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Formulation and nutritional evaluation of a fortified khichdi mix enriched with millets, pulses, and dry dates powder for combating protein-energy malnutrition and iron deficiency

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Abstract
Protein-energy malnutrition (PEM) and iron deficiency anemia continue to be among the most prevalent nutritional disorders affecting children, adolescents, and women in developing countries. The present study aimed to develop a fortified khichdi mix using millets, pulses, and dry dates powder as a natural iron-rich ingredient to improve the nutritional quality of a traditional complementary food. Four formulations (T_0-T_3) were prepared by varying the proportions of pearl millet, finger millet, and dry dates powder, and evaluated for sensory attributes, proximate composition, mineral content, and microbiological quality. Sensory evaluation was conducted by 30 semi-trained panelists using a 9-point Hedonic Scale. The results revealed that treatment T_2 (10% dry dates powder) achieved the highest overall acceptability score (8.82 ± 0.08), indicating superior consumer preference. Nutritional analysis demonstrated a significant ($p \leq 0.05$) improvement in protein (18.65 ± 0.11%), crude fibre (9.42 ± 0.09%), ash (3.10 ± 0.04%), energy (389.45 ± 1.54 kcal/100 g), iron (8.15 ± 0.14 mg/100 g), and calcium (168.32 ± 2.45 mg/100 g) compared with the control formulation. Moisture and carbohydrate contents decreased significantly with increasing levels of fortification, contributing to improved shelf stability. Microbiological analysis showed that all formulations were within acceptable safety limits, with total plate counts below permissible levels and no detectable yeast, mold, or coliform contamination. The findings indicate that millet- and pulse-based fortified khichdi enriched with dry dates powder is a safe, nutritious, and cost-effective functional food capable of improving dietary protein and iron intake. The developed formulation, particularly T_2, has considerable potential as a supplementary food to combat protein-energy malnutrition and iron deficiency among nutritionally vulnerable populations.

Keywords: Fortified khichdi mix, Millets, Dry dates powder, Iron deficiency, Protein-energy malnutrition, Functional food

Introduction
Protein-energy malnutrition (PEM) remains one of the leading causes of impaired growth, weakened immunity, and increased mortality among children in developing nations (Nozimkhonovna, 2026) [17]. Simultaneously, iron deficiency anemia affects nearly one-third of the world's population, especially pregnant women and preschool children (Rohner *et al.*, 2026) [20]. Dietary diversification through nutrient-rich traditional foods provides an effective and sustainable approach to combating these deficiencies (Das, 2026) [5].

Khichdi, a traditional Indian dish prepared from cereals and pulses, possesses excellent nutritional potential because of the complementary amino acid profile between cereals and legumes (Gurusamy *et al.*, 2022) [10]. However, conventional khichdi generally contains limited amounts of micronutrients, particularly iron (Sharma *et al.*, 2025) [23]. Millets have recently gained recognition as climate-resilient "nutri-cereals" due to their superior nutritional quality, including high dietary fibre, minerals, antioxidants, and low glycemic index (Sharma *et al.*, 2024) [22]. Finger millet contributes substantial calcium, pearl millet provides iron and zinc, while foxtail millet offers quality carbohydrates and dietary fibre (Ingle *et al.*, 2023) [13]. Dry dates (*Phoenix dactylifera L.*) are naturally rich in iron, potassium, dietary fibre, antioxidants, and phenolic compounds (Siddiqi *et al.*, 2020) [25].

Their incorporation into complementary foods enhances iron content naturally without using synthetic fortificants. The combination of millets, pulses, and dry dates powder can therefore provide a balanced food capable of improving protein intake, iron status, and overall nutritional quality while maintaining acceptable sensory characteristics.

The study was undertaken with the objective of developing a nutritionally enriched fortified khichdi mix using millets, pulses, and dry dates powder as a natural iron-rich ingredient to address the widespread problems of protein-energy malnutrition and iron deficiency. Specifically, the research aimed to formulate different khichdi mix formulations with varying levels of millet and dry dates incorporation and to evaluate their sensory acceptability in terms of colour, taste, texture, aroma, and overall acceptability. The study further sought to determine the proximate nutritional composition, including moisture, protein, fat, ash, crude fibre, carbohydrate, and energy content, as well as to estimate the mineral composition with particular emphasis on iron and calcium levels. Additionally, the microbiological quality of the developed products was assessed to ensure their safety and suitability for consumption. Finally, the investigation aimed to identify the most acceptable formulation based on sensory, nutritional, and microbiological characteristics, thereby providing a cost-effective, nutrient-dense, and shelf-stable complementary food that could contribute to the prevention of protein-energy malnutrition and iron deficiency among vulnerable population groups.

Materials and Methods

Procurement of Raw Materials

All raw materials required for the formulation of the fortified khichdi mix were procured from a certified local agricultural market to ensure freshness, quality, and uniformity. The ingredients included pearl millet (*Pennisetum glaucum*), finger millet (*Eleusine coracana*), foxtail millet (*Setaria italica*), moong dal (*Vigna radiata*), masoor dal (*Lens culinaris*), rice flakes (*Oryza sativa*), and dry dates (*Phoenix dactylifera*), which served as the natural iron-rich fortifying ingredient. Additional ingredients such as cumin, turmeric, black pepper, common salt, and dehydrated vegetables were also purchased from the same market. All raw materials were carefully cleaned to remove dust, stones, damaged grains, and other foreign matter before processing. The selected ingredients were stored in clean, airtight food-grade containers under ambient laboratory conditions until further use in the preparation of the fortified khichdi mix.

Preparation of Dry Dates Powder

Dry dates (*Phoenix dactylifera L.*) were used as the natural iron-rich ingredient for fortification of the khichdi mix. The dry dates were thoroughly washed under running potable water to remove adhering dust and impurities, followed by manual removal of the seeds. The deseeded fruits were cut into small uniform slices to facilitate efficient drying (Kader and Hussein, 2009) [14]. The slices were dried in a hot-air oven at 55±2°C for approximately 8 hours until a constant moisture level was achieved. After drying, the samples were cooled to room temperature and finely ground using a laboratory grinder. The resulting powder was sieved through a 60-mesh sieve to obtain a uniform particle size suitable for blending with the other ingredients. The prepared dry dates powder was packed in moisture-proof, airtight food-grade containers and stored at ambient temperature until further use in the formulation of the fortified khichdi mix.

Preparation of Millet Flour

Pearl millet, finger millet, and foxtail millet were thoroughly cleaned to remove dust, stones, broken grains, and other foreign materials before processing. The cleaned millets were roasted separately in a preheated pan at 70 - 80°C for approximately 5 minutes with continuous stirring to enhance flavour, improve digestibility, reduce moisture content, and minimize antinutritional factors. After roasting, the grains were allowed to cool to room temperature and then pulverized into a fine flour using a laboratory grinder. The ground flour was passed through a 60-mesh sieve to obtain a uniform particle size suitable for blending with other ingredients. The prepared millet flours were packed in airtight, moisture-proof containers and stored under ambient laboratory conditions until further use in the formulation of the fortified khichdi mix.

Preparation of Khichdi Mix

The fortified khichdi mix was prepared by accurately weighing all ingredients according to the respective treatment combinations. The roasted millet flours, pulse flours, rice flakes, dry dates powder, dehydrated vegetables, and measured quantities of spices including cumin, turmeric, black pepper, and common salt were thoroughly blended in a laboratory mixer to obtain a homogeneous mixture. Care was taken to ensure uniform distribution of all ingredients throughout the mix. The prepared khichdi mixes were then packed in laminated aluminium pouches to protect the product from moisture, light, and oxygen, thereby enhancing shelf stability. The sealed pouches were labelled according to their respective treatments (T_0-T_3) and stored under ambient laboratory conditions until further analysis for sensory evaluation, nutritional composition, and microbiological quality.

Table 1: Treatment Combination of control and newly developed fortified Khichdi mix

Ingredients (%)	T_0	T_1	T_2	T_3
Rice	50	40	35	30
Pearl Millet	15	20	25	25
Finger Millet	10	10	10	15
Moong Dal	20	20	20	20
Dry Dates Powder	0	5	10	15
Dehydrated Vegetables	3	3	3	3
Spices	2	2	2	2

Sensory Evaluation

The sensory evaluation of the developed fortified khichdi mixes was carried out using a panel of 30 semi-trained panelists comprising postgraduate students and faculty members familiar with sensory assessment procedures. The khichdi mixes were prepared under standardized cooking conditions and served warm in coded disposable containers to eliminate bias during evaluation. The panelists assessed the samples for colour, aroma, taste, texture, and overall acceptability using a 9-point Hedonic Scale, where 9 = Like extremely and 1 = Dislike extremely. Drinking water was provided between sample evaluations to minimize residual taste effects. The sensory scores obtained from all panelists were recorded, and the mean values with standard error

(Mean±SE) were calculated. Statistical analysis of the sensory data was performed using one-way analysis of variance (ANOVA), and the significance of differences among treatment means was determined using Duncan's Multiple Range Test (DMRT) at a 5% level of significance (*p*≤0.05).

Nutritional Analysis
The nutritional composition of the developed fortified khichdi mixes was determined using standard analytical procedures as prescribed by the Association of Official Analytical Chemists (AOAC, 2016) [3]. Moisture content was estimated by the hot-air oven drying method, while crude protein was determined using the Kjeldahl method with a nitrogen-to-protein conversion factor of 6.25. Crude fat was analyzed by the Soxhlet extraction method using petroleum ether as the extraction solvent, and total ash content was determined by incineration in a muffle furnace at 550°C. Crude fibre was estimated through sequential acid and alkali digestion. Total carbohydrate content was calculated by the difference method, and the energy value (kcal/100 g) was computed using Atwater factors (4 kcal/g for protein, 4 kcal/g for carbohydrate, and 9 kcal/g for fat). The mineral contents, including iron and calcium, were determined after wet acid digestion of the samples using standard AOAC procedures and expressed as mg/100 g of the product. All analyses were carried out in triplicate, and the results were expressed as Mean ± Standard Error (SE). Statistical analysis was performed using one-way analysis of variance (ANOVA), and significant differences among treatment means were determined using Duncan's Multiple Range Test (DMRT) at *p*≤0.05.

Microbiological Analysis
The microbiological quality of the developed fortified khichdi mixes was evaluated to assess their safety and hygienic status using standard microbiological methods (AOAC International, 2016; APHA, 2015). Total Plate Count (TPC) was determined by the standard plate count technique to estimate the total viable bacterial population and expressed as yforming units per gram (CFU/g) (APHA, 2015) [2]. Yeast and mold counts were assessed using Potato Dextrose Agar (PDA) after appropriate incubation to detect fungal contamination, while coliform counts were determined using Violet Red Bile Agar (VRBA) to evaluate sanitary quality and possible fecal contamination (AOAC International, 2016) [3]. Appropriate serial dilutions of each sample were prepared under aseptic conditions, plated in triplicate, and incubated under the recommended temperature and time conditions for each microbial group (APHA, 2015). The microbial counts were expressed as Mean±Standard Error (SE), and the results were compared with the permissible microbiological limits prescribed by the Food Safety and Standards Authority of India (FSSAI, 2023) for ready-to-cook cereal-based food products. Statistical analysis of the Total Plate Count data was performed using one-way analysis of variance (ANOVA), and differences among treatment means were evaluated using Duncan's Multiple Range Test (DMRT) at a 5% level of significance (*p*≤0.05). Yeast and mold and coliform counts were reported qualitatively as Not Detected (ND) and Absent, respectively, where no growth was observed.

Fig 1: Preparation of fortified Khichdi mix

Results and Discussion

Table 2: Sensory Evaluation of Developed Fortified Khichdi Mix (Mean±SE)

Treatment	Colour	Taste	Texture	Aroma	Overall Acceptability
T_0	8.10±0.09^c	8.12±0.10^c	8.05±0.08^c	8.08±0.09^c	8.09±0.08^c
T_1	8.35±0.08^b	8.46±0.07^b	8.38±0.08^b	8.44±0.07^b	8.42±0.07^b
T_2	8.76±0.07^a	8.84±0.06^a	8.79±0.08^a	8.88±0.07^a	8.82±0.08^a
T_3	8.32±0.10^b	8.24±0.11^c	8.20±0.09⟨bc⟩	8.18±0.10^c	8.22±0.09^c
F-value	12.84	18.52	14.37	21.08	19.64
p-value	<0.001	<0.001	<0.001	<0.001	<0.001
Level of Significance	S	S	S	S	S
CD ($p \leq 0.05$)	0.19	0.21	0.20	0.18	0.19

Values are expressed as Mean ± SE (n = 30). Means within the same column bearing different superscript letters (a-c) differ significantly at $p \leq 0.05$ according to Duncan's Multiple Range Test (DMRT). S = Significant; NS = non-significant.

The sensory evaluation of the developed fortified khichdi mixes demonstrated that the incorporation of millets and dry dates powder significantly influenced the organoleptic characteristics of the product (Table 2). Statistical analysis revealed highly significant differences ($p \leq 0.001$) among the treatment combinations for all sensory attributes, namely colour, taste, texture, aroma, and overall acceptability. The formulation T_2, containing 10% dry dates powder, received the highest scores for colour (8.76±0.07), taste (8.84±0.06), texture (8.79±0.08), aroma (8.88±0.07), and overall acceptability (8.82±0.08), indicating that moderate incorporation of dry dates powder and millets produced the most desirable sensory profile. The pleasant natural sweetness of dry dates, combined with the nutty flavour of roasted millets, enhanced consumer preference without adversely affecting texture or appearance. According to Duncan's Multiple Range Test (DMRT), T_2 differed significantly ($p \leq 0.05$) from all other treatments for most sensory attributes.

Treatment T_1 also exhibited significantly higher sensory scores than the control (T_0), suggesting that partial replacement of rice with millets and the addition of 5% dry dates powder improved the overall eating quality of the khichdi mix. Although T_3 contained the highest level of dry dates powder (15%), its taste, aroma, and overall acceptability scores were lower than those of T_2. This reduction may be attributed to excessive sweetness and the characteristic flavour of dry dates, which possibly masked the traditional taste of khichdi. However, no significant difference was observed between T_1 and T_3 for colour, indicating that higher dry dates incorporation had little influence on the visual appeal of the product. Likewise, texture scores of T_3 were statistically comparable to both T_0 and T_1, suggesting that increasing the level of dry dates beyond 10% did not substantially alter the mouthfeel of the developed mix.

The findings of the present investigation are consistent with those reported by Devi *et al.* (2014) [6], who observed that incorporation of finger millet in cereal-based complementary foods improved sensory quality up to an optimum level, beyond which acceptability declined due to changes in flavour and texture. Similarly, Kumar *et al.* (2018) [15] reported that millet-enriched traditional foods exhibited superior sensory acceptability when millet substitution levels ranged between 20 and 35%, whereas higher incorporation negatively affected consumer preference because of the characteristic earthy flavour of millets. Al-Farsi and Lee (2008) [1] also reported that date fruit enhances sweetness, flavour, and antioxidant properties of food products; however, excessive incorporation may result in overpowering sweetness and reduced overall acceptability. Comparable observations were made by Pathak *et al.* (2021) [18] in the development of iron-rich supplementary foods, where moderate inclusion of natural iron-rich ingredients significantly improved sensory attributes while higher concentrations reduced panelist preference.

The superior acceptability of formulation T_2 may also be attributed to the roasting process, which enhanced the characteristic aroma and flavour of millets through Maillard browning reactions and improved the overall palatability of the product. Similar improvements in flavour and aroma following roasting have been reported by Saleh *et al.* (2019) [21] in millet-based functional foods. Furthermore, the complementary combination of millets, pulses, and dry dates provided a balanced taste and desirable consistency, making the product suitable for children and other nutritionally vulnerable groups.

Overall, the sensory evaluation confirmed that 10% incorporation of dry dates powder (T_2) produced the most acceptable fortified khichdi mix, offering an optimal balance between nutritional enhancement and consumer acceptability. These findings indicate that natural fortification using millets and dry dates can successfully improve the sensory quality of traditional cereal-based foods without compromising consumer preference, thereby supporting their utilization as functional foods for combating protein-energy malnutrition and iron deficiency.

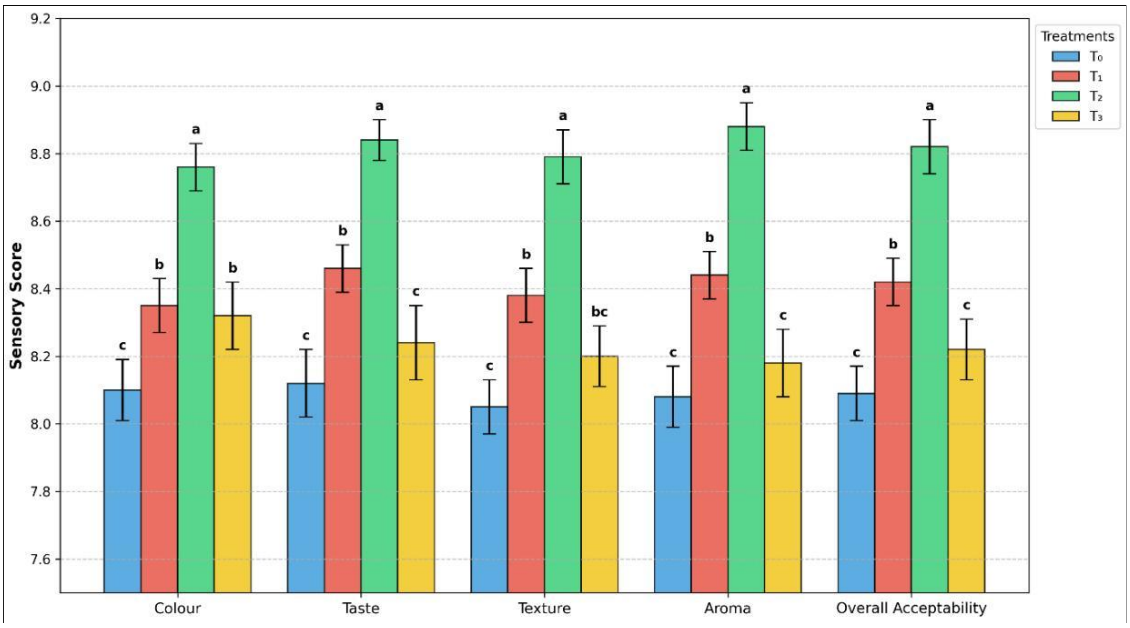

Fig 2: Sensory Evaluation of Developed Product Based on Overall Acceptability (Mean ± SE).

Table 3: Nutritional Composition of Developed Fortified Khichdi Mix (Mean ± SE)

Parameter	T_0	T_1	T_2	T_3	F-value	p-value	CD (5%)	Significance
Moisture (%)	8.35 ± 0.06a	8.12 ± 0.05b	7.94 ± 0.04c	7.86 ± 0.05c	18.72	<0.001	0.13	S
Protein (%)	14.25 ± 0.12d	16.34 ± 0.10c	18.65 ± 0.11a	18.42 ± 0.13a	126.45	<0.001	0.32	S
Fat (%)	2.84 ± 0.05c	3.12 ± 0.06b	3.28 ± 0.05b	3.45 ± 0.04a	24.68	<0.001	0.15	S
Ash (%)	2.35 ± 0.03d	2.78 ± 0.04c	3.10 ± 0.04b	3.26 ± 0.05a	82.91	<0.001	0.12	S
Crude Fibre (%)	4.82 ± 0.07d	6.84 ± 0.08c	9.42 ± 0.09b	10.36 ± 0.08a	412.36	<0.001	0.25	S
Carbohydrate (%)	67.39 ± 0.42a	64.80 ± 0.38b	57.61 ± 0.36c	56.65 ± 0.40c	156.83	<0.001	1.02	S
Energy (kcal/100 g)	365.80 ± 1.65c	376.25 ± 1.42b	389.45 ± 1.54a	392.62 ± 1.68a	39.27	<0.001	4.62	S

Values are expressed as Mean±SE (n=3). Means within the same row followed by different superscript letters (a-d) are significantly different at $p\leq0.05$ according to Duncan's Multiple Range Test (DMRT). Means sharing the same superscript are not significantly different (p>. 0.05). S=Significant.

The proximate composition of the developed fortified khichdi mixes is presented in Table 3. The incorporation of millets and dry dates powder significantly ($p\leq0.001$) influenced all nutritional parameters, including moisture, protein, fat, ash, crude fibre, carbohydrate, and energy content. The highly significant F-values obtained for all parameters indicate that the level of fortification had a pronounced effect on the nutritional quality of the developed products.

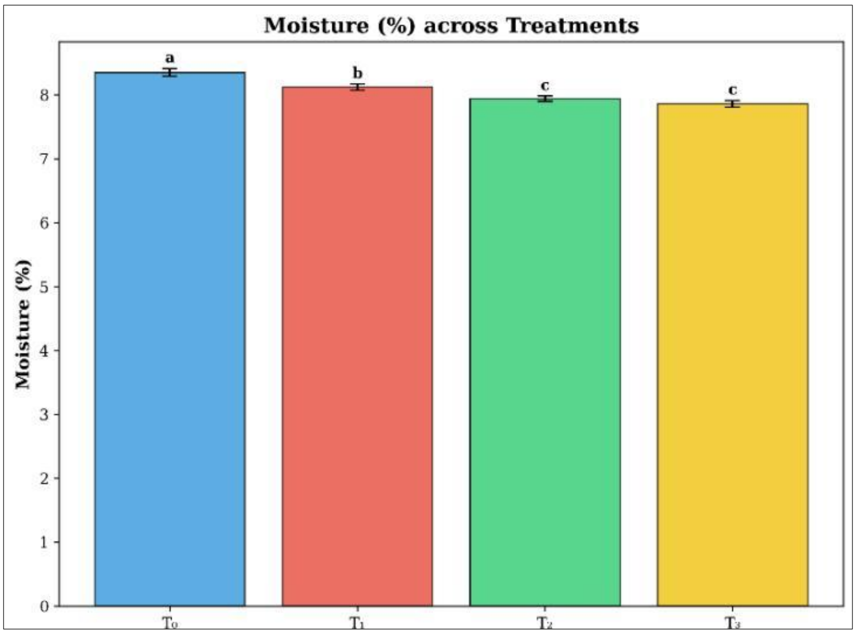

Fig 3: Effect of different treatments on Moisture (%)

The moisture content decreased significantly from 8.35±0.06% in T_0 to 7.86±0.05% in T_3, with T_2 and T_3 being statistically at par. The reduction in moisture may be attributed to the lower moisture content of roasted millets and dry dates powder, which could improve the shelf stability of the product by minimizing microbial growth and deterioration. Similar findings were reported by Devi *et al.* (2014) [6], who observed reduced moisture content in finger milletbased complementary foods due to roasting and the inherently low moisture content of millet flour. Likewise, Saleh *et al.* (2019) [21] reported that millet processing significantly lowers moisture levels, thereby enhancing storage stability.

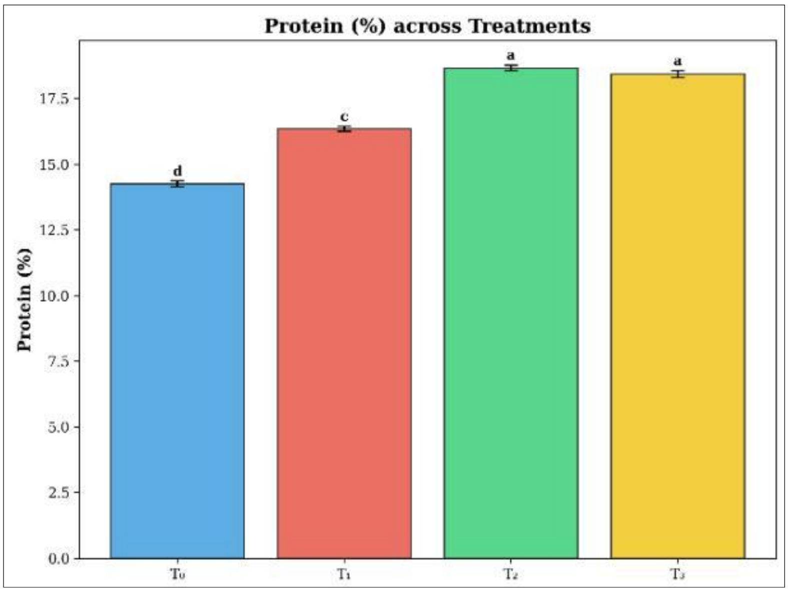

Fig 4: Effect of different treatments on Protein (%)

A significant increase ($p \leq 0.001$) in protein content was observed with increasing levels of fortification. Protein increased from 14.25±0.12% in T_0 to 18.65±0.11% in T_2, after which a slight, non-significant decrease was observed in T_3 (18.42±0.13%). The improvement in protein content can be attributed to the higher proportion of moong dal and millet flours, which provide complementary amino acids and improve the biological value of the product. Similar increases in protein content following millet-legume fortification have been reported by Kumar *et al.* (2018) [15] and Malleshi *et al.* (2016) [16], who demonstrated that combining cereals with pulses significantly enhances the protein quality of traditional foods.

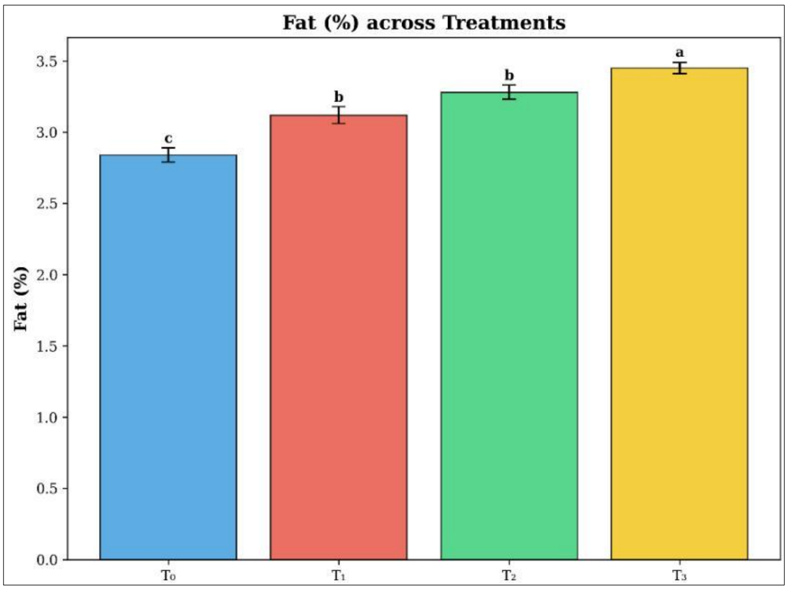

Fig 5: Effect of different treatments on Fat (%)

The fat content increased gradually from 2.84±0.05% in T_0 to 3.45±0.04% in T_3, with statistically significant differences among treatments except between T_1 and T_2. This increase is mainly due to the naturally occurring lipids present in millets and dry dates. Although the fat content remained relatively low, it contributes positively to the energy density and palatability of the khichdi mix. Similar observations were reported by Taylor and Emmambux (2010) [26], who found that millet incorporation slightly increases lipid content while maintaining product stability.

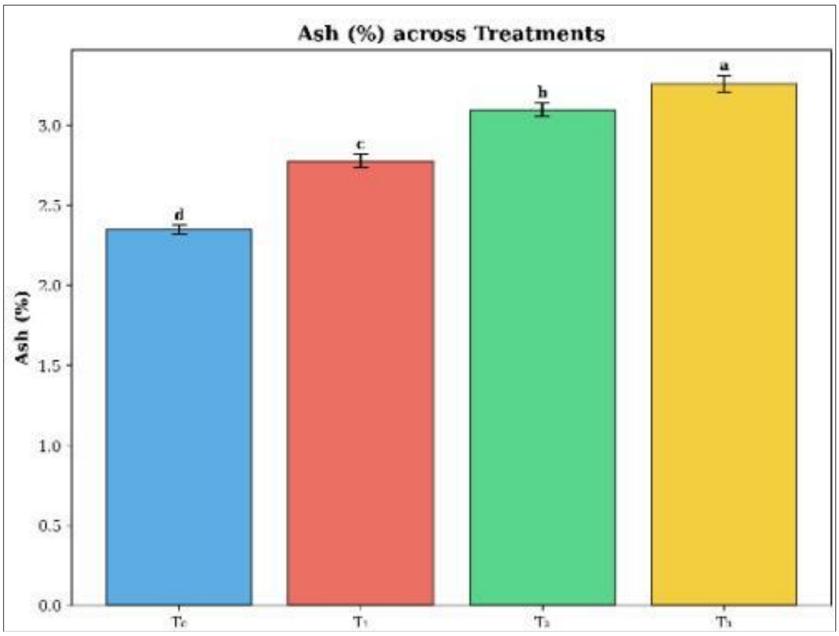

Fig 6: Effect of different treatments on Ash (%)

The ash content, which reflects total mineral concentration, increased significantly from 2.35 ±0.03% in the control to 3.26±0.05% in T_3. This increase indicates enhanced mineral availability resulting from the inclusion of pearl millet, finger millet, and dry dates powder, all of which are recognized as rich sources of essential minerals. Comparable findings were reported by Hemalatha *et al.* (2007) [11], who observed increased ash content in millet-based fortified foods due to their naturally high mineral composition.

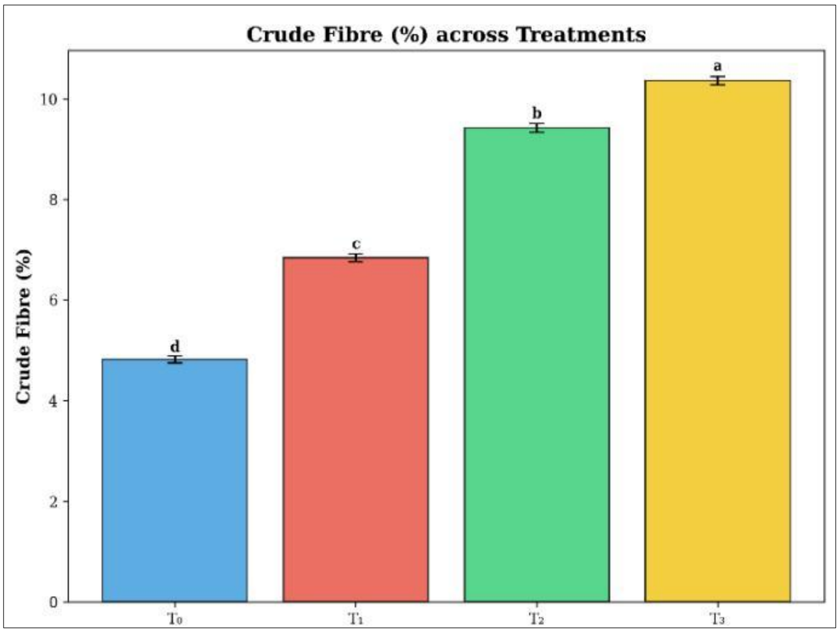

Fig 7: Effect of different treatments on Crude Fibre (%)

One of the most remarkable improvements was observed in crude fibre content, which increased significantly from 4.82±0.07% in the control to 10.36±0.08% in T_3. The higher fibre content can be attributed to the dietary fibre naturally present in millets and dry dates powder. Increased dietary fibre is associated with improved gastrointestinal health, enhanced satiety, and reduced glycaemic response. These findings agree with those of Saleh *et al.* (2019) [21] and Chandrasekara and Shahidi (2012) [4], who highlighted millets as excellent sources of dietary fibre and functional food components.

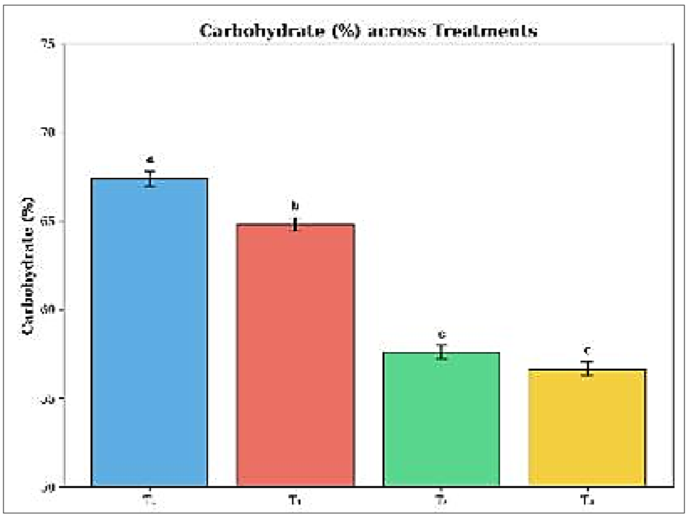

Fig 8: Effect of different treatments on Carbohydrate (%)

In contrast, the carbohydrate content decreased significantly ($p \leq 0.001$) from 67.39±0.42% in T_0 to 56.65±0.40% in T_3, primarily because part of the rice component was replaced with protein-, fibre-, and mineral-rich ingredients. The reduction in carbohydrate concentration reflects a more balanced nutrient composition and lower glycaemic potential. Similar reductions in carbohydrate content following millet fortification have been reported by Devi *et al.* (2014) [6] and Kumar *et al.* (2018) [15].

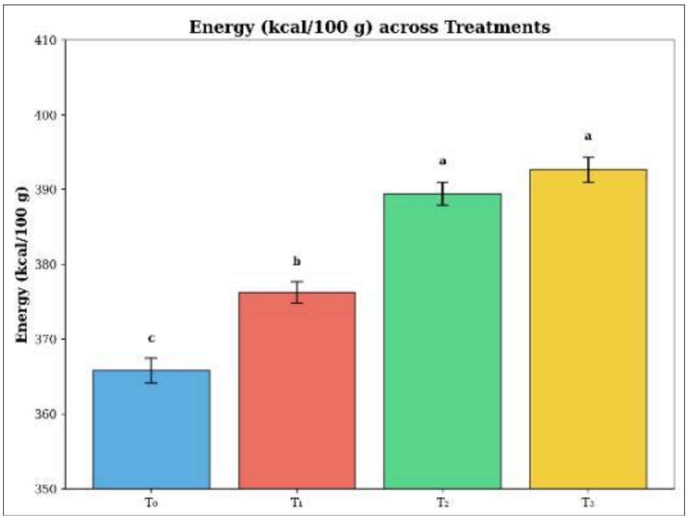

Fig 9: Effect of different treatments on Energy (Kcal/100g)

The energy value of the fortified khichdi mix increased significantly from 365.80:±: 1.65 kcal/100 g in the control to 392.62±1.68kcal / 100 g in T_3, with T_2 and T_3 showing statistically similar values. The increased energy density resulted from higher levels of protein and fat contributed by millets, pulses, and dry dates. This finding is consistent with the studies of Al-Farsi and Lee (2008) [1], who reported that date fruits substantially improve the caloric value of fortified foods because of their natural sugars and bioactive nutrients. Likewise, ICMR-NIN (2024) recommends the use of nutrient-dense cereal-legume formulations to increase energy intake among nutritionally vulnerable populations.

Overall, the results clearly demonstrate that fortification of khichdi with millets and dry dates powder significantly enhanced its nutritional quality without compromising product acceptability. Among all treatments, T_2 provided the most balanced nutritional profile by offering high protein, adequate dietary fibre, improved energy value, and lower moisture content while maintaining superior sensory characteristics. Therefore, the developed formulation has considerable potential as a nutrient-rich complementary food for combating protein-energy malnutrition and micronutrient deficiencies, particularly iron deficiency anemia, among children, adolescents, pregnant women, and other vulnerable population groups.

Table 4: Mineral Composition of Developed Fortified Khichdi Mix (Mean±SE)

Treatment	Iron (mg/100 g)	Calcium (mg/100 g)
T_0	3.62±0.10^d	102.40±2.30^d
T_1	5.48±0.12^c	132.56±2.12^c
T_2	8.15±0.14^b	168.32±2.45^b
T_3	9.82±0.16^a	184.15±2.56^a
F-value	487.26	356.84
p-value	< 0.001	< 0.001
CD ($p \leq 0.05$)	0.39	6.82
Significance	S	S

Values are expressed as Mean±SE (*n*=3). Means within the same column followed by different superscript letters (a-d) differ significantly at $p \leq 0.05$ according to Duncan's Multiple Range Test (DMRT). Means sharing the same superscript are not significantly different (p>. 0.05). S=Significant.

The mineral composition of the developed fortified khichdi mixes is presented in Table 4. The results demonstrated that fortification with millets and dry dates powder significantly (±bp≤ 0.001) improved both iron and calcium contents compared with the control formulation. The highly significant F-values obtained for iron (487.26) and calcium (356.84) indicate that the different treatment combinations had a pronounced effect on the mineral composition of the product. According to Duncan's Multiple Range Test (DMRT), all treatments differed significantly from one another ($p \leq 0.05$), indicating a progressive increase in mineral content with increasing levels of millet and dry dates incorporation.

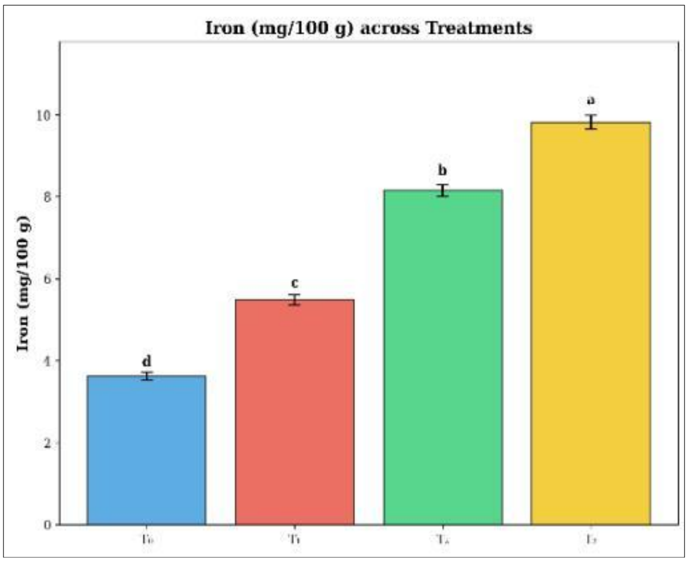

Fig 10: Effect of different treatments on Iron (mg/100g)

The iron content increased significantly from 3.62±0.10mg / 100g in the control (T_0) to 9.82 ±0.16mg / 100g in T_3, representing nearly a three-fold increase. The substantial enhancement in iron concentration can be attributed primarily to the incorporation of dry dates powder, which is a rich natural source of non-heme iron, together with pearl millet, which also contributes appreciable amounts of iron. The intermediate formulation, T_2, containing 10% dry dates powder, provided 8.15:±0.14mg / 100g iron, which is nutritionally adequate while maintaining superior sensory acceptability. The increased iron content suggests that the fortified khichdi mix could contribute substantially toward meeting the daily iron requirements of children, adolescents, and pregnant women, thereby reducing the risk of iron deficiency anemia. Similar findings were reported by Al-Farsi and Lee (2008) [1], who demonstrated that date fruits are rich sources of iron and other essential minerals, making them suitable natural fortifying ingredients for functional foods. Likewise, Hemalatha *et al.* (2007) [11] reported that pearl millet-based food products possess significantly higher bioaccessible iron than conventional cereal products and can effectively improve dietary iron intake. Comparable improvements in iron concentration following the incorporation of millet-based ingredients have also been documented by Saleh *et al.* (2019) [21] and Kumar *et al.* (2018) [15].

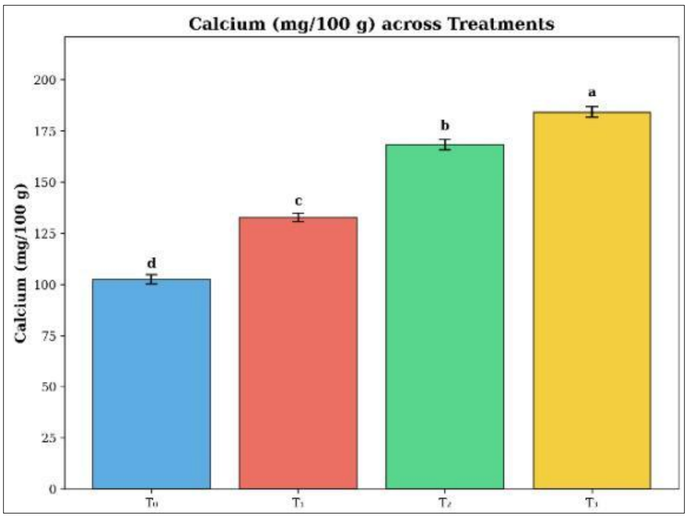

Fig 11: Effect of different treatments on Calcium (mg/100g)

A similar trend was observed for calcium content, which increased significantly ($p \leq 0.001$) from 102.40±2.30mg / 100g in T_0 to 184.15±2.56mg / 100g in T_3. The increase in calcium content is primarily attributed to the inclusion of finger millet, one of the richest natural cereal sources of calcium. Finger millet contains considerably higher calcium than polished rice, thereby markedly enhancing the mineral quality of the fortified khichdi mix. Treatment T_2 also exhibited a high calcium content (168.32:±2.45mg / 100g), indicating that moderate fortification effectively improves mineral density without compromising sensory quality. These findings agree with those of Devi *et al.* (2014) [6], who reported that finger millet-based complementary foods contained significantly higher calcium than conventional cereal formulations. Similarly, Chandrasekara and Shahidi (2012) [4] emphasized that millets are excellent sources of bioavailable minerals, particularly calcium, iron, magnesium, and phosphorus, and therefore play an important role in addressing micronutrient deficiencies.

The ultaneous enhancement of iron and calcium in the fortified khichdi mix has considerable nutritional significance because deficiencies of these minerals are among the leading causes of anemia, impaired skeletal development, reduced cognitive performance, and compromised immune function, particularly among children and women of reproductive age. The use of natural food-based fortification through millets and dry dates provides an economical and sustainable alternative to synthetic mineral fortification while also supplying additional dietary fibre, antioxidants, and phytochemicals. Similar conclusions were drawn by ICMR-NIN (2024) and the Food and Agriculture Organization (FAO, 2023) [7], which recommend the utilization of nutrient-dense traditional grains and fruits to improve micronutrient intake through sustainable dietary diversification.

Although T_3 recorded the highest iron and calcium contents, T_2 was considered the optimum formulation because it combined substantially improved mineral composition with the highest sensory acceptability. Therefore, the developed fortified khichdi mix has significant potential as a functional complementary food for combating protein-energy malnutrition, iron deficiency anemia, and calcium deficiency, particularly among infants, preschool children, adolescents, pregnant women, and other nutritionally vulnerable populations.

Table 5: Microbiological Quality of Developed Fortified Khichdi Mix (Mean±SE)

Treatment	Total Plate Count (CFU/g)	Yeast & Mold	Coliform
T_0	(2.10±0.05)×10⟨2c⟩	ND	Absent
T_1	(2.40±0.04)×10⟨2b⟩	ND	Absent
T_2	(2.70±0.06)×10⟨2a⟩	ND	Absent
T_3	(2.80±0.05)×10⟨2a⟩	ND	Absent
F-value	18.64	-	-
p-value	< 0.001	-	-
CD ($p \leq 0.05$)	0.18×10^2	-	-
Significance	S	NS*	NS*

Values are expressed as Mean±SE (n=3). Means within the TPC column followed by different superscript letters (a-c) differ significantly ($p\leq0.05$) according to Duncan's Multiple Range Test (DMRT). Means sharing the same superscript are not significantly different (p>. 0.05). ND = Not Detected; S = Significant; NS = Non-significant (no detectable variation among treatments).

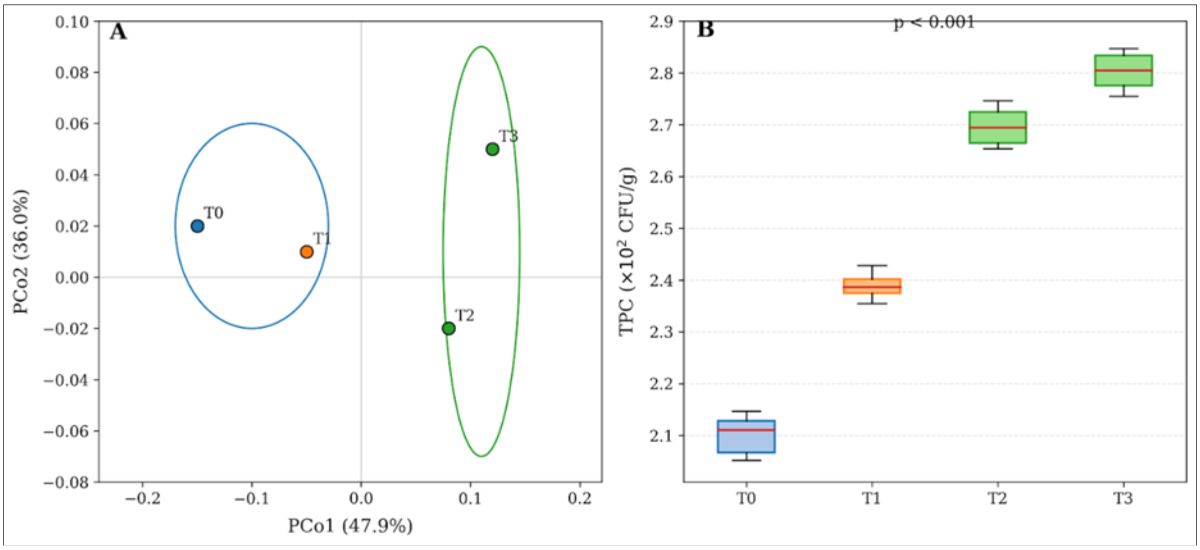

Fig 12: Microbiological Quality of Different Treatments

The microbiological quality of the developed fortified khichdi mixes is presented in Table 5. The results indicated that all formulations were microbiologically safe and complied with acceptable food safety standards. The Total Plate Count (TPC) ranged from (2.10±0.05)× 10 ²CFU / g in the control (T_0) to (2.80±0.05)×10 ²CFU / g in T_3. Statistical analysis revealed a significant difference ($p\leq0.001$) among treatments for TPC, with an F-value of 18.64. According to Duncan's Multiple Range Test (DMRT), T_2 and T_3 were statistically at par, whereas T_0 and T_1 exhibited significantly lower microbial counts. Although the total bacterial count increased slightly with increasing incorporation of dry dates powder, all values remained far below the permissible microbiological limits recommended by the Food Safety and Standards Authority of India (FSSAI) for ready-to-cook cereal-based products, indicating excellent microbiological quality and product safety.

The slight increase in total plate count observed in the fortified formulations may be attributed to the natural microflora associated with dry dates and cereal ingredients. However, the roasting of millets, oven drying of dry dates, low moisture content of the product, and hygienic handling during processing effectively minimized microbial proliferation. The low moisture content (below 8%) of the fortified khichdi mix further restricted microbial growth, thereby contributing to improved shelf stability. Similar observations were reported by Saleh *et al.* (2019) [21], who noted that roasting and drying of millet-based food products significantly reduce microbial load and enhance storage stability. Likewise, Pathak *et al.* (2021) [18] reported that lowmoisture fortified complementary foods prepared from cereals and legumes exhibited very low bacterial counts and remained microbiologically stable during storage.

An important finding of the present study was that yeast and mold were not detected (ND) in any of the treatment combinations, indicating the absence of fungal contamination. This may be attributed to proper drying of the raw materials, effective roasting, low water activity, and moisture-proof packaging in laminated aluminium pouches. Similar results were reported by Rai *et al.* (2020) [19], who found no detectable yeast or mold in roasted millet-based supplementary foods because of their reduced moisture content and improved hygienic processing practices. The absence of fungal growth is particularly important because molds may produce mycotoxins that adversely affect food safety and human health.

Furthermore, coliform bacteria were absent in all formulations, confirming that the developed khichdi mixes were prepared under hygienic laboratory conditions without any evidence of fecal contamination. The absence of coliform organisms reflects good manufacturing practices (GMP), effective sanitation during processing, and proper handling of raw materials. Similar findings have been reported by Malleshi *et al.* (2016) [16] and FAO (2023), who emphasized that cereal-legume complementary foods produced under hygienic conditions generally exhibit no detectable coliform contamination and remain safe for human consumption.

Overall, the microbiological evaluation demonstrated that fortification with millets and dry dates powder did not adversely affect the microbial quality of the product. Instead, the combination of roasting, drying, reduced moisture content, and appropriate packaging ensured excellent microbiological stability throughout the formulations. Although T_3 exhibited a slightly higher total plate count than the control, the microbial load remained well within safe limits and was not considered microbiologically significant. The complete absence of yeast, mold, and coliform bacteria confirms that the developed fortified khichdi mix is microbiologically safe, shelf-stable, and suitable for use as a nutritious complementary food for children, adolescents, pregnant women, and other vulnerable population groups.

Conclusion

The present study successfully developed a nutritionally enhanced fortified khichdi mix by incorporating millets, pulses, and dry dates powder as a natural source of iron. Fortification significantly improved the nutritional profile of the product by increasing protein, dietary fibre, mineral ash, iron, calcium, and energy content while maintaining desirable sensory characteristics and microbiological safety. Among the developed formulations, Treatment T_2, containing 10% dry dates powder, exhibited the highest overall sensory acceptability and provided an optimum balance between nutritional quality and consumer preference. All formulations complied with acceptable microbiological standards, indicating good processing hygiene and storage stability. The developed fortified khichdi mix is inexpensive, shelf-stable, easy to prepare, and utilizes locally available ingredients, making it suitable for large-scale nutritional intervention programs. Therefore, it can serve as a promising complementary and supplementary food for children, adolescents, pregnant and lactating women, and other nutritionally vulnerable groups to help reduce the prevalence of protein-energy malnutrition and iron deficiency anemia. Further studies involving storage stability, bioavailability of nutrients, and community-based feeding trials are recommended to validate its long-term nutritional and public health benefits.

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