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Effect of processing on physical and functional properties of brown top millet (*Brachiaria ramosa*)

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Abstract
Brown top millet (*Brachiaria ramosa*) (BTM) is an underutilized small millet with high nutritional and functional potential. The present study evaluated the effects of dehulling and germination on the physical characteristics, cooking quality, and functional properties of brown top millet. Physical parameters including grain dimensions, 1000-kernel weight, bulk density, density, elongation ratio, and porosity were measured for whole, dehulled, and germinated grains. Cooking quality was assessed through water uptake, cooking time, and expansion ratio, while functional properties such as bulk density, water absorption, oil absorption, and emulsifying capacity were evaluated for the corresponding flours. Results revealed that dehulling reduced grain size, 1000-kernel weight, and porosity, whereas germination decreased density, bulk density and porosity. Water uptake and cooking efficiency were higher in germinated grains, while dehulled grains exhibited faster cooking than whole grains. Functional properties were significantly influenced by processing: germinated flour showed higher water and fat absorption capacities, whereas dehulled flour demonstrated improved emulsifying properties. Overall, germination enhanced hydration and functional behavior, whereas dehulling primarily affected grain dimensions and cooking kinetics. The study provides comprehensive insights into how simple processing methods modulate the physical, cooking, and functional properties of brown top millet, informing its utilization in value-added foods.

Keywords: Physical properties, functional properties, brown top millet, underutilized millet.

Introduction

Millets are small seeded plants belonging to grass family. They are grown in areas which are dry like temperate, tropical and subtropical regions. Millets are meant for their excellent thriving capacity and are drought tolerant (Singh *et al*., 2022) [11].

Different varieties of millets are cultivated all over the world. The millet species of the prehistoric era can be grouped into the following nine genera: *Brachiaria, Digitaria, Echinochloa, Eleusine, Panicum, Paspalum, Pennisetum, Setaria,* and *Sorghum.* Browntop millet, known as "Korale" in Kannada, "Karlakki" in Mandya, and "Andukorralu" in Telangana and Andhra Pradesh, is chiefly grown in the rainfed regions of Tumakuru, Chitradurga, and Chikkaballapura in Karnataka (Sravani *et al*., 2020 [14]). To enhance their digestibility, nutrient accessibility, and sensory properties, millet grains are generally pre-processed using techniques such as decortication, malting, fermentation, roasting, flaking, and comminution (Saleh *et al*., 2013) [9].

Understanding optimal processing strategies and health-enhancing modifications is fundamental to employing brown top millet in home consumption and food product innovation. Despite this, there is a notable lack of studies exploring the effects of processing on its physicochemical attributes (Sravani *et al*., 2020 [14]). The dietary shift toward refined flour–based foods in recent decades has reduced the intake of fibre and vital micronutrients, a trend shaped by urban living, modern practices, and lower physical activity. This transition, driven in part by increasing affluence, has been associated with the growing prevalence of overweight and obesity (Sindhi and Jain 2006) [10]. Rising demand for millet-based foods has intensified research on these grains, yet millets are still regarded as traditional or low-status foods due to the lack of convenient ready-to-cook or ready-to-eat options (Sirisha *et al*., 2022) [12].

Accurate knowledge of dimensional properties such as length, width, thickness, and geometric mean diameter is integral to the engineering and optimization of processes, machinery, structural components, and control systems. Information on these physical properties assists engineers in optimizing process and equipment design. They are equally important for selecting proper cleaning and separation units, where key dimensions dictate the appropriate screen perforation size for efficient handling, storage, and processing. Fundamental knowledge of these physical properties aids engineers in designing efficient processes and equipment. These parameters are also crucial for selecting appropriate cleaning and separation machinery, as the primary dimensions determine the suitable screen perforation size required for handling, storage, and processing (Ojediran *et al*., 2010; Sunil *et al*., 2016; Rao *et al*., 2019; Nagaraju *et al*., 2020) [6, 7, 8, 16]. Despite its growing relevance, information on the physical characteristics, cooking quality and functional properties of brown top millet remains limited. Therefore, the present study was undertaken to determine and characterize these physical attributes, cooking quality and functional properties.

Objectives

To evaluate the impact of processing on physical and functional properties of brown top millet.

Materials and Methods Raw Materials

The experiment was conducted in the Department of Food Science and Nutrition at Yuvaraja's College, University of Mysore, Mysuru. The brown top millet used for the present study was procured from local market Mysuru, Karnataka.

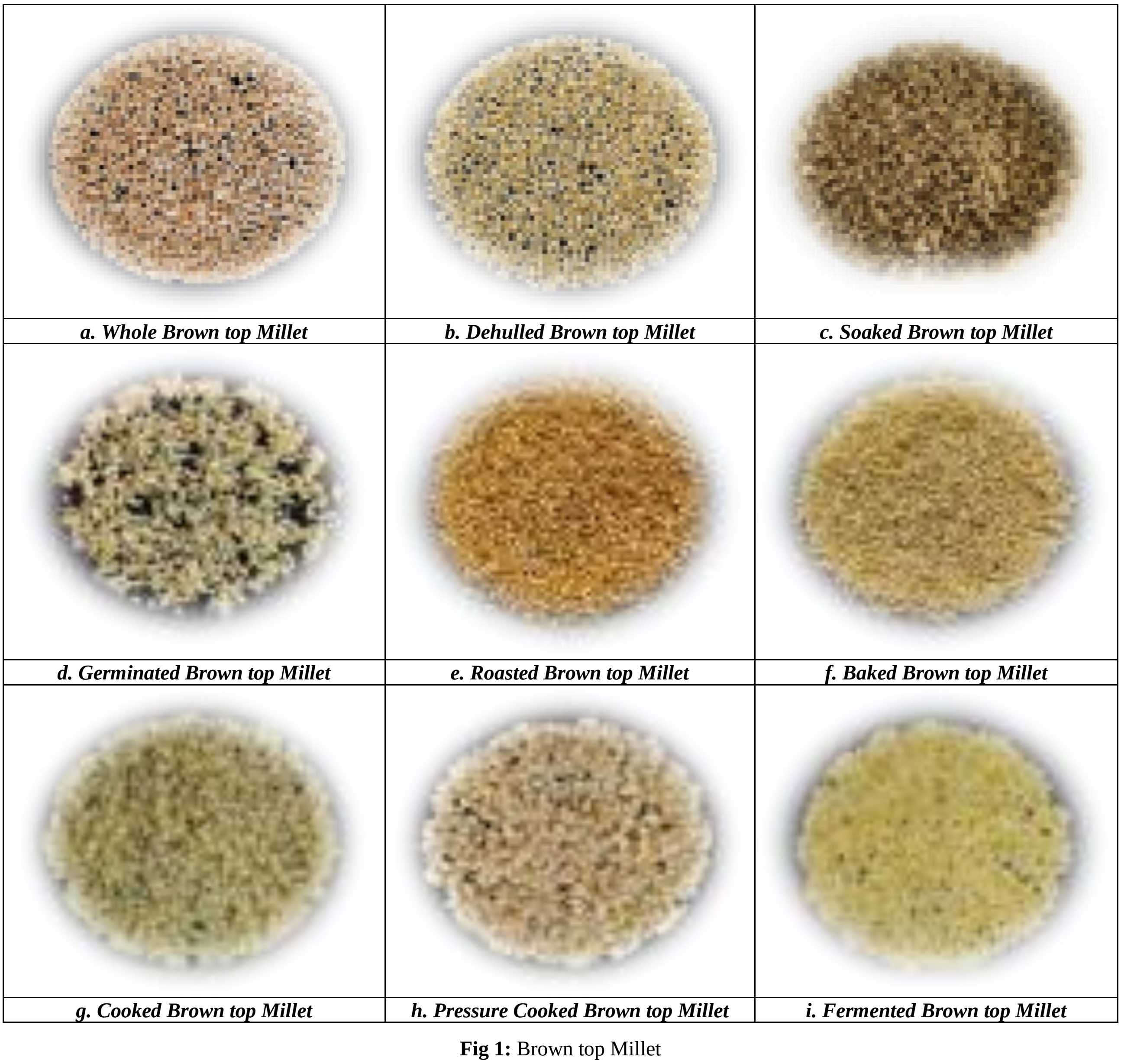
Methods of Processing

The brown top millet grains used for experiment were sorted and cleaned to remove impurities. To determine the impact of processing on physical and functional properties, raw hand pounded whole brown top millet (WBTM), dehulled brown top millet (DBTM), soaked brown top millet (SBTM), germinated brown top millet (GBTM), roasted brown top millet (RBTM), baked brown top millet (BBTM), cooked brown top millet (CBTM), pressure cooked brown top millet (PCBTM) and fermented brown top millet (FBTM) was used.

Table 1: Processing methods applied to brown top millet prior to starch fraction analysis

Processing Method	Optimized Processing Conditions
Whole millet (WBTM)	Cleaned whole grains were used without treatment
Dehulled millet (DBTM)	Cleaned dehulled whole grains were used without treatment
Soaked millet (SBTM)	Cleaned dehulled whole grains were soaked in distilled water (1:3 w/v) for 12 hrs at room temperature
Germinated millet (GBTM)	Cleaned dehulled whole grains soaked for 12 h, germinated for 48hrs at room temperature, then dried
Roasted millet (RBTM)	Cleaned dehulled whole grains dry roasted at 160 °C for 8 min on a roasting pan
Baked millet (BBTM)	Cleaned dehulled whole grains baked at 180 °C for 15 min in a baking oven
Cooked millet (CBTM)	Cleaned dehulled whole grains boiled in water (1:5 w/v) for 20 min at 98 °C
Pressure-cooked millet (PCBTM)	Cleaned dehulled whole grains pressure cooked at 121 °C for 5min
Fermented millet (FBTM)	Cleaned dehulled whole grains slurry fermented naturally for 14hrs at room temperature

The above samples were later dehydrated at 100 °C for 5 hours, ground into flour, passed through a 80µm sieve and stored in airtight container at 4 °C for further analysis.



a. Whole Brown top Millet | *b. Dehulled Brown top Millet* | *c. Soaked Brown top Millet*

d. Germinated Brown top Millet | *e. Roasted Brown top Millet* | *f. Baked Brown top Millet*

g. Cooked Brown top Millet | *h. Pressure Cooked Brown top Millet* | *i. Fermented Brown top Millet*

Fig 1: Brown top Millet

1. Physical Properties

1.1 Length and width ratio: Ten kernels of each variety was taken and arranged them lengthwise and width wise for cumulative measurement in centimeter. The values were recorded in terms of cm (Balasubramanian and Viswanathan, 2010 [2]).

1.2 Bulk density: 100gm of grains was gradually poured to 250ml graduated cylinder by gently tapping until the grain settles uniformly. The volume was recorded and the value was expressed as g/ml (Kumar *et al*., 2018) [3].

1.3 1000 kernel weight: Exactly 1000 grains were counted and the weight was recorded using digital weighing balance. The determined values were expressed in terms of gm (Balasubramanian and Viswanathan, 2010) [2].

1.4 Density: The density was determined by pouring previously weighted 10g of grains into a 50ml graduated cylinder containing 20ml of water. Any air bubbles trapper in between was removed gently and allowed the sample to settle down. The displacement of water was recorded and expressed as gm/ml (Nagaraju *et al*., 2020) [6].

1.5 Porosity: This is calculated using the values of density and bulk density (Nagaraju *et al*., 2020) [6].

$$\text{Porosity } \% = \left(1 - \frac{\text{Bulk Density}}{\text{Particle Density}}\right) \times 100$$

2. Functional Properties

2.1 Water absorption capacity: 1g of sample was weighed and transferred into a centrifuge tube followed by addition of 5ml water. The samples were mixed using a glass rod and allowed to stand for 30min. Centrifuge was performed at 3000rpm for 20min. The supernatant liquid was transferred to a measuring jar and the volume was recorded and expressed as ml of water absorbed by 100g of sample (Janicki and Walczak, 1954).

2.2 Oil absorption capacity: 1g of sample was weighed and transferred into a centrifuge tube followed by addition of 5ml oil. The samples were mixed using a glass rod and allowed to stand for 30min. Centrifuge was performed at 3000rpm for 20min. The supernatant was transferred to a measuring jar and the volume was recorded and expressed as ml of oil absorbed by 100g of sample (Sosulski *et al*., 1976 [13]).

2.3 Swelling power: 0.5 g of sample was in a centrifuge tube and 20 ml of distilled water is added. It is then mixed properly followed by heating to 90°C for 1 hour by mixing periodically. It is then cooled. Centrifugation is done at 5000 rpm for 10 minutes. The volume of supernatant and weight of sediment was noted (Majumdar *et al*., 2023) [4].

$$\text{Swelling Power} = \frac{\text{Weight of the Sediment (g)}}{\text{Initial Sample Weight (g)}} \text{ X100}$$

2.4 Solubility: 0.5 g of sample was taken in centrifuge tube and 20 ml of distilled water was added. The mixture was thoroughly mixed and heated at 90°C for 1 hour by mixing periodically. It is then cooled and centrifuged at 5000 rpm for 10 minutes. The supernatant was separate collected in a dry test tube and transferred to a dry pre weighed petri dish. The petri dish with supernatant was kept in the hot air oven for 110°C. After complete drying, the weight of the petri dish was recorded. It is expressed in % (Amrita *et al*., 2023).

$$\text{Solubility } \% = \frac{\text{Weight of dried residue}}{\text{Weight of Initial Sample}} \text{ X100}$$

3.5 Emulsification capacity: 2g of sample, was added in to 10 ml of distilled water in a measuring cylinder. The height of the solution in the cylinder was measured. The solution was mixed with 5 ml of refined vegetable oil and the resulting mixture was blended using electrical blender for 5 minutes and then poured into centrifugation tube and centrifuged at 2000 rpm for 5min (Maha *et al*., 2012).

$$\text{Emulsification capacity } \% = \frac{\text{Height of emulsion}}{\text{Height of whole layer}} \text{ X100}$$

3.6 Foaming Capacity: 1 g of flour was dissolved in 50 ml distilled water and 7.4 pH was adjusted using 1 N HCl and NaOH, respectively followed by blending for 3 min. Immediately after blending the whole sample was transferred to a 250 ml beaker and the volume of foam was recorded (Mohona and Kavya, 2024).

$$\text{Foaming Capacity (\%)} = \frac{\text{Volume of Foam (ml)}}{\text{Volume of Flour Sample Solution (ml)}} \times 100$$

Result and Discussion

1. Physical Characteristics

Brown top millets were subjected to different processing methods and the processing methods were optimised (Table 1). Differently processed millets were used for the characterisation of physical and functional properties.

1.1 Length and Width ratio

The physical properties of whole, dehulled and processed brown top millets are summarized in Table 2. The findings revealed that length of control whole and dehulled Brown top millet (BTM) was 2.21 ± 0.05mm and 2.04 ± 0.04mm and width was 1.52 ± 0.04mm and 1.41 ± 0.03mm respectively. The length and width of the whole, dehulled and processed BTM were measured using Vernier digital caliper and were found to be in the range of 1.92 ± 0.05mm to 3.02 ± 0.10mm and 1.31 ± 0.04mm to 2.06 ± 0.08mm respectively. The Length and width values were significantly higher for whole BTM, while dehulled and processed BTM showed no significant difference. Similar results were found by Sravani *et al*., (2020); Ramashia *et al*., (2018); Jain and Bal (1997) [14, 17, 18] for length and width of whole and processed brown top millet; finger millet and pearl millet.

1.2 Bulk density

The bulk density of whole and dehulled and processed BTM (Table 2) was found to be significantly decreased from 0.84 ± 0.02 to 0.48 ± 0.01g/ml. It was observed that the bulk density of whole and dehulled BTM was 0.84 ± 0.02g/ml and 0.79 ± 0.01g/ml respectively. It was found that soaking, germination, roasting, baking, cooking and fermentation lead to significant reduction in the bulk density. Similar results were observed by Sravani *et al*., (2020) [14] for bulk density of whole and processed brown top millet.

Table 2: Physical Characteristics of Whole and Processed Brown top Millet

	Length (mm)	Width (mm)	Length and Width ratio	Bulk density (g/ml)	1000 kernel weight (g)	Density (g/ml)	Porosity (%)
WBTM	2.21 ± 0.05	1.52 ± 0.04	1.45 ± 0.03	0.84 ± 0.02	3.28 ± 0.07	1.32 ± 0.03	36.4 ± 1.2
DBTM	2.04 ± 0.04	1.41 ± 0.03	1.45 ± 0.04	0.79 ± 0.01	2.91 ± 0.06	1.29 ± 0.02	38.8 ± 1.1
SBTM	2.28 ± 0.06	1.60 ± 0.05	1.43 ± 0.05	0.72 ± 0.02	3.46 ± 0.08	1.25 ± 0.03	42.4 ± 1.4
GBTM	2.34 ± 0.07	1.58 ± 0.05	1.48 ± 0.04	0.68 ± 0.01	3.14 ± 0.07	1.26 ± 0.03	46.0 ± 1.4
RBTM	2.01 ± 0.04	1.39 ± 0.03	1.45 ± 0.04	0.70 ± 0.02	2.76 ± 0.05	1.34 ± 0.03	47.8 ± 1.3
BBTM	1.98 ± 0.05	1.36 ± 0.04	1.46 ± 0.05	0.66 ± 0.02	2.64 ± 0.06	1.30 ± 0.02	49.2 ± 1.5
CBTM	2.86 ± 0.09	1.94 ± 0.07	1.47 ± 0.06	0.54 ± 0.01	4.92 ± 0.12	1.18 ± 0.02	54.2 ± 1.8
PCBTM	3.02 ± 0.10	2.06 ± 0.08	1.47 ± 0.05	0.48 ± 0.01	5.38 ± 0.15	1.15 ± 0.02	58.3 ± 2.0
FBTM	1.92 ± 0.05	1.31 ± 0.04	1.47 ± 0.05	0.61 ± 0.01	2.58 ± 0.06	1.21 ± 0.02	49.6 ± 1.6

1.3 1000 kernel weight
Notable difference was observed in 1000 kernal weight of the millet. Whole and processed BTM showed 3.28 ± 0.07g and 2.91 ± 0.06g respectively. There was a slight increase in weight after soaking, germination and cooking. Whereas, roasting, baking and fermentation exhibited slightly lower weights; might be due to varying moisture content. Similar values were reported by Manasa and Naik (2024), Sravani *et al*., 2020 [14, 19] for barnyard millet and brown top millet respectively.

1.4 Density
The mean density of whole and dehulled BTM was 1.32 ± 0.03g/ml and 1.29 ± 0.02g/ml respectively. Slight changes in density were noted with different processing methods; might be due to germination and dehulling decreases density as grains may become more smoother and pack less. Similar findings were exhibited by Sravani *et al*., (2020), Nagaraju *et al*., (2020) [6, 14] and Srinivas *et al*. (2019) for brown top millet.

1.5 Porosity
Processing has a greater impact on porosity. Whole and dehulled BTM showed mean porosity values of 36.4 ± 1.2% and 38.8 ± 1.1% respectively. Notable increase in porosity values was observed with respect to different processing methods. Similar values for porosity were reported by Sravani *et al*., (2020 [14]), Balasubramanian and Viswanathan, (2010) [2] for brown top millet and minor millets.

2. Functional Properties of BTM flours
The Functional properties of whole, dehulled and processed brown top millet flour are summarized in (Table 3)

2.1 Water absorption capacity
The Water absorption capacity of the grain increased along with processing. It ranged from 1.18 ± 0.05g/g to 3.68 ± 0.11g/g. Presence of husk in whole millet reduces hydration whereas dehulling leads to partial exposure of endosperm and more access to water for penetration. Where as in germination, due to enzymatic breakdown, partial proteolysis occurs and enhances water binding sites. Thus, increases water absorption. The water absorption capacity of GBTM is 2.48 ± 0.08g/g. Similar values were reported by Sunagar and Sreerama (2024) [15] for brown top millet.

Table 3: Functional Properties of Whole and Processed Brown top Millet Flour

Processing method	Water absorption capacity (g/ml)	Oil absorption capacity (g/ml)	Swelling power (g/g)	Solubility (%)	Emulsifying capacity (%)	Foaming capacity (%)
WBTMF	1.42 ± 0.06	1.22 ± 0.05	4.8 ± 0.2	6.4 ± 0.3	22.6 ± 1.1	8.2 ± 0.4
DBTMF	1.68 ± 0.05	1.28 ± 0.04	5.6 ± 0.3	7.8 ± 0.4	26.4 ± 1.2	10.4 ± 0.5
SBTMF	2.12 ± 0.07	1.35 ± 0.05	6.8 ± 0.3	9.6 ± 0.5	30.2 ± 1.3	13.6 ± 0.6
GBTMF	2.48 ± 0.08	1.39 ± 0.05	7.4 ± 0.3	11.8 ± 0.6	34.6 ± 1.4	17.2 ± 0.7
RBTMF	1.26 ± 0.04	1.48 ± 0.06	4.6 ± 0.2	6.1 ± 0.3	24.8 ± 1.1	9.4 ± 0.4
BBTMF	1.18 ± 0.05	1.43 ± 0.05	4.9 ± 0.2	6.6 ± 0.3	25.6 ± 1.2	9.8 ± 0.4
CBTMF	3.24 ± 0.09	1.33 ± 0.05	8.4 ± 0.4	14.2 ± 0.7	32.6 ± 1.4	14.8 ± 0.6
PCBTMF	3.68 ± 0.11	1.30 ± 0.04	8.8 ± 0.4	15.1 ± 0.7	31.8 ± 1.3	13.9 ± 0.6
FBTMF	2.94 ± 0.09	1.41 ± 0.06	7.6 ± 0.4	12.6 ± 0.6	35.8 ± 1.5	18.6 ± 0.8

2.2 Oil absorption capacity
The OAC of whole, dehulled and processed samples ranged from 1.22 ± 0.05g/ml to 1.48 ± 0.06g/ml. The higher OAC observed in processed samples could be attributed to the increase in lipophilic constituents during germination and the structural modification of proteins, including dissociation and denaturation, which expose hydrophobic amino acid residues and enhance the oil absorption capacity of millet flour (Manasa and Naik 2024) [19]. Similar results were reported by Sosulski *et al*., (1976) and Manasa and Naik (2024) [13, 19] functional properties of rapeseed flours and barnyard millet flours respectively.

2.3 Swelling power
The swelling power of brown top millet increased remarkably upon processing. The mean swelling power value ranged from 4.8 ± 0.2g/g to 8.8 ± 0.4g/g for whole BTM and pressure cooked BTM respectively. Ocheme and Chinma (2008) and (Majumdar *et al*., 2023) [4] also reported increase in swelling power for sorghum flour and brown top millet flour respectively.

2.4 Solubility
The solubility of whole BTM was observed to be 6.4 ± 0.3%. Solubility reflects the presence of low-molecular-weight soluble components such as degraded starch and proteins in flour. Processing methods like soaking, germination, cooking, and fermentation may enhance solubility due to enzymatic hydrolysis and partial starch gelatinization, which increase the release of soluble carbohydrates and peptides. Conversely, dry heat treatments

such as roasting and baking may reduce solubility due to the formation of insoluble complexes and Maillard reaction products (Adebowale et. al., 2005; Kinsella and Melachouris, 1976 [23, 24]; Mbithi *et al*., 2000). Similar values were expressed by Amrita *et al*., (2023) and Manasa and Naik (2024) [19] for browntop and barnyard millet flours.

2.5 Emulsification capacity

The increase in emulsifying capacity observed in processed brown top millet flours, particularly in germinated (34.6 ± 1.4%) and fermented samples (35.8 ± 1.5%), may be attributed to structural modifications of proteins that enhance their surface activity and ability to stabilize oil–water interfaces. Processing treatments can expose hydrophobic and hydrophilic groups of proteins, thereby improving emulsification properties (Kinsella and Melachouris, 1976 [23]). Similar values were reported by Sunagar and Sreerama (2024) [15] and Maha *et al*., (2012) for brown top millet and pearl millet flours respectively.

2.6 Foaming Capacity

Foaming capacity varied among the processed samples and was higher in germinated (17.2 ± 0.7%) and fermented (18.6 ± 0.8%) flours due to partial protein denaturation and increased protein flexibility during processing. These changes enhance the ability of proteins to adsorb at the air–water interface and form stable foams (Sathe and Salunkhe, 1981) [26]. Similar values were observed by Mohona and Kavya (2024) for major and minor millet flours.

Summary and Conclusion

The present study evaluated the effect of various processing methods on the physical and functional properties of brown top millet (*Brachiaria ramosa*). Whole, dehulled, soaked, germinated, roasted, baked, cooked, pressure-cooked, and fermented samples were analyzed to understand the influence of processing on grain characteristics and flour functionality. The results showed that dehulling and processing significantly affected grain dimensions, bulk density, kernel weight, density, and porosity. Bulk density decreased while porosity increased in most processed samples, particularly in cooked and pressure-cooked grains due to structural changes in the grain matrix. Functional properties of the flours were also notably influenced by processing methods. Germination, cooking, and fermentation enhanced water absorption capacity, swelling power, solubility, and foaming capacity due to enzymatic hydrolysis and structural modification of starch and proteins. Oil absorption capacity was comparatively higher in roasted and baked samples, indicating increased interaction with lipophilic components. Emulsifying and foaming capacities were highest in germinated and fermented flours, suggesting improved protein functionality. Overall, the findings indicate that simple processing techniques can effectively modify the physicochemical and functional characteristics of brown top millet, thereby improving its potential for incorporation in nutritious and value-added millet-based food products.

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