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Redefining Millets: A Unique Grain Group Outside the Conventional Cereal Paradigm

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Abstract

Millets are traditionally classified as cereals due to their botanical inclusion in the family *Poaceae* and their role as staple grains. However, growing scientific evidence highlights significant structural, nutritional, ecological and functional differences that distinguish millets from major cereals such as wheat, rice and maize. Although taxonomically true cereals, millets possess smaller grain architecture, a higher bran-to-endosperm ratio and superior micronutrient density. They are rich in dietary fiber, essential minerals, polyphenols and antioxidants. Generally, exhibit a lower glycemic index. Their C_4 photosynthetic efficiency, drought tolerance and adaptability to low-input systems further differentiate them within the cereal group. Unlike globally dominant cereals shaped by intensive domestication and industrial processing, millets remain resilient crops of marginal agro-ecosystems. These distinctive attributes challenge the conventional cereal paradigm and justify a functional reclassification. This review critically examines the cereal-millet distinction from taxonomic, nutritional, and agronomic perspectives. It argues that while botanically cereals, millets represent a nutritionally superior and ecologically resilient grain group deserving recognition beyond traditional cereal categorization.

Keywords: Agro ecosystem, Dietary fibre, Glycemic index, Nutritional

Introduction

Cereals constitute the foundation of global food systems, providing nearly 50-60% of the world's caloric intake and forming the backbone of agricultural economies across continents. Wheat, rice and maize dominate global production landscapes and policy frameworks, shaping research investments, trade patterns, and nutritional strategies. Within this cereal-centric paradigm, millets have historically occupied a peripheral yet resilient niche. Frequently described as "coarse grains," "minor cereals" or more recently "nutri-cereals," millets are often perceived as distinct from mainstream cereals in both academic discourse and public understanding. This has led to a recurring misconception that millets are not true cereals. However, such differentiation arises more from agronomic convention and socio-economic hierarchies than from botanical reality.

Cereals are defined broadly as the edible seeds of grasses (Poaceae family) that serve as staple foods worldwide. Major cereals include rice (*Oryza sativa*), wheat (*Triticum spp.*), maize (*Zea mays*), barley (*Hordeum vulgare*) and oats (*Avena sativa*). While millets also are recognized as *small-seeded grasses* with substantial environmental resilience and nutritional potential belong to Poaceae and are cultivated as grains, which includes pearl millet (*Pennisetum glaucum*), finger millet (*Eleusine coracana*), foxtail millet (*Setaria italica*), little millet (*Panicum sumatrense*), kodo millet (*Paspalum scrobiculatum*), barnyard millet (*Echinochloa* spp.) and proso millet (*Panicum miliaceum*). many researchers argue that they differ significantly not in familial taxonomy but in agronomic traits, nutrient composition, historical utilization patterns and global recognition relative to staple cereals. A common misconception is that "millets are not cereals." Scientifically, this statement is incorrect from a botanical standpoint. Millets are a subset of cereals. However, they are sometimes differentiated based on grain size, agronomic traits, and economic importance. This review clarifies the distinction through four analytical lenses:

1. Evolutionary and domestication
2. Taxonomy
3. Morphology
4. Nutritional biochemistry
5. Trade and policy classification

Evolutionary and domestication perspective

Archaeobotanical evidence suggests that millets were among the earliest domesticated cereal crops, particularly in Africa and Asia. Pearl millet was domesticated in the Sahel region of Africa around 2500 BCE, finger millet in East Africa, and foxtail millet in northern China around 6000 BCE (Fuller, 2006). Their domestication in semi-arid regions shaped their adaptation to drought, high temperatures, and low-input agricultural systems. These traits reinforce their classification as climate-resilient cereals rather than a separate grain category.

Taxonomical differences

Although millets are taxonomically cereals, they display morphological distinctions compared to major cereals. One primary difference lies in grain size and structure. Millet grains are generally smaller caryopses with a relatively higher bran-to-endosperm ratio, which contributes to their higher dietary fibre content (Saleh *et al*., 2013). The higher proportion of outer layers also influences milling recovery and processing characteristics.

Inflorescence architecture further illustrates morphological diversity within Poaceae. Pearl millet produces a dense, spike-like panicle, while foxtail millet has a compact cylindrical panicle. Wheat forms a true spike, whereas rice develops a branched panicle (Simpson, 2019). These differences represent intra-family structural variation driven by evolutionary divergence but do not justify separation from the cereal category. Hence, morphological variation explains agronomic differentiation without altering taxonomic placement.

In reality, what distinguishes millets from "major cereals" is not taxonomy but scale and specialization. Millets are generally small-seeded, short-duration, C_4 photosynthetic grasses adapted to drought-prone and low-input environments. Their grain architecture, with a higher bran-to-endosperm ratio, contributes to elevated dietary fibre and micronutrient density. Their resilience traits deep rooting systems, efficient water-use efficiency, and tolerance to abiotic stresses make them ecologically distinct within the cereal family. Yet, these are adaptive divergences within Poaceae, not evidence of taxonomic separation.

Environmental and sustainability metrics

Compared to major cereals, millets demonstrate substantially lower resource requirements and greater ecological adaptability. They generally require two to five times less water than irrigated rice systems and are well suited to rainfed agro-ecosystems where fertilizer inputs are minimal. Their short growth duration allows them to escape terminal drought and heat stress, thereby reducing exposure to climatic risks. Because millet cultivation depends less on intensive irrigation and synthetic inputs, it is associated with lower greenhouse gas emissions and fits well within low-carbon agricultural frameworks. Under projected temperature increases of 2-3°C, yield stability models suggest that millets are likely to outperform wheat in semi-arid regions due to their C_4 physiology and superior water-use efficiency. Moreover, integrating millets into cropping systems enhances agrobiodiversity, diversifies production landscapes, and reduces the vulnerability associated with monocropping of major cereals. In this context, millets may be understood as resilience-oriented cereals, contrasting sharply with the input-intensive production systems that characterize dominant global staples.

Nutritional and biochemical distinctions

Millets are nutritionally distinct when compared with major cereals. They generally contain higher levels of dietary fiber, essential minerals, and certain bioactive compounds (Saleh *et al.,* 2013). Finger millet, for example, is particularly rich in calcium, while several millet species demonstrate higher iron and zinc concentrations than polished rice. Protein content in millets is moderate; however, some species possess a more favourable amino acid profile, including relatively higher methionine levels compared to rice (Quinoa, 2011).

Millets are also rich in phytochemicals such as phenolic acids, flavonoids, and antioxidant compounds, which contribute to their functional food properties. Due to their higher fiber and polyphenol content, many millets exhibit a lower glycemic index than refined wheat and polished rice (Taylor & Emmambux, 2008). Recognition of these nutritional advantages led the Government of India to designate millets as "Nutri-cereals" in 2018, emphasizing their health benefits without implying taxonomic reclassification.

Nutritionally, millets further reinforce their distinct identity. Compared to polished rice and refined wheat, millets possess higher mineral density, greater antioxidant activity, and lower glycemic response. These attributes have led to their rebranding as "nutri-cereals," subtly reinforcing the perception of difference. However, enhanced nutritional quality does not remove them from the cereal category rather, it highlights the biochemical diversity within cereals.

Table 1: Proximate composition of small millets and other cereals on dry matter basis

Millets crops	Protein	fat	Ash	Crude fibre	carbohydrates	Energy
Finger millet	7.7	1.5	2.6	3.6	3.6	72.6
Foxtail millet	11.2	4.0	3.3	6.7	6.7	63.2
Kodo millet	9.8	3.6	3.3	5.2	5.2	66.6
Barnyard millet	11.0	3.9	4.5	13.6	13.6	55.0
Proso millet	12.5	3.5	3.1	5.2	5.2	63.8
Little millet	9.7	5.2	5.4	7.6	7.6	60.9

Source: Saleh *et al*. (2013)

Pseudocereals and millets

Confusion sometimes arises from conflating millets with pseudocereals. True cereals belong exclusively to the Poaceae family and produce a caryopsis. In contrast, pseudocereals such as quinoa (*Chenopodium quinoa*, Amaranthacea) and buckwheat (*Fagopyrum esculentum*, Polygonaceae) are non-grass species whose seeds are used similarly to cereals (Quinoa, 2011). Millets, being members of Poaceae and producing a true caryopsis, are taxonomically classified as true cereals and not pseudocereals.

Trade and policy

Millets and major cereals differ significantly in trade integration and policy support despite sharing botanical classification. Major cereals such as wheat, rice, and maize dominate global grain markets, with well-established export networks, futures trading systems, and strong international demand. In contrast, millet trade remains largely localized, with limited participation in global commodity markets. Governments heavily procure rice and wheat under food security schemes, ensuring assured markets and buffer stocking, whereas millet procurement volumes have historically been lower. Major cereals receive substantial input subsidies, irrigation support, and mechanization incentives, particularly since the Green Revolution. Millets, primarily grown in rainfed and marginal areas, have received comparatively limited institutional backing (Ceasar & Baker, 2025).

Research and development investments have traditionally favoured high-yielding major cereals, while millet improvement gained momentum only in recent years. Processing infrastructure and value chains are highly developed for major cereals but remain emerging for millets due to dehusking and storage challenges. Policy narratives also differ, with major cereals framed around calorie security and trade competitiveness. Millets are increasingly positioned within nutrition security and climate resilience agendas. The declaration of millets as "nutri-cereals" and the International Year of Millets (2023) reflects this policy shift. Thus, while botanically similar, millets and major cereals are handled differently in trade, subsidy regimes, and food policy framework.

Conclusion

Millets, while taxonomically within Poaceae, constitute a phylogenetically diverse assemblage distinct from the globally dominant cereal crops such as rice, wheat, and maize. Their C_4 photosynthetic pathway, short growth cycle, and superior abiotic stress tolerance position them ecologically apart from input-intensive cereals. Agronomically, they thrive in low-fertility, rainfed systems were major cereals exhibit yield instability. Nutritionally, millets demonstrate higher micronutrient density, resistant starch, and bioactive phytochemicals, conferring functional food advantages. Therefore, reducing millets to the category of conventional cereals obscures their unique evolutionary, ecological, and nutritional identity within sustainable food systems.

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