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Development and Optimization of a Novel Hybrid Paneer Formulation

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ABSTRACT

The growing demand for plant-based and sustainable protein alternatives has driven research into innovative dairy substitutes. Conventional paneer production relies heavily on animal milk, which raises environmental, ethical, and dietary concerns, especially among vegan and lactose-intolerant consumers. Hence, the present study was focused on creating an innovative coagulated protein product using mung bean (*Vigna radiata* L.) as the primary ingredient. Four different formulations were prepared: T1 (pure mung bean extract), T2 (70% mung bean extract + 30% buffalo milk), T3 (70% mung bean extract + 30% cow milk) and T4 (50% mung bean extract + 50% soy milk). A kinnow-derived bioenzyme was effectively used to induce coagulation. Sensory evaluation revealed that T3 scored the highest in key attributes, including color (7.8), flavor (7.1), appearance (7.5), texture (7.2), and overall acceptability (7.5). Although T1 demonstrated strong nutritional qualities, its sensory characteristics differed from the other formulations. The results highlight the viability of mung bean-based coagulated proteins as a sustainable, nutritious, and palatable alternative to conventional paneer, particularly for the expanding vegan consumer base.

Key Words: Bio-Enzyme, Coagulation, Hybrid Paneer,Mung bean, Sensory evaluation.

INTRODUCTION

India leads global milk production, achieving a record output of 207 million MT in 2023, a 2% increase from the previous year (Kangare *et al,* 2024). Nearly half of this milk is processed into traditional dairy products, including paneer, curd, butter, and sweets, primarily through heat/acid coagulation and fermentation (Pal, 2019). Cow and buffalo milk dominate India's dairy sector (Pal and Jadhav, 2013), serving as a vital nutritional source-providing calcium (55% of daily intake), phosphorus (25%), potassium (10-14%), zinc (6.7%), riboflavin (13.5%), vitamin B12 (10.3%), and vitamin A (11%) (Warsewicz *et al,* 2019). However, the rise of non-dairy alternatives reflects shifting consumer preferences due to lactose intolerance, ethical concerns over animal welfare, and the environmental impact of dairy farming (Jovandaric, 2021). Lactose maldigestion affects a significant population, while ethical issues like intensive livestock practices drive demand for plant-based substitutes. Additionally, dairy production's high resource consumption and greenhouse gas emissions have accelerated research into sustainable protein sources, particularly from pulses, cereals, and oilseeds.

Pulses, especially mung bean (*Vigna radiata* L.), offer an excellent base for hybrid paneer due to their high protein content (25-28%) and balanced amino acid profile (Singh *et al,* 2017; Boye *et al,* 2010). Government initiatives like the National Food Security Mission-Pulses (Ministry of Agriculture & Farmers Welfare, 2021) further support pulse cultivation, reinforcing their role in food security. Mung bean's superior digestibility (Mubarak, 2005) and nutritional richness: carbohydrates (62-65%), fiber (3.5-4.5%), iron, potassium, and vitamins B, E, A, and C make it ideal for dairy alternatives (Singh *et al,* 2017). Its bioactive compounds (e.g., polyphenols, polysaccharides) provide additional health benefits, including antioxidant, antihypertensive, and immunomodulatory effects (Cao *et al,* 2011; Manan *et al,* 2019). Sprouting further enhances its nutritional value by increasing B vitamins, ascorbic acid, and isoflavones (Sharma, 1996; Rao, 2002; Randhir *et al,* 2004).

This study focuses on formulating a novel hybrid paneer using mung bean as the primary protein source, offering a lactose-free, cholesterol-free, and sustainable alternative to conventional paneer. By combining mung bean with dairy or plant-based

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T1 (Mung bean 100%)

T2 (Mung bean 70% + Buffalo milk 30%)

T3 (Mung bean 70%+ Cow milk 30%)

T4 (Mung bean 50% + Soy milk 50%)

Fig. 1: Trials performed for the determination of ratios of cow milk, buffalo milk, and soy milk to mung

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ingredients, the developed product aims to meet the sensory and nutritional expectations of consumers while catering to vegan and lactose-intolerant populations. The research highlights the potential of mung beans in advancing plant-based dairy innovations, promoting both health and environmental sustainability.

MATERIALS AND METHODS

Procurement and preparation of raw materials

High-quality mung beans (*Vigna radiata* L. variety SML1827) were procured from Krishi Vigyan Kendra, Moga, ensuring authenticity and traceability. The beans were split using a Mini Dal Mill (Central Institute of Post-Harvest Engineering and Technology, CIPHET, Ludhiana) and thoroughly cleaned to remove impurities. The cleaned split mung beans were stored in breathable fiber fabric bags under cool, dry conditions before being transferred to airtight containers to prevent moisture absorption and contamination.

Preparation of Mung Bean Extract

Soaking and Dehulling: 500 g of split mung beans were soaked in water for 4 hours at room temperature. After soaking, the seed coats were manually removed by rubbing the beans together.

Grinding & Filtration: The dehulled beans were ground with 2 liters of water until a uniform slurry was obtained. The slurry was filtered through double-layered muslin cloth to separate the extract from residual solids.

Starch Separation: The filtered extract was refrigerated at 4°C for 30 minutes to allow starch sedimentation. The clear supernatant (mung bean extract) was collected for further processing.

Note: Preliminary trials involving soaking + blanching, germination, and germination + blanching were conducted, but soaking alone yielded the most desirable product.

Formulation of Hybrid Paneer

Based on sensory evaluation (taste, texture, overall acceptability), four final formulations were selected: T1 (Control): 100% mung bean extract, T2: 70% mung bean extract + 30% buffalo milk, T3: 70% mung bean extract + 30% cow milk and T4: 50% mung bean extract + 50% soy milk.

Coagulation Process

Various coagulants (vinegar, citric acid, $CaCl_2$, $MgCl_2$, $CaSO_4$, kinnow bioenzyme) were tested. Kinnow-based bioenzyme was selected for producing firm, stable coagulation.

Heating & Coagulation: Each blend was heated to 85°C. Kinnow bioenzyme was added gradually in optimized quantities: T1: 60 mL per 2 L extract, T2: 75 mL per 2 L extract, T3: 78 mL per 2 L extract and T4: 86 mL per 2 L extract. The mixture was stirred gently until complete protein-whey separation.

Molding and Pressing: The coagulated mass was strained through muslin cloth. Pressed under 5 kg weight in cheese molds for 40 minutes. The formed paneer blocks were cooled in chilled water and stored in ziplock bags (4°C, ≤5 days).

Sensory Evaluation

The sensory evaluation of the novel hybrid paneer formulations was conducted by a semi-trained panel of 30 members using a 9-point hedonic scale (1 = "dislike extremely" to 9 = "like extremely") to assess color, flavor, appearance, texture, and overall acceptability. Samples of each treatment (T1: 100% mung bean extract; T2: 70% mung bean extract + 30% buffalo milk; T3: 70% mung bean extract + 30% cow milk and T4: 50% mung bean extract + 50% soy milk) were randomly coded and served at 10-12°C under controlled lighting conditions, with water and unsalted crackers provided for palate cleansing between samples. The panelists evaluated the samples independently in individual booths to prevent bias, and the collected data were analyzed using one-way ANOVA and Duncan's multiple range test ($p < 0.05$) to determine significant differences between the formulations. Ethical compliance was ensured through written consent and institutional review board approval.

RESULTS AND DISCUSSION

Sensory analysis demonstrated significant variation ($p<0.05$) among the four hybrid paneer formulations across all evaluated parameters. The cow milk-enriched formulation (T3: 70% mung bean/30% cow milk) consistently outperformed other variants, achieving peak scores for color (7.8), flavor (7.1), appearance (7.5), texture (7.2), and overall acceptability (7.5) (Table 1). This superior performance can be attributed to cow milk's whitening effect on color and its complementary flavor profile that effectively masked the characteristic beany notes of mung bean. In contrast, the 100% mung bean formulation (T1) received the lowest ratings, particularly for its greenish hue (color) and pronounced legume flavor, highlighting the sensory challenges of pure plant-based alternatives. The hybrid nature of T3 successfully replicated conventional paneer's textural properties, with milk proteins and kinnow bioenzyme synergistically creating a desirable firm yet cohesive matrix. These findings align with current research emphasizing the importance of dairy components in achieving optimal sensory characteristics in hybrid products (Goyal *et al,* 2020). While T1's nutritional profile remains advantageous, its sensory limitations suggest the need for additional processing interventions like germination or thermal treatment to improve consumer acceptance (Sánchez-Velázquez *et al,* 2019). The successful application of kinnow bioenzyme as a natural coagulant (Singh *et al,* 2018) presents opportunities for developing cleaner-label hybrid dairy products. T3 emerges as the most promising formulation, effectively balancing the nutritional benefits of plant proteins with the sensory familiarity of traditional paneer, making it particularly suitable for flexitarian consumers transitioning to more sustainable diets.

CONCLUSION

This study successfully developed innovative hybrid paneer formulations using mung bean as a plant-based protein source, with the 70% mung bean/30% cow milk blend (T3) emerging as the optimal formulation. Sensory evaluation demonstrated T3's superior performance in all quality parameters, achieving the highest scores for color (7.8), flavor (7.1), texture (7.2) and overall acceptability (7.5). The incorporation of cow milk effectively mitigated typical legume-associated sensory challenges, while kinnow bioenzyme proved an effective natural coagulant, producing paneer with desirable textural properties. These results position mung bean-cow milk hybrid paneer as a promising alternative that combines nutritional benefits with sensory appeal, addressing growing demands for sustainable dairy alternatives. The findings highlight two key innovation pathways like strategic blending of plant and dairy proteins to optimize sensory quality, and utilization of fruit-based bioenzymes for clean-label processing. Future research should focus on shelf-life stability, large-scale production feasibility, and detailed nutritional characterization to facilitate commercial translation. This work contributes to the evolving dairy-alternative sector by demonstrating a viable approach to developing hybrid products that balance sustainability with consumer acceptance.

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