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Proximate composition of ragi, jowar, foxtail and barnyard millet flours: A comparative review

Shreya Jawalkar, Nayan Nandavate, Bhabya*, Kapil F Ubarhande
School of Allied Health Sciences, PCET's Pimpri Chinchwad University, Pune, Maharashtra, India
Corresponding Author: Bhabya
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Abstract
Millet flours are increasingly used in traditional and value-added foods, but their reported proximate composition varies with genotype, dehulling, milling, processing, sample basis and analytical method. This review compared the proximate composition of ragi (finger millet), jowar (sorghum), foxtail millet and barnyard millet flours using published secondary data. Literature was identified through PubMed, ScienceDirect, Google Scholar, Wiley Online Library and Oxford Academic and was supplemented by authoritative food-composition and regulatory sources. Studies were selected when millet identity and proximate values were clearly reported, and direct comparison was restricted to flour observations reported on an as-is (fresh-weight) basis. Ragi control flours showed 10.51–10.60 g/100 g moisture, 10.75–10.80 g/100 g protein and 1.70–1.72 g/100 g fat. Jowar flour contained 12.03 g/100 g protein and 3.56 g/100 g fat, while foxtail millet flour contained 11.65 g/100 g protein, 3.48 g/100 g fat and 2.21 g/100 g crude fiber. Barnyard millet flour contained 10.50 g/100 g protein, 3.60 g/100 g fat and the highest ash content (3.40 g/100 g); its crude fiber was not reported. Mean ± SD could be calculated only for the two comparable ragi observations. The selected flours differed measurably in composition, and part of this difference was attributable to sample preparation and analytical method. Standardized flour preparation, reporting basis and analytical procedures are needed before values from different studies can be pooled as species-level estimates.

Keywords: Millet flour, proximate composition, finger millet, sorghum, foxtail millet, barnyard millet

Introduction

Millets are small-seeded cereals traditionally consumed in South Asia and Africa, and they now attract attention as ingredients for diversified food products because they contribute carbohydrates, proteins, lipids, dietary fiber, minerals and bioactive compounds. Sorghum and millets have long been recognized as important staples in human nutrition (Food and Agriculture Organization, 1995) [14], and current Indian dietary guidelines encourage their inclusion in the diet (ICMR-NIN, 2024) [16]. Recent reviews have catalogued the nutrient composition of the major and minor millets (Amadou et al., 2013; Borah et al., 2026) [5, 9]. Their composition, however, varies with genotype, cultivation conditions, geographical origin, dehulling, milling, storage and processing, so both the raw material and its processing history must be considered when nutritional data are interpreted (Saleh et al., 2013; Sharma et al., 2021; Yousaf et al., 2021) [31, 32, 40].

Proximate analysis (moisture, ash, crude protein, crude fat, crude fiber and carbohydrate by difference) is useful for evaluating and comparing flours, but meaningful comparison requires a common basis and comparable procedures (AOAC International, 2019) [7]. Dehulling removes fiber- and mineral-rich outer layers, and milling alters the bran and germ contribution. Germination, popping, fermentation, malting, wet processing and hydrothermal treatment further modify flour properties (Adebiyi et al., 2016; Chauhan & Sarita, 2018; Jindal & Nikhanj, 2023; Li et al., 2017; Paliwal et al., 2022; Rathore & Singh, 2017) [3, 11, 17, 20, 27, 30], and processing also alters the phenolic profile of millets (Pradeep & Sreerama, 2015; Taylor & Duodu, 2015) [28, 35].

Ragi (*Eleusine coracana*) is a low-fat cereal with useful fiber and minerals, yet ten finger-millet genotypes varied in moisture (7.50–11.75%), protein (6.7–8.0%), fat (1.2–1.7%), fiber (3.1–3.8%) and ash (3.1–3.8%) (Nakarani et al., 2021) [24], and its physical and functional properties also differ between sources (Ramashia et al., 2018) [29]. Jowar (*Sorghum bicolor*) flour composition depends on the degree of dehulling and bran retention (Adebo & Kesa, 2023; Yoganandan et al., 2021) [4, 39], and germination and fermentation alter its functional properties (Elkhalifa & Bernhardt, 2010; Olamiti et al., 2020) [13, 26]. Foxtail millet (*Setaria italica*) varies with variety, milling fraction and processing (Amadou et al., 2014; Devisetti et al., 2014; Kamara et al., 2009) [6, 12, 18]. Barnyard millet has been studied in gluten-free bakery products, and its characteristics change with processing (Chakraborty et al., 2016; Nazni & Devi, 2016) [10, 25]. Crude fiber and total dietary fiber are different analytical fractions and must not be substituted for one another (Sharma et al., 2021) [32].

Some studies have analysed several millet flours side by side (Munshi & Dashora, 2024; Tiwari et al., 2025) [22, 37], but direct comparison across ragi, jowar, foxtail and barnyard millet flours remains complicated by differences in preparation, reporting basis and method. The present review therefore aimed to compile and compare the moisture, ash, crude protein, crude fat, crude fiber and carbohydrate contents of these four flours from published secondary data and to examine the nutritional and technological implications of the differences.

Materials and Methods

Study design, sources and search strategy

A comparative secondary-data review was conducted; no laboratory measurements were generated. PubMed, ScienceDirect, Google Scholar, Wiley Online Library and Oxford Academic were searched for material available up to

September 2026. The official methods of AOAC International (2019) [7], the Indian Food Composition Tables (Longvah et al., 2017) [21], USDA FoodData Central (U.S. Department of Agriculture, 2024) [38] and the FSSAI cereal standards (Food Safety and Standards Authority of India, 2024) [15] were consulted for analytical, compositional and regulatory information. Search strings included "finger millet flour proximate composition", "ragi flour AOAC", "sorghum flour proximate composition", "jowar flour protein fat ash fiber", "foxtail millet flour proximate analysis", "barnyard millet flour proximate composition" and "millet flour moisture ash protein fat crude fiber carbohydrate".

Inclusion, exclusion and data extraction

Studies were included when they identified the millet species or flour and reported one or more of the six proximate parameters. Flour-specific studies were prioritized; processed flours were retained when the treatment was clearly identified, and whole-grain studies were used only as supporting evidence. Wild barnyard grass (*Echinochloa crus-galli*) was excluded, total dietary fiber was not used to replace crude fiber, and values whose basis could not be harmonized without assumptions were excluded. The extraction sheet recorded author, year, millet identity, sample preparation, the six proximate values, analytical method, reporting basis, journal and DOI. Values were expressed as g/100 g; dry-basis observations were kept separate from fresh-weight observations, and missing values were recorded as NR (not reported) rather than estimated.

Analytical methods and data synthesis

The source studies used conventional proximate procedures: oven drying for moisture, incineration for ash, Kjeldahl or related nitrogen estimation for protein, Soxhlet or petroleum-ether extraction for fat, acid–alkali digestion or AOAC procedures for crude fiber, and carbohydrate by difference. Murungweni et al. (2024) [23] reported AOAC method numbers for finger-millet flour, and Abedin et al. (2022) [1] described oven drying, ash incineration, micro-Kjeldahl protein, Soxhlet petroleum-ether fat and AOAC crude fiber. Where a source gave insufficient method detail, this limitation was retained. Mean ± SD was calculated only for ragi, from two control flours in one study; jowar, foxtail and barnyard millet were each represented by one comparable observation, so single values were reported rather than an artificial SD. Each value was linked to its source, and sample type, fiber definition, method and basis were checked during extraction.

Results and Discussion

Proximate composition of the selected flours

Published evidence was found for all four millets, but the number of directly comparable flour observations was smaller than the number of publications discussing millet composition. Table 1 presents the comparable observations and Table 2 the descriptive summary. Ragi control flours showed 10.51–10.60 g/100 g moisture, 1.46–1.57 g/100 g ash, 10.75–10.80 g/100 g protein, 1.70–1.72 g/100 g fat, 1.81–1.90 g/100 g crude fiber and 72.03–72.57 g/100 g carbohydrate (Murungweni et al., 2024) [23]. Jowar flour contained 13.55 g/100 g moisture, 1.62 g/100 g ash, 12.03 g/100 g protein, 3.56 g/100 g fat, 1.76 g/100 g crude fiber and 67.48 g/100 g carbohydrate (Singh et al., 2024) [34]. Foxtail flour contained 5.94, 1.39, 11.65, 3.48, 2.21 and 75.33 g/100 g, respectively (Abedin et al., 2022) [1]. Barnyard flour contained 6.70 g/100 g moisture, 3.40 g/100 g ash, 10.50 g/100 g protein, 3.60 g/100 g fat and 75.80 g/100 g carbohydrate, with crude fiber not reported (Chakraborty et al., 2016) [10]. Protein and crude fat are compared in Fig 1 and Fig 2.

Table 1: Directly comparable millet-flour observations (g/100 g, as-is/fresh-weight basis)

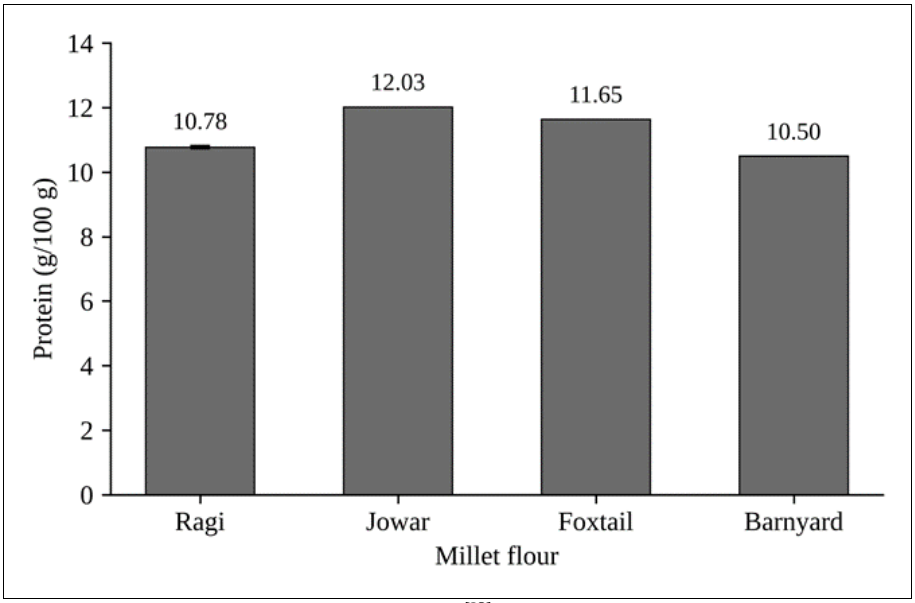
Millet flour	Moisture	Ash	Protein	Fat	Crude fiber	CHO	Source and sample	Analytical method
Ragi (finger millet)	10.51–10.60	1.46–1.57	10.75–10.80	1.70–1.72	1.81–1.90	72.03–72.57	Murungweni et al. (2024) [23]; light- and dark-brown control flours	AOAC 934.01, 923.03, 978.10, 920.39, 990.03; CHO by difference
Jowar (sorghum)	13.55	1.62	12.03	3.56	1.76	67.48	Singh et al. (2024) [34]; native sorghum flour	AOAC-based proximate analysis; CHO by difference
Foxtail millet	5.94	1.39	11.65	3.48	2.21	75.33	Abedin et al. (2022) [1]; foxtail millet flour	Oven drying; incineration; micro-Kjeldahl; Soxhlet; AOAC crude fiber; CHO by difference
Barnyard millet	6.70	3.40	10.50	3.60	NR	75.80	Chakraborty et al. (2016) [10]; dehusked barnyard flour	Method details not fully stated in accessible text

CHO = carbohydrate; NR = not reported. Values are source observations, not pooled species means. Barnyard crude fiber was retained as NR because the cited flour composition did not provide it.

Table 2: Descriptive summary of comparable flour observations (g/100 g)

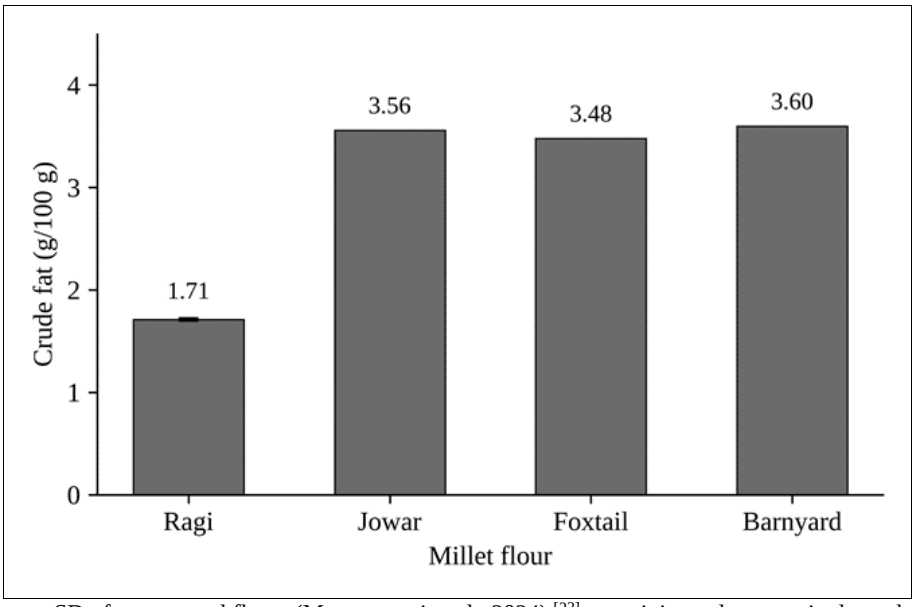
Millet	Moisture	Ash	Protein	Fat	Crude fiber	CHO	Observation basis
Ragi	10.56 ± 0.06	1.52 ± 0.08	10.78 ± 0.04	1.71 ± 0.01	1.86 ± 0.06	72.30 ± 0.38	n = 2; two control flours from one study
Jowar	13.55	1.62	12.03	3.56	1.76	67.48	n = 1; single study observation
Foxtail	5.94	1.39	11.65	3.48	2.21	75.33	n = 1; single study observation
Barnyard	6.70	3.40	10.50	3.60	NR	75.80	n = 1; crude fiber not reported

CHO = carbohydrate; NR = not reported. Mean ± SD is shown only where two comparable observations were available; for ragi these are two flours within one study, not two independent publications.



Ragi is the mean ± SD of two control flours (Murungweni et al., 2024) [23]; other values are single observations (Singh et al., 2024; Abedin et al., 2022; Chakraborty et al., 2016) [34, 1, 10].

Fig 1: Protein content of the selected millet flours (g/100 g, as-is basis)



Ragi is the mean ± SD of two control flours (Murungweni et al., 2024) [23]; remaining values are single study observations.

Fig 2: Crude fat content of the selected millet flours (g/100 g, as-is basis)

Comparison among the flours

Proximate composition differed among the selected flours, but the differences describe particular flour preparations rather than fixed species-level values, because genotype, origin, dehulling, milling, processing, analytical procedure and reporting basis all influence measured composition. Ragi showed comparatively low fat (mean 1.71 g/100 g) with 10.78 g/100 g protein and 72.30 g/100 g carbohydrate; even its two control flours differed in ash and crude fiber, in line with reported genotype and processing variation (Abioye et al., 2022; Shobana et al., 2013) [2, 33]. Jowar contained more protein (12.03 g/100 g) and fat (3.56 g/100 g) than ragi, which may reflect retention of protein- and lipid-rich bran and germ during milling (Adebo & Kesa, 2023; Olamiti et al., 2020; Yoganandan et al., 2021) [4, 26, 39]. Foxtail flour (11.65 g/100 g protein, 2.21 g/100 g crude fiber) illustrates how milling fractions redistribute nutrients and influence functionality (Amadou et al., 2014; Devisetti et al., 2014) [6, 12]. Barnyard millet had the highest ash (3.40 g/100 g), which indicates inorganic residue but not the amount or bioavailability of individual minerals; its crude fiber was kept as NR rather than substituting total dietary fiber.

Nutritional and technological implications

Carbohydrate was the largest fraction for ragi, foxtail and barnyard millet; because it is calculated by difference, errors in the other components carry into it. Protein and fiber influence water absorption and dough structure, lipid affects flavor and mouthfeel, carbohydrate governs pasting and gelatinization, and moisture affects handling and storage. Millet flours are already used in composite and blended

products such as biscuits and extrudates (Balasubramanian et al., 2012; Krishnan et al., 2011) [8, 19]. They suit gluten-free products, but the lack of gluten may require blending or hydrocolloids (Chakraborty et al., 2016; Jindal & Nikhanj, 2023) [10, 17]. Milled lipid-containing flours may oxidize, and pre-milling treatments influence storage stability (Tiwari et al., 2014; Yousaf et al., 2021) [36, 40], so shelf-life decisions should be based on the actual flour and storage system. Proximate composition alone does not establish regulatory compliance, which also involves ingredients, contaminants, microbiological quality, hygiene and labelling (Food Safety and Standards Authority of India, 2024) [15].

Limitations

The principal limitation was the small number of directly comparable flour observations. Studies differed in cultivar, geography, dehulling, particle size, processing, methods and basis; some reported total dietary fiber instead of crude fiber, and fresh- and dry-weight reporting were mixed, which restricted statistical pooling. The ragi mean ± SD rests on two flours from one study, and the figures are descriptive rather than controlled experimental comparisons. Future work should standardize flour preparation, report sample basis and processing history, apply consistent AOAC procedures and provide replicate observations for each millet.

Conclusion

The reviewed evidence demonstrated measurable differences in moisture, ash, protein, fat, crude fiber and carbohydrate among ragi, jowar, foxtail and barnyard millet flours, with the magnitude partly dependent on sample preparation and analytical method. Jowar and foxtail flours showed the highest protein, ragi the lowest fat, and barnyard millet the highest ash. Proximate data are useful for nutritional interpretation, formulation and storage decisions, but standardized preparation, reporting basis and methods are required before values from different studies can be pooled as species-level estimates.

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Conflict of interest statement

The authors declare no conflict of interest.

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Author contributions

Shreya Jawalkar: conception, organization of comparative material, drafting, tabulation and interpretation. Nayan Nandavate: literature retrieval, source verification, reference organization, critical revision and correspondence. Bhabya: supervision, methodological guidance and critical revision of the manuscript. Kapil F. Ubarhande: critical review and editing of the manuscript. All authors approved the final version and accept responsibility for the integrity of the work.

Data availability

The data extraction sheet supporting this review is available from the corresponding author on reasonable request.

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