub–PJTAU mentoring collaboration with Nutricircle Pvt. Ltd. were guided by the following key objectives:

1. **Screening of Protein-Rich Plant Materials:**
    - To identify and screen various plant-based raw materials for their protein content and suitability as potential sources for plant protein ingredient development.
2. **Development of Protein Isolation Procedures**
    - To develop and evaluate alkaline extraction–based methodologies for the efficient extraction and isolation of plant proteins at laboratory scale.
3. **Air Classification for Fractionation**
    - To study air classification techniques for the separation of protein-rich and starch-rich fractions from selected plant materials.
4. **Characterization of Protein Fractions**
    - To analyze the protein content of resultant fractions obtained through extraction and air classification processes, enabling comparative assessment of processing efficiency.
5. **Product Development and Formulation Advisory**
    - To provide scientific and technical guidance for product development and formulation using plant protein ingredients, aligned with intended food and nutraceutical applications.
6. **Technical Support for Market-Facing Activities**
    - To support Nutricircle Pvt. Ltd. **in** liaisoning for end-product preparation and tasting activities during exhibitions and industry events.
    - To assist in the preparation of technical content for product formulations, brochures, and exhibition materials, ensuring scientific accuracy and clarity.
7. **Mentoring for Translation of R&D to Applications**
    - To bridge laboratory-level R&D outcomes with practical application, communication, and commercialization readiness through continuous mentoring and technical inputs.

3. R&D ACTIVITIES UNDERTAKEN

3.1 Screening of Plant-Based Protein Sources for Protein Fractionation

Objective: To screen a range of millets, legumes, and defatted oilseed cakes for their suitability as raw materials for plant protein ingredient development using alkaline extraction and air classification (dry fractionation) approaches.

Materials Studied*:* The following categories of plant materials were evaluated:

- Millets and cereals (e.g., bajra, jowar, barley, samai, broken rice)
- Pseudo-cereals (e.g., amaranth, quinoa)
- Legumes and pulses (e.g., cowpea, horse gram, lentil)
- Defatted oilseed cakes/flours (e.g., groundnut, mustard, sesame, sunflower, coconut, defatted soy)

Initial screening was based on native protein content, fat content, and anticipated enrichment potential through fractionation.

Methodology

1. **Alkaline Extraction Trials**
    - Selected raw materials were subjected to alkaline extraction protocols for protein isolation.
    - Protein recovery, purity, and preliminary quality aspects were assessed.
2. **Assessment for Air Classification**
    - The same set of materials was evaluated for suitability for air classification, considering fat content and physical handling characteristics.
    - Due to the non-availability of air classification facilities at MFPI–Quality Control Laboratory, suitable materials were forwarded to an external facility at Chennai for dry fractionation.
    - The protein-rich and starch-rich fractions obtained were sent back to the laboratory for analysis.

Key Observations and Results

a) Alkaline Extraction Approach

- Protein isolates obtained through alkaline extraction showed high protein recovery (>70%).
- However, the process was found to be resource-intensive, involving:
    - High usage of chemicals, water, and processing resources
    - Challenges related to chemical residues in the final protein isolates
- Additionally, it was observed that:
    - Functional properties of proteins were adversely altered
    - Resultant isolates showed poor suitability for food formulation, particularly with respect to sensory attributes and application performance

Inference: Despite high protein recovery, alkaline extraction was considered technically and practically unsuitable for further development due to sustainability concerns, residue issues, and compromised functional quality.

b) Defatted Oilseed Cakes

- Defatted oilseed cakes showed high native protein content.
- However, residual fat levels ranging from 6–12% led to:
    - Operational issues during air classification, particularly clogging of filters
- Due to these limitations, defatted oilseed cakes were not pursued further in the current phase.

Recommendation: Oilseed cakes may be reconsidered for air classification if defatting levels can be reduced to below 5%, which may improve process feasibility.

c) Air Classification (Dry Fractionation)

- Suitable millet, legume, and pseudo-cereal materials were forwarded to Chennai for air classification at laboratory scale.
- The resultant protein-rich and starch-rich fractions were received and analyzed at MFPI–Quality Control Laboratory.
- Protein enrichment trends observed were consistent with expectations for dry fractionation, with:
    - Moderate increase in protein concentration in protein-rich fractions
    - Potential application of both fractions in food formulations

Outcome / Decision

- Alkaline extraction route was discontinued due to sustainability, safety, and functionality limitations.
- Defatted oilseed cakes were excluded from further experimentation in the current phase due to fat-related processing issues.
- Air classification was identified as the preferred approach for continued experimentation with suitable low-fat millets and legumes.

Relevance to Product and Process Development: This screening experiment played a critical decision-making role by:

- Eliminating technically unsuitable and non-scalable approaches at an early stage
- Establishing air classification as a viable, cleaner, and formulation-friendly pathway
- Providing direction for subsequent focused experiments on selected raw materials

3.2 Initial Air Classification Trials

Objective: To evaluate the feasibility of air classification (dry fractionation) for protein enrichment in selected grains and pulses, and to assess the extent of protein partitioning into protein-rich and starch-rich fractions under initial processing conditions.

Materials Evaluated

- Quinoa
- Bajra
- Black gram
- Kesari dhal
- Jowar

Each material was milled under defined conditions and subjected to air classification, and the resultant fractions were analyzed for protein content and yield.

Key Observations

1. **Protein Enrichment Achieved Across All Materials**
    - All grains and pulses showed a clear partitioning of protein into the protein-rich fraction following air classification.
    - The protein-rich fractions consistently exhibited higher protein content than the respective whole grain/flour protein levels.

2. **Magnitude of Protein Enrichment Varied by Raw Material**
    - Pulses demonstrated superior enrichment compared to cereals and pseudo-cereals.
        - Black gram protein increased from ~22% in the grain to ~39% in the protein-rich fraction.
        - Kesari dhal showed substantial enrichment, with protein levels reaching ~45% in the protein-rich fraction.
    - Quinoa showed moderate enrichment, with protein content increasing from ~14% to ~23% in the protein-rich fraction.
    - Cereals such as bajra and jowar exhibited modest protein enhancement, indicating scope for improvement through process optimization.

3. **Effective Separation of Starch-Rich Fractions**
    - Starch-rich fractions generally showed lower protein content compared to whole grain, confirming effective separation of macronutrient-rich components.
    - These fractions remain potentially useful for secondary food applications, supporting whole-material utilization.

4. **Influence of Processing Parameters**
    - Variation in milling conditions and air classification parameters influenced:
        - Fraction yield
        - Degree of protein enrichment
    - Initial trials indicated that equipment settings play a critical role in determining protein concentration and recovery efficiency.

Outcome and Decision: Based on the initial air classification results:

- All tested grains and pulses were selected for further trials, as each demonstrated:
  - Successful fractionation
  - Meaningful protein enrichment
- The variability observed in protein content across materials highlighted the need for systematic optimization of:
  - Milling parameters
  - Air classifier operational conditions (speed, feed rate, duration)

These results provided a strong technical justification to proceed with controlled experiments aimed at studying the effect of processing parameter variations on protein enrichment and recovery.

Relevance to Subsequent R&D Work: This phase established air classification as a technically viable and scalable dry fractionation approach, and formed the basis for:

- Advanced trials focusing on process optimization
- Selection of material-specific operating windows
- Development of protein-rich fractions suitable for formulation and product development

3.3 Evaluation of Protein Fractions for Health Benefits and Product Application

Objective: To study the health-relevant attributes and functional suitability of protein-rich fractions obtained through air classification, and to provide scientific recommendations for their application in food product formulations.

Approach: Protein-rich fractions obtained from selected grains and pulses were evaluated based on:

- Protein content of dry fractions
- Documented bioactive and health-promoting properties
- Compatibility with food formulation requirements, including intended use in staple foods, convenience foods, and functional products

Based on these parameters, application-specific guidance was provided to Nutricircle Pvt. Ltd. for potential product development pathways.

Summary of Key Findings and Recommendations

1. **Horse Gram Protein Fraction** (≈25.7%): The protein fraction exhibited notable antioxidant and radical scavenging activity, along with naturally occurring bioactive compounds such as phenolics, fiber, and phytic acid. The presence of proteinase inhibitors suggests potential roles in anti-inflammatory, anti-obesity, and immune-modulating functions.
   Recommended applications:
   - Atta fortification
   - Weaning foods
   - Ready-to-cook (RTC) porridge mixes

2. **Rajma (Kidney Bean) Protein Fraction** (≈46.1%): This fraction demonstrated high protein enrichment along with resistant starch, mineral richness, and diverse bioactive compounds associated with cardiometabolic health. The protein fraction showed potential hypolipidemic, hypoglycemic, antioxidant, and digestive health benefits.
   Recommended applications:
   - Instant soup mixes
   - Cookies and baked products
   - Protein-enriched yogurt formulations

3. **Amaranth Protein Fraction** (≈31.7%): Amaranth protein fractions exhibited a well-balanced amino acid profile and the presence of bioactive peptides with antioxidant, anti-inflammatory, antihypertensive, and antimicrobial activities.
   Recommended applications:
   - Ready-to-eat (RTE) extruded snacks
   - Beverage formulations
   - Traditional snack products

4. **Foxtail Millet Protein Fraction** (≈24.2%): The protein fraction was rich in iron and calcium and showed relevance to glycemic control and immune support. Literature-supported evidence indicates the presence of bran-associated proteins with potential protective effects against colon cancer cell migration.
   Recommended applications:
   - Atta fortification
   - Weaning foods
   - Cookies and composite health mixes

5. **Quinoa Protein Fraction** (≈23.1%): Quinoa protein fractions demonstrated high digestibility, an excellent balance of essential amino acids, and the presence of beneficial phytochemicals such as saponins, phytosterols, and phytoecdysteroids. These attributes support metabolic, cardiovascular, and gastrointestinal health.
   Recommended applications:
   - Bread and bakery products
   - Pasta and spaghetti
   - Extruded ready-to-eat snack products

Outcome and Advisory Provided

- All protein-rich fractions demonstrated distinct health-promoting attributes and application-specific suitability.
- The study enabled ingredient–application mapping, allowing Nutricircle Pvt. Ltd. to align protein fractions with:
  - Target consumer health needs
  - Appropriate food formats
  - Functional and sensory expectations
- Scientific inputs were provided to guide product formulation strategies, selection of end-use categories, and communication of health relevance.

Relevance to Product Development

This evaluation strengthened the translation of laboratory R&D outcomes into market-relevant food applications, supporting Nutricircle Pvt. Ltd. in developing plant protein–based functional ingredients with defined nutritional and health positioning.

3.4 Exploratory Trials for Development of Pharma-Grade Protein Fractions

Objective: To explore the feasibility of producing pharma-grade / high-purity protein fractions through air classification, with the intent of enabling their use in functional foods, therapeutic foods, and nutraceutical formulations.

Experimental Approach: Protein-rich fractions obtained from selected grains and pulses were subjected to refined air classification trials, with the aim of achieving:

- Higher protein concentration
- Improved consistency and purity of fine protein fractions

The trials were conducted using external air classification facilities at Chennai, with defined ranges of:

- Material feed rate
- Classifier rotor speed (ATP RPM)
- Micronization time

Protein content was analyzed in both fine (protein-rich) fractions and coarse (starch-rich) fractions.

Key Observations

- Across all tested raw materials (little millet, quinoa, horse gram, rajma, and foxtail millet), protein enrichment in fine fractions was achieved, but the absolute protein levels remained moderate.
- Protein content in fine fractions ranged approximately from:
    - ~15–19% for millets and quinoa
    - ~21–27% for legumes such as horse gram and rajma
- The improvement over native grain protein content was not sufficient to meet expectations for pharma-grade or high-purity protein ingredients.
- Starch-rich fractions continued to retain appreciable protein levels, indicating sub-optimal separation efficiency.

Root Cause Analysis

A detailed analysis of the experimental outcomes identified the following critical limitation:

- Since air classification trials were conducted externally, there was limited control over key processing parameters, including:
    - Fine-tuning of feed rate
    - Dynamic adjustment of classifier speed
    - Iterative optimization of milling and classification conditions

- The inability to systematically vary and standardize operating parameters prevented:
    - Process optimization
    - Maximization of protein enrichment
    - Reproducibility of results across trials

As a result, achieving pharma-grade protein concentrations using the existing experimental setup was not feasible.

Outcome and Decision

- The objective of obtaining pharma-grade protein fractions could not be met under the current experimental constraints.
- The limitation was identified as process-control related, rather than material-related, indicating that the raw materials themselves remain promising.

Recommendation and Way Forward

Based on the findings, it was strongly recommended that:

- A laboratory-scale air classification unit be acquired to:
    - Enable full control over processing parameters
    - Facilitate systematic optimization and standardization
    - Study the effect of individual variables on protein enrichment

- Such an in-house facility would allow:
    - Iterative trials
    - Reproducible process development
    - Improved chances of achieving higher protein purity suitable for nutraceutical and therapeutic applications

Relevance to Overall R&D Strategy

This experiment provided critical process-level insights and helped define the infrastructure requirements necessary for advancing from food-grade to pharma-grade plant protein ingredients. The outcomes directly informed future R&D planning and investment decisions.

3.5 Development and Evaluation of Rice Protein Concentrate (Rpc) as A Market-Ready Protein Ingredient

Objective

To explore alternative, sustainable protein sources capable of delivering consistent high protein content, suitable functional properties, and strong consumer acceptability for use in functional foods, therapeutic foods, and nutraceutical formulations.

Background and Rationale

Following limitations observed with air-classified grain protein fractions, attention was shifted towards rice protein concentrate (RPC) derived as a by-product of rice-based bioethanol production. Broken rice used for ethanol production yields a residual fermented slurry rich in protein, offering an opportunity for:

- High-value protein recovery
- Sustainable by-product valorization
- Alignment with circular economy principles

RPC procured from Praj Matrix, Pune, was selected for detailed evaluation due to its high and consistent protein content

Experimental Approach

The rice protein concentrate was evaluated for:

- Nutritional composition
- Anti-nutrient levels and bioavailability indicators
- Functional suitability in food formulations
- Product development feasibility
- Sensory acceptability

Subsequently, RPC was incorporated into multiple staple and convenience food formulations, followed by sensory evaluation and protein enhancement assessment.

Key Findings

Nutritional and Functional Quality

- RPC exhibited very high protein content (~80%), with good consistency across batches.
- It was also a good source of iron, calcium, magnesium, and zinc.
- Anti-nutritional factors such as saponins and oxalates were present only in minimal quantities, indicating good nutrient bioavailability.
- The fermented nature of the protein supports enhanced digestibility and bioabsorbability

Product Development and Protein Enhancement

1. **Staple Food Fortification (Wheat and Jowar Roti)**
    - Incorporation of RPC at 5–30% levels significantly enhanced protein content.
    - Protein content increased:
        - From ~10.6% to ~31.8% in jowar roti
        - From ~11.1% to ~30.4% in wheat roti
    - Sensory evaluation showed that 5–20% incorporation levels were highly acceptable, with 10% RPC identified as optimal, achieving good balance between nutrition and sensory quality.

2. **Other Food Applications:** RPC was successfully incorporated into:
    - Jowar cookies
    - Ragi malt and ragi flour
    - Wheat and jowar atta
    - Rawa dosa mix, moong dhal dosa mix
    - Porridge pre-mixes

Protein enhancement ranged from 30–70% improvement over control products, with high sensory acceptability (≥95% in cookies)

Sensory Evaluation Outcomes

- Products fortified with RPC consistently achieved good overall acceptability scores (≈7–8 on a 9-point hedonic scale).
- Texture, taste, aroma, and functional handling properties remained within consumer-acceptable limits, particularly at 5–10% incorporation levels.

Outcome and Decision

- Rice Protein Concentrate demonstrated excellent nutritional quality, functional performance, batch-to-batch consistency, and sensory acceptability.
- Unlike air-classified protein fractions, RPC met the requirements for scalability, formulation compatibility, and market readiness.
- Based on comprehensive evaluation, RPC was approved ("green signal") for commercialization as a protein ingredient for incorporation into multiple food categories.

Relevance to Product Development and Commercialization

This experiment represented a major R&D success, enabling:

- Transition from exploratory research to market-oriented ingredient development
- Positioning of RPC as an allergen-free, sustainable, high-protein ingredient
- Expansion of Nutricircle Pvt. Ltd.'s portfolio into functional foods, therapeutic products, and nutraceutical formulations

Way Forward

RPC was recommended for use across a wide range of formulations, including:

- Atta fortification, RTC mixes, weaning foods
- Bakery products, extruded snacks, beverages
- Pasta, noodles, confectionery, and protein bars

with optimized incorporation levels ranging from 3–15%, depending on product type

3.6 Demonstration of Application Potential of Rice Protein Concentrate (RPC) through Culinary Innovation

Objective

To demonstrate the compatibility, versatility, and protein enhancement potential of Rice Protein Concentrate (RPC) across diverse food formats through practical culinary applications, and to assess its acceptance in real-world recipe development.

Activity Overview

Based on the successful laboratory evaluation and product development outcomes of RPC, the ingredient was extended for application demonstration through a cooking competition organized in collaboration with academic stakeholders.

Rice Protein Concentrate was provided on behalf of Nutricircle Pvt. Ltd. for use in a cooking competition conducted by the Department of Foods & Nutrition, College of Community Science, Saifabad, under Professor Jayashankar Telangana State Agricultural University.

The event titled "Protein-Infused Millet Recipes: A Culinary Journey towards Health" was organized on 19 December 2023, coinciding with the International Year of Millets – 2023
RPC cooking competition report

Structure of the Competition

- Participants: Undergraduate, Postgraduate, and Ph.D. students
- Total participation: 15 students
- Recipe categories:
    - Main course
    - Health mixes
    - Snacks
    - Baked products
- RPC incorporation levels ranged from 5% to 20%, depending on product type

Recipes were evaluated based on:

- Appearance and presentation
- Texture, flavour, taste, and colour
- Nutritional value and protein enhancement
- Innovation and culinary skill

Key Outcomes

- A wide range of recipes were successfully developed using RPC, including traditional millet-based foods, snacks, health mixes, and baked products.
- Across all categories, incorporation of RPC led to a significant improvement in protein content without adversely affecting sensory quality.
- The competition clearly demonstrated:
    - High formulation flexibility of RPC
    - Compatibility with traditional and modern food formats
    - Ease of incorporation across low-heat, high-heat, and baked applications
- Sensory evaluation outcomes and participant feedback indicated good consumer acceptability of RPC-fortified foods.

Industry Engagement and Support

To encourage innovation and participation, Nutricircle Pvt. Ltd. sponsored cash prizes worth ₹10,000, which were formally provided to the Associate Dean, College of Community Science, Saifabad. The competition was executed by the Department of Foods & Nutrition.

Relevance to R&D and Commercialization

This activity served as:

- A proof-of-application exercise validating RPC's suitability across multiple food categories
- A technology demonstration platform bridging laboratory R&D and consumer-facing products
- Supporting evidence for market readiness of RPC as a versatile protein ingredient

The outcomes reinforced the decision to position Rice Protein Concentrate as a commercially viable, application-friendly, and nutritionally impactful ingredient within Nutricircle Pvt. Ltd.'s product portfolio.

Overall Significance

The cooking competition strengthened the R&D programme by:

- Demonstrating real-world usability beyond controlled lab conditions
- Generating formulation ideas and visibility
- Enhancing stakeholder engagement and confidence in RPC as a functional protein ingredient

3.7 Analysis of Air-Classified Fine (Protein-Rich) Fractions and Starch Fractions of Millets and Pseudocereals

Objective

To strengthen ingredient-level R&D evidence by conducting a detailed nutritional and functional characterization of air-classified fine (protein-rich) fractions and starch fractions of selected millets, pseudocereals, and legumes obtained from an external air classification facility at Chennai, and to assess their consistency, suitability, and commercial viability as protein ingredients.

Materials and Experimental Overview

Air-classified fractions of the following raw materials were analyzed:

- Millets & pseudocereals: Quinoa, Little millet, Foxtail millet
- Legumes: Rajma, Chickpea, Horse gram

Both fine fractions (intended as protein-rich) and starch fractions (where received) were evaluated for:

- Proximate composition (protein, fat, fiber, carbohydrates, energy)
- Functional properties (water absorption, oil absorption, emulsifying activity, foaming capacity)
- Starch digestibility parameters (RDS, SDS, resistant starch – where applicable)

Key Results and Observations

Protein Content of Fine Fractions

- Protein levels in the air-classified fine fractions ranged from ~13 to 26%, depending on the raw material:
    - Chickpea: 26.54%
    - Rajma: 23.35%
    - Horse gram: 18.63%
    - Quinoa: 16.10%
    - Little millet: 15.17%
    - Foxtail millet: 13.24%
- Although legumes showed comparatively higher protein than millets, protein enrichment was modest and significantly lower than expected for a marketable protein ingredient.

Protein Distribution Across Fractions

- Appreciable protein content was also detected in starch fractions:
    - Quinoa starch fraction: 13.08%
    - Rajma starch fraction: 19.98%
    - Little millet starch fraction: 12.46%
    - Foxtail millet starch fraction: 12.75%
- This indicated inefficient separation between protein and starch phases, suggesting sub-optimal air classification conditions.

Functional Properties

- Water absorption capacity of fine fractions ranged from 1.87–3.37 g/g, indicating suitability for dough-based and hydrated food systems.
- Emulsifying activity was moderate, with higher values observed in rajma and quinoa fine fractions.
- Foaming capacity was generally low to moderate and limited to certain legume fractions.
- Functional performance was acceptable, but not superior enough to compensate for low protein enrichment when positioning the fractions as protein ingredients.

Starch Fraction Characteristics

- Starch fractions were rich in carbohydrates (≈68–74%) and showed:
    - High slowly digestible starch (SDS) in foxtail millet (40.82%) and little millet (39.75%)
    - Moderate resistant starch levels, beneficial for gut health and glycemic moderation
- These results indicate good potential for starch fractions as energy-rich or functional carbohydrate ingredients, rather than protein ingredients.

Critical Interpretation and Validation

This experiment validated a key technical concern identified in earlier trials:

- Protein content in air-classified fine fractions is highly sensitive to processing conditions such as classifier speed, feed rate, and micronization time.
- Since air classification was carried out at an external facility, there was no scope for iterative optimization or standardization.
- As a result:
    - Large variation in protein content was observed
    - Batch-to-batch uniformity could not be ensured

Such variability is not acceptable for commercial ingredient applications, where protein content must remain consistent across batches to:

- Support label claims
- Meet regulatory and customer expectations
- Build market trust

Limitation Identified

The primary limitation was lack of process control, not raw material potential. Dependence on an external air classification facility restricted:

- Optimization of separation efficiency
- Reproducibility of protein enrichment
- Development of a standardized ingredient specification

Recommendation and Way Forward

Based on cumulative experimental evidence, it is strongly recommended that:

- A laboratory-scale air classification unit be established to:
    - Standardize and optimize operating parameters
    - Achieve higher and reproducible protein enrichment
    - Generate ingredient specifications suitable for commercialization

Commercial Outlook

Despite current limitations:

- Protein-rich fine fractions and starch fractions from millets and pseudocereals demonstrate significant market potential
- With optimized processing, they can be positioned as:
    - Indigenous plant protein ingredients
    - Sustainable alternatives to imported protein concentrates
    - Functional carbohydrate ingredients for sports, therapeutic, and traditional foods

Conclusion

This study conclusively demonstrated that process optimization is critical for successful commercialization of air-classified plant protein ingredients. Establishing in-house air classification capability is essential to unlock the full potential of millet- and legume-based protein and starch fractions for the Indian market.

3.8 Evaluation of Chickpea Varieties for Protein Content and Suitability for Air Classification

Objective: To evaluate selected chickpea varieties for their native protein content and assess their suitability for air classification–based protein enrichment, prior to undertaking process-level experimentation.

Experimental Overview: Chickpea samples were received from an external source with the claim of high protein content, and the material was proposed for promotion as a candidate raw material for air classification.

The samples were analyzed at the MFPI–Quality Control Laboratory for:

- Crude protein content
- Preliminary assessment of enrichment potential based on baseline protein levels

Key Observations

- The analyzed chickpea varieties showed protein content lower than the values claimed at the time of sample submission.
- The observed protein levels were within the normal range for conventional chickpea, and did not indicate a clear advantage over routinely available varieties.
- Based on the measured protein content, the expected protein enrichment through air classification was projected to be limited.

Inference and Decision

- Since baseline protein content is a critical determinant of achievable enrichment through air classification, the evaluated chickpea varieties were not considered suitable for further air classification trials at this stage.
- Proceeding with air classification on material with moderate protein content was assessed as not technically or economically justified.

Recommendation

- It was recommended not to proceed with air classification experiments on the current chickpea samples.
- To validate whether the observed protein levels were influenced by seasonal, environmental, or agronomic factors, it was advised that:
    - The same chickpea varieties be re-evaluated in the subsequent growing season
    - Protein content be reassessed prior to considering further processing interventions

Relevance to R&D Strategy

This evaluation highlights the importance of:

- Independent laboratory verification of raw material claims
- Evidence-based screening prior to resource-intensive processing
- Considering seasonal variability in crop composition during ingredient R&D

The exercise ensured that R&D efforts remained focused, data-driven, and cost-effective, avoiding premature scale-up of unsuitable raw materials.

3.9 Ongoing Patent-Oriented Research on Air-Classified Protein and Starch Fractions of Millets and Pseudocereals

Objective

To generate novel, optimized, and application-ready knowledge on air-classified protein and starch fractions of foxtail millet and grain amaranth, with the intent of intellectual property (IP) generation and development of standardized, value-added indigenous ingredients.

Background and Rationale

Building on earlier R&D outcomes that highlighted:

- The importance of process optimization in air classification, and
- The need to enhance nutritional, functional, and consistency parameters of protein and starch fractions,

A focused research programme was initiated to explore process interventions and quality enhancement strategies capable of yielding technically superior and commercially viable ingredients.

This work is designed to address key limitations identified in earlier trials, particularly variability in protein enrichment and the presence of anti-nutritional factors.

Scope of the Patent-Related Work

The ongoing research titled: "Quality Evaluation of Air-Classified Protein and Starch Fractions of Foxtail Millet and Grain Amaranth" focuses on:

- Integration of pre-treatment (soaking) and post-treatment (cold plasma) strategies
- Improvement of:
    - Nutritional quality
    - Techno-functional properties
    - Digestibility
    - Reduction of anti-nutritional factors
- Preservation of native protein functionality through dry fractionation approaches

The work is positioned at the intersection of:

- Ingredient R&D
- Process optimization
- Sustainable and clean-label protein technologies

Collaborative and Academic Framework

- The research is being carried out as a collaborative activity between Nutricircle Pvt. Ltd. and PJTAU.
- A Ph.D. student is currently engaged in this work under academic supervision, ensuring:
    - Scientific rigor
    - Depth of experimentation
    - Comprehensive data generation

Current Status

- January 2026:
    - Air-classified materials were recently received from the Chennai air classification facility for advanced analysis and experimentation.
    - Laboratory studies are currently underway focusing on nutritional, functional, and anti-nutritional profiling.
- The work is ongoing and progressing as per the approved research plan.

Expected Outcomes

- Generation of novel process–property relationships for air-classified millet and pseudocereal fractions
- Development of standardized processing strategies leading to improved ingredient consistency
- Identification of unique, patentable features related to:
    - Processing methodology
    - Ingredient composition
    - Functional performance

Intellectual Property and Commercial Relevance

- The outcomes of this research are intended to be submitted for a possible patent as a joint collaborative effort between:
    - Nutricircle Pvt. Ltd.
    - Professor Jayashankar Telangana State Agricultural University (PJTAU)
- The work is expected to strengthen Nutricircle's ingredient innovation pipeline, particularly in the domain of:
    - Indigenous plant proteins
    - Gluten-free, non-allergenic ingredients
    - Functional and therapeutic food applications

Significance to the R&D Programme

This ongoing work represents a transition from exploratory R&D to innovation-led research, reinforcing:

- Long-term academic–industry collaboration
- Capacity building through doctoral research
- Strategic movement towards IP creation and technology ownership

3.10 R&D Support through Preparation of Research and Funding Proposals

Overview

In addition to experimental R&D activities, the MFPI-Quality Control Laboratory extended strategic R&D and technical support to Nutricircle Pvt. Ltd. through the conceptualization and preparation of multiple research and funding proposals. These proposals were aimed at securing external funding and institutional collaborations to advance Nutricircle's work in plant protein ingredients, functional foods, and therapeutic nutrition.

All proposals were prepared based on:

- Identified research gaps during laboratory experimentation
- Market relevance and scalability potential
- Alignment with national and international funding priorities

The finalized proposals were submitted to Nutricircle Pvt. Ltd. for onward submission to the respective funding and collaborative agencies.

Details of Proposals Prepared

1. Proposal to CCMB, Hyderabad

Title: Collaboration to Test and Characterize Protein-Rich Flours for Health-Relevant Functional and Allergenicity Profiles

Scope and Objective: To establish the bio-functional relevance, safety, and allergenicity profiles of protein-rich flours derived from five traditional crops:

- Chickpea
- Horse gram
- Grain amaranth
- Foxtail millet
- Bajra (pearl millet)

The proposal emphasized:

- Functional bioactivity assessment
- Allergenicity profiling
- Nutritional validation to support functional food and nutraceutical applications

2. Proposal to CFTRI, Mysuru and Biotech Consortium India Limited (BCIL)

Title: Process for Production of Fermented Chickpea Protein for Sports Nutrition Applications

Submitted to:

- CSIR–CFTRI, Mysuru
- Biotech Consortium India Limited (BCIL), an initiative of the Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India

Key Objectives: Development of a fermented chickpea protein ingredient tailored for sports nutrition, focusing on:

- High digestibility and improved PDCAAS
- Reduction of anti-nutritional factors (phytates, trypsin inhibitors, oligosaccharides)
- Mild flavor profile with reduced beany notes
- Improved solubility, dispersibility, and emulsification for shakes and bars
- Retention of essential amino acids (lysine, leucine, valine, isoleucine)

3. Proposal to Gro Food Park and Food & Bio Cluster Denmark

Title: Development of Gluten- and Allergen-Free Protein Fractions from Indian Millets and Pseudocereals Using Air Classification Technology

Focus Areas:

- Development of clean-label, gluten-free, and allergen-free protein ingredients
- Application of air classification technology for sustainable dry fractionation
- Exploration of international collaboration for technology advancement and market access

4. Concept Note Submitted to BIRAC, Government of India

Title: Air-Classified Proteins from Indian Millets and Underutilized Legumes: Therapeutic Bioactivities and Commercialization Potential

Scope:

- Identification of therapeutic bioactivities of air-classified plant proteins
- Establishment of commercialization pathways for indigenous protein ingredients
- Alignment with national priorities on millets, nutrition security, and sustainable food systems

Significance of Proposal Development Activity

The preparation of these proposals:

- Strengthened Nutricircle's R&D and funding pipeline
- Enabled multi-institutional and international collaboration opportunities
- Demonstrated readiness to move from laboratory-scale R&D to technology validation and commercialization
- Complemented ongoing experimental and patent-oriented research activities

Role of MFPI–Quality Control Laboratory

- Conceptualization of research themes
- Technical content development and experimental justification
- Alignment of proposals with funding agency priorities
- Submission-ready documentation provided to Nutricircle Pvt. Ltd.

3.11 Scientific Content Development and Technical Advisory Support

Overview

In addition to laboratory-based R&D activities and proposal development, the MFPI–Quality Control Laboratory extended continuous scientific and technical support to Nutricircle Pvt. Ltd. through preparation of knowledge documents, industry-oriented articles, technical content, and advisory inputs.

These efforts were aimed at strengthening Nutricircle's positioning in the emerging plant protein and millet-based ingredient sector, while supporting evidence-based communication and product development strategies.

Technical Articles Prepared and Communicated

The following technical articles were prepared and shared with Nutricircle Pvt. Ltd. for onward submission and knowledge dissemination:

1. **From Heritage to Health: Millets in Reformulated Product Design**
    - Focused on integrating traditional millets into modern product formulations
    - Emphasized nutritional advantages and reformulation strategies
2. **Plant-Based Proteins – Exploring the Untapped Sources to Meet the Escalating Demand in the Food Industry**
    - Examined emerging protein sources
    - Discussed market trends, sustainability, and innovation opportunities
3. **Tapping the Underutilized Protein Sources for Production of Plant-Based Proteins**
    - Highlighted indigenous and lesser-utilized crops
    - Addressed value addition through fractionation and processing technologies
4. **Production of Plant-Based Proteins (Ready-to-Cook and Ready-to-Reconstitute) from Indian Grain Sources**
    - Discussed ingredient processing approaches
    - Explored applications in functional foods and convenience products

These articles contributed to scientific positioning, industry visibility, and knowledge dissemination in the plant protein domain.

Technical Content and Advisory Inputs

The laboratory also provided:

- Technical inputs for brochure development
- Guidance for label content and regulatory-aligned communication
- Scientific content for exhibition materials and promotional literature
- Technical suggestions for product formulation documentation
- Content inputs for panel discussions and knowledge-sharing platforms

All inputs were prepared to ensure:

- Scientific accuracy
- Industry relevance
- Regulatory sensitivity
- Alignment with emerging plant protein trends

Product Formulation and Exhibition Support

In addition to scientific documentation and advisory inputs, the laboratory extended active support to Nutricircle Pvt. Ltd. in developing and refining product formulations for participation in various exhibitions and industry events. This included guidance on ingredient optimization, protein fortification strategies, functional compatibility of plant protein fractions, and improvement of sensory attributes to enhance consumer acceptance. Technical inputs were provided to ensure that the showcased products effectively demonstrated the nutritional strength, application versatility, and commercial potential of indigenous plant protein ingredients. Such formulation and exhibition support enabled Nutricircle to present scientifically validated, market-ready concepts at public platforms, thereby strengthening brand credibility and industry visibility.

Strategic Contribution to the Plant Protein Ecosystem

Through experimental R&D, proposal development, patent-oriented research, and knowledge dissemination, the MFPI–Quality Control Laboratory has consistently provided multidimensional support to Nutricircle Pvt. Ltd.

The laboratory has actively contributed to:

- Strengthening the scientific foundation of plant protein ingredient development
- Promoting indigenous millets and underutilized legumes as sustainable protein sources
- Enhancing technical credibility in the plant-based protein sector
- Supporting innovation, commercialization pathways, and industry outreach

The lab has continuously provided inputs for the progress of the plant protein industry in all possible ways through research, advisory support, capacity building, and knowledge generation.

4. LIMITATIONS AND CHALLENGES

The three-year R&D engagement has generated significant scientific insights into plant protein fractionation, functional properties, and product development potential. At the same time, certain technical and operational challenges were identified, which require strategic strengthening to ensure scientific validation, consistency, and scalability.

4.1 Dependence on External Air Classification Facility

One of the primary technical limitations encountered during the course of experimentation was the reliance on a third-party air classification facility for dry fractionation of protein-rich materials.

While preliminary fractionation trials yielded encouraging insights, it was observed that:

- Variability in processing conditions (air flow rate, rotor speed, feed rate, particle size distribution, etc.) significantly influenced protein enrichment levels.
- Batch-to-batch variation in protein content was observed in the received fractions.
- Lack of direct control over operational parameters limited systematic optimization studies.
- Reproducibility and fine-tuning of processing variables could not be conducted in a structured, experimental design framework.

For ingredient commercialization, protein content consistency across batches is critical, as variability directly affects:

- Label claims
- Nutritional positioning
- Functional performance in product formulations
- Market credibility

Without standardized control over fractionation parameters, it becomes challenging to generate validated, reproducible data that can support regulatory, commercial, and patent-related claims.

4.2 Need for Process Standardization and Optimization

The R&D findings strongly indicate that installation of a laboratory-scale air classification unit is essential for:

- Controlled optimization of processing parameters
- Establishment of standardized operating protocols
- Minimization of product variability
- Generation of scientifically validated, reproducible datasets
- Development of scale-up models for commercial production

A lab-scale unit would enable:

- Experimental design–based optimization
- Technical precision in protein enrichment
- Development of process–property correlations
- Stronger technical validation for IP filing and commercialization

Such infrastructure would significantly enhance the scientific robustness of ingredient development and reduce uncertainties associated with outsourced processing.

4.3 Raw Material Variability

Screening experiments also demonstrated that:

- Protein content varies due to varietal, seasonal, and agronomic factors.
- Not all protein-rich materials are equally suitable for air classification.

This highlights the need for:

- Rigorous raw material selection protocols
- Baseline compositional screening before processing
- Establishment of minimum protein thresholds for fractionation

4.4 Scaling and Commercial Translation Challenges

For successful commercialization of plant protein ingredients, the following must be addressed:

- Process reproducibility
- Quality consistency across batches
- Functional property stability
- Standardized technical documentation for regulatory compliance

These elements require integrated infrastructure and technical control mechanisms.

Positive Outlook and Strategic Direction

Despite these challenges, the R&D journey clearly establishes that Nutricircle Pvt. Ltd. is pursuing a scientifically sound and strategically important innovation pathway.

The focus on developing:

- Indigenous plant protein ingredients
- Millet- and legume-based protein fractions
- Gluten- and allergen-free protein sources
- Sustainable dry fractionation technologies, represents a forward-looking approach aligned with:
    - National millet promotion initiatives
    - Nutrition security priorities
    - Sustainable food systems
    - Import substitution in protein ingredients

Currently, a significant portion of high-value plant protein ingredients used in India are imported. By developing standardized protein fractions from Indian crops, Nutricircle is contributing toward:

- Strengthening domestic ingredient ecosystems
- Supporting Indian farmers and traditional crops
- Reducing dependency on imported protein isolates
- Advancing the vision of Atmanirbhar Bharat (Self-Reliant India)

The work undertaken so far demonstrates that the foundational scientific framework has been established. With appropriate infrastructure strengthening, particularly installation of a lab-scale air classification unit, the R&D outcomes can transition into validated, scalable, and commercially robust technologies.

5. RECOMMENDATIONS AND WAY FORWARD

Based on the experimental findings, technical evaluations, proposal development activities, and patent-oriented research undertaken during the reporting period, the following recommendations are proposed to strengthen and accelerate Nutricircle Pvt. Ltd.'s plant protein innovation pathway.

5.1 Installation of a Laboratory-Scale Air Classification Unit

The most critical technical recommendation emerging from the R&D programme is the establishment of an in-house laboratory-scale air classification unit.

This infrastructure is essential to:

- Standardize processing parameters (airflow rate, rotor speed, feed rate, particle size distribution)
- Optimize protein enrichment efficiency
- Minimize batch-to-batch variability
- Generate reproducible, scientifically validated data
- Strengthen technical documentation for regulatory and commercialization purposes
- Enable systematic experimental design for scale-up modelling

Control over fractionation conditions will significantly enhance ingredient consistency, improve protein recovery, and build confidence for commercial positioning. It will also support IP development, publication-quality research, and industry-grade validation.

5.2 Development of Standard Operating Protocols (SOPs)

Parallel to infrastructure development, standardized SOPs should be established for:

- Raw material selection and pre-processing
- Baseline compositional screening
- Air classification parameter optimization
- Protein and starch fraction quality evaluation
- Functional property characterization
- Batch validation and quality assurance

This will ensure technical precision and facilitate seamless scale-up.

5.3 Strategic Focus on High-Potential Ingredients

Based on R&D outcomes, the following ingredient streams show strong commercial potential:

- Rice Protein Concentrate (RPC)
- Air-classified millet protein fractions
- Air-classified starch fractions (as co-products)
- Fermented chickpea protein (sports nutrition segment)

These ingredient categories should be prioritized for:

- Product portfolio expansion
- Pilot-scale validation
- Market testing
- Brand positioning as indigenous plant proteins

5.4 Strengthening Academic–Industry Collaboration

The ongoing patent-oriented research involving a Ph.D. scholar should be expanded to:

- Generate high-quality scientific publications
- Establish technical credibility in the ingredient ecosystem
- Create defensible intellectual property
- Develop technology transfer models

Structured collaboration between Nutricircle and PJTAU can evolve into a long-term innovation partnership.

5.5 Bio-Functional and Clinical Validation

To enhance market credibility, the next phase should include:

- In vitro bio-functional validation
- Digestibility and PDCAAS assessment
- Anti-nutritional factor reduction studies
- Allergenicity profiling
- Clinical or pre-clinical evaluation where feasible

This will position Nutricircle's products in:

- Functional foods
- Therapeutic nutrition
- Sports nutrition
- Nutraceutical markets

5.6 Branding Indigenous Plant Proteins – Atmanirbhar Approach

Nutricircle's strategy of focusing on:

- Indian millets
- Underutilized legumes
- Indigenous grain-based proteins

is both scientifically relevant and nationally significant.

The way forward should include:

- Branding as "Indian-Origin Plant Proteins"
- Leveraging millet missions and national nutrition initiatives
- Promoting import substitution of plant protein isolates
- Building farmer-linked value chains

This aligns strongly with the vision of Atmanirbhar Bharat, contributing to domestic ingredient innovation and reduced reliance on imported protein sources.

5.7 Commercial Roadmap

A phased roadmap is recommended:

Phase I – Infrastructure & Standardization

- Install lab-scale air classification unit
- Optimize processing conditions
- Establish validated ingredient specifications

Phase II – Pilot Scale & Validation

- Conduct pilot-scale trials
- Generate commercial sample lots
- Perform shelf-life and stability studies

Phase III – IP & Market Launch

- File patents (collaboratively)
- Develop regulatory dossiers
- Launch ingredient portfolio
- Expand B2B partnerships

Forward Outlook

The R&D work undertaken over the last three years has laid a strong scientific foundation for indigenous plant protein innovation. With targeted infrastructure strengthening, systematic optimization, and strategic commercialization planning, Nutricircle Pvt. Ltd. is well-positioned to emerge as a credible contributor to India's plant protein ecosystem. The journey thus far has established proof of concept. The next phase should focus on precision, consistency, validation, and scalable translation.

6. OVERALL CONCLUSIONS OF THE THREE-YEAR R&D PROGRAMME

The three-year R&D collaboration between Nutricircle Pvt. Ltd. and the MFPI – Quality Control Laboratory has established a comprehensive scientific foundation for the development of indigenous plant protein ingredients from Indian crops. The programme systematically progressed from:

- Screening and evaluation of diverse protein-rich raw materials
- Comparative assessment of alkaline extraction and air classification methodologies
- Functional and nutritional characterization of protein and starch fractions
- Product formulation and sensory validation
- Proposal development for external funding and institutional collaboration
- Patent-oriented advanced research initiatives

Through structured experimentation, critical learnings were generated regarding:

- Suitability of raw materials for dry fractionation
- Limitations of chemical extraction approaches in terms of scalability and functionality
- Importance of maintaining native protein structure for improved sensory and functional performance
- Need for strict process control to ensure ingredient consistency

The successful evaluation and commercialization readiness of Rice Protein Concentrate (RPC) stands out as a major achievement of the programme, demonstrating the feasibility of developing stable, nutritionally relevant, and formulation-compatible plant protein ingredients.

The R&D activities also confirmed that air classification is a promising, sustainable, and clean-label technology for protein enrichment of millets and pseudocereals. However, the work clearly established that process standardization and optimization are indispensable for achieving consistent protein enrichment levels suitable for commercial deployment.

A key technical insight from the programme is that in-house control over fractionation parameters is essential to generate reproducible, validated, and market-ready ingredients. Infrastructure strengthening, particularly through installation of a laboratory-scale air classification unit, will significantly enhance technical precision, reduce variability, and enable structured scale-up.

Beyond laboratory outputs, the collaboration contributed to:

- Strategic funding proposal development
- Scientific article preparation and knowledge dissemination
- Product formulation and exhibition support
- Advisory inputs for branding, labeling, and technical communication
- Advancement toward intellectual property generation

Importantly, the work undertaken aligns strongly with national priorities, particularly:

- Promotion of millets and traditional crops
- Development of sustainable plant-based protein systems
- Reduction of dependency on imported protein isolates
- Advancement of the Atmanirbhar Bharat vision

Nutricircle Pvt. Ltd.'s initiative to focus on indigenous plant protein sources represents a scientifically valid, economically relevant, and nationally significant direction. The R&D programme has provided clarity on technological pathways, material suitability, and commercialization requirements.

In conclusion, the three-year engagement has:

- Established proof of concept
- Identified scalable ingredient opportunities
- Defined technical gaps requiring infrastructure strengthening
- Initiated patent-oriented research
- Positioned Nutricircle for future innovation-driven growth

With continued collaboration, process optimization, and strategic infrastructure development, Nutricircle Pvt. Ltd. has strong potential to emerge as a credible contributor to India's plant protein ingredient ecosystem.