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Research Article

COMPARATIVE ANALYSIS OF PHYSICAL, FUNCTIONAL, AND NUTRITIONAL PROPERTIES OF EMMER WHEAT (*Triticum dicoccum*) AND COMMON WHEAT (*Triticum aestivum*) SEMOLINA

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Abstract: This study conducted a thorough comparative analysis of semolina derived from two wheat varieties, Emmer wheat (*Triticum dicoccum*) and Common wheat (*Triticum aestivum*). Emmer wheat exhibited distinctive physical traits, including a reddish-brown colour, smaller length (8.736mm), and a higher thousand kernel weight (35.3grams) compared to common wheat. Nutritional analysis indicated that emmer wheat had lower moisture content (10.13%), higher fat content (2.8%), significantly higher protein content (19.01%), lower gluten content (8.72%), and higher ash content (2.47%) compared to common wheat. Emmer wheat semolina displayed unique functional properties, with slightly lower water absorption capacity, higher oil absorption capacity, lower swelling capacity, and significantly higher solubility and water holding capacity. Emmer wheat semolina was darker in colour with increased redness and reduced yellowness compared to common wheat semolina. Cooking characteristics showed that emmer wheat semolina generally required longer cooking times and reached a saturation point at a 1:9 semolina-to-water ratio.

Keywords: *Emmer wheat, Common wheat¸ Functional properties, Nutritional, Cooking*

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Introduction

India is the second largest producer of wheat in the world, with production hovering around 68–75 million tons for the past few years. The most recent projection for wheat production in the year 2020 stands at approximately 87.5 million tons, which represents an increase of approximately 13 million tons when compared to the previous record production of 75 million tons achieved during the 1999-2000 crop season. Since the turn of the millennium, India has encountered significant difficulties in replicating this record production figure, thereby presenting a substantial challenge in preserving food security amidst its expanding population [1]. Emmer wheat, known scientifically as *Triticum turgidum* ssp. *dicoccum*, is an annual plant primarily characterized by self-pollination, featuring large, elongated grains and brittle ears. This species possesses two homologous chromosome sets, denoted as BBAA, likely arising from spontaneous interspecific hybridization and the selective propagation of desirable morphological traits. The contribution of two wild diploid grass species is anticipated in the origin of emmer wheat. *Triticum urartu* (AA) is presumed to have acted as the pollen donor, while the female parent likely belonged to the S genome group of Aegilops, possibly *Aegilops speltoides* Tausch, which contributed to the B genome. This hybridization event gave rise to the tetraploid wild species *Triticum turgidum* ssp. dicoccoides ($2n = 4x = 28$), characterized by the hard, raised form of the cultivated tetraploid wheat [2]. In India, the production share of *Triticum dicoccum* (emmer wheat) accounts for 1% of the total wheat production, while *Triticum aestivum* (common wheat) holds the majority share of 95%, and *Triticum durum* (durum wheat) contributes 5%. The states of Karnataka, Maharashtra, and Tamil Nadu are the primary producers of *Triticum dicoccum*, cultivating and harvesting this wheat variety. Emmer wheat, a type of ancient wheat, is rich in protein, containing 15.4% protein content, higher than common wheat which has 11.0%. It also contains a significant level of lipids, with 2.43% lipids, compared to 1.78% in common wheat. Emmer wheat has a high ash content of 2.16%, and its crude fiber content is notably higher than that of common wheat. Total carbohydrate concentration in emmer wheat is relatively lower compared to common wheat and spelt.

Emmer wheat stands out for its protein and lipid content, making it a valuable and nutritious grain option [3]. *Triticum dicoccum* wheat, an ancient wheat species, is becoming increasingly popular due to its suggested health benefits and suitability for organic farming. In certain regions, traditional foods made from *dicoccum* wheat are preferred for their superior taste, texture, and flavor. This wheat variety is abundant in bioactive compounds, and its starch is known for its slow digestibility. However, the content and composition of these bioactive compounds may vary based on factors such as geographical location, seasonal changes, wheat varieties, and analytical methods used [4].

Semolina, which is the coarsely purified middlings of wheat, serves as a fundamental ingredient in the creation of numerous traditional Indian dishes. These include both sweet and savory options, and it is commonly used in breakfast and snack foods like upma, kesaribath, chiroti, ladu, and semia (vermicelli). Upma, also known as uppuma or uppittu, is a South Indian breakfast dish prepared by cooking dry-roasted semolina into a thick porridge. The addition of various seasonings and vegetables during the cooking process allows for customization based on individual preferences [5].

Semolina is a versatile ingredient widely used in the food industry, with its quality specifications varying across regions to suit different processing practices and end-product requirements. Semolina plays a crucial role in the production of pasta, where its granulation and moisture content specifications can differ based on the type of pasta-processing system. High-quality pasta, processed traditionally with slow and extended mixing and drying at moderate temperatures, demands specific semolina characteristics. Conversely, high-throughput pasta production facilities in Europe often require finer semolina granulation specifications [6].

Materials and Methods

Sample Collection

The Emmer wheat (Khapli wheat) and Common wheat were collected from the Wheat and Maize Research Unit, VNMKV, Parbhani, Maharashtra.

Physical Properties

The physical properties such as thousand kernel weight, seed dimensions (length and width), and bulk density, were determined with the methodologies given by Al-Mahasneh and Rababah (2007) [7]. Porosity was calculated following the procedure outlined by Varnamkhasti, *et al.,* (2008) [8], while true density and the angle of repose were determined by Sunil*, et al*., (2016) [9].

Proximate Analysis and Gluten content

The moisture, protein, fat, crude fibre, and carbohydrate content of wheat seed samples were analyzed by A.O.A.C. (2005) [10] methods while ash was determined by A.O.A.C. (1990) [11] method. Gluten content was determined by AACC (2000) [12] method.

Milling

In the production of semolina, the wheat grains were subjected to a thorough cleaning process to remove lighter foreign matter, followed by washing to eliminate any remaining impurities. The grains were then pre-conditioned by wrapping them in a cloth, allowing moisture absorption to soften the outer layer. Subsequently, the grains were milled to produce semolina, using a 14-mesh sieve to achieve the desired consistency.

Sieve Analysis

In analytical sieve shaker, the sample (100 g) was subjected to granulometry equipped with 18, 22, 25, 30 and 36 mesh sieves (B.S.S). Place 100 g of sample on top sieve and stir for 20 minutes. The sample retained on each sieve was carefully measured and calculated as a per cent of the actual sample weight and measured as retention value according to the American Association of Cereal Chemists approved methods 66-20 [12].

Colour Characteristics

The semolina mix's colour analysis was conducted using a Hunter Lab Colour Flex 45/0 optical sensor, calibrated against a standard light yellow reference tile (L^* = 77.14, a^* = 1.52, b^* = 21.88), with L^*, a^*, b^*, Chroma and hue angle values recorded to assess lightness, redness, and yellowness, where L^* represents lightness (L^* = 0 for black, L^* = 100 for pure white), a^* indicates redness (+ for red, - for green), and b^* signifies yellowness (+ for yellow, - for blue) [13]. Moreover, the analysis of colour was done in the Department of Horticulture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.

Functional Properties

Water absorption and oil absorption capacities were determined using the methods of Ige, *et al.,* (1984) [14] and Sosulski, *et al.,* (1976) [15] respectively, while swelling power and solubility were determined by the method described by Iyer and Singh (1997) [16]. The water-holding capacity of the flour was measured by the modified procedure described by Poshadri, *et al.,* (2023) [17].

Quality of Cooked Semolina

The study determined the water-to-raw semolina ratios needed for well-cooked semolina by varying the ratio from 1:1 to 1:12 (v/v), visually assessing cooking completion, texture, and water evaporation time after boiling water was added to 10 grams of raw semolina in a glass beaker [18].

Statistical analysis

All analyses unless otherwise specified, were done in triplicate. Statistical significance was established using one-way analysis of variance (ANOVA), and data were reported as mean ± standard deviation. Mean comparison and separation were done using Tukey's test ($P < 0.05$). Statistical analysis was carried out using the Jamovi 2.4.11 software (https://www.jamovi.org/).

Results and Discussion

Physical properties of wheat grains

The design of machinery and equipment for harvesting, post-harvesting, milling processes, and food processing relies heavily on specific physical characteristics. These characteristics play a vital role in various operations such as separation, sorting, and transfer. Various physical parameters of wheat were examined, including colour, length, width, bulk density, true density, thousand kernel weight, porosity, and angle of repose, and the results are presented in [Table-1].

Emmer wheat exhibited a reddish-brown colour, while common wheat displayed a straw yellow to amber colour. In terms of length, emmer wheat measured approximately 8.736 mm, which was significantly different ($p < 0.05$) from the length of common wheat at 7.12 mm.

Table-1 Physical Properties of Emmer and Common Wheat

Parameter	Emmer Wheat	Common Wheat
Colour	Reddish Brown	Straw yellow to amber
Length (mm)	8.736 ± 0.4^a	7.12 ± 0.5^b
Width (mm)	2.53 ± 0.1^a	2.43 ± 0.3^a
Thousand Kernel Weight (g)	35.3 ± 1.0^a	46.367 ± 0.8^b
True Density (g/ml)	1.27 ± 0.01^a	1.25 ± 0.5^a
Bulk Density (g/ml)	0.76 ± 0.05^a	0.85 ± 0.01^b
Porosity (%)	39.88 ± 0.7^a	31.467 ± 0.9^b
Angle of repose (°)	24.92 ± 1.1^a	25.4 ± 0.6^a

Values expressed are average ±SD.

Means in the rows with different superscripts are significantly ($p < 0.05$) different.

The width of emmer wheat was about 2.53 mm, which was not significantly different ($p > 0.05$) from the width of Common Wheat at 2.43 mm. Notably, the thousand kernel weight of emmer wheat was determined to be 35.3 grams, which is significantly ($p < 0.05$) higher than common wheat (46.367 grams). True density for emmer wheat was approximately 1.27 g/ml, and for common wheat, it was 1.25 g/ml, with no significant difference ($p > 0.05$) between the two. However, bulk density showed a significant difference ($p < 0.05$), with emmer wheat at 0.76 g/ml and common wheat at 0.85 g/ml. Emmer wheat exhibited higher porosity at 39.88%, significantly different ($p < 0.05$) from the porosity of common wheat at 31.467%. The angle of repose was found to be 24.92° for emmer wheat and 25.4° for common wheat, with no significant difference ($p > 0.05$) observed. These detailed measurements provide valuable information about the physical attributes of the cereal grains, aiding in further understanding the properties and potential applications. Similar results were reported for the physical characteristics of wheat grains [19].

Proximate Analysis of wheat grains

The analysis was conducted on wheat of both emmer wheat and common wheat to determine key parameters such as moisture content, protein, fat, carbohydrates, crude fiber, and ash. The results of this analysis are presented in [Table-2] as shown below.

Table-2 Proximate Analysis of wheat grains

Parameters	Emmer Wheat	Common Wheat
Moisture (%)	10.13 ± 0.03^a	11.46 ± 0.3^b
Fat (%)	3.79 ± 0.02^a	2.48 ± 0.04^b
Protein (%)	19.01 ± 0.07^a	16.06 ± 0.07^b
Gluten (%)	8.72 ± 0.13^a	13.83 ± 0.35^b
Ash (%)	2.47 ± 0.03^a	1.49 ± 0.01^b
Carbohydrates (%)	64.55 ± 0.08^a	68.49 ± 0.3^b
Fibre (%)	5.05 ± 0.01^a	1.71 ± 0.02^b

Values expressed are average ±SD.

Rows with different superscripts in the means are significantly different ($p < 0.05$).

The proximate analysis of wheat grains, specifically comparing emmer wheat (*Triticum dicoccum*) and common wheat (*Triticum aestivum*), reveals notable differences in key nutritional parameters. Emmer wheat showed a moisture content of 10.13% which is significantly ($p < 0.05$) lower compared to common wheat (11.46%). This difference in moisture levels can impact the texture and storability of the grains. In terms of fat content, emmer wheat showed a significantly ($p < 0.05$) higher value than Common wheat. This divergence in fat content can influence the flavor and nutritional profile of products derived from these grains. As reported in the other studies, the lipid content of emmer in nine emmer genotypes was found to be 2.8% (dry basis) which was higher than soft wheat varieties, all grown under identical agronomical conditions [20].

The protein content in emmer wheat (19.01%) was also found to be significantly ($p < 0.05$) higher than that in common wheat (16.06%). This disparity may influence the suitability of the grains for various food applications, especially those requiring higher protein content. Blanco, *et al*., (1990) [21] discovered a protein content range of 8.7 to 18% in fifty emmer accessions, while assessments by Blanco, *et al.,* (1990) [21] in Apulia, southern Italy, over two years (1992-1993), found a mean protein content of 20.6-21.9% in emmer landraces. However, the gluten content was significantly ($p < 0.05$) lower in emmer wheat (8.72%) compared to common wheat (13.83%). Ash content, representing the mineral content, showed significantly ($p < 0.05$) higher in emmer wheat at approximately 2.47%, whereas common wheat has a lower ash content of around 1.49%. From the studies it was found that emmer wheat typically had a higher ash content (>2.0% dry basis) compared to durum and soft wheat (1.7 – 1.8% dry basis), with the lower ash content in modern wheat cultivars being a result of selective breeding to improve milling yield, as evidenced by a range of 1.75% to 2.33% dry basis (mean value of 2.00% dry basis) in 50 emmer accessions [22]. Carbohydrate levels were found to be higher in common wheat, approximately 68.49%, compared to emmer wheat 64.55% carbohydrates. The variation in carbohydrate content can impact the energy and glycemic properties of products made from these grains.

The fiber content shows a significant difference ($p < 0.05$) between the two wheat varieties. Emmer wheat has a notably higher fiber content of approximately 5.05%, while common wheat contains a lower fiber content of about 1.71%. This discrepancy in fiber content can influence the digestive and health benefits associated with consuming products derived from these grains. The proximate analysis of these wheat varieties highlights their distinct nutritional profiles, indicating that emmer wheat tends to have higher protein, fat, ash, and fiber content, while common wheat exhibits higher moisture and carbohydrate levels. Similar results reported emmer wheat is a highly nutritious cereal with moderate moisture content, high protein, low fat, moderate ash, high crude fiber, and a substantial amount of total carbohydrates, making it a healthy choice due to its rich protein, carbohydrate, and mineral content [4].

Milling Yield of wheat grains

The Milling yield of Emmer wheat (*Triticum dicoccum*) and Common wheat (*Triticum aestivum*) varieties are presented in [Table-3].

Table-3 Milling Yield of Wheat Grains

Wheat	Total weight (g)	% yield of semolina	% yield of flour	% yield of bran
Emmer Wheat	2000	53	26.5	17.5
Common Wheat	2000	58	31.5	9.5

The data on the yield of semolina, flour, and bran from two different types of wheat, emmer wheat (*Triticum dicoccum*) and common wheat (*Triticum aestivum*) is presented in [Table-3]. Each wheat type was subjected to a total weight of 2000 grams, and the percentage yield of each component was recorded. For emmer wheat, the semolina yield was 53%, the flour yield was 26.5%, and the bran yield was 17.5%. In contrast, common wheat exhibited a slightly higher semolina yield at 58%, a higher flour yield at 31.5%, and a lower bran yield at 9.5%.

The percentages from [Table-3] provide valuable information about the milling characteristics of the two wheat types. Common wheat yielded a higher percentage of semolina and flour compared to Emmer Wheat, suggesting that it may be more suitable for semolina and flour production. Emmer wheat, on the other hand, yielded a higher percentage of bran, which is the outer layer of the wheat kernel and contains dietary fiber and nutrients.

These findings align with the discussions regarding the preference for common wheat in semolina production due to its higher gluten content and better milling characteristics [23]. In other studies, the semolina yield varied among different wheat varieties, with the highest semolina yield observed for the variety PDW 215 at 62.0% and the lowest for WH 896 at 57.3% [24]. In a standardized process using an ultra-grinding mill, semolina preparation from sorghum grain yielded between 46.51% and 54.29%, with the highest yield obtained from Hybrid CSH-15R, and the starch content in semolina ranged from 59.93% to 66.43% [25].

Particle size distribution of semolina

The analysis for particle size distribution was conducted using different mesh sizes (denoted in B.S.S, British Standard Sieve). [Table-4] below provides the results of a particle size distribution or sieve analysis of two types of semolina from emmer wheat and common wheat. It presents both the material retained on each sieve and the material that passed through.

Table-4 Particle size distribution or sieve analysis of semolina

Mesh No. (B.S.S)	Material retained (%)	
	Emmer Wheat	Common Wheat
18 (850 µm)	0.91 ± 0.01^{aA}	1.29 ± 0.01^{bA}
22 (710 µm)	6.58 ± 0.01^{aB}	2.61 ± 0.01^{bB}
25 (600 µm)	17.69 ± 0.01^{aC}	23.88 ± 0.03^{bC}
30 (500 µm)	56.24 ± 0.12^{aD}	43.91 ± 0.03^{bD}
36 (425 µm)	11.77 ± 0.02^{aE}	22.32 ± 0.04^{bE}
	Material Passed (%)	
Pan	6.8 ± 0.02^{aF}	6.03 ± 0.05^{bF}

Values expressed are average ±SD.
Rows with different superscripts in the means are significantly different ($p < 0.05$).
Columns with different superscripts in the means are significantly different ($p < 0.05$).

Significant differences ($p < 0.05$) were observed both within the rows and columns of the table. When comparing the two wheat varieties of the same sieve size, it was found that there were significant differences ($p < 0.05$) in the percentage of material retained. When using an 18 (850$_{µm}$) mesh, 0.91% of the material was retained for emmer wheat, while 1.29% of the material was retained for common wheat. When the mesh size was reduced to a finer 22 (710 $_{µm}$) mesh, the retention increased significantly, with 6.58% for emmer wheat and 2.61% for common wheat. At a further reduction in mesh size to 25 (600 $_{µm}$), emmer wheat retained 17.69%, whereas common wheat retained 23.88%. Most semolina particles passed through the 25 (600 $_{µm}$) mesh. However, most emmer wheat particles were retained through the 30 (500$_{µm}$) mesh, with a retention of 56.24%, while common wheat had 43.91% retention. The 36 (425$_{µm}$) mesh showed 11.77% retention for emmer wheat and 22.32% for common wheat. Additionally, a portion of the material passed through the finest mesh (425$_{µm}$), with 6.8% for emmer wheat and 6.03% for common wheat which was collected at the bottom of the pan. The best quality halwa was achieved using semolina with a particle size of 500$_{µm}$ for 56% of the semolina material, emphasizing the importance of particle size distribution in determining product quality.

Similarly, when comparing two sieve sizes within the same wheat variety, significant differences ($p < 0.05$) were noted. From [Table-4], at the 25 (600$_{µm}$) mesh size, emmer wheat retained 17.69% of the material, whereas at the 30 (500$_{µm}$) mesh size, it retained 56.24%. This significant difference suggests variations in the particle size distribution as the material passes through different sieve sizes for the same wheat type.

The particle size distribution curve as depicted in [Fig-1] represents the particle size distribution of both emmer wheat and common wheat semolina samples. It shows the percentage of material retained on each mesh size and compares the distribution of particle sizes between the two samples. The difference in particle size distribution between durum wheat semolina and egg powder can impact hydration properties, with semolina showing a mono-modal distribution predominantly above 250$_{µm}$ and egg powder exhibiting a modified mono-modal distribution between 250$_{µm}$ and 180$_{µm}$, potentially allowing for more uniform hydration during dough formation and drying [26].

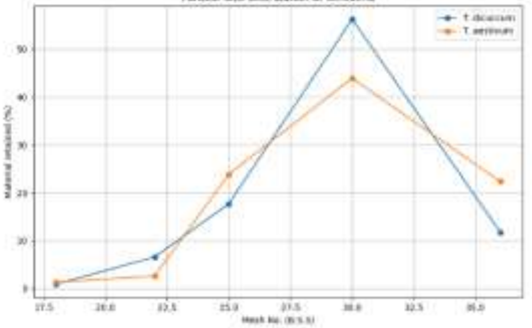

Fig-1 Particle size distribution curve of Emmer wheat (*Triticum dicoccum*) and Common wheat (*Triticum aestivum*) semolina

Similar results of particle size distribution analysis of semolina show that most of the semolina particles were in the size range of $250_{\mu m}$ to $600_{\mu m}$ [27]. The particle size distribution of semolina from different wheat varieties showed variations, with varying percentages of semolina particles falling into specific size ranges, such as $+500_{\mu m}$, $+425_{\mu m}$, $+250_{\mu m}$, $+180_{\mu m}$, $+150_{\mu m}$, and below $150_{\mu m}$, demonstrating distinct characteristics among the varieties studied [24]. The traditional pasta-making process relies on coarse-particle semolina, which is typically produced in traditional durum mills through three granulations such as semolina I ($630–200_{\mu m}$), semolina II and middlings ($400–125_{\mu m}$), and semolina II and middlings II ($315–125_{\mu m}$), with all three granulations containing less than 2% of flour ($<125_{\mu m}$), resulting in a total semolina yield of approximately 68%, subject to the quality of durum wheat [6].

Colour Characteristics

The colour characteristics of semolina from two different varieties emmer wheat (*Triticum dicoccum*) and common wheat (*Triticum aestivum*) are summarized in [Table-5]. The colour characteristics are expressed using the CIELAB colour space parameters, including L*, a*, b*, C*, and h* illustrating differences in lightness, tint, hue, chroma, and dominant colour direction between the two varieties of semolina.

Table-5 Colour Characteristics of Semolina

Parameter	Emmer wheat semolina	Common wheat semolina
L*	75.83 ± 0.02^a	82.62 ± 0.02^b
a*	3.23 ± 0.01^a	1.82 ± 0.02^b
b*	19.45 ± 0.09^a	23.38 ± 0.02^b
C*	19.69 ± 0.01^a	23.48 ± 0.01^b
h*	80.55 ± 0.02^a	85.55 ± 0.03^b

Values expressed are average ±SD.
Columns with different superscripts in the means are significantly different (p < 0.05).

Emmer wheat showed a significantly lower ($p < 0.05$) L* value (75.83) compared to common wheat (82.62), indicating that emmer wheat is darker in colour. The a* value for emmer wheat (3.23) was also significantly ($p < 0.05$) higher than that of common wheat (1.82), suggesting a more pronounced redness in emmer wheat. Similarly, emmer wheat exhibited a lower b* value (19.45) compared to common wheat (23.38), indicating a reduced yellowness in emmer wheat. The C* value for emmer wheat (19.69) was significantly ($p < 0.05$) lower than that of common wheat (23.48), suggesting a lower colour intensity in emmer wheat. Lastly, the h* value for emmer wheat (80.55) was significantly ($p < 0.05$) lower than that of common wheat (85.55), indicating a difference in the hue angle between the two varieties.

The colour characteristics of semolina derived from emmer wheat and common wheat vary significantly, with emmer wheat generally being darker, more red, less yellow, and having lower colour intensity compared to common wheat. These differences are statistically significant ($p < 0.05$), highlighting the distinct colour profiles of the two types of wheat. Similar results of the colour values of durum wheat semolina exhibited duller colour with lower brightness and greater redness, while also showing higher yellowness [28].

Functional Properties

Functional properties play a crucial role in determining the suitability of semolina for various food and industrial applications. Comparative analysis of the functional properties of semolina derived from two different wheat varieties, emmer wheat (*Triticum dicoccum*) and common wheat (*Triticum aestivum*) [Table-6].

Table-6 Functional properties of semolina

Parameters	Emmer wheat semolina	Common wheat semolina
Water absorption capacity (g/g)	1.75 ± 0.04^a	2.0 ± 0.17^a
Oil absorption capacity (g/g)	2.17 ± 0.17^a	1.81 ± 0.14^a
Swelling capacity (%)	53.26 ± 1.00^a	62.45 ± 0.55^b
Solubility (%)	3.73 ± 0.25^a	2.69 ± 0.43^b
Water holding capacity (g/g)	3.13 ± 0.01^a	2.48 ± 0.01^b
Rehydration ratio	4.563 ± 0.001^a	4.10 ± 0.002^b

Values expressed are average ±SD.
Columns with different superscripts in the means are significantly different (p < 0.05).

Common wheat exhibited a slightly higher water absorption capacity value of 2.0 g/g compared to emmer wheat's 1.75 g/g, suggesting that common wheat semolina had a greater ability to absorb water. Gluten, which is primarily composed of glutenin and gliadin proteins, can absorb and hold water. Higher gluten content generally means that there are more proteins available to interact with water. These proteins can form a hydrated network that traps and holds water, leading to increased water absorption capacity [29].

In another study it was observed that the addition of gliadins (a gliadin-rich fraction) decreased the dough's peak height and water absorption capacity, indicating a weakening of the dough. Conversely, the addition of glutenins increased the peak height, demonstrating a strengthening effect on the dough and higher water absorption capacity [30]. The study found that the content of gliadins varied across the species, with common wheat having the lowest content (4.7 g/100g) and emmer, spelt, and durum wheat having the highest (7.0 g/100g). However, einkorn and emmer had the lowest glutenin content (0.8 and 1.1 g/100g, respectively), while durum wheat, spelt, and common wheat had about twice the amount (2.0-2.2 g/100g) [31].

The oil absorption capacity of emmer wheat was found to be higher than common wheat with a value of 2.17 g/g, while common wheat recorded 1.81 g/g. This indicated that emmer wheat semolina had a higher affinity for absorbing oils, making it potentially more suitable for certain fried or oil-based preparations. It was observed that when analyzing dough with 38% water content the products with lower gluten content absorbed more oil. Products with 8% gluten content absorbed significantly more oil than those with 12% gluten content [32]. A similar trend has been observed in water absorption capacity and oil absorption capacity [33]. These differences in water and oil absorption capacities between the two wheat types were not statistically significant ($p > 0.05$).

The swelling capacity of Common Wheat semolina was notably higher at 62.45 % compared to Emmer Wheat's 53.26 %. The observed variation in swelling capacity was statistically significant ($p < 0.05$). The difference could be attributed to the lower gluten content in emmer wheat semolina, as discussed [34]. This implied that common wheat semolina could expand and absorb liquids to a greater extent during cooking, potentially resulting in a softer and more voluminous product. Emmer wheat semolina demonstrated a solubility rate of 3.73 %, while common wheat recorded a slightly lower value of 2.69 ± 0.43%. This difference in solubility was statistically significant ($p < 0.05$), with emmer wheat demonstrating a significantly higher tendency to dissolve in water. Oladunmoye, *et al.,* (2014) [35] observed a decline in the solubility of wheat semolina as it was replaced with cassava starch. This implies that the solubility decreased as cassava starch, which is a starch-rich ingredient, was incorporated into the mixture. The difference in solubility could also be attributed to the higher gluten content in common wheat semolina. This is because high levels of gluten can limit the solubility of starch by forming a network that restricts the starch's ability to dissolve in water [35].

Furthermore, emmer wheat semolina exhibited a higher water-holding capacity of 3.13 ± 0.01 g/g compared to common wheat's 2.48 ± 0.01 g/g. This disparity in water holding capacity was statistically significant ($p < 0.05$) and attributed to the higher dietary fiber percentage in emmer wheat semolina, as greater dietary fiber content generally resulted in higher water holding capacity. Dietary fiber, being a hydrophilic component, can effectively contribute to an increase in the ability to hold water. Pentosans are an example of hydrophilic compounds that can absorb a significant amount of water [36].

This suggested that emmer wheat semolina could retain more water, which could lead to improved texture and moisture retention in food products. The rehydration ratio of emmer wheat semolina was higher at 4.563 compared to common wheat's 4.09. The difference in rehydration ratio between the two wheat types was not statistically significant ($p > 0.05$). The rehydration ratio reflected the semolina's ability to regain moisture after drying, and a higher rehydration ratio could be desirable for products where rehydration was critical, such as instant food mixes.

Proximate Composition of Semolina samples

The proximate composition of two different types of semolina, emmer wheat, and common wheat, is presented in [Table-7] to determine key parameters such as moisture content, protein, fat, carbohydrates, crude fiber, and ash.

Table-7 Proximate Composition of Semolina

Parameters	Emmer Wheat	Common Wheat
Moisture (%)	9.12 ± 0.07^{a}	10.5 ± 0.01^{b}
Fat (%)	2.67 ± 0.02^{a}	1.49 ± 0.01^{b}
Protein (%)	17.01 ± 0.07^{a}	13.98 ± 0.02^{b}
Gluten (%)	7.34 ± 0.57^{a}	12.37 ± 0.79^{b}
Ash (%)	1.45 ± 0.01^{a}	0.46 ± 0.02^{b}
Carbohydrates (%)	69.73 ± 0.02^{a}	73.54 ± 0.02^{b}
Fibre (%)	4.04 ± 0.16^{a}	1.25 ± 0.01^{b}

Values expressed are average ±SD.
Rows with different superscripts in the means are significantly different ($p < 0.05$).

The proximate composition of semolina, as observed in two different wheat varieties, emmer wheat, and common wheat, reveals significant differences in their nutritional content. Moisture content was found to be significantly different ($p < 0.05$) between the two types of semolina. Emmer wheat semolina had a lower moisture percentage (9.12%) compared to common wheat semolina (10.5%). Emmer wheat semolina contained a significantly ($p < 0.05$) higher fat percentage (2.67%) in comparison to common wheat semolina (1.49%). The protein content in emmer wheat semolina was significantly higher (17.01%) than that in Common Wheat semolina (13.98%). The protein content in wheat flour experiences some reduction during the milling process, although the loss of protein is generally less dramatic than the losses observed for dietary fiber, vitamins, and minerals [37]. Gluten, a crucial factor in dough formation, shows significant differences ($p < 0.05$) between the two types of wheat semolina. Emmer wheat semolina contains 7.34% gluten. Common wheat semolina, on the other hand, contains a substantially higher gluten content of 12.37%. The ash content, indicative of mineral content, was significantly higher ($p < 0.05$) in emmer wheat semolina, with 1.45%, compared to common wheat semolina's 0.46%.

Carbohydrates make up a significant portion of both semolina varieties, with emmer wheat semolina containing approximately 69.73% carbohydrates and common wheat semolina containing 73.54% carbohydrates. Finally, the fiber content in emmer wheat semolina is notably higher at 4.04%, while common wheat semolina contains a lower fiber content of 1.25%. Milling significantly reduces the dietary fiber content in wheat grains. The bran, which is rich in dietary fiber, is separated during the milling process [37].

The proximate composition analysis of semolina from different wheat varieties revealed that *Triticum dicoccum* had the highest protein content (14.02±0.07%), *Triticum aestivum* had the lowest moisture content (10.52±0.19%), and Triticum durum had the highest ash content (1.45±0.01%) [38]. From other studies, the proximate composition of semolina shows it has approximately 12.85% moisture, 12.01% crude protein, 1.67% crude fat, 1.00% ash, and 72.47% total carbohydrates [39]. In the study of the proximate composition of wheat semolina, it was found to contain approximately 14.3% protein, 1.5% lipids, 0.8% ash, 79.2% carbohydrates, and 4.2% fiber on a dry weight basis. This composition indicates that wheat semolina is a good source of carbohydrates and dietary fiber, with moderate levels of protein and low lipid content [40].

Quality of Emmer and Common wheat semolina cooked in varying proportions of water

The weight of cooked semolina (expressed in grams) is presented in [Table-8] for two types of semolina, emmer wheat semolina and common wheat semolina, at various mixing ratios of semolina to water (v/v). The ratios tested include 1:1, 1:3, 1:6, 1:9, and 1:12.

Table-8 Quality of Emmer and Common wheat semolina cooked in varying proportion of water

Semolina*/water (v/v)	Weight of cooked semolina (g)	
	Emmer wheat semolina	Common wheat semolina
1:1	17.96 ± 0.20^{a}	19.46 ± 1.12^{b}
1:3	32.16 ± 0.35^{a}	35.62 ± 0.84^{b}
1:6	40.93 ± 0.30^{a}	45.63 ± 0.20^{b}
1:9	56.86 ± 0.40^{a}	59.19 ± 0.14^{b}
1:12	63.83 ± 0.35^{a}	67.5 ± 0.3^{b}

Values expressed are average ±SD.
Rows with different superscripts in the means are significantly different ($p < 0.05$).

The cooked weight of emmer and common wheat semolina cooked in varying proportions of water are presented in [Table-8]. The Cooking quality when accessed at a 1:1 ratio of semolina to water, emmer wheat semolina exhibited a weight of approximately 17.96 grams. In contrast, common wheat semolina cooked under the same conditions had a slightly higher weight of approximately 19.46 grams. The difference in weight was found to be statistically significant ($p < 0.05$). As the proportion of water increased to 1:3 (semolina to water), both emmer wheat and common wheat semolina exhibited an increase in weight, with emmer wheat semolina weighing approximately 32.16 grams and common wheat semolina weighing approximately 35.62 grams.

At higher water proportions of 1:6, 1:9, and 1:12, both varieties of semolina continued to show a trend of increased weight with increased water content. In each case, the difference in weight was statistically significant ($p < 0.05$). In the 1:6 ratio, the trend of increasing cooked weight continued. Emmer wheat semolina reached a cooked weight of around 40.93 grams, while common wheat semolina had a cooked weight of approximately 45.63 grams. Further increasing the water content with 1:9 resulted in even higher cooked weights. Emmer wheat semolina achieved a cooked weight of approximately 56.86 grams, while common wheat semolina had a cooked weight of around 59.19 grams. Finally, in the 1:12 ratio, both semolina types continued to absorb more water, resulting in cooked weights of approximately 63.83 grams for emmer wheat semolina and 67.5 grams for common wheat semolina.

Emmer wheat semolina and Common wheat semolina were analyzed and compared for cooking time at various mixing ratios as presented in [Fig-2]. The cooking times, expressed in seconds, were examined across five different mixing ratios: 1:1, 1:3, 1:6, 1:9, and 1:12. [Fig-2] clearly shows that as the mixing ratio increases (from 1:1 to 1:12), the cooking time generally increases for both types of semolina. Additionally, it's noteworthy that emmer wheat semolina consistently exhibits longer cooking times compared to common wheat semolina at each mixing ratio. The difference in cooking time at 1:1 and 1:12 ratios shows statistically significant ($p < 0.05$) for all mixing ratios, as indicated by the distinct superscripts 'a' and 'b'.

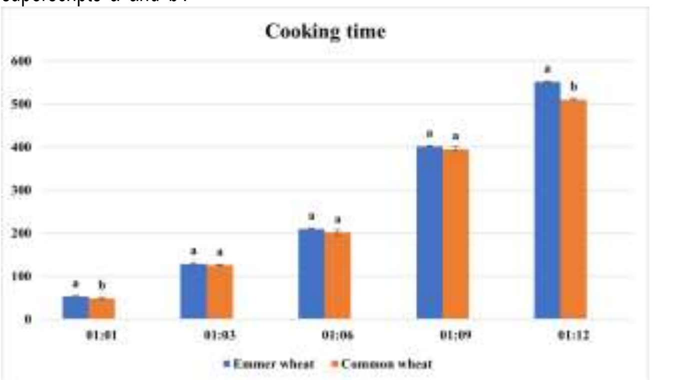

Fig-2 Comparison of Cooking Times for Emmer Wheat Semolina and Common Wheat Semolina at Different Mixing Ratios

Bars carrying different letters are significantly different ($p < 0.05$) from each other.

From the studies, einkorn wheat shows higher onset temperature (To) and peak temperature (Tm) values which infer to take a longer time to cook or gelatinize compared to common wheat [41]. Studies showed that the mixing or incorporation of protein into the starch had an important impact on starch gelatinization parameters. Mixing increased both the onset and peak temperatures of starch gelatinization. This indicates that the presence of protein in the blend delayed the start and completion of the gelatinization process, which in turn, prolongs the cooking time [42]. Emmer wheat and common wheat semolina exhibit an increase in weight with an increasing proportion of water until they reach a saturation point at 1:9, beyond which no further water absorption occurs as illustrated in [Table-8]. Annapurna (2000) [18] conducted a similar experiment with fine semolina using different water ratios, finding varying cooking times. A cooking duration of 618 seconds for einkorn wheat supports the notion that ancient wheat varieties such as emmer and einkorn typically demand longer cooking times [43].

Average cooking times of 12.33 minutes for boiling water and 13.67 minutes for steam have been reported for barley semolina [44]. Additionally, the Optimum Cooking Time (OCT) for dry semolina spaghetti, with values ranging from 492 to 669 seconds, demonstrating the influence of cooking time on pasta quality has been investigated [45].

Conclusion

A comparative analysis was conducted to assess the physical, functional, nutritional, and sensory properties of semolina derived from Emmer Wheat (*Triticum dicoccum*) and Common Wheat (*Triticum aestivum*). The results reveal distinct differences between the two wheat varieties in terms of physical characteristics, nutritional profiles, milling yields, particle size distribution, colour attributes, and functional properties. Emmer wheat exhibited unique characteristics, including higher protein, fat, ash, and fiber content, while common wheat displayed better milling yields and water absorption properties. These findings provide valuable information for selecting the most suitable wheat variety for specific food and industrial applications, emphasizing the importance of understanding the diverse properties of different wheat grains.

Application of research: This research can be applied by food manufacturers to make informed decisions about the utilization of Emmer wheat and Common wheat semolina in various food products based on their distinct physical, nutritional, and functional properties

Research Category: Food Science, Cereal Science

Abbreviations: ANOVA- Analysis of variance
SD- Standard deviation
B.S.S- British Standard Sieve
CIELAB- Commission Internationale de l'Eclairage
g/g- gram per gram
g/ml- gram per millilitre
g/100g- gram per hundred gram
v/v- volume per volume

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Study area / Sample Collection: Wheat and Maize Research Unit, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, 431402

Cultivar / Variety / Breed name: Emmer Wheat (*Triticum dicoccum*) and Common Wheat (*Triticum aestivum*) semolina

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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