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DEVELOPMENT OF INSTANT RAGI MUDDE MIX WITH RICE FLOUR AND GRITS: EVALUATION OF PHYSICO-CHEMICAL, RE-CONSTITUTIONAL, FUNCTIONAL, AND ORGANOLEPTIC PROPERTIES

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ABSTRACT

Instant food products are gaining popularity due to modern lifestyle changes. Finger millet (ragi) is a highly nutritious cereal known for its mineral content and health benefits. This study aims to develop an instant ragi mudde mix using germination and cooking methods for ragi grains blended in different ratios with rice grits and rice flour to improve convenience and sensory acceptance. Twelve formulations of ragi mudde were prepared using varying proportions of cooked ragi flour (CRF) and germinated cooked ragi flour (GCRF) with rice grits (RG) and rice flour (RF). Ratios included 60:40, 70:30, and 80:20. Sensory evaluation, physico-chemical, functional and reconstitutional properties were analysed to determine the best formulation. Among the formulations, GCRF with RG at a 70:30 ratio exhibited best sensory characteristics, including superior taste and texture. This formulation showed acceptable Nutritional and sensory results, making it a convenient and promising option for commercial ragi mudde mix production.

Keywords **:** Ragi Mudde Mix; Physico-chemical properties; Functional properties; Organoleptic Properties; Finger Millet.

Introduction

Finger millet, or ragi (*Eleusine coracana*), is highly nutritious, providing essential minerals such as calcium (344 mg/100g) and potassium (408 mg/100g) (Shobana *et al*., 2013), as well as amino acids like lysine (4.47 g/100g), which are limited in major cereals (Mbithi-Mwikya *et al*., 2000). Regular consumption of finger millet may offer health benefits, including anti-aging, antioxidant, anticancer, antidiabetic effects, and protection against gastrointestinal and cardiovascular diseases. Its complex carbohydrates and dietary fibers, slows down the sugar release into the bloodstream, making it beneficial for diabetic patients (Chandra *et al*., 2016). Traditionally, whole finger millet is ground to prepare foods such as roti, kanji (porridge), and mudde/kazhi (dumplings/millet balls).

Mudde, a soft, smooth-textured dumpling prepared with finger millet flour and cooked rice grits, is widely consumed in Karnataka (Gull *et al*., 2024; Patel & Pissalkar, 2015; Teena *et al*., 2019). Despite its popularity, systematic studies on mudde preparation, such as optimal particle size, are limited; for example, fractions of 600–750 µm are more suitable for mudde than finer flour (150 µm) (Gurumallu *et al*., 2022). High-fiber mixes like dosa, roti, and mudde mixes have been developed, containing protein (15.8 g/100g), fat (2.6 g/100g), carbohydrate (60.75 g/100g), energy (320 kcal), and dietary fiber (29.5 g/100g) (Geetha *et al*., 2019). However, mudde preparation is labor-intensive and time-consuming, leading to reduced daily consumption and a shift toward instant rice- and wheat-based foods (Divate *et al*., 2016; Patel & Pisalkar, 2015; Shivakumara & Ramachandra, 2023).

To preserve traditional foods in modern lifestyles, this study aimed to develop a ready-to-cook instant finger millet dumpling mix (Bhardwaj *et al*., 2023; Pravat *et al*., 2024). Using household processing techniques such as soaking, cooking, germination, and drying, a ready-to-cook finger millet mudde mix can be prepared with minimal cooking time. The present study evaluates the effects of cooked and germinated ragi grains, combined with rice flour and grits, on the nutritional profile and sensory acceptance of the final finger millet mudde mix.

Materials and Methods

Raw Materials

Finger millet grains were procured from the Seed Research Centre, ICAR-Indian Institute of Millet Research, Rajendra Nagar, Hyderabad, India. The finger millet grains were cleaned and graded using a destoner cum aspirator cum grader (Perfura Technologies Pvt. Ltd., Coimbatore, Tamil Nadu, India). Rice was procured from the local market of Rajendra Nagar, Hyderabad. All chemicals and reagents used are of analytical grade.

Ragi and Rice processing

Cooked ragi flour and germinated cooked ragi flour preparation

To prepare the cooked ragi flour, ragi grains were washed and soaked for 5 hours under ambient temperature. The soaked grains were cooked with potable water in a 1:4 ratio for 45 min at 100ºC. Then, the grains were washed with cold water and surface-dried before being placed in a deep freezer at -18ºC for 24 h. The frozen cooked grains were then thawed and tray-dried at 60ºC for 3 h. After drying, the grains were milled using a Hammer Mill (Balajee Pvt. Ltd, Dhanbad, Jharkhand, India) to obtain flour, which was sieved through 180 µm sieve. For the preparation of germinated cooked ragi flour, an additional step of germination was carried out for the grains after soaking for 5 h, in germinating trays for 24 h at ambient temperature. All remaining flour preparation steps were the same.

Rice flour and rice grits preparation

For the preparation of rice flour, washed rice was cooked with potable water in a 1:3 ratio for 20 minutes at 80°C. After the rice was fully gelatinized, the excess water was drained, and the rice was surface-dried. The surface-dried rice was then placed in a deep freezer at -18ºC for 24 h. The frozen cooked grains were thawed and tray-dried at 60ºC for 3 h. After drying, the grains were milled using a Plate mill and Hammer Mill (Balajee Pvt. Ltd, Dhanbad, Jharkhand, India) to obtain flour and grits respectively. The flour was sieved through a 180 µm mesh sieve, and the grits were sieved through a 420 µm mesh sieve.

Formulation of ragi mudde mix

Based on the preliminary trails, twelve different formulations of ragi mudde mix were prepared using cooked and germinated ragi flour with rice flour and rice grits. The ragi flour with rice flour and grits were formulated into the ratios of 60:40 (F1), 70:30 (F2), 80:20 (F3), respectively. The control premix was prepared using a standardized traditional ratio of 70:30 (F0) consisting of untreated ragi flour and untreated rice grits respectively.

Ragi mudde preparation

The formulated instant ragi mudde mix were added into the boiling water at the ratio of 1:5. Continuously stir the mix and cook it for 3 min. The consistency of the mix thickened and formed as a tightened dough. The cooked dough was made into balls to prepare a mudde.

Physico-chemical properties of premixes

Chemical analysis

The chemical analysis such as Moisture (method no.925.10), Total ash (method no.923.03), Crude fat (method no.945.38) and Alcoholic acidity were analysed for all the premixes (AOAC, 2005). Crude protein (method no.920.87) in the premix were estimated using Kjeldhal method on the basis of nitrogen content (Karthik *et al*., 2024).

Physical analysis

Bulk density and Tapped density

Bulk density and tapped density were calculated according the method described by (Budnimath *et al*., 2023).

$$Bulk\ density\ (g/cm^3) = \frac{Mass\ of\ powder\ (g)}{Initial\ volume\ of\ powder\ (cm^3)} \quad (1)$$

$$Tapped\ density\ (g/cm^3) = \frac{Mass\ of\ powder\ (g)}{Tapped\ volume\ of\ powder\ (cm^3)} \quad (2)$$

Particle density

The particle density was determined using the method described by measured by (Jinapong *et al*., 2008). Below given formula is used to calculate the particle density.

$$\text{Particle}\ density\ (g/cm^3) = \frac{Mass\ of\ powder\ (g)}{Total\ volume\ of\ petroleum\ ether\ and\ suspended\ particles\ (ml) - 6} \quad (3)$$

Flowability and cohesiveness

Flowability and cohesiveness of the premix were expressed as Carr index (CI) and Hausner index (HR), respectively. Both flowability and cohesiveness were calculated from the tapped density and bulk density of the premix by using the below mentioned formula (Budnimath *et al*., 2023).

$$Carr\ Index(\%) = \frac{(tapped\ density - bulk\ density)}{tapped\ density} \times 100 \quad (4)$$

$$Hausner\ Index = \frac{tapped\ density}{bulk\ density} \quad (5)$$

Reconstitution properties of premixes

Porosity

The particle density and tapped density of the premix were used to calculate the porosity by using the below mentioned formula (Jinapong *et al*. 2008).

$$Porosity(\%) = \frac{(Particle\ density - Tapped\ density)}{Particle\ density} \times 100 \quad (6)$$

Hygroscopicity

Hygroscopicity of the premix were calculated by placing approximately 1 g of premix in Petri dishes and stored in the glass desiccator for 7 days at 25°C (Caparino *et al*., 2012).

$$Hygroscopicity\ (\%) = \frac{Weight\ gain\ by\ powder\ after\ 7\ days\ (g)}{Initial\ weight\ of\ the\ premix(g)} \times 100 \quad (7)$$

Dispersibility

Dispersibility of the premix was determined by adding 1 g of premix in 10 ml of water into a 50 ml of beaker. The premix was mixed vigorously for 15 s and the reconstituted premix was allowed to pass through a 250 µm sieve. The sieved premix was transferred to a weighed and dried petri dishes for 4 hours in a hot air oven at 105°C. The dispersibility of the premix was calculated by using the given equation (Budnimath *et al*. 2023) below.

$$Dispersibility\ (\%) = \frac{(10 + a) \times \%TS}{a \times (100 - b)/100} \quad (8)$$

Where, a = amount of premix used (g), b = moisture content of the premix (%), %TS = dry matter in percentage of the reconstituted premix after it has been passed through the sieve

Wettability

Wettability was calculated by the time taken for 2 g of premix to submersed completely in 400 ml of distilled water at 25°C (Caparino *et al*., 2012). The results are given in sec.

Functional properties of premixes

Water absorption capacity (WAC) and oil absorption capacity (OAC)

To measure the water absorption and oil absorption capacity, 1 gram of the premix was added to 10 ml of distilled water in a 50 ml centrifuge tube and mixed thoroughly using a vortex mixer. After 30 minutes, the premix was centrifuged at 4000 rpm for 15 minutes. The supernatant was discarded, and the final residue in the centrifuge tube was weighed. For the oil absorption capacity, distilled water was replaced by refined sunflower oil (Arzoo *et al*., 2024).

$$Water\ absorption\ capacity\ (\%) = \frac{Weight\ of\ the\ water\ absorbed}{Weight\ of\ the\ sample(g)} \times 100 \quad (9)$$

$$Oil\ absorption\ capacity\ (\%) = \frac{Weight\ of\ the\ oil\ absorbed}{Weight\ of\ the\ sample(g)} \times 100 \quad (10)$$

Swelling power and solubility

The swelling power and solubility were observed by the method described by Rao *et al*. (2021). The swelling power and solubility were calculated using the equations given below.

$$Swelling\ Power\ (g/g) = \frac{sediment\ weight \times 100}{weight\ of\ the\ premix \times (100 - S\%)} \quad (11)$$

Where, S% = Solubility (%)

$$Solubility\ (\%) = \frac{Dry\ supernant\ weight}{Weight\ of\ the\ dry\ premix} \times 100 \quad (12)$$

Sensory evaluation

The sensory quality characteristics such as flavor, taste, texture, color, and appearance were analyzed using a 9-point hedonic scale (9 – liked extremely and 1–disliked extremely) (Naseer *et al*., 2021). The ragi mudde mix was cooked as per the method 2.2.4, then made into a ball and served with potable water for palate cleaning before evaluating each mudde prepared from the premix. 10 healthy male and female semi-trained (n=10) panellists aged between 18 to 50 years old in Nutrihub, ICAR-IIMR were used to evaluate the mudde

Statistical Analysis

All the analysis were carried out in triplicates, and the generated data were expressed in Mean ± Standard deviation form. Statistical significance between the data was determined by One way – ANOVA using the Duncan's method ($p \leq 0.05$).

Results and Discussion

Chemical analysis of ragi mudde premixes

In this study, the control with a traditional 70:30 ratio of untreated ragi flour and rice grits had a moisture content of 6.59%. The pretreated formulations showed significantly higher ($p \leq 0.05$) moisture content values: CRF:RG (7.79%), CRF:RF (7.73%), and GCRF:RG (7.53%) (Table 1), while GCRF:RF premix had the lowest value (7.42%). The higher moisture in CRF:RG may result from additional hydration during cooking, consistent with findings by

Kaur *et al*. (2023), who reported increased moisture after soaking and boiling treatments. The slighly lower moisture in CRF:RF compared to CRF:RG coould be due to faster drying of rice flour than rice grits, similar to differences noted by Liu *et al*. (2015) in wheat flours. The reduced moisture in GCRF:RG compared to other pretreated samples might be due to the higher dry matter content of germinated ragi, aligning with Ocheme & Chinma (2008). Similar moisture trends were observed for the F2 (70:30) and F3 (80:20) formulations.

The control premix showed the highest ash content (1.80%), which was significantly greater ($p \leq 0.05$) than that of the F1 (60:40) formulations - CRF:RG (1.35%), CRF:RF (1.34%), GCRF:RG (1.22%), and GCRF:RF (1.17%) (Table 1). The reduction may be attributed to soaking, washing and cooking, which leach soluble minerals (Mensah *et al*., 2022). Germinated samples (GCRF:RG and GCRF:RF) showed slightly lower ash values, likely due to mineral utilization during sprouting (Navyashree *et al*., 2022). Although no significant ($p>0.05$) difference was observed between rice grit and rice flour premixes, ash content increased significantly ($p \leq 0.05$) with a decrease in rice proportion, consistent with the findings of Twinomuhwezi *et al*. (2020).

The untreated control premix had a protein content of 7.25%, while the F1 (60:40) formulations showed lower values CRF:RG (6.16%) and CRF:RF (6.41%) (Table 1). This reduction may be due to protein denaturation and leaching during cooking (Kaur *et al*., 2023). The CRF:RF sample exhibited significantly higher ($p \leq 0.05$) protein content than CRF:RG, possibly because the finer particle size of rice flour facilitates more efficient protein estimation (Yang *et al*., 2022). Germinated formulations, GCRF:RG (6.63%) and GCRF:RF (7.19%), showed significantly higher ($p \leq 0.05$) protein content, attributed to reduced antinutritional factors and improved protein bioavailability during germination (Kulla *et al*., 2021). Across formulations (F1–F3), protein content increased with higher ragi flour proportions, consistent with the findings of Twinomuhwezi *et al*. (2020).

The control premix had a fat content of 1.77% (Table 1), while the F1 (60:40) formulations showed significantly lower ($p \leq 0.05$) values: CRF:RG (1.16%), CRF:RF (1.17%), GCRF:RG (1.40%), and GCRF:RF (1.37%). This reduction may be attributed to preprocessing steps such as cooking and drying, which can lead to fat leaching and removal along with moisture. In a study, it was observed that a similar decrease in fat content in whole foxtail millet, which was reduced from 5.60% to 4.60%, following soaking and boiling treatment (Kaur *et al*., 2023). A slight increase in fat content in germinated samples (GCRF:RG and GCRF:RF) may result from enzymatic activity during germination, particularly lipoxygenase, enhancing fatty acid content, as reported in little millet (Kulla *et al*., 2021). No significant difference ($p>0.05$) was observed between rice grits and rice flour premixes. Across formulations (F1–F3), fat content gradually increased with higher ragi flour proportion, consistent with previous findings (Twinomuhwezi *et al*., 2020)

The control premix had an alcoholic acidity of 0.12%. Compared to the control, F1 (60:40), F2 (70:30), and F3 (80:20) formulations of CRF:RG and CRF:RF showed no significant difference ($p>0.05$) (Table 1). However, alcoholic acidity in GCRF:RG and GCRF:RF increased gradually with higher ragi flour content, due to pH changes during germination, which may reduce shelf life by causing off-flavors. The maximum limit for alcoholic acidity in millet flour set by FSSAI is 0.18%, which ensures that the premix values remain within the acceptable range.

Physical properties of ragi mudde premixes

In the F1 (60:40) formulations, CRF:RG (0.58 g/cm³) and CRF:RF (0.56 g/cm³) premixes had significantly higher ($p \leq 0.05$) bulk densities than the control (0.53 g/cm³) (Table 2), likely due to gelatinization, drying, and milling, which produce denser products. Similarly, hydrothermally treated amaranth grains showed increased bulk density from 0.80 to 0.84 g/cm³ (Malik *et al*., 2021). Between RG and RF, rice grits had higher bulk density due to larger particle size allowing better compaction, as also observed in lentil flour (455.5–596 g/cm³) (Nkurikiye *et al*., 2023). In contrast, GCRF:RG (0.5 g/cm³) and GCRF:RF (0.45 g/cm³) had significantly lower bulk densities ($p \leq 0.05$), likely due to enzymatic activity during germination creating more porous particles, consistent with germinated finger millet flour decreasing from 0.82 to 0.71 g/cm³ (Yenasew & Urga, 2023). This reduction may also result from the breakdown of complex compounds like proteins and starches into smaller constituents (Ocheme & Chinma, 2008; Yenasew & Urga, 2023). Across the 60:40, 70:30, and 80:20 formulations, bulk density decreased gradually with increasing ragi flour and decreasing rice proportion.

In the F1 (60:40) formulation, CRF:RG (0.77 g/cm³) had higher tap density than control (0.72 g/cm³), while CRF:RF (0.72 g/cm³) was lower, likely due to particle size, as finer particles create more voids. For example, tapped density of grass pea flour varies from 500 kg/m³ (179 µm) to 520 kg/m³ (74 µm) (Bala *et al*., 2020). No significant difference ($p>0.05$) was observed for GCRF:RG and GCRF:RF (0.71 g/cm³) compared to the control (Table 2). Across F1–F3 formulations, tap density gradually decreased with higher ragi flour and lower rice proportion. Similar ranges (0.76–0.84 g/cm³) have been reported for cereal-based flours (Singh *et al*., 2021)

All the treated premixes in every formulation have significantly lesser ($p\leq0.05$) Particle density when compared to control as shown in Table 2. This reduction is attributed to the freezing of the grains, which causes ice sublimation and creates more pores within the premixes (Buzera *et al*., 2022). Similar studies have observed that freeze-dried premixes have a lower particle density compared to oven-dried premixes, with values decreasing from 1.65 g/cm³ to 1.46 g/cm³ (Buzera *et al*., 2022). There is no significance between ($p>0.05$) the F1(60:40), F2(70:30), and F3(80:20) formulations in terms of particle density.

The untreated control premix had a Carr Index (CI) of 26.31%. In the F1 (60:40) formulations, CI values were CRF:RG (23.69%), CRF:RF (21.89%), GCRF:RG (30.11%), and GCRF:RF (36.45%) (Table 2). Compared to F0, CRF:RG and CRF:RF had significantly lower ($p\leq0.05$) CI values, indicating better flowability, likely due to milling and sieving producing finer, uniform particles. CI for CRF:RG was slightly higher than CRF:RF, possibly because rice grits contain both fine and larger particles that may interlock. In contrast, GCRF:RG and GCRF:RF had higher CI values, showing reduced flowability, likely due to germination increasing hygroscopicity and moisture absorption, which causes the flour to clump together.

All ragi mudde premixes prepared from millet flours obtained from cooked ragi exhibited better flowability (1.27 to 1.31) compared to the control (1.35). However, the incorporation of germinated millet flour reduced flowability (Table 2), with the HR value increasing to 1.57 in the premix containing a F2(70:30) ratio of ragi to rice flour. In contrast, germination improved the flowability of sorghum, as the process reduced the Carr index of the starch in sorghum from 39.2% to 34.3% (Elkhalifa & Bernhardt, 2018). This reduction in flowability of germinated ragi flour might be because of the change in starch structure and increase in protein content in the flour, which makes the flour more sticker and less free flowing of the premix.

Reconstitution properties of ragi mudde premixes

Porosity of all mixes prepared from processed ragi flours ranged from 23.50 to 38.69%, significantly lower ($p\leq0.05$) than the control (65.76%) (Table 3). This reduction is attributed to preprocessing: cooking induces swelling that reduces void spaces, dehydration lowers moisture causing particle shrinkage, and milling alters particle shapes, all decreasing porosity. Similarly, hydrothermally treated amaranth grains showed a slight porosity decrease from 54.19% to 53.60% (Malik *et al*., 2021). Differences between cooked and germinated flours arise from enzymatic activity during germination, which initially increases porosity, as seen in germinated finger millet grains decreasing from 36.61% to 29.93% with prolonged germination (Kumar *et al*., 2020). CRF:RG had significantly lower porosity than CRF:RF, likely due to the more uniform particle size of rice grits, which settle more closely. In the F1(60:40), F2(70:30), and F3(80:20) formulations, porosity gradually increased with higher ragi and lower rice proportions. Similar reductions in porosity have been reported in frozen products due to ice sublimation (Oikonomopoulou *et al*., 2011)

Hygroscopicity values were significantly higher ($p\leq0.05$) for all processed premixes compared to the control (0.46%) (Table 3), due to pretreatments like cooking and milling that enhance moisture absorption. GCRF premixes had significantly higher hygroscopicity than CRF, because germination increases soluble fiber content, enhancing water retention. Similarly, germination increased finger millet hygroscopicity by 33% (Paliwal *et al*., 2022). Rice flour formulations showed higher hygroscopicity than rice grits due to finer particle size and larger surface area. In the F1(60:40), F2(70:30), and F3(80:20) formulations, hygroscopicity gradually increased with higher ragi flour and lower rice content.

The processed premixes showed higher dispersibility than the control (9.33%). RG premixes had significantly lower dispersibility ($p\leq0.05$) than RF, because of the larger particle size of rice grits. Similarly, increased particle size in yam flour reduced dispersibility from 99% to 27.6% (Pravat *et al*., 2024). In RG premixes, dispersibility increased with higher ragi flour proportion, due to the greater content of finer particles, which disperse more easily, whereas larger particles settle faster. In RF premixes, dispersibility decreased with increasing ragi flour, because ragi flour has higher density than rice flour. GCRF premixes showed slightly lower dispersibility than CRF, potentially due to reduced flour density from germination, consistent with reports of 11% bulk density reduction in germinated flour (Paliwal *et al*., 2022)

The untreated control premix had a wettability of 68.7 sec. In the 60:40 formulations, values were CRF:RG (46.5 sec), CRF:RF (51 sec), GCRF:RG (29 sec), and GCRF:RF (39 sec) (Table 3), all lower than the control. Cooking and germination modify starch and protein structures, making water more accessible and reducing wetting time. GCRF premixes had shorter wetting times than CRF premixes due to softer starch structures from germination, consistent with decreases observed in germinated, fermented sorghum flour from 84.9 to 71.1 sec (Elkhalifa & Bernhardt, 2018). RG formulations had the shortest wetting time due to smaller particle size, while rice grits with larger particles settled faster, reducing wetting time. Across F1(60:40), F2(70:30), and F3(80:20) formulations, wetting time decreased as ragi flour proportion increased and rice decreased. Similar studies reported that phirni premixes wetting time increased from 2 to 4.3 min with higher rice flour content, and larger particle sizes with more void space can decrease wetting time compared to rice flour (Naseer *et al*., 2021)

Functional properties of ragi mudde premixes

Compared to the control (3.91%), the WAC of CRF:RG and CRF:RF increased (Table 4), might be due to starch gelatinization and protein denaturation during cooking, enhancing water absorption. Similar results were reported by Arzoo *et al*. (2024), where WAC of finger millet increased from 18.83% to 31.55% due to processing, improving hydrophilic properties. The lower WAC in GCRF:RG and GCRF:RF compared to CRF:RG and CRF:RF may result from excessive degradation during germination, reducing water retention, consistent with observations of WAC decreasing from 0.97 to 0.85 ml/g in native compared to germinated finger millet flour (Navyashree *et al*., 2022). No significant difference ($p>0.05$) was observed between rice grits and rice flour. Across F1(60:40), F2(70:30), and F3(80:20) formulations, WAC gradually decreased, likely due to reduced rice proportion and increased ragi flour, although a similar study reported WAC increasing from 5.85% to 6.35% as rice decreased and millet increased (Twinomuhwezi *et al*., 2020).

The F0 (control) premix had an OAC of 0.87%, while the treated premixes showed significantly higher ($p\leq0.05$) values (Table 4). In the 60:40 formulations, OAC values were: CRF:RG (0.99%), CRF:RF (0.99%), GCRF:RG (1.02%), and GCRF:RF (1.03%). The increased OAC in CRF:RG and CRF:RF compared to the control results from damaged starch and the porous structure formed during cooking and drying. Higher OAC in GCRF:RG and GCRF:RF than CRF samples is due to the exposure of lipophilic groups from protein denaturation. Similar trends were reported for parboiled (22.93%) and germinated (28.24%) finger millet flour compared to control (23.48%) (Arzoo *et al*., 2024). No significant difference ($p>0.05$) was observed between rice grits and rice flour. Across F1–F3 formulations, OAC gradually decreased with lower rice and higher ragi proportions

The control premix had a swelling power of 10.14 g/g, while the 60:40 formulations were: CRF:RG (6.95 g/g), CRF:RF (7.13 g/g), GCRF:RG (7.8 g/g), and GCRF:RF (7.68 g/g) (Table 4). CRF:RG and CRF:RF showed significantly lower ($p\leq0.05$) swelling power than the control, attributed to cooking and drying processes that alter starch granule structure and reduce water absorption. For example, unmodified sorghum flour has a swelling power of 3.34 g/g, which decreases to 2.55 g/g after hydrothermal treatment (Ridwan Ariyantoro *et al*., 2020). GCRF:RG and GCRF:RF had lower swelling power than the control but higher than CRF:RG and CRF:RF, possibly due to starch structural changes during germination. Similarly, finger millet flour swelling power decreased from 3.45% to 1.34% with increased germination time (Yenasew & Urga, 2023). Swelling power decreased progressively in F1–F3 formulations with higher ragi and lower rice proportions.

The control premix had a WSI of 8.19%. In the F1 (60:40) formulations, solubility values were CRF:RG (2.61%), CRF:RF (3.97%), GCRF:RG (3.37%), and GCRF:RF (4.86%) (Table 4). All premixes showed significantly lower ($p\leq0.05$) solubility than the control, likely due to cooking and drying reducing hydroxyl groups in starch, which limits water absorption and swelling (Arzoo *et al*., 2024). CRF:RG and GCRF:RG had lower solubility than CRF:RF and GCRF:RF, as coarser rice grits interact more slowly with water, whereas finer rice flour allows easier water penetration (Lapčíková *et al*., 2021). Germinated premixes (GCRF) showed slightly higher solubility than CRF, due to increased water absorption from germination, which can enhance solubility by up to 177% in finger millet (Paliwal *et al*., 2022). Across F1–F3 formulations, solubility increased with higher ragi flour content, reflecting the lower solubility of rice grits compared to ragi flour

Sensory evaluation

The sensory evaluations of all ragi mudde premixes in different formulations were compared with the control. It was observed that all the mudde had lower acceptability across all aspects compared to the control (Figure 1). The sensory score received for the control mudde were as follows: color (7.16), flavor (6.66), texture (7), taste (7.16), appearance (7.16), and overall acceptability (7.66). Among all the processed mudde, GCRF:RG (70:30) achieved the highest acceptability in all aspects: color (6.83), flavor (7.16), texture (7), taste (7), appearance (7), and overall acceptability (7.16). Also, GCRF:RG mudde prepared at 70:30 formulation exhibited a good texture, less stickiness and improved flavor than all other processed ragi mudde premixes. As a result, GCRF:RG (70:30) formulation was selected as the best combination for ragi mudde premix preparation.

Conclusion

Among the different formulations tested, the GCRF:RG (germinated cooked ragi flour to rice grits) ratio of 70:30 (F2) demonstrated the most promising characteristics, particularly in terms of sensory attributes, including taste, texture, and overall acceptability. This formulation exhibited a notably favorable balance in texture and flavor compared to other ratios. The germination process applied to the ragi flour contributed to enhanced flavor profiles and improved texture, making the final product more appealing to consumers. Due to processing the germinated cooked ragi flour formulation with rice grits lost some nutritional profile but it adds a desirable sensory quality, thus supporting the traditional appeal of ragi mudde while adapting to modern convenience. In terms of physical properties, GCRF:RG (70:30) showed lower results with a bulk density, which was comparable to other formulations but reflected a balance between density and texture. From the nutritional perspective, the GCRF:RG (70:30) mix protein and fat content was reduced but lies within an acceptable range. The moisture content of this formulation was lesser compared to all the other treated premixes, ensuring optimal shelf life and product stability. Functionally, the WAC was significantly similar and OAC was increased when compared to control for GCRF:RG (70:30), indicating good hydration and oil retention properties which contribute to the mix's overall quality and performance. Overall, the GCRF:RG (70:30) formulation represents a significant advancement in the development of an instant ragi mudde mix. This keeps the traditional taste of ragi mudde while also improving the flavor, texture, and nutritional value, making it a good choice for today's busy lifestyle. The successful use of germinated ragi flour shows how traditional foods can adapt to meet modern consumer needs, helping to preserve cultural food traditions while offering better nutrition.

Table 1 : Chemical analysis of ragi mudde premixes

Formulation	F(x:y)	F1 (60:40)	F2 (70:30)	F3 (80:20)
Moisture (%)	Control (70:30)	6.59±0.11 ^{a}	6.59±0.11 ^{a}	6.59±0.11 ^{a}
	CRF: RG	7.79±0.01 ^{c2}	8.21±0.17 ^{c3}	7.48±0.01 ^{b1}
	CRF: RF	7.73±0.04 ^{c1}	8.06±0.02 ^{c2}	7.76±0.01 ^{c1}
	GCRF: RG	7.54±0.07 ^{b1}	7.38±0.36 ^{b1}	7.46±0.07 ^{b1}
	GCRF: RF	7.42±0.09 ^{b1}	7.59±0.11 ^{b1}	7.37±0.17 ^{b1}
Total ash (%)	Control (70:30)	1.80±0.01 ^{c}	1.80±0.01 ^{b}	1.80±0.01 ^{d}
	CRF: RG	1.35±0.01 ^{b1}	1.43±0.02 ^{a2}	1.66±0.01 ^{c3}
	CRF: RF	1.34±0.00 ^{b1}	1.46±0.00 ^{a2}	1.46±0.01 ^{a2}
	GCRF: RG	1.22±0.10 ^{a1}	1.62±0.27 ^{b2}	1.75±0.01 ^{bc2}
	GCRF: RF	1.17±0.02 ^{a1}	1.45±0.03 ^{a2}	1.60±0.05 ^{b3}
Crude protein (%)	Control (70:30)	7.25±0.00 ^{cd}	7.25±0.00 ^{b}	7.25±0.00 ^{ab}
	CRF: RG	6.16±0.28 ^{a1}	6.66±0.56 ^{a12}	7.08±0.35 ^{a2}
	CRF: RF	6.41±0.19 ^{b1}	6.95±0.0 ^{b2}	7.20±0.25 ^{ab2}
	GCRF: RG	6.63±0.17 ^{b1}	6.91±0.02 ^{a1}	7.17±0.29 ^{ab1}
	GCRF: RF	7.19±0.41 ^{d1}	7.34±0.23 ^{b1}	7.65±0.17 ^{b2}
Crude fat (%)	Control (70:30)	1.77±0.15 ^{d}	1.77±0.15 ^{b}	1.77±0.15 ^{c}
	CRF: RG	1.16±0.05 ^{b1}	1.23±0.15 ^{a1}	1.43±0.15 ^{b1}
	CRF: RF	1.17±0.05 ^{b1}	1.35±0.15 ^{a1}	1.53±0.15 ^{b1}
	GCRF: RG	1.40±0.05 ^{c1}	1.47±0.0 ^{a1}	1.46±0.1 ^{b1}
	GCRF: RF	1.37±0.05 ^{c1}	1.60±0.05 ^{b2}	1.63±0.1 ^{bc2}

Alcoholic Acidity (%)	Control (70:30)	0.12±0 ^{a}	0.12±0 ^{b}	0.12±0 ^{bc}
	CRF: RG	0.12±0 ^{a2}	0.11±0.01 ^{ab12}	0.09±0 ^{a1}
	CRF: RF	0.12±0 ^{a1}	0.11±0.01 ^{ab1}	0.11±0.01 ^{ab1}
	GCRF: RG	0.11±0.01 ^{a1}	0.12±0 ^{b1}	0.12±0 ^{bc1}
	GCRF: RF	0.11±0.01 ^{a1}	0.09±0 ^{a1}	0.13±0.01 ^{c2}

Values are represented as Mean ± SD of triplicates. The terms x and y in the formulation F(x:y) indicates the ratio of ragi (cooked or germinated cooked) and rice (rice flour or rice grits), respectively. Values in the same column different superscript letter differs significantly ($p \leq 0.05$) and the values in same row with different superscript number differs significantly ($p \leq 0.05$). CRF – cooked ragi flour; RG – Rice grits; RF – Rice Flour; GCRF – Germinated cooked ragi flour

Table 2 : Physical properties of ragi mudde premixes

Formulation	F(x:y)	F1 (60:40)	F2 (70:30)	F3 (80:20)
Bulk density (g/cm^3)	Control (70:30)	0.53±0.00 ^{b}	0.53±0.00 ^{b}	0.53±0.00 ^{b}
	CRF: RG	0.58±0 ^{c2}	0.56±0.00 ^{c1}	0.56±0.00 ^{c1}
	CRF: RF	0.56±0.00 ^{c2}	0.56±0.00 ^{c2}	0.52±0.00 ^{b1}
	GCRF: RG	0.5±0.00 ^{b2}	0.45±0 ^{a1}	0.45±0 ^{a1}
	GCRF: RF	0.45±0 ^{a1}	0.45±0 ^{a1}	0.45±0 ^{a1}
Tap density (g/cm^3)	Control (70:30)	0.72±0 ^{a}	0.72±0 ^{a}	0.72±0 ^{c}
	CRF: RG	0.77±0.00 ^{b2}	0.72±0.00 ^{a1}	0.71±0.0 ^{c1}
	CRF: RF	0.72±0.00 ^{a2}	0.71±0.00 ^{a2}	0.67±0.00 ^{b1}
	GCRF: RG	0.71±0.00 ^{a2}	0.71±0 ^{a2}	0.67±0 ^{b1}
	GCRF: RF	0.71±0 ^{a3}	0.67±0 ^{a2}	0.62±0 ^{a1}
Particle density (g/cm^3)	Control (70:30)	2.09±0.09 ^{b}	2.09±0.089 ^{b}	2.09±0.09 ^{b}
	CRF: RG	1.01±0.01 ^{a1}	1.01±0.00 ^{a1}	1.01±0.00 ^{a1}
	CRF: RF	1.03±0.02 ^{a1}	1.03±0.02 ^{a1}	1.03±0.01 ^{a1}
	GCRF: RG	1.03±0.03 ^{a1}	1.03±0.02 ^{a1}	1.01±0.01 ^{a1}
	GCRF: RF	1.05±0.01 ^{a1}	1.04±0.03 ^{a1}	1.02±0.02 ^{a1}
CI (%)	Control (70:30)	26.31±0 ^{c}	26.31±0 ^{b}	26.31±0 ^{b}
	CRF: RG	23.69±0.27 ^{b2}	22.22±0 ^{a1}	21.97±0.27 ^{a1}
	CRF: RF	21.89±0.68 ^{a1}	22.05±0.24 ^{a1}	21.55±0.43 ^{a1}
	GCRF: RG	30.11±0.11 ^{d1}	36.29±0.01 ^{d3}	31.79±0.13 ^{d2}
	GCRF: RF	36.45±0.00 ^{e3}	31.82±0 ^{c2}	27.16±0.00 ^{c1}
HR	Control (70:30)	1.36±0 ^{c}	1.36±0 ^{b}	1.36±0 ^{b}
	CRF: RG	1.31±0.00 ^{b2}	1.28±0 ^{a1}	1.28±0.00 ^{a1}
	CRF: RF	1.28±0.01 ^{a1}	1.28±0.00 ^{a1}	1.27±0.01 ^{a1}
	GCRF: RG	1.43±0.00 ^{d1}	1.57±0.00 ^{d3}	1.46±0.00 ^{d2}
	GCRF: RF	1.57±0 ^{e3}	1.47±0 ^{c2}	1.37±0 ^{c1}

Values are represented as Mean ± SD of triplicates. The terms x and y in the formulation F(x:y) indicates the ratio of ragi (cooked or germinated cooked) and rice (rice flour or rice grits), respectively. Values in the same column different superscript letter differs significantly ($p \leq 0.05$) and the values in same row with different superscript number differs significantly ($p \leq 0.05$). CRF–cooked ragi flour; RG–Rice grits; RF–Rice Flour; GCRF–Germinated cooked ragi flour

Table 3 : Reconstitution properties of ragi mudde premixes

Formulation	F(x:y)	F1 (60:40)	F2 (70:30)	F3 (80:20)
Porosity (%)	Control (70:30)	65.77±1.42 ^{d}	65.77±1.42 ^{e}	65.77±1.42 ^{d}
	CRF: RG	23.50±0.25 ^{a1}	28.78±0.25 ^{a2}	28.96±0.09 ^{a2}
	CRF: RF	34.49±0.98 ^{b2}	30.46±1.35 ^{b1}	30.09±0.91 ^{b1}
	GCRF: RG	34.16±0.54 ^{b2}	31.07±1.68 ^{c1}	30.48±1.21 ^{b1}
	GCRF: RF	38.69±1.03 ^{c2}	36.53±0.87 ^{d2}	31.37±2.22 ^{c1}
Hygroscopicity (%)	Control (70:30)	0.46±0.22 ^{a}	0.46±0.22 ^{a}	0.46±0.22 ^{a}
	CRF: RG	0.64±0.38 ^{ab1}	0.65±0.48 ^{a1}	0.85±0.12 ^{b1}
	CRF: RF	1.24±0.0 ^{cd1}	1.17±0.41 ^{b1}	1.13±0.08 ^{c1}
	GCRF: RG	0.92±0.33 ^{bc1}	1.02±0.59 ^{b1}	1.14±0.29 ^{c1}
	GCRF: RF	1.36±0.68 ^{d1}	1.14±0.58 ^{b1}	1.07±0.31 ^{bc1}
Dispersibility (%)	Control (70:30)	9.33±1.2 ^{a}	9.33±1.2 ^{a}	9.33±1.2 ^{a}
	CRF: RG	19.41±1.11 ^{c1}	24.45±1.18 ^{c2}	25.27±1.06 ^{d2}

	CRF: RF	25.57±0.59 [e1]	22.85±1.5 [c1]	23.6±2.78 [d1]
	GCRF: RG	15.68±0.66 [b1]	16.87±0.62 [b12]	18.27±1.25 [b2]
	GCRF: RF	23.51±0.81 [d2]	23.1±2.03 [c12]	20.3±1.23 [c1]
Wettability (sec)	Control (70:30)	68.7±0.3 [e]	68.7±0.3 [e]	68.7±0.3 [d]
	CRF: RG	46.5±1.5 [c3]	42±0 [c2]	30.5±0.5 [a1]
	CRF: RF	51±0 [d3]	44±1 [d2]	40±0 [c1]
	GCRF: RG	29±0 [a1]	32±0 [a2]	37±0 [b3]
	GCRF: RF	39±1 [b2]	35.5±0.5 [b1]	36±0 [b1]

Values are represented as Mean ± SD of triplicates. The terms x and y in the formulation F(x:y) indicates the ratio of ragi (cooked or germinated cooked) and rice (rice flour or rice grits), respectively. Values in the same column different superscript letter differs significantly ($p \leq 0.05$) and the values in same row with different superscript number differs significantly ($p \leq 0.05$). CRF–cooked ragi flour; RG–Rice grits; RF–Rice Flour; GCRF–Germinated cooked ragi flour

Table 4 : Functional properties of ragi mudde premixes

Formulation	F(x:y)	F1 (60:40)	F2 (70:30)	F3 (80:20)
WAC (%)	Control (70:30)	3.91±0.77 [ab]	3.91±0.77 [ab]	3.92±0.77 [ab]
	CRF: RG	4.52±0.08 [a1]	4.44±0.00 [a1]	4.40±0.07 [a1]
	CRF: RF	4.52±0.12 [a1]	4.47±0.13 [a1]	4.22±0.16 [a1]
	GCRF: RG	3.47±0.19 [b1]	3.44±0.13 [b1]	3.26±0.21 [b1]
	GCRF: RF	3.51±0.09 [b1]	3.47±0.09 [b1]	3.41±0.07 [b1]
OAC (%)	Control (70:30)	0.87±0.02 [b]	0.87±0.02 [a]	0.87±0.02 [b]
	CRF: RG	0.99±0.04 [a2]	0.92±0.01 [ab2]	0.86±0.02 [b1]
	CRF: RF	0.99±0.04 [a1]	0.97±0.02 [b1]	0.94±0.01 [ab1]
	GCRF: RG	1.03±0.04 [a1]	1.02±0.00 [c1]	0.99±0.03 [a1]
	GCRF: RF	1.03±0.01 [a1]	0.99±0.00 [bc1]	0.98±0.07 [a1]
SP (g/g)	Control (70:30)	10.14±0.07 [c]	10.14±0.07 [b]	10.14±0.07 [b]
	CRF: RG	6.95±0.49 [a1]	6.94±0.21 [a1]	6.65±0.40 [a1]
	CRF: RF	7.13±0.69 [ab1]	7.13±0.53 [a1]	6.99±0.41 [a1]
	GCRF: RG	7.8±0.00 [b2]	7.12±0.18 [a1]	7.03±0.51 [a1]
	GCRF: RF	7.68±0.6 [ab1]	7.32±0.49 [a1]	7.00±0.69 [a1]
Solubility (%)	Control (70:30)	8.19±1.96 [b]	8.19±1.96 [b]	8.19±1.96 [b]
	CRF: RG	2.62±1.18 [a1]	3.88±1.23 [a1]	3.89±0.49 [a1]
	CRF: RF	3.98±0.28 [a1]	3.83±0.94 [a1]	3.71±0.77 [a1]
	GCRF: RG	3.37±0.70 [a1]	3.40±0.92 [a1]	3.80±0.054 [a1]
	GCRF: RF	4.86±0.53 [a1]	4.18±0.22 [a1]	4.06±0.84 [a1]

Values are represented as Mean ± SD of triplicates. The terms x and y in the formulation F(x:y) indicates the ratio of ragi (cooked or germinated cooked) and rice (rice flour or rice grits), respectively. Values in the same column different superscript letter differs significantly ($p \leq 0.05$) and the values in same row with different superscript number differs significantly ($p \leq 0.05$). CRF – cooked ragi flour; RG – Rice grits; RF – Rice Flour; GCRF – Germinated cooked ragi flour

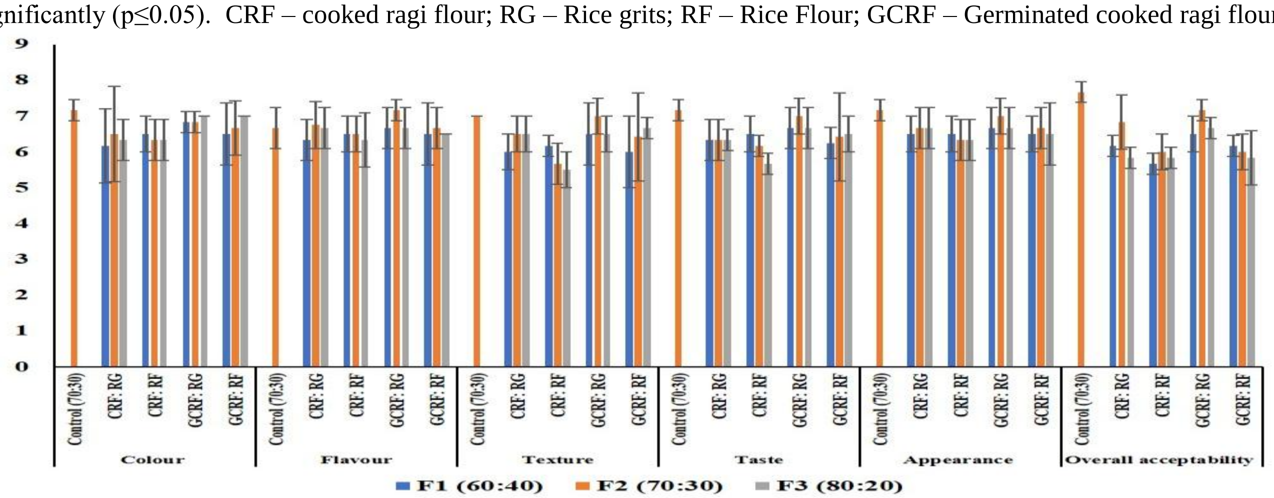

Fig. 1: Sensory properties of ragi mudde premixes

Abbreviations

CRF	Cooked Ragi Flour
GCRF	Germinated Cooked Ragi Flour
RG	Rice Grits
RF	Rice Flour
WAC	Water Absorption Capacity
OAC	Oil Absorption Capacity
WSI	Water Solubility Index
SP	Swelling Power

Disclosure of Interest

The authors declare that they have no competing interests

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References

AOAC. (2005). *Official methods of analysis* (K. Helrich, Ed.; 15th ed.). Association of Official Analytical Chemists, Inc.

Arzoo, N., Shukla, A. K., Panwar, S., & Kumar, A. (2024). Effect of processing techniques on functional, antioxidants, and structural properties of finger millet (*Eleusine coracana*) flour. *Food and Humanity*, **2**, 100305.

Bala, M., Gul, K., Riar, C. S., & Singh, S. (2020). Physicochemical, functional and rheological properties of grass pea (*Lathyrus sativus* L.) flour as influenced by particle size. *Heliyon*, **6**(12), e05471.

Bhardwaj, Y., Taboh, M., Pulicherla, Y., Cheemanapalli, S., Bhuyan, B., & Mathapati, S. (2023). Traditional and common millet-based food recipes of the tribal communities of Arunachal Pradesh. *Journal of Drug Research in Ayurvedic Sciences*, **8**(Suppl. 1), S121–S130.

Budnimath, S. H., Ganiger, V. M., Goudar, G., Patil, S. N., & C., V. M. (2023). Physical, reconstitution and phenolic properties of instant drink mix prepared with *Moringa oleifera* leaf, raw banana and whey protein concentrate. *Measurement: Food*, **11**, 100108.

Buzera, A., Gikundi, E., Orina, I., & Sila, D. (2022). Effect of pretreatments and drying methods on physical and microstructural properties of potato flour. *Foods*, **11**(4).

Caparino, O. A., Tang, J., Nindo, C. I., Sablani, S. S., Powers, J. R., & Fellman, J. K. (2012). Effect of drying methods on the physical properties and microstructures of mango (Philippine "Carabao" var.) powder. *Journal of Food Engineering*, **111**(1), 135–148.

Chandra, D., Chandra, S., Pallavi, & Sharma, A. K. (2016). Review of finger millet (*Eleusine coracana* (L.) Gaertn): A powerhouse of health-benefiting nutrients. *Food Science and Human Wellness*, **5**(3), 149–155.

Divate, A. D., Atkari, V. T., Thakor, N. J., & Sawant, A. A. (2016). Potential functional implications of finger millet (*Eleusine coracana*) in health and disease. *The Indian Journal of Nutrition and Dietetics*, **53**(4), 475.

Elkhalifa, A. E. O., & Bernhardt, R. (2018). Combination effect of germination and fermentation on functional properties of sorghum flour. *Current Journal of Applied Science and Technology*, **30**(1), 1–12.

Geetha, K., Yankanchi, G. M., & Hiremath, N. (2019). Development and evaluation of traditional food products from high fibre food mix. *Journal of Pharmacognosy and Phytochemistry*, **8**(3), 2431–2434.

Gull, A., Jan, R., Nayik, A., Prasad, K., & Kumar, P. (2014). Significance of finger millet in nutrition, health and value-added products: A review. *Journal of Environmental Science*, **3**(3), 1601–1608.

Gurumallu, S. C., Senthil, A., Ramesh, G., & Nagaraju, V. D. (2022). Effect of particle size of ragi flour on physico-chemical and sensory profile of ragi mudde. *Indian Journal of Traditional Knowledge*, **21**(3), 653–659.

Jangam, S. V., & Thorat, B. N. (2010). Optimization of spray drying of ginger extract. *Drying Technology*, **28**(12), 1426–1434.

Jinapong, N., Suphantharika, M., & Jamnong, P. (2008). Production of instant soymilk powders by ultrafiltration, spray drying and fluidized bed agglomeration. *Journal of Food Engineering*, **84**(2), 194–205.

Karthik, K. V. D., Rao, B. D., Das, A., Kiranmai, E., Dharini, M., Mogulla, S. R., & Sharma, D. (2024). Personalized kodo millet rice analogue (KMRA): Formulation, nutritional evaluation, and optimization. *Future Foods*, **10**, 100389.

Kaur, T., Panesar, P. S., & Riar, C. S. (2023). Combined effect of hydrothermal treatments and drying temperature on the physicochemical, milling, and nutritional characteristics of foxtail millet. *Journal of Cereal Science*, **114**, 103788.

Kulla, S., Hymavathi, T. V., Kumari, B. A., Reddy, R. G., & Rani, C. V. D. (2021). Impact of germination on the nutritional, antioxidant and antinutrient characteristics of selected minor millet flours. *Annals of Phytomedicine: An International Journal*, **10**(1), 178–184.

Kumar, A., Kaur, A., Kumar, V., & Gat, Y. (2020). Effects of soaking and germination time on the engineering properties of finger millet (*Eleusine coracana*). *Carpathian Journal of Food Science and Technology*, **12**(1), 61–70.

Lapčíková, B., Lapčík, L., Valenta, T., Majar, P., & Ondroušková, K. (2021). Effect of the rice flour particle size and variety type on water holding capacity and water diffusivity in aqueous dispersions. *LWT*, **142**.

Liu, C., Liu, L., Li, L., Hao, C., Zheng, X., Bian, K., Zhang, J., & Wang, X. (2015). Effects of different milling processes on whole wheat flour quality and performance in steamed bread making. *LWT*, **62**(1), 310–318.

Malik, A., Khamrui, K., & Prasad, W. (2021). Effect of hydrothermal treatment on physical properties of amaranth, an underutilized pseudocereal. *Future Foods*, **3**, 100027.

Mbithi-Mwikya, S., Ooghe, W., Van Camp, J., Ngundi, D., & Huyghebaert, A. (2000). Amino acid profiles after sprouting, autoclaving, and lactic acid fermentation of finger millet (*Eleusine coracana*) and kidney beans (*Phaseolus vulgaris* L.). *Journal of Agricultural and Food Chemistry*, **48**(8), 3081–3085.

Mensah, E. E., Asamoah, Y. D., Yunus, S., Issah, N., & Kofi, E. (2022). A comparative study of the effect of microwave and conventional heating methods on proximate composition of spiced millet porridge. *International Journal of Food Science and Nutrition*, **7**(2), 56–61.

Naseer, B., Naik, H. R., Hussain, S. Z., Bhat, T., & Nazir, N. (2021). Development of instant phirni mix (a traditional dairy dessert) from high amylose rice, skim milk powder and carboxymethyl cellulose-resistant starch, predicted glycemic index and stability during storage. *Food Bioscience*, **42**, 101213.

Navyashree, N., Singh Sengar, A., Sunil, C. K., & Venkatachalapathy, N. (2022). White finger millet (KMR-340): A comparative study to determine the effect of processing and their characterisation. *Food Chemistry*, **374**, 131665.

Nkurikiye, E., Pulivarthi, M. K., Bhatt, A., Siliveru, K., & Li, Y. (2023). Bulk and flow characteristics of pulse flours: A comparative study of yellow pea, lentil, and chickpea flours of varying particle sizes. *Journal of Food Engineering*, **357**, 111647.

Ocheme, O. B., & Chinma, C. E. (2008). Effects of soaking and germination on some physicochemical properties of millet flour for porridge production. *Journal of Food Technology*, **6**(5), 185–188.

Oikonomopoulou, V. P., Krokida, M. K., & Karathanos, V. T. (2011). The influence of freeze drying conditions on microstructural changes of food products. *Procedia Food Science*, **1**, 647–654.

Paliwal, A., Sharma, N., & Singh, R. (2022). Effects of wet processing on physicochemical and functional characteristics of millet flour. *Current Research in Nutrition and Food Science*, **10**(3), 980–993.

Patel, S., & Pisalkar, P. S. (2015). Finger millet: A potential commodity for nutritional security and entrepreneurship development—A perspective. *Journal of Postharvest Technology*, **3**(3), 67–73.

Pravat, S., Yadav, S., Khadka, A., Katel, S., & Karki, R. (2024). *Finger millet: A holistic exploration of its cultural, historical, religious, indigenous knowledge, and culinary significance*.

Rao, M. V., Kg, A., Ck, S., Venkatachalapathy, N., & Jaganmohan, R. (2021). Effect of microwave treatment on physical and functional properties of foxtail millet flour. *International Journal of Chemical Studies*, **9**(1), 2762–2767.

Ridwan Ariyantoro, A., Sigit Amanto, B., & Kiswuri. (2020). Effect of heat moisture treatment (HMT) on physicochemical characteristics of sorghum flour (*Sorghum bicolor* L. Moench). *IOP Conference Series: Earth and Environmental Science*, **518**(1).

Shivakumara, D. C., & Ramachandra, N. U. (2023). Exploring the aesthetic values of finger millet-ragi (*Eleusine coracana* L.): A multifaceted perspective. *Journal of Survey in Fisheries Sciences*.

Shobana, S., Krishnaswamy, K., Sudha, V., Malleshi, N. G., Anjana, R. M., Palaniappan, L., & Mohan, V. (2013). Finger millet (Ragi, *Eleusine coracana* L.): A review of its nutritional properties, processing, and plausible health benefits. In *Advances in Food and Nutrition Research* (Vol. 69, pp. xx–xx).

Singh, V., Das, M., & Seth, D. (2021). Chemical and functional evaluation of Burma black rice based instant beverage mix (BBIBM). *The Pharma Innovation Journal*, **10**(7), 931–937.

Teena, R., Singh, R., Kamble, D. B., Ashutosh, U., & S, T. (2019). Review on finger millet: Processing and value addition. *The Pharma Innovation Journal*, **8**(4), 283–291.

Twinomuhwezi, H., Awuchi, C. G., & Rachael, M. (2020). Comparative study of the proximate composition and functional properties of composite flours of amaranth, rice, millet, and soybean. *American Journal of Food Science and Nutrition*, **6**(1), 6–19.

Yang, L., Wang, S., Zhang, W., Zhang, H., Guo, L., Zheng, S., & Du, C. (2022). Effect of black soybean flour particle size on the nutritional, texture and physicochemical characteristics of cookies. *LWT*, **164**, 113649.

Yenasew, A., & Urga, K. (2023). Effect of the germination period on functional properties of finger millet flour and sensorial quality of porridge. *Food Science & Nutrition*, **11**(5), 2336–2343.