



A Comparative Investigation into the Chemical Composition and Nutritional Attributes of Various Millets

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Abstract

Millets constitute small-seeded cereal grains that have historically represented a significant element of diets across Asia and Africa. Over recent years, their nutritional worth, resilience to climate conditions, gluten-free character, and prospective role in advancing food and nutritional security have drawn substantial attention within the scientific community. This comparative investigation examines the chemical composition and nutritional attributes of eight prominent millets: pearl millet (*Pennisetum glaucum*), finger millet (*Eleusine coracana*), foxtail millet (*Setaria italica*), proso millet (*Panicum miliaceum*), barnyard millet (*Echinochloa* spp.), kodo millet (*Paspalum scrobiculatum*), little millet (*Panicum sumatrense*), and sorghum (*Sorghum bicolor*). Composition data drawn from published sources reveal substantial interspecies variation among millets with respect to protein, fat, dietary fibre, calcium, iron, zinc, phosphorus, magnesium, and B-complex vitamins. Finger millet stands out in particular owing to its extraordinarily elevated calcium content, whereas pearl millet furnishes comparatively greater quantities of fat, iron, and zinc. Foxtail and proso millets are comparatively abundant in protein, while barnyard millet exhibits elevated dietary fibre across a number of composition datasets. Millets further encompass phenolic acids, flavonoids, tannins, phytosterols, and other bioactive compounds possessing antioxidant capacity. Nevertheless, phytate, tannins, and other antinutritional factors are capable of diminishing the bioavailability of minerals and protein. Processing techniques including soaking, germination, and fermentation are able to markedly lower the levels of these compounds and thereby enhance nutritional quality. Taken as a whole, the comparative evidence establishes that millets ought not to be regarded as nutritionally equivalent; instead, each species possesses distinctive nutritional merits and may be strategically integrated into diversified diets.

Keywords: Millets, chemical composition, nutritional properties, protein, dietary fibre, minerals, antioxidants, phytochemicals, antinutrients

Introduction

Millets comprise a varied assemblage of cereal grains that belong chiefly to the Poaceae family. These encompass major millets, namely pearl millet, finger millet, and foxtail millet, together with a number of minor millets such as proso, barnyard, kodo, and little millet. Sorghum, too, is commonly grouped with millets on account of its analogous nutritional and agronomic traits. Millets have conventionally been cultivated in semi-arid and marginal environments, a consequence of their comparatively brief growing periods and their capacity to withstand drought and infertile soils. The Food and Agriculture Organization has underscored their significance for food security, nutrition, and climate-resilient agriculture. From a nutritional standpoint, millets serve as significant reservoirs of carbohydrates, proteins, lipids, dietary fibre, vitamins, minerals and phytochemicals. Nevertheless, their composition differs markedly depending on species, genotype, the environment in which they are grown, soil conditions, stage of maturity, storage and processing. A systematic review of millet genotypes revealed substantial variability even among genotypes belonging to the same millet species, which indicates that a single universal figure cannot reliably capture nutritional composition. In the compiled global dataset, finger millet, for instance, exhibited consistently elevated calcium concentrations, whereas pearl millet displayed especially high

concentrations of zinc. Accordingly, the present paper undertakes a comparison of the chemical and nutritional characteristics of various millets and considers their possible nutritional benefits, drawbacks and consequences for human diets.

Objectives

The principal aims of this comparative investigation are as follows:

- To draw comparisons among different millet species with respect to their proximate chemical composition.
- To compare the protein, carbohydrate, fat and dietary-fibre contents across these species.
- To assess variations in key minerals, including calcium, iron, zinc, magnesium and phosphorus.
- To investigate the vitamin and phytochemical attributes of millets.
- To deliberate upon the nutritional importance and health-related properties associated with individual millets.
- To analyse how antinutritional factors and processing practices influence nutrient availability.

Materials and Methods

This paper constitutes a comparative review grounded in published scientific literature and authoritative sources of food-composition data. Nutritional data were assembled

from the Indian Council of Agricultural Research (ICAR), the National Institute of Nutrition (NIN), the Food and Agriculture Organization (FAO), along with peer-reviewed scientific reviews and systematic reviews.

The central comparison relied upon composition values expressed per 100 g of grain. Since distinct databases employ differing analytical methods, cultivars and definitions of dietary fibre, these values ought to be regarded as representative rather than absolute.

As an illustration, the ICAR publication designates the Indian Food Composition Tables (NIN, 2017) as a principal source, while observing that certain figures for proso, foxtail, and barnyard millet were obtained from previously published Indian food-composition records.

A Comparative Analysis of the Chemical Composition of Millets

Table 1: Approximate nutritional composition of selected millets per 100 g

Millet	Energy (kcal)	Protein (g)	Carbohydrate (g)	Fat (g)	Dietary/Crude fibre (g)
Pearl millet	348	10.96	61.8	5.43	11.49
Finger millet	321	7.16	66.8	1.92	11.18
Kodo millet	332	8.92	66.2	2.55	6.39
Little millet	346	10.13	65.6	3.89	7.72
Proso millet	341	12.50	70.4	1.10	2.20*
Foxtail millet	331	12.30	60.1	4.30	8.00*
Barnyard millet	307	6.20	65.6	2.20	9.80*
Sorghum	334	9.97	67.7	1.73	10.22

*In the referenced Indian composition dataset, these figures represent the crude-fibre values recorded for the millets in question.

Origin: Assembled from Indian food-composition records documented by ICAR/NIN together with contemporary review articles.

1. Carbohydrates

Carbohydrates represent the predominant component of millet grains, typically comprising roughly 60–70 g per 100 g. Nevertheless, the carbohydrate level differs across species. Within the Indian composition dataset, proso millet exhibits a relatively elevated carbohydrate level of about 70.4 g/100 g, whereas foxtail and pearl millet contain roughly 60.1 and 61.8 g/100 g, respectively. Even though millets are abundant in carbohydrates, their nutritional value is shaped by starch architecture, dietary fibre, polyphenols and processing methods. Such attributes may affect the digestion of starch and the glycaemic response following a meal. Hence, the physiological impact of foods derived from millet cannot be inferred merely from their total carbohydrate content.

2. Protein

Protein concentration ranks among the notable distinctions between millet species. Proso millet and foxtail millet possess comparatively elevated protein levels, at approximately 12.5 and 12.3 g/100 g, respectively. Pearl millet holds roughly 11 g/100 g, while finger millet and barnyard millet display lower figures of about 7.2 and 6.2 g/100 g, respectively, within the dataset cited. Pearl millet has been documented as containing about 11.6–11.8% protein, in contrast to finger millet, which typically holds about 5–8%, though substantial variation between varieties is observed.

The amino-acid profile of millet protein likewise carries nutritional importance. Contemporary reviews suggest that millet proteins supply meaningful quantities of various essential amino acids and, contingent on species and cultivar, may furnish considerable amounts of sulfur-

containing amino acids. Nonetheless, as with the majority of cereal proteins, millet proteins are best complemented by pulses, legumes, dairy products or alternative protein sources so as to achieve a more balanced amino-acid profile.

3. Fat

Millets typically hold greater lipid quantities than polished rice, yet this varies markedly across species. Pearl millet provides roughly 5.4 g fat/100 g, which places it among the more lipid-rich millets. Foxtail millet holds about 4.3 g/100 g and little millet around 3.9 g/100 g. Proso millet, by contrast, possesses a comparatively low fat level of roughly 1.1 g/100 g.

The lipids of millet comprise unsaturated fatty acids, among them oleic and linoleic acids, which add to their nutritional worth. The inclusion of lipids further elevates the energy density characteristic of millet-based diets and may facilitate the absorption of fat-soluble compounds.

4. Dietary Fibre

An essential nutritional attribute of millets is their dietary fibre content. Within the ICAR/NIN dataset, pearl millet and finger millet were found to contain roughly 11.5 and 11.2 g fibre/100 g, respectively, whereas barnyard millet exhibited approximately 9.8 g crude fibre and foxtail millet approximately 8.0 g crude fibre. Comparable findings were reported in a recent review, which documented elevated fibre levels in barnyard, finger, foxtail and kodo millets relative to polished rice. Intestinal health, enhanced satiety and a moderating effect on the rate of carbohydrate digestion can all be supported by dietary fibre. Consequently, the substitution of highly refined cereal products with suitably processed whole-millet foods could elevate dietary fibre intake.

5. Mineral Composition

Millets constitute especially significant sources of

minerals. Nevertheless, the concentration of any given

mineral differs considerably across species.

Table 2: Selected mineral composition of different millets per 100 g

Millet	Calcium (mg)	Phosphorus (mg)	Magnesium (mg)	Zinc (mg)	Iron (mg)
Pearl millet	27	289	124	2.76	6.42
Finger millet	364	210	146	2.53	4.62
Kodo millet	15	101	122	1.65	2.34
Little millet	16	130	91	1.82	1.26
Proso millet	14	206	153	1.40	0.80
Foxtail millet	31	188	81	2.40	2.80
Barnyard millet	20	280	82	3.00	5.00
Sorghum	28	274	133	2.96	3.95

Source: Indian food-composition data summarized by ICAR/NIN.

1. Calcium

Within the present investigation, finger millet stands out as the pre-eminent calcium source among the millets subjected to comparison. According to the ICAR/NIN dataset, its calcium level reaches roughly 364 mg/100 g, a value markedly exceeding those recorded for pearl millet (27 mg/100 g), foxtail millet (31 mg/100 g) and proso millet (14 mg/100 g). A worldwide systematic review likewise determined that calcium concentrations in finger millet were uniformly elevated, averaging approximately 331 mg/100 g over the genotype data that were compiled.

Consequently, finger millet possesses distinctive promise as a calcium source of plant origin. Nevertheless, the elevated calcium concentration of this grain cannot be assumed to correspond directly to elevated calcium absorption, since phytate and other mineral-binding substances are capable of affecting bioavailability.

2. Iron

In the ICAR/NIN dataset, pearl millet supplies millet at approximately 4.6 mg/100 g. Considerable variation in iron content may occur among roughly 6.4 mg iron/100 g, with barnyard millet next at approximately 5.0 mg/100 g and finger cultivars. A systematic review documented notably elevated iron values for finger millet throughout the global literature, thereby illustrating that genotype and analytical methodology are able to yield substantial discrepancies relative to standard food-composition tables.

3. Zinc

In the ICAR/NIN dataset, barnyard millet provides approximately 3.0 mg zinc/100 g, whereas pearl millet holds approximately 2.76 mg/100 g and finger millet approximately 2.53 mg/100 g. From the standpoint of zinc biofortification, pearl millet is of particular interest. The FAO identifies pearl millet as a favourable source of zinc, iron, magnesium, phosphorus and selenium.

4. Magnesium and Phosphorus

As a rule, millets supply nutritionally meaningful amounts of magnesium and phosphorus. Within the dataset referenced, proso millet supplies roughly 153 mg of magnesium per 100 g, finger millet 146 mg, and sorghum 133 mg. Pearl millet delivers about 289 mg of phosphorus per 100 g, whereas barnyard millet delivers approximately 280 mg. Such minerals play essential roles in skeletal development, energy metabolism, cellular functioning, and normal physiological processes.

Vitamin Composition

Millets supply a number of B-complex vitamins, notably thiamine, riboflavin, and niacin. The levels of these vitamins differ markedly from one species to another. Indian composition data, for instance, record comparatively elevated thiamine in foxtail and proso millet, and proso millet in particular displays a notably high reported niacin concentration. Pearl millet and finger millet likewise furnish substantial quantities of B vitamins. According to the FAO, finger millet serves as a source of thiamine together with several minerals, while pearl millet is recognized as a source of thiamine and vitamin B6. Given that milling and polishing strip away nutrient-dense outer layers, eating whole grains or grains subjected to suitable processing may retain a greater share of micronutrients than extensive refining does.

Phytochemicals and Antioxidant Properties

The dietary significance of millets reaches beyond the standard nutrients. They harbour an array of biologically active substances, among them phenolic acids, flavonoids, tannins, phytosterols, and further secondary metabolites. Such substances underpin antioxidant activity and may exert an influence on metabolic and physiological functions. Phenolic compounds are capable of neutralizing or scavenging reactive species, and they may thus add to the antioxidant capacity exhibited by foods based on millet. Both the quantity and the nature of phenolic compounds differ considerably across species and cultivars. Certain varieties of sorghum, along with particular coloured millets, may harbour notably elevated levels of phenolic compounds and tannins. Nevertheless, the presence of phytochemicals ought not to be regarded, as a matter of course, as conferring protection against disease in human beings. The evidence supporting health advantages differs depending on the particular compound involved, the dose administered, the food matrix in which it is delivered, and the wider dietary context.

Antinutritional Factors

Millets harbour a number of compounds capable of diminishing the bioavailability of nutrients. Among the most significant of these are phytic acid, tannins and oxalates, together with enzyme inhibitors in certain varieties. Phytic acid is able to bind minerals including iron, zinc and calcium, thereby potentially diminishing the extent to which they are absorbed. Tannins are capable of interacting with proteins and with digestive enzymes, and may consequently lower protein digestibility. Such compounds are by no means uniformly detrimental; numerous among them also

qualify as bioactive substances possessing antioxidant activity. Consequently, the nutritional impact they exert is contingent upon their concentration, the processing to which the food is subjected, and the diet as a whole. The existence of antinutrients accounts in part for the fact that the mineral content determined chemically in a grain need not correspond to the amount that the human organism actually takes up.

Effect of Processing on Nutritional Quality

Conventional processing methods are capable of altering the nutritional profile of millets to a considerable degree. Among the methods commonly employed are soaking, germination, malting, fermentation, roasting, popping, milling and cooking. Soaking may bring about the leaching of water-soluble antinutrients, whereas germination sets in motion endogenous enzymes, notably phytase, which is able to hydrolyse phytic acid. Fermentation is capable of diminishing phytate and tannins still further, and may enhance the digestibility of both protein and starch. By way of illustration, research collated in a recent review demonstrated that germination and fermentation are able to lower phytate and tannin concentrations in pearl, finger, proso and foxtail millets appreciably. Under certain experimental conditions, the combination of germination with fermentation yielded larger decreases in antinutritional factors than either treatment applied separately. The antioxidant capacity may likewise be modified through processing. Sprouting can potentially enhance the liberation or synthesis of specific phenolic acids and flavonoids, yet extended soaking or processing may equally lead to the depletion of water-soluble phenolic constituents. Hence, an ideal processing approach needs to reconcile the diminution of antinutrients with the preservation of beneficial phytochemicals.

An examination of over 100 investigations determined that processing methods markedly modify the nutritional and functional properties of millet and, when suitable techniques are applied, are capable of enhancing protein and starch digestibility while diminishing antinutritional constituents.

Nutritional Benefits of Millets in Comparative Perspective

1. Pearl Millet

A defining trait of pearl millet is its comparatively elevated protein and fat content, together with its status as an especially rich source of iron and zinc. Because of its substantial energy value and mineral density, it holds considerable worth for populations experiencing food insecurity. Furthermore, from an agronomic standpoint it is suited to semi-arid environments.

2. Finger Millet

Finger millet stands out owing to its remarkably elevated calcium concentration. It additionally furnishes appreciable quantities of dietary fibre, magnesium, phosphorus and iron. Such a nutritional profile renders it particularly noteworthy for dietary patterns that depend on plant-derived calcium sources.

3. Foxtail Millet

Within the Indian composition dataset, foxtail millet provides roughly 12.3 g of protein and 4.3 g of fat per 100 g. It further contributes dietary fibre, phosphorus and B

vitamins. Owing to its comparatively elevated protein level, it proves advantageous for diversifying protein sources in cereal-based foods.

4. Proso Millet

Among the millets examined, proso millet exhibits one of the greatest protein concentrations, at approximately 12.5 g/100 g. It likewise contains noteworthy amounts of phosphorus and magnesium. Nevertheless, within the dataset under consideration, the levels of fibre and iron it contains remain comparatively limited.

5. Barnyard Millet

Barnyard millet stands out owing to its dietary-fibre content, and it supplies noteworthy quantities of iron, phosphorus and zinc. The fact that its energy value is comparatively low relative to a number of other millets could likewise be of consequence when formulating food products high in fibre.

6. Kodo Millet

Kodo millet exhibits moderate amounts of protein and fat together with a comparatively elevated fibre concentration. Magnesium and phosphorus are supplied by it as well. Owing to its nutritional profile, it is well suited for use in whole-grain food products.

7. Little Millet

Within the Indian dataset, little millet supplies roughly 10.1 g of protein and 3.9 g of fat per 100 g. Its dietary fibre content is moderate, and it offers beneficial quantities of phosphorus and magnesium.

8. Sorghum Millet

Per 100 g, sorghum provides approximately 10 g of protein and 10.2 g of dietary fibre, in addition to considerable magnesium and phosphorus. Certain sorghum varieties, pigmented ones in particular, are additionally abundant in phenolic compounds.

Comparative Discussion

The comparative analysis makes evident that, from a nutritional standpoint, no individual millet excels in all respects. Rather, every species has its own particular strengths. As a cereal rich in calcium, finger millet is plainly superior. Pearl millet offers clear advantages as a source of iron, zinc, protein and lipids. Relatively elevated protein levels are supplied by proso millet as well as foxtail millet. In multiple datasets, barnyard millet and finger millet stand out owing to their fibre content. Whereas kodo millet offers dietary fibre together with minerals, little millet furnishes a well-balanced blend of protein, fat and fibre. Moreover, the comparison highlights how essential it is to employ standardized analytical methods. Divergent nutrient values for one and the same millet are documented across different studies. For instance, protein in finger millet has been documented at roughly 6–8% across a number of sources, yet it may be substantially greater in specific cultivars. In a comparable manner, mineral levels may fluctuate owing to genotype, soil, cultivation practices and analytical procedures.

This variability was underscored by a recent systematic review, which identified notable differences among genotypes within single millet species. Accordingly, it is suggested that forthcoming nutritional studies ought to

document cultivar, geographical origin, growing conditions, processing method and analytical methodology, instead of offering a single value as representative of a whole species. The contrast drawn with conventional cereals likewise merits attention. In the cited Indian food-composition dataset, rice possesses a comparatively high carbohydrate concentration, yet its dietary fibre, calcium, magnesium, iron and zinc are markedly lower than those of several millets. Wheat displays a protein and fibre profile akin to that of certain millets, but it contains gluten, while millets are inherently gluten-free.

Consequently, substituting millets for rice or wheat ought not to entail choosing a single millet to the exclusion of others. Complementary proteins, minerals and bioactive compounds may be delivered through a diversified pairing of millets and legumes.

Nutritional and Public-Health Significance

Owing to their nutritional properties, millets hold potential value for tackling a number of dietary challenges. Their dietary fibre, mineral content and bioactive compounds render them appropriate for creating nutrient-dense foods. Their capacity to withstand drought and to thrive under comparatively harsh environmental conditions lends further weight to their contribution to food security. Millets could likewise prove beneficial in formulating foods intended to slow carbohydrate digestion. Nevertheless, assertions concerning the management of diabetes ought to be viewed with caution, since the glycaemic response is contingent upon the millet species, the variety concerned, particle size, the method of cooking, processing, the combination of foods and the size of the portion. Consequently, it is more scientifically defensible to assert that foods based on millet may constitute a component of a dietary pattern that is high in fibre and minimally refined, rather than to presume that all millet products possess a low glycaemic index.

A further consideration of significance pertains to the processing of food. Millet in its whole-grain form may harbour antinutritional compounds that restrict the bioavailability of minerals. Soaking, germination and fermentation, when applied appropriately, are capable of diminishing these compounds and may possibly augment nutritional value.

Conclusion

A nutritionally varied category of cereals, millets have significant potential to enhance dietary quality and promote sustainable food systems. Significant variations in the chemical makeup of millet species are shown by the comparative study. Proso and foxtail millets have comparatively high protein concentrations, whereas pearl millet offers significant amounts of protein, fat, iron, and zinc. The extraordinarily high calcium content of finger millet sets it apart. A number of species supply substantial amounts of magnesium and phosphorus, and barnyard, finger, pearl, and foxtail millets offer beneficial amounts of dietary fibre. Millets contain phytosterols, flavonoids, phenolic acids, and other bioactive substances in addition to standard nutrients. However, nutrient absorption may be limited by phytate, tannins, and other antinutritional agents.

The nutritional value and digestibility of millet foods can be enhanced by reducing these chemicals through conventional methods including soaking, germination, and fermentation.

In general, the evidence is in favour of using a variety of millet species instead than depending just on one. A more balanced diet can be achieved by combining various millets with pulses, fruits, vegetables, and other nutrient-dense foods. To determine the physiological advantages of particular millet-based foods, more study should concentrate on standardised cultivar-level comparisons, nutrient bioavailability, processing optimisation, and carefully monitored human intervention studies.

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