UDK 633.17:613.26-053.6 **Review Paper**
Doi: 10.7251/SANUS2604001P

NUTRITIONAL AND HEALTH BENEFITS OF MILLETS

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Abstract. *The term millets refers to a group of small-seeded cereal grasses whose grains, and in some cases vegetative parts, are used for human food and animal feed. Millets are cultivated in 93 countries on more than 30 million hectares, mainly in Asia (around 50%) and Africa (about 40%), where they remain important food sources. In terms of global production, millets rank fifth among cereal crops, after maize, wheat, barley, and sorghum. In the Western Balkans, common millet, barnyard millet, foxtail millet, and canary grass (Phalaris canariensis) are among the species with potential for cultivation, with common millet being the most widely grown. Millets provide energy, dietary fibre, slowly digestible starch, and resistant starch. They also supply protein, essential amino acids, minerals, and vitamins, although nutrient composition varies among species, cultivars, and processing methods. Dietary fibre and selected bioactive compounds in millets may support aspects of metabolic and gastrointestinal health. However, evidence for specific disease-prevention effects varies in strength and includes laboratory, animal, and a limited number of human studies; millets should therefore be considered components of a balanced diet rather than treatments for disease. Millet grains also contain antinutritional factors that can reduce nutrient bioavailability. Some compounds, including polyphenols, may also have antioxidant activity. Appropriate pretreatment and processing can reduce some antinutritional factors and improve nutrient availability.*

Keywords*: millets, food security, dietary fibre, nutritional quality, metabolic health*

Introduction

Wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), and rice (*Oryza sativa* L.) provide more than 60% of the energy consumed by the human population and constitute the major staple crops in the human diet (Cakmak and Kutman 2018; Vetriventhan and Upadhyaya 2019). Heavy reliance on these three cereals in human

nutrition has contributed to inadequate intake of essential micro- and macromineral elements among approximately two billion people worldwide (Bekkering and Tian 2019). This situation highlights the need to diversify crop production by promoting the cultivation and dietary use of traditional and regionally important crops that possess high nutritional value and are well adapted to less favourable agroecological conditions (Vetriventhan and Upadhyaya 2019). In recognition of their importance to global food security, the Food and Agriculture Organization of the United Nations (FAO 2024) declared 2023 the International Year of Millets.

Millets is a collective term for small-seeded cereal species belonging to the grass family (Poaceae), used as food for humans and feed for domestic animals and birds. The Old Slavic term proso refers to plant species with similar morphological characteristics, cultivation practices, and uses. Under the agroecological conditions of the Western Balkans, common millet (*Panicum miliaceum*), foxtail millet (*Setaria italica*), and canary grass (*Phalaris canariensis*) can be cultivated, with common millet being the most widely represented in production.

Millet has a fibrous root system that can reach a depth of up to 1 m. Its roots have a high capacity for water uptake, allowing the crop to grow under conditions of limited soil moisture. Common millet can reach 1 m in height, whereas Italian millet can reach 2 m. The panicle may reach a length of up to 50 cm. From the bases of the panicle branches, 10–40 lateral branches develop and terminate in spikelets whose individual florets produce grains. Millet seeds are among the smallest cereal grains, with a thousand-kernel weight of 5–8 g. Grain volume density is relatively high, with a hectolitre weight of approximately 70–75 kg.

Millets are generally short-day plants originating from tropical regions of Africa and Asia. Under shorter-day conditions (less than 12 h of daylight), they accelerate development and shorten the growing period, particularly the reproductive phase. Under long-day conditions, the growing period is prolonged. Depending on photoperiod and temperature, the growing season lasts from approximately 60 days when the crop is sown as a second or catch crop to about 120 days when sown in spring. At sowing, soil temperature should exceed 10 °C, with 12–15 °C considered optimal. When grown as a second crop, millet reaches maturity early because of high temperatures and the shortening photoperiod. Millets require abundant light and can grow on relatively poor, non-acidic soils. Monocropping is not recommended, partly because of the risk of severe infestation by the European corn borer. Millets can also be used as cover crops, contributing to soil-water conservation, erosion control, maintenance of soil fertility, and weed suppression. They may provide additional income from arable land that would otherwise remain out of production during summer and can be a useful crop option in drought years, which are becoming increasingly frequent in the region.

A narrative review approach was used for this paper. The sources discussed were drawn from the peer-reviewed studies and institutional publications cited in the manuscript and were selected for their relevance to millet origin, taxonomy, cultivation, nutritional

composition, processing, and human health. The manuscript does not report a systematic database search or formal screening protocol; accordingly, it presents a narrative synthesis rather than a systematic review. The aim of the paper is to summarize the origin and characteristics of millets, their position in global agriculture, taxonomy, chemical composition, and significance in human nutrition. This paper forms part of the monograph Nutraceutical Cultivated Plants, published by the Academy of Sciences and Arts of the Republic of Srpska. The authors gratefully acknowledge the Academy of Sciences and Arts of the Republic of Srpska for permission to use the relevant material.

Origin, History and Distribution of Millets

The centre of origin of millets has not yet been fully established. Weedy forms of these crops have a broad distribution across Central Asia, suggesting that millets may have spread from this region eastward towards East Asia and westward towards Europe (Jones and Liu 2009). Various millet species were particularly important and widely cultivated in India and China, while individual species were also cultivated in Africa, the Middle East, and Europe.

Millet is thought to have reached Europe through Georgia, where millet grains were discovered at archaeological sites associated with Neolithic settlements dating to the fourth and fifth millennia BC. From this region, millets spread into Eastern and Central Europe and subsequently reached Italy and Greece and, much later, the Middle East (Kirleis et al. 2022). Millets are essentially crops of warm, southern regions; however, their short growing season allows cultivation considerably farther north and somewhat farther north than maize. The optimal geographical zone for millet cultivation lies between approximately 30–50° N and 20–35° S latitude.

Millets are cultivated in 93 countries worldwide on more than 30 million hectares. Today, they are predominantly grown in Asia (approximately 50%) and Africa (approximately 40%), where they remain important sources of human food. The largest cultivated areas and leading producers of millet grain are India (39%), Nigeria (11%), China (9%), Niger, and Mali (6%) (Meena et al. 2021). Russia accounts for approximately 7% of the world's millet-growing area, while the remaining 3% occurs in other regions, including Europe. According to the Food and Agriculture Organization of the United Nations (FAO 2024), total production of all millet species ranks fifth among the world's cereal crops, after maize, wheat, barley, and sorghum.

Taxonomy of Millets

The millet group comprises a diverse range of cereal species, including finger millet (*Eleusine coracana* (L.) Gaertn.), foxtail millet (*Setaria italica* (L.) P. Beauv.), common millet (*Panicum miliaceum* L.), barnyard millet (*Echinochloa crus-galli* (L.) P. Beauv. and *Echinochloa colona* (L.) Link), kodo millet (*Paspalum scrobiculatum* L.), little millet (*Panicum sumatrense* Roth ex Roem. & Schult.), teff or Ethiopian millet (*Eragrostis tef* (Zucc.) Trotter), fonio millet (*Digitaria exilis* Stapf and D.

iburua Stapf), Job's tears (*Coix lacryma-jobi* L.), guineagrass millet (*Brachiaria deflexa* (Schumach.) C.E. Hubb. ex Robyns = *Urochloa deflexa* (Schumach.) H. Scholz), and browntop millet (*Brachiaria ramosa* (L.) Stapf = *Urochloa ramosa* (L.) T.Q. Nguyen).

Characteristics of Millets

Millets are small-seeded cereals, generally with oval-shaped grains, and were among the earliest cereal crops domesticated in Africa and Asia (Bhat et al. 2018). Historically, they served as important food crops. Today, their adaptability to climate variability and their capacity to grow under relatively unfavourable environmental conditions have renewed interest in their role in future food systems (Maitra and Shankar 2019). Their advantages include their use as food and as ingredients in nutritionally enriched products, their value as animal feed, their contribution to agrobiodiversity, relatively low nutrient requirements, efficient carbon fixation as C4 plants, potential to reduce soil erosion in some environments, and contribution to food security among smallholder farmers.

Major constraints on expanding millet cultivation beyond traditional growing areas and increasing its use include limited awareness among producers and consumers, insufficient breeding efforts, inadequate seed availability, and limited knowledge of suitable production technologies. Their tolerance to some abiotic and biotic stresses and relatively low requirements for agrochemicals can make millet species suitable for sustainable production systems (Thilakarathna and Raizada 2015). Compared with major cereals, millets generally have lower productivity and yield potential, reflecting their genetic background and genotype × environment interactions (Bai et al. 2021). Farmers have traditionally cultivated millets with little or no fertilizer input (Devkota et al. 2016). Table 1 presents the origin, common names, and selected physical characteristics of important millet species (Kalse et al. 2022).

Chemical Composition of Millets

Nutritional quality is a key factor determining the dietary importance of cereals and their contribution to human health. Millets have nutritional value comparable in several respects to that of other major cereals (Table 2). They provide energy, dietary fibre, slowly digestible starch, and resistant starch, which may contribute to a more gradual release of glucose and prolonged satiety; these effects depend on the millet species and the way the grain is processed and prepared (Nithiyanantham et al. 2019; Annor et al. 2017).

Table 2. Nutritional composition of millets and other cereals (Das et al. 2019)

Cereals	Protein (%)	Fat (%)	Crude fibre (%)	Ash (%)	Starch (%)	Total dietary fibre (%)	Total phenolics (mg/100 g)
Wheat	14,4	2,3	2,9	1,9	64,0	12,1	20,5
Rice	7,5	2,4	10,2	4,7	77,2	3,7	2,51
Maize	12,1	4,6	2,3	1,8	62,3	12,8	2,91
Sorghum	11,0	3,2	2,7	1,8	73,8	11,8	43,1
Barley	11,5	2,2	5,6	2,9	58,5	15,4	16,4
Oats	17,1	6,4	11,3	3,2	52,8	12,5	1,2
Rye	13,4	1,8	2,1	2,0	68,3	16,1	13,2
Finger millet	7,3	1,3	3,6	3,0	59,0	19,1	102
Pearl millet	14,5	5,1	2,0	2,0	60,5	7,0	51,4
Common m.	11,0	3,5	9,0	3,6	56,1	8,5	13,3
Foxtail millet	11,7	3,9	7,0	3,0	59,1	19,1	106,0
Kodo millet	8,3	1,4	9,0	3,6	72,0	37,8	368,0

Millets provide protein and are consumed as part of plant-based diets. Their amino-acid profiles include essential amino acids such as methionine, phenylalanine, tryptophan, and valine, although the amounts vary by species and cultivar (Saleh et al. 2013) (Table 3). They also provide the sulfur-containing amino acids methionine and cysteine. Lysine is often a limiting amino acid, and tryptophan content also varies among species. Antinutritional factors can reduce protein digestibility; appropriate processing, including dehulling, milling, soaking, and heating, may reduce some of these factors and improve in vitro protein digestibility.

Table 1. Selected characteristics of different millet species (Kalse et al. 2022)

Millet species	Scientific name	Common names	Physical characteristics of the seed	Origin	Plant	Grain
Foxtail millet	Setaria italica	Indian paspalum, Kangni, Water couch, Italian millet, Rala	Colour - Pale yellow to orange Shape - Ovoid Size - 2 mm length	China		
Finger millet	Eleusine coracana	Ragi, Wimbi, Mandua, Nakni, Kapai, Nagli, Marua	Colour - Light brown to dark brown. Shape – Spherical Size - 1–2 mm in diameter	East Central Africa (Uganda)		
Pearl millet	Pennisetum glaucum	Bajra, Cattail millet, Black millet, German millet	Colour-White, grey, pale yellow, brown, or purple. Shape - Ovoid Size 3–4 mm length	Tropical West Africa (Sahel)		

Proso millet	Panicum miliaceum	Cheena, Common millet, Broom millet, Vari	Colour - White cream, yellow, orange Shape - Spherical to oval; Size - 3 mm long and 2 mm in diameter	Central and East Asia		
Kodo millet	Paspalum scrobiculatum	Kodara, Ditch millet, Creeping paspalum	Colour- Blackish brown to dark brown Shape - Elliptical to oval Size - 1.2 to 9.5 µm long	India and West Africa		
Barnyard millet	Echinochloa crusgalli	Bhagar, Sawan, Jhingora, Kudraivali, Oodalu, Barti	Colour – White Shape – Tiny round Size – 2-3 mm long	Japan and India		
Little millet	Panicum sumatrense	Kutki, Samai, Samalu, Haliv	Colour - Grey to straw white Shape - Elliptical to Oval Size - 1.8 to 1.9 mm long	Southeast Asia		

Table 3. Essential amino acid composition (mg/100 g) of different millet species (Singh et al. 2019)

Millets	Ile	Leu	Lys	Met	Cys	Phe	Tyr	Thr	Trp	Val
Pearl millet	256	598	214	154	148	301	203	241	122	345
Finger millet	275	597	181	194	163	325	-	263	191	413
Foxtail millet	475	1044	138	175	-	419	-	194	61	431
Common millet	405	762	189	160	-	307	-	147	49	407
Little millet	416	679	114	142	-	297	-	212	35	379
Japanese millet	288	725	106	133	175	362	150	231	63	388
Kodo millet	188	419	188	94	-	375	213	194	38	238

Abbreviations: Ile – isoleucine; Leu – leucine; Lys – lysine; Met – methionine; Cys – cysteine; Phe – phenylalanine; Tyr – tyrosine; Thr – threonine; Trp – tryptophan; Val – valine

Lipids provide energy, support brain development, and facilitate the absorption and transport of vitamins A, D, E, and K in the body. Germination affects the lipid content of millet grains. For example, raw and conditioned flour from germinated foxtail millet contained 4.4% and 3.6% fat, respectively, considerably less than the ungerminated sample. This reduction occurs because lipids serve as an energy source during germination (Sharma et al. 2015). High-pressure soaking of foxtail millet reduces its fat content by 28%, possibly because enzymatic activity generates free and soluble nutrients during germination.

The carbohydrate content of millet grains generally ranges from approximately 60 to 75% (Table 2). Starch is the predominant carbohydrate in millets, as in other cereal grains. The amount of carbohydrate available for digestion and absorption in cereal-based foods depends on processing and cooking methods, including soaking, germination, pressure cooking, autoclaving, and related treatments (Rao et al. 2017).

The bran fraction of millet is a major source of dietary fibre, consisting primarily of complex polysaccharides that human digestive enzymes cannot readily degrade. Consequently, dehulling and removal of the bran substantially reduce dietary fibre content (Yousaf et al. 2021). Because most millets undergo dehulling before consumption, careful control of dehulling intensity can help maximize fibre retention. The contents of insoluble dietary fibre components, including lignin, cellulose, and hemicellulose, are lower in the milled fraction than in whole-grain flour (Sharma and Niranjan 2018). In foxtail millet, however, dietary fibre content increases significantly with increasing germination time (Sharma et al. 2017).

Millets provide minerals such as potassium (K), magnesium (Mg), iron (Fe), calcium (Ca), and zinc (Zn), as well as vitamins. The concentrations of these nutrients vary among species and are influenced by growing conditions and processing; many are concentrated in the aleurone layer, germ, and pericarp (Rao et al. 2017). Soaking millet grains before cooking can reduce some antinutritional factors and improve mineral bioavailability. However, minerals such as Zn and Fe may also leach into the soaking water, reducing their concentration in the grain (Bindra and Manju 2019).

Table 4. Mineral composition of the millets and other cereals (Das et al. 2019)

Cereals	Ca (%)	P (%)	K (%)	Na (%)	Mg (%)	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Thiamin	Riboflavin	Nicotinic acid
									(mg/100 g)		
Wheat	0,04	0,35	0,36	0,04	0,14	40,1	40,0	30,9	0,57	0,12	7,40
Rice	0,02	0,12	0,10	0,00	0,03	19,0	12,0	10,0	0,07	0,03	1,60
Maize	0,03	0,29	0,37	0,03	0,14	30,0	5,0	20,0	0,38	0,14	2,80
Sorghum	0,04	0,35	0,38	0,05	0,19	50,0	16,3	15,4	0,46	0,15	4,84
Barley	0,04	0,56	0,50	0,02	0,14	36,7	18,9	23,6	0,44	0,15	7,20
Oats	0,11	0,38	0,47	0,02	0,13	62,0	45,0	37,0	0,77	0,14	0,97
Rye	0,05	0,36	0,47	0,01	0,11	36,0	58,4	32,2	0,69	0,26	1,52
Finger millet	0,33	0,24	0,43	0,02	0,11	46,0	7,5	15,0	0,48	0,12	0,30
Pearl millet	0,01	0,35	0,44	0,01	0,13	74,9	18,0	29,5	0,38	0,22	2,70
Common Millet	0,01	0,15	0,21	0,01	0,12	33,1	18,1	18,1	0,63	0,22	1,32
Foxtail millet	0,01	0,31	0,27	0,01	0,13	32,6	21,9	21,9	0,48	0,12	3,70
Kodo millet	0,01	0,32	0,17	0,01	0,13	7,0	-	-	0,32	0,05	0,70

Millets in Human Nutrition

Millet grains are versatile and can be readily incorporated into rice- or maize-based diets or used as substitutes for rice in a wide range of recipes. They are also important ingredients in traditional foods and beverages, multigrain products, and gluten-free foods. Fermented millet beverages can improve nutrient availability, including the bioavailability of proteins and minerals, enhance digestibility, and reduce the levels of antinutritional factors (Rao et al. 2017).

During the Roman Empire, millets were among the staple foods available to poorer populations and were used to prepare bread, flatbreads, pastries, porridges, and similar dishes. In some countries, they were also cultivated for beer production. In ancient Egypt, millet flatbread soaked in water served as a raw material for the production of early forms of beer (Omran et al. 2023). In Romania and Bulgaria, people have used millets to produce boza, a traditional fermented beverage containing approximately 1% alcohol. Historically, boza was among the alcoholic beverages tolerated by the Ottoman authorities despite religious restrictions, as Janissaries consumed it for warmth and courage. In ancient China, people used millet to produce wine, and during the Han dynasty, this beverage was more popular than tea (Tursi 2022). This tradition continues in China, Taiwan, Korea, and Japan, where millet wine, together with rice wine (sake), remains valued by consumers (Tursi 2022).

Millets generally undergo processing before consumption to remove inedible components, extend shelf life, and improve nutritional and sensory properties. Primary processing techniques include dehulling, soaking, germination, roasting, drying, polishing, and milling. Modern and secondary processing methods, including fermentation, boiling, cooking, malting, baking, dehulling, extrusion, and related processes, produce a wide range of millet-based foods (Birania et al. 2020). Although

these techniques can improve nutrient digestibility and bioavailability, subsequent processing may also cause substantial nutrient losses (Nazni and Devi 2016).

Millets can also serve as animal feed, particularly in poultry nutrition, while cattle and other large livestock can consume the grain, straw, green biomass, and husks. Millet grain can be stored for extended periods and may retain germination capacity for up to five years.

Role of Millets in Human Health

The nutritional composition of millets provides a rationale for studying their possible contribution to health, but the strength of evidence differs by outcome. Laboratory and animal studies have reported effects of selected millet compounds or extracts in cancer-related models (Ramadoss and Sivalingam 2020; Yang et al. 2020); these findings do not establish that eating millets reduces cancer incidence in humans. Some human studies have examined millet-based diets and glycaemic responses, including in people with impaired glucose tolerance (Ren et al. 2018), while other evidence on obesity, cardiovascular health, and gastrointestinal outcomes remains heterogeneous or indirect. The fibre content and glycaemic properties of some millet foods suggest that they may be included as part of a balanced dietary pattern for people managing blood glucose, but effects depend on the species, food formulation, processing, portion size, and overall diet (Kam et al. 2016; Nainwal 2018). Millets can also contribute nutrients to diets, particularly where food diversity is limited (Anbukkani et al. 2017). The potential nutritional and health-related attributes discussed in the literature are summarized in Table 5.

Millets are rich in niacin, which supports healthy skin and the normal function of various organs. They also contain beta-carotene, particularly in dark-coloured grains, which the body can convert to vitamin A. Vitamin A contributes to antioxidant defence mechanisms and supports normal immune function (Debnath et al. 2023).

Some millet foods have a relatively low glycaemic index, although values vary considerably with species, processing, recipe, and cooking method. Such foods may help moderate postprandial blood-glucose responses when included in an appropriate dietary pattern. Their dietary fibre and slowly digestible carbohydrate fractions may be relevant to people with type 2 diabetes, but millets are not a substitute for individualized medical or dietary advice (Kam et al. 2016).

Millets contain soluble and insoluble dietary fibre. Evidence on dietary fibre more generally suggests associations with several health outcomes, including cardiovascular and metabolic health; however, these findings should not automatically be interpreted as proof of a millet-specific protective effect (Chandrasekara and Shahidi 2010). Insoluble fibre can support normal bowel function and may influence the intestinal microbiota. Soluble fibre can affect lipid absorption and may contribute to maintaining healthy blood cholesterol levels (Jacob et al. 2024). These mechanisms provide a plausible basis for including whole-grain

millet foods in a varied diet, but the magnitude of any effect depends on the overall dietary pattern and the specific food consumed. Millets also provide magnesium, which is required for normal muscle and nerve function, including normal cardiac function (Gahalawat et al. 2024).

Tannins, phytates, and other phenolic compounds in millets have been investigated for antioxidant activity and possible effects on markers of oxidative stress. These findings, including those from experimental studies, do not by themselves demonstrate prevention of hypertension, diabetes, or hypercholesterolaemia in humans. Research on finger millet has suggested potential antioxidant-related effects, but further human evidence is needed before firm conclusions can be drawn about healthy ageing (Kumar et al. 2021).

Some millet species are excellent sources of B-group vitamins, which play important roles in numerous physiological processes, from brain function to normal cell division. Vitamin B9, also known as folate or folic acid, is essential for the formation of healthy red blood cells (Rao et al. 2017).

Table 5. Potential nutritional and health-related attributes of millets (Rasika et al. 2024)

Millet type	Nutritional attributes	Potential health relevance (evidence varies)	Other attributes	Limitations / considerations	References
Finger millet	Provides calcium, iron and dietary fibre	May contribute useful nutrients to the diet; no disease-prevention effect is established by composition alone	Naturally gluten-free; contains phenolic compounds	Mineral bioavailability may be affected by antinutritional factors	Saleh et al. 2013
Pearl millet	Provides protein and B-group vitamins	May contribute to dietary quality; effects on glycaemic controll depend on the food and overall diet	Drought-tolerant crop suitable for some arid environments	Human evidence on long-term health outcomes is limited	Saleh et al. 2013; Gupta et al. 2018
Foxtail millet	Contains dietary fibre and phenolic compounds	Some studies report favourable glycaemic responses or antioxidant activity; clinical	Can be used in a variety of foods; naturally gluten-free	Digestive tolerance depends on individual and preparation	Saleh et al. 2013; Chandrasekara and Shahidi 2010

Millet type	Nutritional attributes	Potential health relevance (evidence varies)	Other attributes	Limitations / considerations	References
		evidence remains limited			
Common (proso) millet	Provides protein and other nutrients; composition varies by cultivar	May be included in balanced diets; evidence for direct cardiovascular or glucose-controll effects is not conclusive	Versatile ingredient with relatively short cooking time in some preparations	Availability and food composition vary by region and product	Saleh et al. 2013; Singh and Singh 2015
Barnyard millet	Provides dietary fibre and protein	Potential contribution to dietary diversity; specific health effects require further study	Naturally gluten-free	Nutritional composition and long-term outcomes are not equally well studied	Saleh et al. 2013
Little millet	Provides iron and other minerals	Can contribute to mineral intake; effects on blood pressure have not been established by the cited composition data	Adapted to a range of growing conditions	Consumer awareness and market availability may be limited	Saleh et al. 2013
Kodo millet	Contains dietary fibre and phenolic compounds	Experimental findings suggest potential bioactivity, but evidence for weight loss or diabetes controll in humans is insufficient	Fast-growing crop in suitable environments	Taste and processing characteristics may affect consumer acceptance	Saleh et al. 2013; Chandrasekara and Shahidi 2010

Antinutritional Factors

Antinutrients are phytochemical compounds produced by plants as part of their natural defence mechanisms. In foods, these compounds may interfere with the absorption or utilization of nutrients and thereby reduce their bioavailability (Bora et al. 2019). High levels of some antinutritional compounds in raw or inadequately processed foods may contribute to nutritional problems, including micronutrient deficiencies, reduced nutrient utilization, or gastrointestinal discomfort. The effects depend on the compound, concentration, overall diet, and processing method.

One limitation of millets is their relatively high concentration of antinutritional factors compared with wheat and rice. Finger millet contains polyphenols, tannins (0.61%), phytates (0.48%), trypsin inhibitors, and oxalates, which may reduce micronutrient bioavailability and impair protein digestibility. Goitrogenic compounds in pearl millet include phenolic flavonoid derivatives such as C-glycosyl flavones, while their metabolites have been associated with undesirable odours in millet flour during storage. Through metal chelation and enzyme-inhibitory activity, antinutritional factors can reduce the bioavailability of nutrients, particularly minerals and proteins.

However, researchers increasingly recognize certain antinutritional factors, particularly polyphenolic compounds, for their nutraceutical potential because of their antioxidant properties (Rao et al. 2017). Some secondary metabolites that function as antinutrients can have adverse biological effects, whereas others have applications in nutrition and pharmacology. Various pretreatment and processing techniques can reduce or remove antinutritional factors from cereal grains intended for food use, including bran removal, soaking, germination, fermentation, and autoclaving. These processes can enhance the nutritional value of millet-based foods by increasing the bioavailability of minerals such as Ca, Fe, and Zn and improving protein absorption (Birania et al. 2020).

Conclusion

Millets have favourable nutritional characteristics and are adapted to a range of growing conditions, making them relevant to crop diversification and sustainable food systems. As cover crops, some millet species can help protect the soil surface and reduce erosion when used appropriately within a cropping system. Millet grains provide starch, dietary fibre, minerals, and vitamins, although their composition varies by species and processing. Because most millets are naturally gluten-free, they may be suitable ingredients for people who require a gluten-free diet; however, products must be protected from cross-contamination with gluten-containing cereals. Evidence suggests that selected millet foods may influence glycaemic responses and that some millet-derived compounds have antioxidant activity. Nevertheless, current evidence does not justify broad claims that millet consumption prevents or treats cardiovascular disease, type 2 diabetes, cancer, or obesity. Millets are best considered

as one potential component of a varied, balanced diet, with further well-designed human studies needed to clarify specific health effects.

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NUTRITIVNE I ZDRAVSTVENE KORISTI PROSA I DRUGIH VRSTA ŽITA

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Sažetak. *Proso i druge vrste prosa obuhvataju grupu sitnosjemenih žitarica čije se zrno, a kod pojedinih vrsta i vegetativni dijelovi, koriste u ishrani ljudi i životinja. Proso se uzgaja u 93 zemlje na više od 30 miliona hektara, uglavnom u Aziji (oko 50%) i Africi (oko 40%), gdje predstavlja važan izvor hrane. Prema ukupnoj svjetskoj proizvodnji, proso zauzima peto mjesto među žitaricama, poslije kukuruza, pšenice, ječma i sirka. Na području Zapadnog Balkana potencijal za gajenje imaju obično proso, barnyard proso, foxtail proso i kanarska trava (Phalaris canariensis), pri čemu je obično proso najviše zastupljeno u proizvodnji. Proso i druge vrste iz ove grupe obezbjeđuju energiju, dijetetska vlakna, sporo svarljivi i rezistentni skrob, proteine, aminokiseline, minerale i vitamine, a sastav zavisi od vrste, sorte i načina prerade. Dijetetska vlakna i pojedina bioaktivna jedinjenja mogu imati značaj za metaboličko i gastrointestinalno zdravlje. Ipak, jačina dokaza o uticaju na pojedine bolesti nije jednaka; dio nalaza potiče iz laboratorijskih i životinjskih istraživanja, dok je broj kvalitetnih istraživanja na ljudima ograničen. Zbog toga proso treba posmatrati kao mogući dio uravnotežene ishrane, a ne kao sredstvo za liječenje ili prevenciju bolesti. Zrno sadrži i antinutritivne faktore koji mogu smanjiti biodostupnost hranljivih materija. Neka od tih jedinjenja, naročito polifenoli, pokazuju i antioksidativnu aktivnost. Odgovarajući predtretmani i postupci prerade mogu smanjiti dio antinutritivnih faktora i poboljšati dostupnost hranljivih materija.*

Ključne riječi: *proso, bezbjednost hrane, dijetetska vlakna, nutritivna vrijednost, metaboličko zdravlje*