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ECONOMIC MILLET PRODUCTION, FUNCTIONAL FOOD AND HEALTH BENEFIT

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Abstract: Millets is an alternative cereal. Functional food, rich in protein, vitamins, minerals, nutrients, and energy. Millet is a highly nutritious and climate-adapted crop. Although millet food products are known for their nutritional value, consumer awareness is low, especially regarding their nutritional and therapeutic benefits. Millet does not contain gluten, making it a useful grain in the diet of people with celiac disease. Millet is a rich source of fiber, nutrients, minerals, B-complex vitamins and phytochemicals such as polyphenols, lignans, phytosterols, phytoestrogens, and phytocyanins. High fibre content and the presence of some anti-nutritional factors such as phytate and tannin in millet affect the bioavailability of minerals. The economic and health benefits of millet are explained in detail in this study. The production of millet in the world is showing an increasing trend. The world area of millet in 2023 was 31.3 million ha, with a yield of about 1.0 t ha^{-1} and a total production of 31.6 million tons. Millet has numerous health benefits. Millet phytochemicals: polyphenols, lignans, phytosterols, phytoestrogen, phytocyanin, act as antioxidants, immunomodulators, detoxifiers, etc. and therefore protect against degenerative diseases associated with aging, such as cardiovascular disease (CVD), diabetes, cancer, etc. Consuming millet can help reduce liver disease.

Keywords*: Panicum miliaceum* L., Production, Yield, Functional food, Health advantage

INTRODUCTION

Panicum miliaceum L., or proso millet, is an annual grass. It is said to have originated in the Central areas of Europe as early as 2000 B.C. Dry conditions like those found in central Russia, the Middle East, northern India, Africa, Manchuria, and the Great Plains region of North America are particularly ideal for this plant. First brought to Canada in the 17th century, millet was rarely used as livestock feed in the early 20th century. It has been cultivated in East Asia for the last 10.000 years. Diseases are unknown, and proso millet is a comparatively low-demanding crop. For this reason, millet is often used in European organic farming methods. It is often used as an inter-cropping in the United States.

Continuous crop rotation is possible with millet, which can help prevent a summer fallow. Proso millet is a useful intercrop between two crops that require water and pesticides because of its superficial root system and tolerance to atrazine residue. Millet grows more quickly and earlier because the stubbles of the previous crop enable more heat to enter the soil. Throughout human history, millet have been significant food mainstays, especially in Asia and Africa. For generations, millets have been vital staples in the semi-arid tropical regions of Asia and Africa. For millions of the poorest people in these areas, millets continue to be their main source of protein, energy, vitamins, and minerals. Millets are cultivated under severe conditions that hinder the growth or productivity of other crops. They are cultivated using scarce water resources (Popović et al., 2025a).

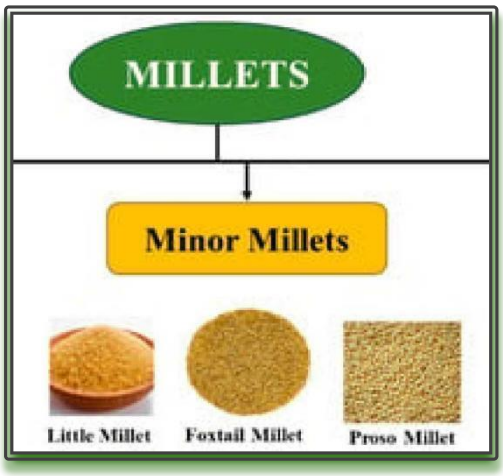
Modern plant production is becoming more and more reliant on cutting-edge technological solutions that enhance nutritional value and productivity. Through intelligent crop management, new agricultural technology, particularly smart agriculture and precision farming methods, allow farmers to maximize resource allocation and enhance the nutritional profile of cereal grains.

The development of superior grains that satisfy the increasing customer demand for functional foods with improved health benefits is made possible by this technical advancement (Popović et al., 2013; 2020a,b; Pejanović et al., 2024a,b; Pejanović and Urekar, 2025; Popović, 2025; Pejanović and Ergunova, 2025).

Because they contain vitamins, minerals, and bioactive compounds that promote human health and recovery, millets (*Panicum* sp.) are adaptable, small-grained grains of therapeutic importance. Millets include both large millets like finger millet and pearl millet and small millets like foxtail millet, little millet, kodo millet, proso millet, brown top millet, fonio, teff, and barnyard millet, Picture 1. A significant growth in knowledge of millets' nutritional benefits has led to an increase in demand for millets like food and value-added products. Millets include roughly 65-75% carbohydrates, 7-12% proteins, 2-5% fat, and 8-15% fibre. They have more essential amino acids than typical cereals, and millets' prolamin facilitates the digestion of proteins (Bhattacharya, 2023). The therapeutic potential of millets needs to be considered. Eating millet has been shown to enhance glycaemic control, reduce body mass index (BMI), halt the progression of pre-diabetes, and reduce the risk of atherosclerotic cardiovascular disease (Geetha et al., 2020; Popović et al., 2020a, 2022, 2024, 2025a,b).

Millet are helpful dietary grains since they are gluten-free. Fibre, minerals, and B-complex vitamins are abundant in millet. The bioavailability of minerals is impacted by millets' high fibre content and the presence of some anti-nutritional elements like phytates and tannins. Few human investigations have indicated that millet tend to absorb less iron than rice or even wheat. Oxidative stress is now recognized as an important etiological factor in the causation of several chronic diseases including cancer, cardiovascular diseases, osteoporosis, and diabetes. Antioxidants play an important role in mitigating the damaging effects of oxidative stress on cells. Lycopene, a carotenoid antioxidant, has received considerable scientific interest in recent years (Rao et al., 2006; Popović et al., 2025a). Phytochemicals that promote health, such as polyphenol, lignan, phytosterol, phyto-estrogen, and phytocyanin, are also abundant in millet. These defend against age-related degenerative diseases like cancer, diabetes, and cardiovascular disease (CVD) by acting as

antioxidants, immunological modulators, detoxifying agents, etc. (Rao et al., 2006, 2007). In addition to their established roles in avoiding diseases caused by dietary deficiencies, certain of the well-known nutrients' vitamins, minerals, and essential fatty acids also offer advantages in terms of preventing degenerative diseases. Millet is safe for those with celiac disease and gluten allergies because they are non-glutinous.



Picture 1. Little Millet, Foxtail Millet and Proso Millet

They don't generate acid, are simple to digest, and don't cause allergies (Saleh et al., 2013). Millet may offer protection against degenerative disorders that develop with ageing. Eating millet lowers the risk of heart disease, prevents diabetes, enhances the digestive system, lowers the risk of cancer, detoxifies the body, boosts immunity in respiratory health, boosts energy, improves the muscular and neural systems, and protects against a number of degenerative diseases, including Parkinson's disease and metabolic syndrome (Manach et al., 2005; Scalbert et al., 2005; Chandrasekara and Shahidi, 2011, 2012). Resistant starch, oligosaccharide, lipids, and antioxidants like phenolic-acids, avenanthramide, flavonoid, lignan, and phytosterol are among the significant nutrients found in millet. These nutrients are thought to be responsible for numerous health benefits (Miller, 2001; Edge et al., 2005; Popović et al., 2022). The purpose of this study is to highlight millet production as a significant functional food and to show how millet affects health. The aim of the research was to show the production of millet in the world and in our country and to point out the importance of millet as a functional food.

MATERIAL AND METHODS

FAO 2025 data on millet production in our nation and globally is used in the study (FAO 2025; www.fao.org/faostat/en/#data/QCL). Additionally, the literature and other materials from congresses, symposiums, and conferences that addressed the issue of millet production under study were used. Descriptive statistics were used to process all the data. The analyzed data is shown in tables and figures to make the features under investigation plainly evident.

RESULTS AND DISCUSSION

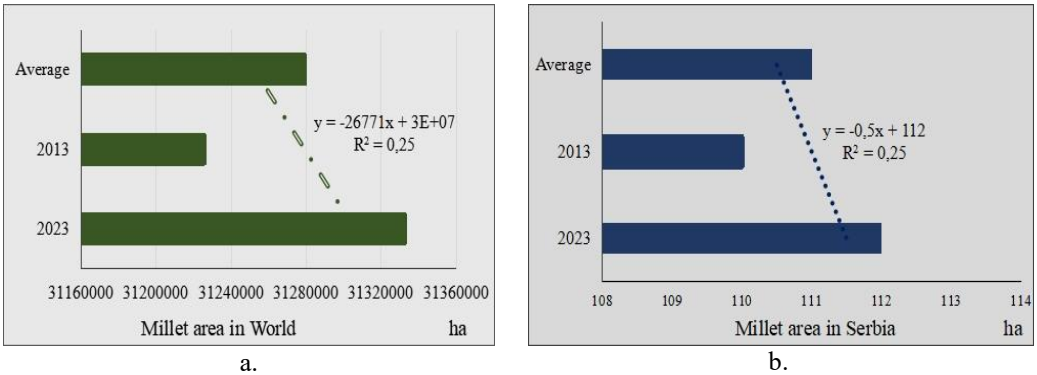
Global Cereals Production

Millet are important staples to millions of people worldwide. These are rain fed crops grown in areas with low rainfall and thus resume greater importance for sustained agriculture and food security. Almost all millets are used for human consumption in most of the developing countries, but their use has been primarily restricted to animal feed in developed countries. The average area sown with millet and the average millet production in the world and in Serbia is showing a growing trend, Table 1, Figures 1a and 1b and Figures 3a and 3b. The average area sown with millet is increasing globally, in 2023 the area was 31.322.668 ha and was higher than in 2013 (31.225.586 ha) (Table 1). Appropriate growing techniques, climatic conditions and variety selection are key to profitable millet production.

Table 1. Parameters of millet production in the world, 2023

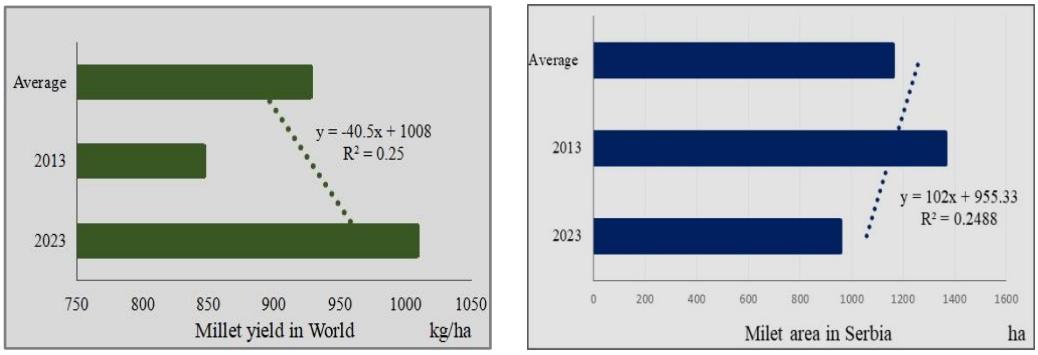
Parameter	World	Serbia	Share in the world (%)	
Year		**Area (ha)**		
2023	31332668	112	0.0004	
2013	31225586	110	0.0004	
Average	31279127	111	0.0004	
		Production (t)		
2023	31596316	107.0	0.0004	
2013	26423961	150.0	0.0006	
Average	29010139	128.5	0.0005	
		Yield (kg/ha)	**Increase (kg)**	**Increase (%)**
2023	1008	955,0	53.0	5.5
2013	846.2	1363.6	517.4	61.1
Average	927.1	1159.3	232.2	25.1
IV	161.8	408.6	-	-

In the world in 2023, millet grain yields were lower by 161.8 kg compared to 2013, or 19.1%, Table 1, Figure 2a. Average yields in Serbia in 2013 were significantly higher (1363.6 kg/ha) compared to 2023 (955 kg/ha), or 42.7% or 408.6 kg/ha, Table 1, Figure 2b.



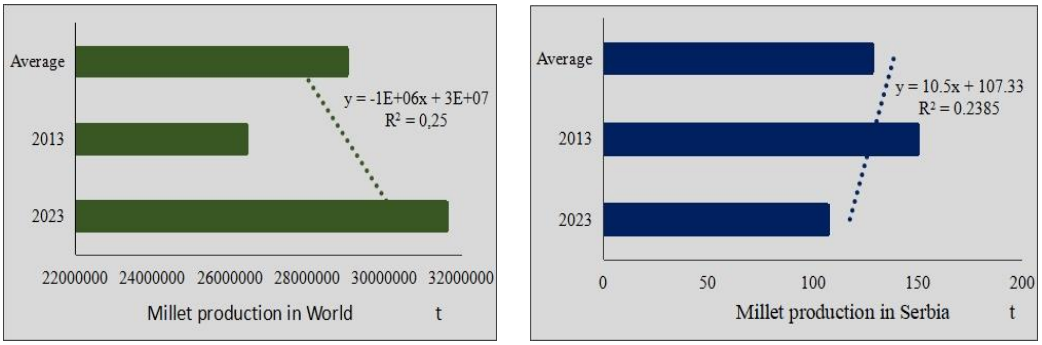
a. b.

Figure 1. Milet area in world (a.) and in Serbia (b.)



a. b.

Figure 2. Milet grain yield in world (a.), and in Serbia (b.)



a. b.

Figure 3. Milet production in world (a.), and in Serbia (b.)

Both the amount of precipitation in shorter time intervals and the frequency of extreme (dry) periods throughout the year have increased. Climate change adaptation strategies are becoming more and more crucial in this context (Popović et al., 2025a,b).

Sustainable food production systems guarantee future food production while addressing the requirement to expand food production on current agricultural land in ways that do not negatively impact the environment. The aforementioned suggests that cereals are crucial to our nation's economic and food security, and that advancing production technologies and adjusting to new problems are critical considerations (Popović et al., 2025a,b).

Millets Chemical Composition

Millet is nutritionally comparable to major cereals and serves as good source of protein, micronutrient and phytochemical. Processing methods like soaking, malting, decortications, and cooking affect the antioxidant content and activity (Saleh et al., 2013). While sorghum and most of the millets contain about 10% protein, 3.5% lipids, finger millet contains 12-16% protein and 2-5% lipids. Millet are very good sources of micronutrients such as vitamins and minerals. Major portion of sorghum protein is prolamin (kaffirin) which has a unique feature of lowering digestibility upon cooking whereas, the millet has a better amino acid profile. Millet contain fewer cross-linked prolamin, which may be an additional factor contributing to higher digestibility of the millet proteins. For both people and domestic animals, millet is a crucial component of a comprehensive, functioning diet.

They serve a variety of functions, such as raw materials for human nourishment (flour, bread, oil, beer, soft drinks), animal feed, coarse food (i.e., animal feed), a source of bedding or straw for animal breeding, mulching, and the generation of bioethanol, among other uses. The principles of organic agriculture make millet suited for production. Because of its many applications, suitable chemical makeup, and researched growing methods, millet is considered a vital source of both human and animal protein and energy. After a complicated industrial processing procedure, millet can be used to manufacture a variety of food products, such as flakes, groats (semolina), different confections, and more. The average nutrient composition of some millet grains is summarized in Table 2. Millet's chemical makeup varies greatly (Table 2, Figure 4). About 12.5% of protein is present in millet, 70% carbohydrates, 15% dietary fiber, 2.5-3.5% minerals, and good source of phosphorous and iron, Table 2.

Table 2. Chemical composition of millet *Panicum miliaceum* L.

Parameter	Energy	Protein	Carbohydrates	Oil	Dietary Fiber	Minerals	Copper	Phosphorus	Iron
	KJ			g				mg/100g	
Millet	341	12.5	70.05	2.2	15.1	2.5	1.6	206	10.1

Finger millet contains roughly 5-8% protein, 65-75% carbs, 15-20% dietary fibre, and 2.5-3.5% minerals (Chethan and Malleshi, 2007; Chethan et al., 2008). Epidemiological studies have demonstrated that regular eating of whole grain cereals and their products can reduce the incidence of cardiovascular disease, gastrointestinal disorders, and diabetes mellitus (McKeown, 2002).

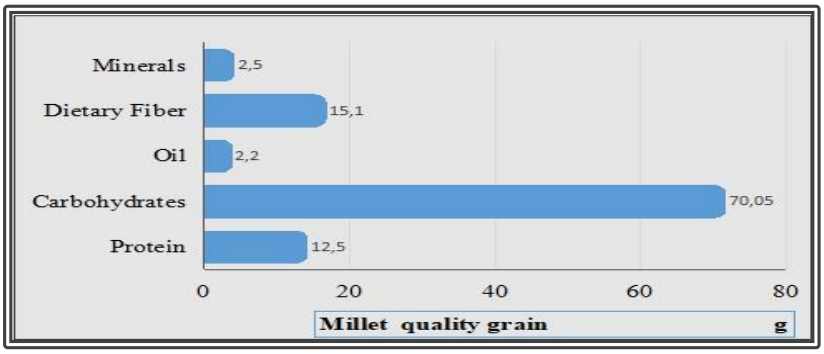


Figure 4. Millet grains quality composition (g)

When millet is used as whole grains, the vital nutrients such as dietary fibre, minerals, phenolics, and vitamins concentrated in the grain's outer layer or seed coat become part of the food and provide its nutritional and health advantages (Antony et al., 1996). In addition to having nutritional characteristics like those of main cereals, millet are excellent suppliers of carbohydrates, minerals, and phytochemical with nutraceutical qualities.

Compared to maize, millet protein has superior essential amino acid profiles. While finger millet proteins are distinct due to their sulfur-rich amino acid composition, pearl millet has a greater niacin level than any other crop. Millet proteins are low in lysin, much like cereal proteins, but they work well with lysin - rich vegetable (leguminous) and animal proteins

to create nutritionally balanced composites with high biological value. When it comes to nutrition, little millets are superior to fine cereals (Popović, 2025a).

Millet is a staple food for many cultures in Asia and Africa and are grown in arid and semi-arid parts of the planet. Because they are high in vitamins and minerals, they are known as nutricereals. Additionally, because millet contain advantageous phytochemicals that offer medicinal properties for a range of ailments, they have nutraceutical relevance. A wide variety of biological compounds can be found in both plant parts and grains. Eating millet has been shown to be beneficial for lifestyle and metabolic illnesses. Two methods to assess millets' therapeutic potential include the existence of phytochemicals and speciality compounds like flavonoid, phenolic, anthocyanidin, and others with antioxidant capacity, as well as additional nutrition through minerals and vitamins. Millet has a low glycaemic index, are gluten-free, and contain phytochemicals that help treat lifestyle problems and prevent diseases like cancer. Additional benefits include treatment for anaemia and calcium deficits, especially in young children and pregnant people (Stevanović et al., 2023, 2024; Popović et al., 2025a,b). Amino acids, particularly those containing sulphur, like cysteine and methionine, are abundant in millet. Millet species are a great source of essential amino acids since they have a high proportion of methionine in addition to lysine and threonine (Saleh et al., 2013). Compared to rice, sorghum, and maize, millet has higher lipids (Obilana and Manyasa, 2002). The protein content of millet grains is influenced by both genetic and environmental variables, especially the availability of nitrogen fertilizers (Dragičević et al., 2014). The nutritional profile of cereals is greatly impacted by agronomic practices. Numerous agronomic practices, including fertilization, weed control, nitrogen regulation, and varietal selection, have a significant impact on millet's nutritional composition. These techniques improve the macro-nutrient and micro-nutrient levels of the grain while also increasing its overall yield and quality.

Benefit of Millet

A useful food is millet. Beyond their nutritional value, functional foods which contain vitamins or other additional ingredients offer health benefits. Millet is supplemented with fibre, vitamins, minerals, and probiotics. In addition to their primary nutrients, millet have therapeutic qualities due to the presence of phenolic compounds, the predominant form of secondary metabolites. Lignins, polyphenols, phytocyanins, phytoestrogens, and phytosterols are among them. These compounds protect genetic material and cellular membranes by functioning as antioxidants. Numerous health-promoting and protective properties, such as antimicrobial, immuno-modulatory, anti-inflammatory, antiviral, anticancer, antiplatelet aggregation, and inhibitory activities on digestive enzymes and cataract formation, have been associated with millet phenolics (Viswanath et al., 2009; Shobana et al., 2009).

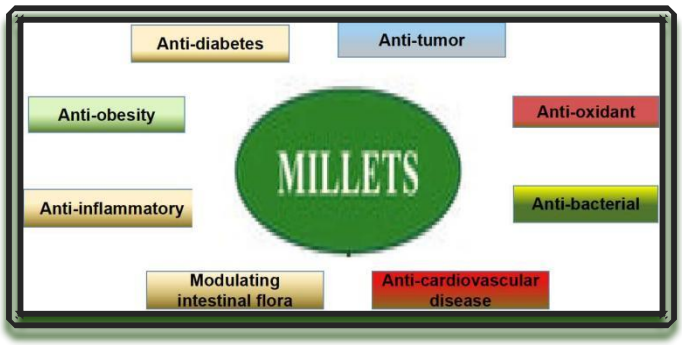
Polyphenols exist in both bound and unbound forms. The pharmacological activities of bound polyphenols include antioxidant, anticancer, immunomodulatory, antifungal, and anti-hyperglycemia characteristics (Shi et al., 2010), Picture 2. Protein glycation, protein aggregation formation, oxidative DNA damage, and hydroxyl radical-induced protein fragmentation are all prevented by millet phenolics (Anis and Sreerama, 2020). Chethan et al. (2008) identified nine phenolic acids, including gallic acid, protocatechuic acid, p-hydroxybenzoic acid, vanillic acid, ferulic acid, syringic acid, trans-cinnamic acid, and p-

coumaric acid, in millets. Hydroxycinnamic acids and their derivatives were the main contributors to the total phenolic compounds of the insoluble-bound phenolic fraction of millet varieties, according to Chandrasekara and Shahidi (2011).

One of the most prevalent hereditary disorders is celiac disease (CD), which is caused by a reaction to gluten proteins in wheat and other cereals in those who are genetically predisposed. This illness, which can produce excruciating stomach pains, is brought on by the immune system's negative response to gluten. Because millet is gluten-free, it can be a nutritious diet for people with celiac disease (Carolina et al., 2007).

It is well known that millet grains are high in phytate, tannins, and phenolic acids (Thompson, 1993). According to Graf and Eaton (1990), these nutrients lower the risk of breast and colon cancer in mice. Compared to people who eat wheat or maize, sorghum and millet have a lower incidence of esophageal cancer due to their fibre and phenolic content (Van Rensburg, 1981). Fibre is one of the greatest and simplest strategies to stop women from developing breast cancer, according to recent research. Millet's anti-carcinogenic qualities are widely known.

Antioxidant Properties and Detoxification Many of the antioxidants in millet have a positive effect on removing other toxins from the body, such as those in the kidney and liver, and neutralizing free radicals, which can cause cancer. By encouraging appropriate excretion and neutralizing enzymatic activity in those organs, quercetin, cucurmin, ellagic acid, and other advantageous catechins can aid in the removal of any foreign substances and poisons from the body. Because of their functions in human health, polyphenols have received a great deal of interest (Tsao, 2010).



Picture 2. Millets health benefit

Zhang et al. (2014) examined the phytochemical makeup, antioxidant capability, and anti-proliferative characteristics of three millet cultivars. In vitro studies were conducted to examine anti-proliferative properties against MDA human breast cancer and HepG2 hepatocellular carcinoma. The results show that millet has some anti-proliferative qualities. Consuming millet lowers cholesterol and phytate, which are associated with a higher risk of cardiovascular disease and cancer. Essential phytonutrients included in millet, known as lignans, lower the risk of heart disease and help prevent hormone-dependent malignancies, such as breast cancer. Postmenopausal women with high blood pressure and cholesterol can benefit from regular millet consumption (Shahidi and Chandrasekara, 2013; Saleh et

al., 2013; Changmei and Dorothy, 2014). Millet helps prevent age-related illnesses and slows down the ageing process (Pathak, 2013; Shahidi and Hadrasekara, 2013).

Given this, it is reasonable to expect that it will be effectively addressed in international economic relations and development policy. This would enable output to grow sustainably, boost exports, and be free of imports all of which are made feasible by favourable, even extraordinary, conditions in the country (Lakić et al., 2022; Milunović et al., 2022; Ljubičić et al., 2023; Popović et al., 2020a,b, 2023, 2024, 2025a,b). Over the past century, some cereals have been referred to as functional, biologically superior, and nutritionally superior dietary goods that improve certain elements of health. The main reasons for the rise in interest in functional foods are the effects of industrialisation and urbanisation on lifestyle, demographic changes (population ageing, especially in developed countries), the disappearance of traditional eating habits, and awareness of the negative health effects of urban living (Kaur and Singh, 2017; Ameratunga et al., 2016). Due to its lack of gluten, millet (*Panicum miliaceum* L.) is a grain that is becoming more and more popular. It was consumed 10.000 years ago in China (Lu et al., 2009) and roughly 4.000 years ago in central Europe. The areas of Russia, Eastern Europe, northern India, and some portions of Africa are where it is most commonly grown. According to recent studies, millet's functional significance in human nutrition is growing (Dykes and Rooney, 2006; Kalinova and Moudry, 2006; Zarnkow et al., 2007). Essential amino acids (leucine, isoleucine, and methionine) (Kalinova and Moudry, 2006), proteins (13 g/100 g dry matter), carbs (72 g/100 g dry matter), polyphenols (phenolic acids and flavonoids), and a high concentration of minerals and dietary fibre are all found in millet (Ravindran, 1991). The aforementioned suggests that millet may be used in nutrition as a component that enhances functionality. It also suggests that it is necessary to investigate the chemical composition and elucidate the possibility of using millet in nutrition as a component that enhances the functionality of specific nutritional products.

CONCLUSION

Because millet has a number of useful components, such as water-soluble fibre, oligosaccharide, and resistant starch, it can be used to create a wide range of products with different purposes and health benefits. There is a developing tendency in the millet area. With an average millet area of 31.32 million hectares worldwide and a yield of 1 t/ha, 31.596.316 t of millet were produced in 2023. There are numerous health benefits of millet. Eating millet may help reduce liver disease, according to several studies. Millet's lignan aid in the prevention of heart disease and some hormone-dependent malignancies, including breast cancer. The metabolism of cholesterol is positively impacted by millet proteins. HDL cholesterol levels in plasma rise after millet protein is digested. Plant breeders should choose millet for better health benefits in addition to raising yields.

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is also the result of a technical solution: Technological process of millet - *Panicum miliaceum* L. organic production to obtain gluten-free grain, raw material for functional food. / Tehnološki postupak organske proizvodnje prosa (*Panicum miliaceum* L.) za dobijanje bezglutenskog zrna, sirovine za funkcionalnu hrane.

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