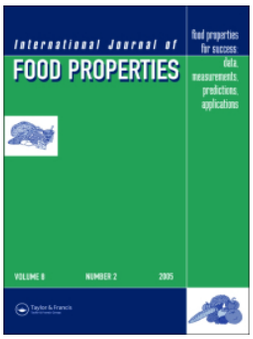

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Millets: sustainable treasure house of bioactive components

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ABSTRACT

Food security has become a major issue around the globe. Even today food is not accessible to every person of this world. United Nations has set a target food for everyone by 2030, but still, we are very far away from the target. Millets are four season crop, which is cultivated globally but post-green revolution era, their cultivation has significantly declined due to more accentuation on rice, wheat and maize. The primary suppliers of carbohydrates on which humanity is dependent lack essential amino acids and minerals cardinal for proper nutrition. This lack of nutrients in diet lifestyles welcomes numerous diseases like cardiovascular diseases, obesity and diabetes. Millets are unique for their richness in dietary fibers, antioxidants, protein, carbohydrates and fats. The present global spectacle of climate alternate has forced us to sustain our natural resources. In this case, millets are the ones that are cultivated in poor soils. This review article reviews the beneficiaries of millet in contrast to human health as certain polyphenols like catechin, and sinapic acid, polyphenols found in millets have many sustaining health benefits like prevention against arthritis, cardiovascular diseases, cancer, inflammation, and environment as compared to our staple grains minimum water requirement, less fertile soils, less usage of pesticides and fertilizers for millet cultivation provides many nurturing benefits to our ecosystem. The incorporation of millet into the daily diet of an individual might help in curing many health complications.

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Introduction

An old saying "The rice eater is frictionless like a bird; the one that eats Jowar is powerful like a tiger; one that eats Ragi remains nirogi." Since Independence, India has made impressive progress in terms of growth, education and achieving Universal health care has been a key goal since the IndianConstitution was drafted. But considering, India's growing malnutrition problem, both under-nutrition (vitamin, mineral, and protein deficiencies) and over-nutrition (obesity, metabolic syndrome, and lifestyle

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diseases), there is a growing awareness of the need to move to healthier, more accessible, and inexpensive diets that include millets. In addition to being naturally gluten-free and nutrient-dense, millets are also a rich source of protein, essential fatty acids, dietary fiber, and vitamin. Millets are known as "yesterday's coarse grains and today's nutri-cereals. Millets, four-season, tiny seeded turfs, widely sown as grain crops, are among the ancient foods consumed by humans.[1]

Millets are considered cops of the future as they are resistant to the majority of pests and insects and could easily be grown in harsher environments like arid and semi-arid zones in most parts of Asia and Africa. Large populations in the Xeric and steppe climate zones rely on millets as a source of nutrition. Millets are typically grown in regions where other major crops, such as wheat (*Triticum aestivum*), rice (Oryza sativa), and maize (*Zea mays*), are unable to provide adequate support for sustainable agricultural production.[2,3] The crop has a number of advantageous characteristics, including rapid maturation, resistance to stress and drought, and the capacity to be kept for an adequate amount of time without being damaged by insects.[4] Millets have been entirely ignored, especially since the Green Revolution era, even though the bulk of the world's population relies on wheat, rice, and maize as their primary source of nutrition.[5] Millets are recognized as "penurious people's grains" or crop cereals.[6] These grains are cultivated because of their significance as both food and animal feed. The crop was previously ignored because of changes in people's eating habits and status symbols, but today these nutria crops are making a powerful upturn in the world's crop production sectors.[7,8]

There are different varieties of millets, for instance, sorghum/great millet; pearl millet (*Pennisetum glaucum*); foxtail millet (*Setaria italica)*, proso millet (*Panicum miliaceum*); finger millet (*Eleusine corcana*); Kodo millet (*Paspalumsetaceum); barnyar*d millet (Echinochloa spp.); and little millet (*Panicum sumatrense*).[9–11] Millets are incredibly rich in vitamins, minerals, dietary fiber, calcium, and antioxidants. Methionine and cysteine, two amino acids, are found in significant levels.[12] In contrast to other cereals, millets contain bioactive components and a number of bioactive minerals.[13] In terms of the vitamins alpha-tocopherol, thiamine, riboflavin, niacin, and folic acid, as well as the minerals calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), iron (Fe), and manganese (Mn), they are exceptionally abundant in millets.[14] Millets provide a plethora of health benefits, including a reduction in the chance of developing diabetes, obesity,[14] cancer,[15] difficulties with the gastro-intestinal tract (GIT),[16] and cardiovascular diseases (CVDs).[17] In addition, millets do not contain gluten, they may be the best choice for people with celiac disease.[18]

Millets are processed before ingestion to improve shelf life and nutritional value.[19] Traditional clarification methods such as fermenting, malting, flaking, baking, cooking, and puffing are encouraged to innovate millet-based value-added processed food items.[20] Industrial methods that are used for enhancing these grains are not properly modified as they lead to the loss of important nutrients.[21] So, the researchers should focus on high-yielding varieties of millet so that both the producer and the farmer can make more money and get better nutrition.[1] Despite hopes that the world would emerge from the COVID-19 pandemic in 2021 and food security would begin to improve, world hunger rose further in 2021. In 2021, hunger affected 278 million people in Africa, 425 million in Asia and 56.5 million in Latin America and the Caribbean – 20.2, 9.1, and 8.6% of the population, respectively. While most of the world's undernourished people live in Asia, Africa is the region where the prevalence is highest.

Food security is an ongoing problem, and current staple foods are not sufficient to overcome challenges such as the present COVID-19 pandemic. Though the United Nations have set a goal to remove hunger by 2030 in reality we are very far from achieving this target. Millets have the potential to become new staple crops, especially in hunger hotspots. The world is facing agrarian as well as nutritional challenges. Agricultural lands with irrigation facilities have been exploited to the maximum, and hence we need to focus on dry lands to further increase grain production.[22] Owing to low fertility, the utilization of dry lands to produce sufficient quality grains is a big challenge. Millets as climate change-compliant crops score highly over other grains like wheat and rice in terms of marginal growing conditions and high nutritional value. These nutri-cereals abode vitamins, minerals, essential fatty acids, phytochemicals and antioxidants that can help to eradicate the plethora of nutritional deficiency diseases. Millet cultivation can keep dry lands productive and ensure future food and nutritional security.[3] In light of the fact that the nutritional value

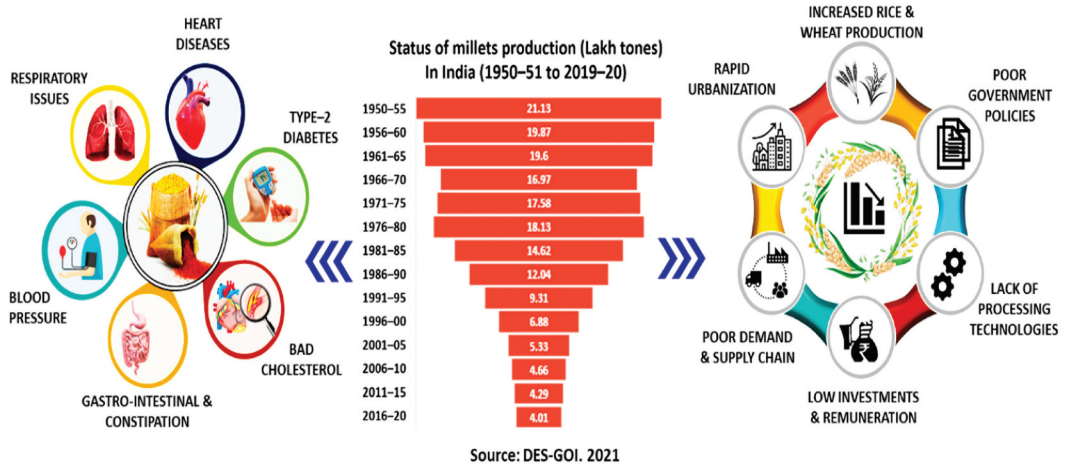

Figure 1. Millets: health benefits, production, and challenges in India. Data were taken from various issues.[20]

of the staple grains was insufficient to meet the immediate problems, such as the pandemic era, the immunological advantages of millets proved to be of great assistance. Figure 1 is exhibiting health benefits, production, and challenges related to millets in India.

With the declaration of 2023 as an "International millet year," the research in the field of millets has increased significantly. Within 2–3 months scientific domain have several articles on the processing and health benefits of millet. So, a detailed study is much needed in this field which emphasizes the bioactive compounds of millets.

The main objective of this current review work was to determine environmental effects of millet. Another objective was to find the various underlying reasons for the underestimation of highly nutritious nutria cereals. Another objective was to find what could be the future approach of these nutria cereals in terms of good disease-free health. One final objective was to find out the strategies for introducing millet in prevailing agriculture.

Nutria cereals: a boon or bane for the environment

The outcome of an individual's venture is one of the par-amounts of major global problems. Individual ventures have generated many environmental problems. Poor government policies, rapid urbanization, and inadequate agricultural practices have smashed the environment.[23] A polluted environment is straightaway proportional to the nation's economy; as a good eco-friendly atmosphere is required for reliable wealth. And at present, the big challenge our country is facing is to feed the unstoppable enlarging population with food that is not only nutritious but as an environmental savior.[24] Considering the pandemic situation, the changing environment along with the co-vid problem has seriously impacted agricultural production which caused socioeconomic insecurities and health problems globally. A large number of malnourished humans rely on agri-business for wealth, food, and shelter. The above situation resulted in the value of current climate-resilient and low-yield grains with many traditional agricultural applications.[25] Here, the founding millets contributed greatly to the malnourished as well as poor population's livelihood and food security. Recognizing this, the UN Food and Agriculture Organization (FAO) has declared 2023 as the "International Year of Millets."[26] However, millets are making a powerful comeback and are called "multi-omics" resource generation.[22] More than 5000 plant varieties are calculated as food plants, less than 20 plant species give the major nation's food and the three main cereal crops that are wheat, rice and maize provide approx. 60% of the calories from the daily menu.[27] Orphan crops perform better than the major crops in terms of climatic scenarios. Figure 2 shows a comparison between the two types of crops i.e., millets and rice/wheat/maize.

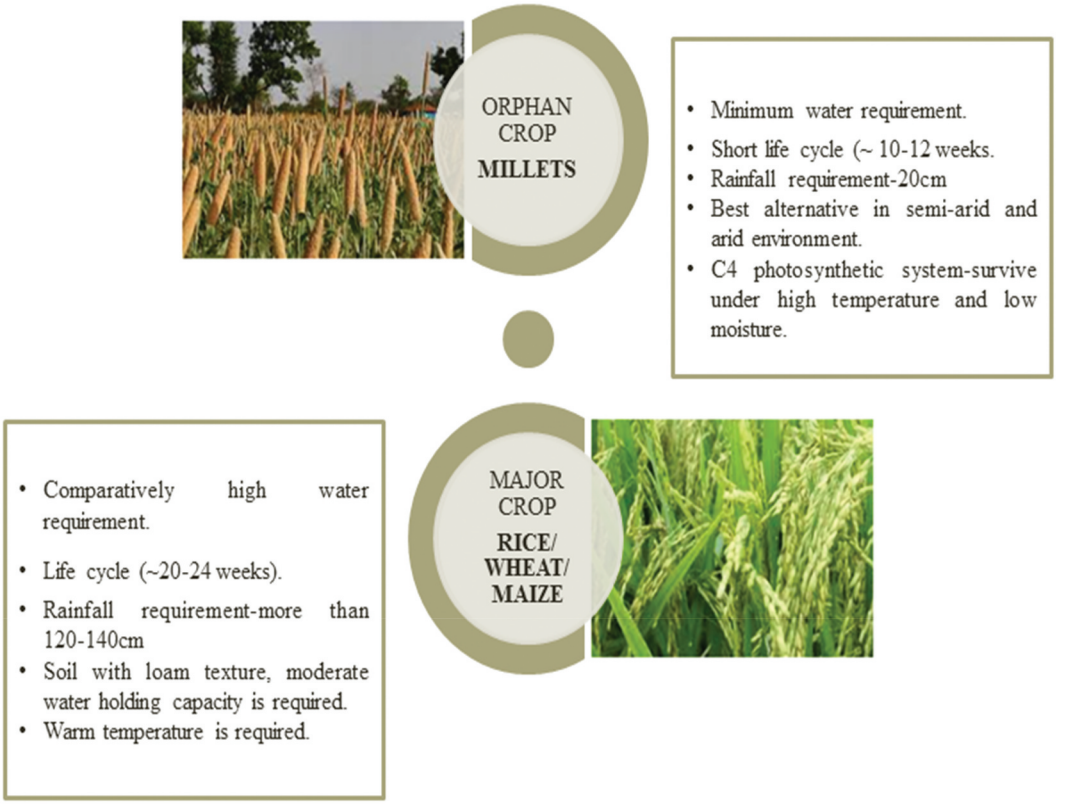

Figure 2. Comparison between two different types of crops.

Cultivation of millet

Cereal crops serve an abundant amount of major macro-nutrients and major nutrients which have a consequential global warming potential.[28] The global warming potential of Wheat and rice are around 4 tons of carbon-dioxide eq/ha which is the highest among all the important cereal crops. Wheat and rice have a carbon emission for around 1000,956 kg C/ha.[29] In spite of their large discharge values, they are majorly sown and are the main roots of nutrition for all overpopulation. Although carbon emission footprints of millets and sorghum are comparably lower.[30] So, for being in a safe eco-friendly environment and to consume safe and nutritious food it is our primary duty to keep our planet cooler, and poison-free because we know that if our planet warms up, it will lead to climate change and that will worsen our livelihood. So, the millet could be a great alternative in terms of all situations. Table 1, shows the list of major millets crops, their common and botanical name, properties, and their origin while Table 2 is the list of minor millet crops. Table 3 is showing proximate nutritional content of millets, Table 4 is showing a comparison between millets and staple crops, and Table 5 is showing the nutritive advantages of millet.

Bio-active components of millets

Millet grains hold a good quantity of bio-active compounds that involve polyphenols- (vanillic acid, sinapic acid, coumaric acid), Flavonoids- (quercitin, luteolin, catechin, myricetin), tannins, photo-sterols. These components possess numerous health benefits for sustaining a healthy life. Table 6 is showing bio-active components along with their health benefits.

Table 1. Major millets crops, their common and botanical name, properties, and their origin.

Millet (Major Crop)	Common name	Botanical name	Unique properties	Origin Production area in India	References
Pearl Millet	Bajra	*Pennisetum glaucum*	Grow in arid, semi-arid regions Rich source of vitamin B9 High in omega-3 fatty acids.	India Production area stands at first all over other crops	[31]
Finger Millet	Ragi	*Eleusine coracana*	Drought tolerant due to efficient antioxidant potential The richest source of calcium Highest dietary fiber content.	Africa, South Asia Production area stands sixth all over other crops	[32]
Proso Millet	Cheena	*Panicum miliaceum*	Late-seeded summer crop. Heat tolerant crop	China, Japan, Africa, India Production area is one-third of the world's population	[33]
Foxtail Millet	Kangni	*Setaria italica*	Short life cycle High water use efficiency	Australia, south-eastern Europe, China. Production area ranks second all over other crops.	[34]

Table 2. Minor millets crops, their common and botanical name, properties and their origin.

Minor Crops	Common Name	Botanical Name	Unique Properties	Origin Production area in India	References
Barnyard Millet	Sawan	*Echinochloa spp.*	tall growing capacious fodder	Asia, Japan, China, Korea, India 4th minor crop India is the largest Producer.	**References**
Kodo Millet	Cow grass, Kodo	*Paspalum scrobiculatum*	mainly grown in moist, shady places. long growth duration	South Asian countries –	[16,35]
Little Millet	Samai, kutki	*Panicum sumatrense*	highly tolerant to moisture stress and waterlogging	India 80% of production is in India	[36]
Guinea Millet	Bajra, babala	*Brachiaria deflexa*	potential as a grain crop	–	[37]
Browntop Millet	korale	*Brachiaria ramosa*	fast maturing cereal crop	India	[38,39]
Sorghum	Bajra	*Sorghum bicolor*	extreme drought tolerant crop than other cereals	America, Australia In India, its production is in the fifth position	[40]

Catechin

Catechin is a naturally occurring polyphenolic compound belonging to the flavonoid family. The rich dietary source of catechin is green tea.[63] The seed coat part of the millet is found rich in catechin.[64,65] The component has many health benefits that can be exerted through direct and indirect mechanisms. The direct mechanism includes-Reactive Oxygen Scavenging (ROS) and the metal Chelating ions and the indirect mechanism includes inhibiting anti-oxidant enzyme inducers, pre-oxidating enzyme inhibitors and suppressing stress signaling pathways.[42] The free radical scavenging property of the compound is due to the presence of a phenolic hydroxyl group present in its chemical structure. Hence, catechin prevents the cells from damage caused by free radicals. The antioxidant activity of these compounds is also credited to their ability to chelate metal ions that are also included in the formation of free radicals. Thus, helps in the prevention of oxidative stress and many diseases like- diabetes, cancer, aging, and cardiovascular diseases.[66] As indirect anti-oxidants, they undergo protein synthesis and signaling pathways. Along with that, they regulate anti-oxidant enzymes like Superoxide dismutase (SOD), Catalase (CAT), and Glutathione peroxidase (GSH) that possess a role in ROS scavenging which in turn provide health benefits like cataracts, Alzheimer's diseases, Parkinson's disease. Catechins can inhibit pre-oxidant enzymes- cyclooxygenase (COX), Xanthine oxidase (XO), and lipoxygenase. This

Table 3. Proximate composition of Millet.

Millets → Properties	Pearl millet	Finger millet	Proso millet	Foxtail millet	Barnyard millet	Little millet	Kodo millet	Sorghum
Carbohydrate(g)	61.78 ± .85	66.82 ± 0.73	7.04 ± .03	60.09 ± 0.02	65.55 ± 0.09	65.55 ± 1.29	66.19 ± 0.19	67.68 ± 0.03
Fat (g)	5.43 ± .64	1.92 ± 0.14	1.10 ± .43	4.30 ± 0.54	2.20 ± 0.54	2.55 ± 0.13	2.55 ± 0.13	5.43 ± 0.64
Dietary fiber(g)	11.49 ± .62	11.18 ± 0.14	-	-	-	06.39 ± 0.60	06.39 ± 0.60	11.49 ± 0.62
Protein (g)	1.96 ± .26	07.16 ± 0.63	12.50 ± .01	12.30 ± 0.20	06.20 ± 0.32	08.92 ± 1.09	08.92 ± 0.09	09.97 ± 0.43
Calcium (mg)	27.35 ± .16	364 ± 0.58	-	-	-	16.06 ± 154	15.27 ± 0.28	27.60 ± 0.71
Iron (mg)	6.42 ± .04	4.62 ± 0.36	-	-	-	1.26 ± 0.44	2.34 ± 0.46	3.95 ± 0.94
Folate (B9)(µg)	36.11 ± .05	34.66 ± 0.97	-	-	-	36.20 ± 0.04	39.49 ±0.52	39.42 ± 0.13
Ω-6 fatty acids Linoleic acid	1844 ± .04	362 ± 0.03	-	66.50 ± 0.04	34.90 ± 0.05	1230 ± 0.42	576 ± 0.17	508 ± 0.18
Ω-9 fatty acidOleic acid	1040 ± .39	585 ± 0.36	-	13.0 ± 0.04	53.80 ± 0.03	868 ± 0.24	291 ± 0.07	3.14 ± 0.13

Source: Indian Food Composition Tables, NIN – 2017 and *Nutritive value of Indian foods, NIN – 2007 (44)

Table 4. Nutritional and anti-nutritional comparison of major staple cereals.

Properties	Wheat	Rice	Maize	Millets (pearl millet)
Carbohydrate (g)	64.72 ± 0.74	74.80 ± 0.85	64.77 ± 1.58	61.78 ± .85
Protein (g)	10.59 ± 0.60	09.16 ± 0.75	08.80 ± 0.49	1.96 ± .26
Fat (g)	1.47 ± 0.05	1.24 ± 0.08	3.77 ± 0.48	5.43 ± .64
Dietary fiber (g)	11.23 ± 0.77	04.43 ± 0.54	12.24 ± 0.93	11.49 ± .62
Vitamins (µg)	30.09 ± 0.07	11.51 ± 0.69	25.81 ± 0.44	36.11 ± .05
Polyphenol (mg)	80.24 ± 0.13	70.08 ± 0.02	-	102 ± .01
Minerals calcium (mg)	39.36 ± 0.65	10.93 ± 0.79	8.94 ± 0.61	27.35 ± .16

Source: Indian Food Composition Tables, NIN – 2017 and *Nutritive value of Indian foods, NIN – 2007

antioxidant property helps in preventing the body from arthritis, and inflammation.[67] They modulate the interaction of the ligand with the receptor like tumor necrosis factor alpha (TNF-α) and also suppress many oxidative relatives signaling pathways for the inflammation process.[68] Figure 3 is showing the antioxidant behavior of the bio-active compound Catechin.

Sinapic acid

Sinapic acid is a bio-active phenolic compound that is known to exhibit anti-oxidant, anti-inflammatory, anti-cancer, anti-mutagenic, neuro-protective and anti-bacterial properties. Inflammation plays an important role in many chronic complications and Nrf2 contributes to the anti-inflammatory by regulating gene expression through the antioxidant response element (ARE).[69] Nrf2 signaling pathways lead to the inhibition of many inhibitory mediators and enzymes like cyclooxygenase (COX-2) and inducible nitric oxide synthase (iNOS). Regulation of these enzymes plays a crucial role in anti-inflammation that leads to inhibition of TNF-α, IL-1β, and COX-2 that prevents diseases like arthritis, epithelial neoplasms, and mucosa skeletal system.[70] Matrix metalloproteinases are present in the extracellular matrix and are involved in many pathological processes like cell proliferation, wound healing, differentiation, apoptosis and tumor-metastasis.[71] Cytokines are basically the peptides that play an important role in cell growth, and immune function and are included in cell inflammation and wound healing chemokines are a family of cytokines, which play an important role in the migration of inflammatory cells. These mediators are pro-inflammatory mediators, exposure to oxidative stress results in the overproduction of cytokines which causes oxidative stress in target cells. This stress further causes the activation of NF-kB and the activation of the Nrf2 signaling pathway stops this cycle.[72] Figure 4 represents the antioxidant behavior of sinapic acid.

Polyphenols (flavonoids and phenolic acids)

Millets like finger millet, kodo, foxtail and barnyard millet are rich in flavonoids and phenolic acids which have high nutritional values in our diets. Various pieces of literature have shown that this phenolic acid and flavonoids could be extracted by organic solvents (methanol, ether, ethanol, etc.). Further, various investigations have supported the nutritional benefits of these compounds for instance when these were given to mice along with food it showed changes in the metabolism. It was found that these biomolecules impacted the inflammatory factor, tumor necrosis factor, and also insulin secretion and signaling pathway. In cell lines, it has shown a positive effect on apoptosis and enzymatic activity. Figure 5 is showing the extraction of flavonoids and phenolic acids from various millets and their effect on the experimental animals or cell lines.

Processing of millet

Millet processing is one of the major steps because millets in the form of whole cereal grains cannot be consumed uncooked form. To enhance the nutritive value and the survival life of the cereal, the millets are processed by various methods. The major components of millets are – the pericarp, endosperm and germ. Processing usually includes initial methods (dehulling, milling, wetting) and subsidiary methods (fermentation, weaning/malting, parboiling, extrusion). Basically, the first step of processing the cereals is to separate them from their inedible portion also called offal.[74,75]

Table 5. The nutritive advantages of millet.

Diseases	Pearl millet	Finger millet	Barnyard millet	Proso millet	Sorghum	Foxtail millet
Cardiovascular disease	Lignin and phytonutrients act as antioxidants-preventing heart disease	Low concentration of serum triglycerides-may prevent CVDs	Rats that were fed on a barnyard millet diet had shown lower blood glucose, and serum cholesterol	Improved plasma levels of high-density lipoprotein (HDL), were seen in obese type 2, diabetic mice under high-fat conditions on feeding with proso millet	Regular intake of a diet rich in whole grains reduces heart disease by 40%.	Reduces the risk of heart attacks
References	[41]	[42]	[43,44]	[45]	[46]	[47,48]
Diabetes Mellitus	High fiber content reduces the rate of digestion and releases glucose into the blood slowly	Alpha amylase inhibition properties lower starch digestibility and absorption	Has been proven beneficial for diabetes type 2	Under high-fat feeding conditions, type 2 diabetic mice had shown improved glycemic responses	Slowly digestible starch (SDS) in a good amount prolongs digestion and carbs in the intestine Fibers, tannins, vitamin E, and phenolic compounds are present that reduce the risk of diabetes	The extracts of these millets have wonderful ant-hyperglycemic activity
References	[49]	[50]		[51]	[52]	
Coeliac disease	Millets are the ones that are gluten-free, hence preventing celiac disease	As millets are gluten-free, suitable for celiac patients.	It provides all the major nutrients that make it a complete diet for celiac patients.	Being gluten-free suitable for celiac patients.	Sorghum millets don't increase the level of anti-transglutaminase antibodies after constipation	Gluten-free millets prevent celiac diseases.
References	[53]	[54]	[55]	[56]	[48]	[57]
Obesity	Satisfies hunger for a longer period of time, lowering calorie intake.	Finger millet contains an amino acid called tryptophan, which lowers appetite and keeps weight in control	Being rich in dietary fiber, reduce the risk of obesity.	Reduces the risk of obesity.	Rich in dietary fiber, has excellent physical properties that satisfy hunger, increases satiety	Rich in dietary fiber, reduces hunger.
References		[57]			[33]	
Cancer	-	-	-	Complex carbohydrates are present that can be valuable in preventing cancer	Polyphenols and tannins present have anti-mutagenic and anti-cancerous properties	It shows the anti-colon cancer effect.
References				[30]	[58]	
Oxidative stress		-	Phytates and Phytic acid present give protection against oxidative stress by chelating effect	-	Sorghum has potential antioxidant property that reacts against oxidative species	-
References					[33]	

Table 6. Bio-active components along with their health benefits.

Bioactive component	Examples	Chief Millet source	Benefits	References
Polyphenols	Hydroxycinnamic acids protocatechuric, vanillic acidHydroxybenzoic acids-coumaric acid, snapic, ferulic acid	Finger millet (BRAN LAYER)	Prevents Arthritis, inflammation, epithelial neoplasms, and neuro-degenerative orders.	[59]
Flavonoids	Quercitin, catechin, tricin, luteolin, myricetin	Pearl millet, Finger millet, Sorghum (SEED COAT)	Cyro-protective, anti-inflammation, anti-cancerous potential	[60]
Tannins	Polymers of flavon-3-ol	Barnyard millet (SEED COAT)	Rich in phosphorus (P), calcium (Ca)-osteo-malacia in adults, rickets in children	[61]
Phyto-sterols	b-sito sterol, campestrol, stigmasterol	Proso, foxtail millet	Prevents CVDs, heart attack, stroke	[62]

Dehulling or decortication is the process that is used for offal (outer husk) removal from the grain.[7] Due to dehulling, there is a significant decrease in the availability of iron, zinc, and calcium. In addition to this, there is a reduction in the mineral content also.[74] In the case of milling, there is a reduction in the size of the grain along with the removal of bran.[76] By applying this processing technique, a significant reduction in the vitamins and minerals has been noticed.[77] Another processing method is fermentation where a particular bacterial/or yeast strain is grown over the mineral grain under optimized conditions. By applying fermentation as a processing method a lowering in the bioaccessibility of the nutrient has been found whereas an increase in the total phenolic content was

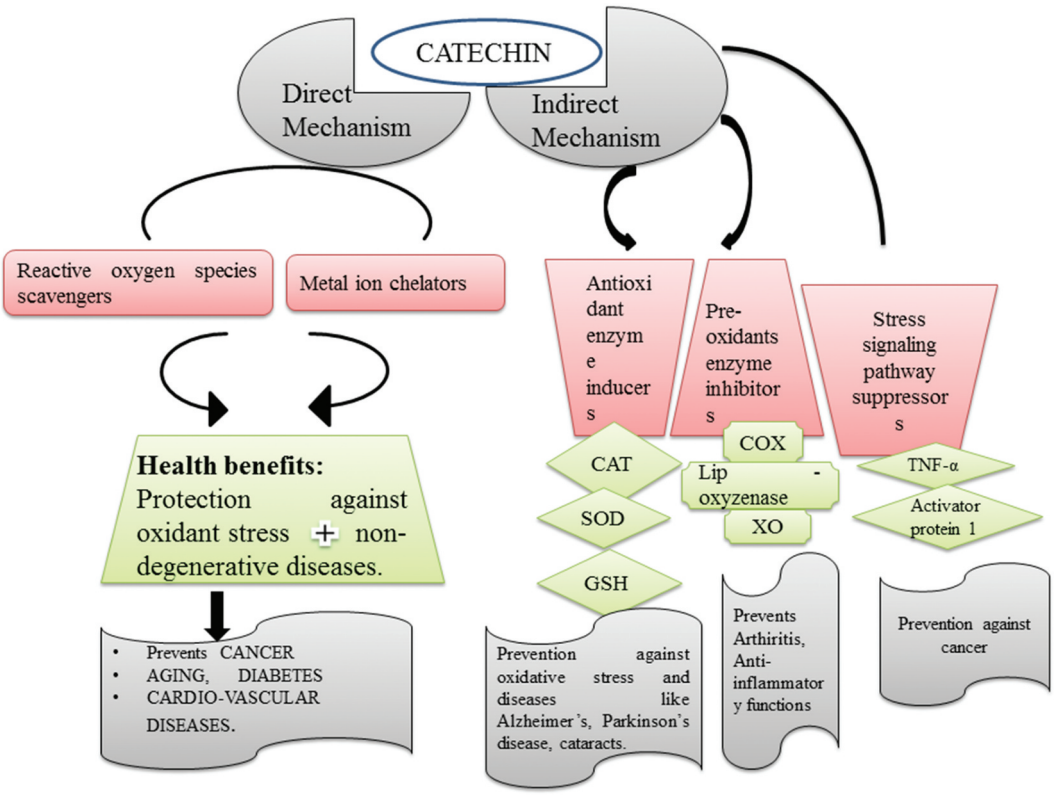

Figure 3. Antioxidant behavior of the bio-active compound catechin.

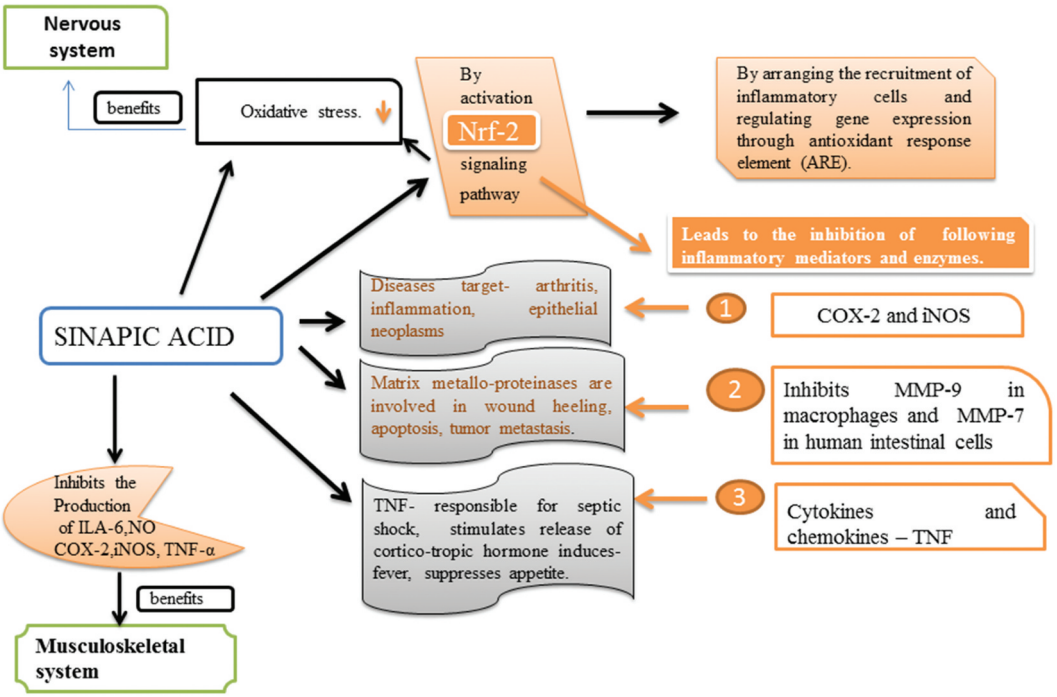

Figure 4. Represents the antioxidant behavior of sinapic acid.

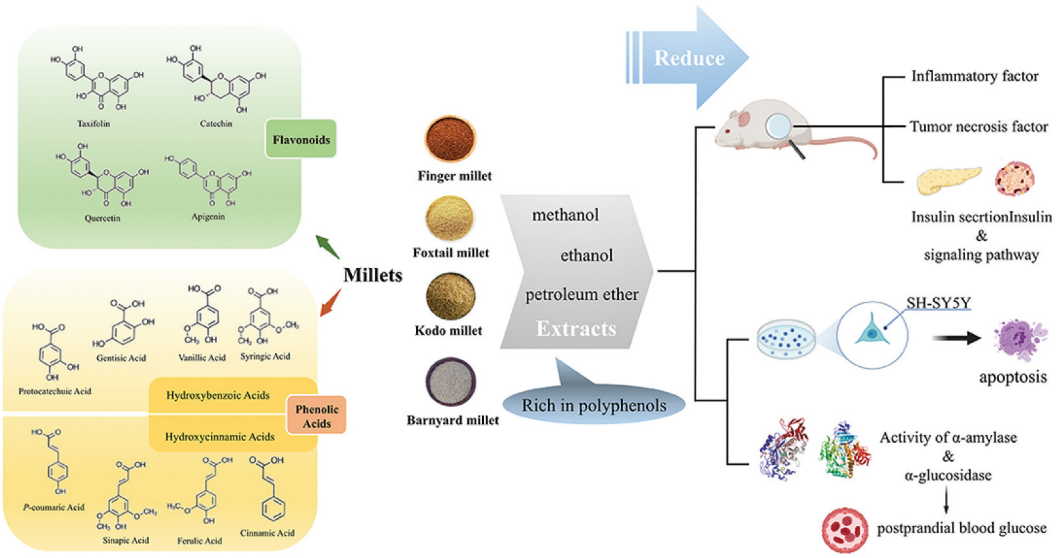

Figure 5. Polyphenols in millets and their effect on diabetes-related factors.[73]

observed.[73,78] Malting is another method of processing that includes a combination of a series of steps like germination, drying, toasting, and sieving.[79] From the various pieces of literature, it has been observed that during malting the antioxidant properties and total phenolic content increase in the millet while the tannin content decreases. In the extrusion method of processing, millets are plasticized and cooked in an enclosed barrel with a single or two screws. The extrusion method

Figure 6. Steps involved in the processing of the millet.

involves feed transport, mixing, and forming as a unit operation. Due to the extrusion method, the total flavonoid content of the millet decreases. This method also results in an increase in the breakdown of the lower compounds from the higher compounds. In the case of the parboiling method of processing either while or dehulled grains having defined moisture content is mixed with hot sand. This method of millet processing has resulted in increased micronutrient and phenolic content while reduction in the protein's digestibility. The steps involved in the processing of millet are shown below in Figure 6, while Figure 7 shows the inference on nutritional values after the processing millet of millet. There are several pieces of literature where it has been shown that the processing of millet leads to the loss of several important nutritional values.

Recently, Gowda and their group have shown that the processing methods of millets change the nutritional composition of millets. Here the investigators have mentioned the role of baking, germination, malting, soaking, fermentation, etc. in the inference of the nutritional value of millets.[20]

Recently, a team led by Kaur showed the effect of popping and malting processing methods on the physicochemical, antioxidant, and antinutrient features of millet flour. Here the investigators took five genotypes each of finger, and pearl millet, and sorghum and analyzed them after popping and malting processing. All the nutritional features were studied in raw, popped, and malted millet flours. Further, the investigators observed that after popping there was an increase in the crude protein and energy, while after malting both values got decreased. In addition to this investigator also observed that the crude fiber content decreased significantly in all the samples of popped and malted flours in comparison to raw flours. After the processing of the raw millets, the total soluble carbohydrates increased significantly. The investigators also observed an increase in the enzymatic activities of lipoxygenase and α-amylase after the malting of the millet flours. Moreover, in comparison to raw flour, the alkaloids and antioxidants (FRAP, DPPH, and ascorbic acid) increased after processing while the starch and amylose decreased. Moreover, investigators also observed an increase in the total phenols and tannins and a lowering of antinutrients like phytic acid,

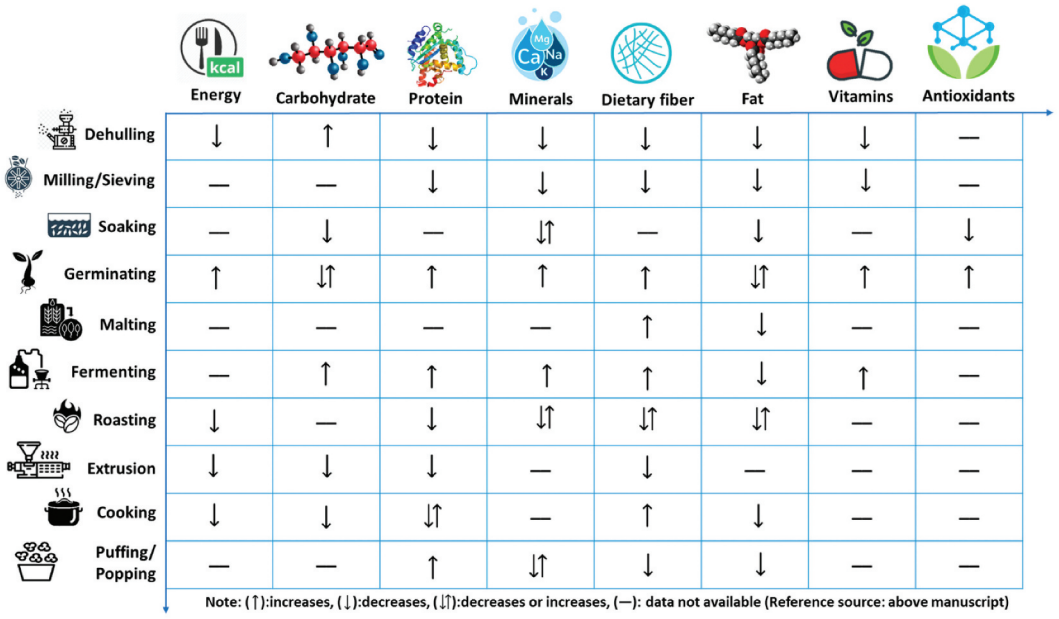

Figure 7. Inference on nutritional properties changes during different processing methods adapted from.[20]

saponins, and oxalic acid after processing. Finally, the investigators concluded that the homemade processing technique (popping and malting) is effective in the improvement of the nutritional composition and antioxidant potential and in lowering the down of anti-nutritional compositions in all the millet variants. The investigators further suggested the consumption of raw and processed pearl millet genotype PC-166 in poor communities requiring nutritional feed, as this genotype was found suitable in terms of nutritional and antioxidant potential. Moreover, the authors also concluded that processed millet flours could, be suitable for the preparation of value-added materials.[79] The summarized results of this investigation are shown in Figure 8.

Supply chain of millets

The supply chain of millets involves five major aspects that are producers (farmers), FPOs (aggregators or facilitators of the produce), processors (have own processing unit), retailers (mandis, harts, local market), and finally the consumers (people living in both rural and urban areas). Due to the lack of availability of efficient machinery for the processing of millets, which is increasing the processing cost and low-quality end product the supply chain is disrupted. Moreover, due to a lack of suitable market strategies to generate demand for value addition in the farm gate and other setups in the sphere. This requires the need for suitable strategies to promote the production of millet.

Strategies and government policies for uplifting millets

Mainstreaming millets in publicly funded programs that are introducing millets in the Public Distribution System, making millets a part of (ICDS) Integrated child development care. Enhancing the role of the private sector that is encouraging millet-based startups, providing seed support to the diversified products, and more involvement of big companies like Britannia, (ITC) Imperial Tobacco Company in the promotion of millets.

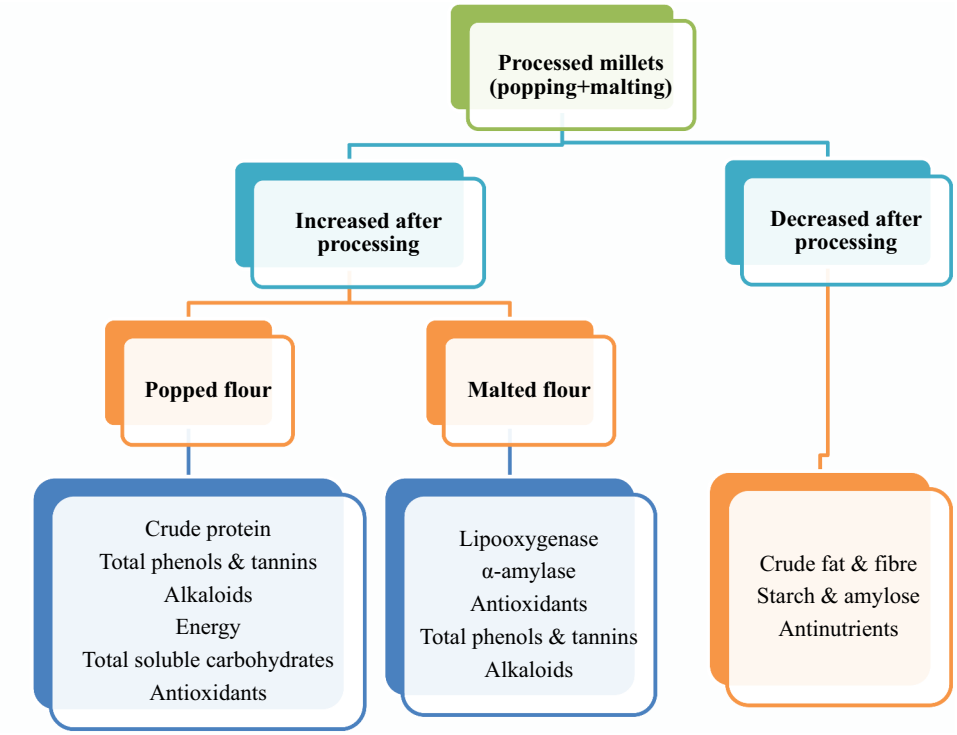

Figure 8. Nutritional changes on the processed millet after popping and malting.

Planning for introducing millets into daily life

The modernized sedentary lifestyle related to many health problems had forced people toward healthy and nutritious diets. Considering this in mind, millets are wonderful alternatives in terms of nutrition as well as a healthy lifestyle. Millets are a storehouse of nutrition. After, the green revolution, suddenly the millet's use decreased because the aim of the revolt was securing the food surety, neglecting food insecurity. The disadvantage of neglecting the millet led to several health issues worldwide. Presently, millets are in a huge is the huge count of millet-based eatables and drinks devoured in many parts of many countries. They are known as whole-grain foods, floor-based foods, and alcoholic and nonalcoholic beverages.[80] Table 7 is showing the application of millet in various dishes.

Uplifting of millet: strategies and approaches

Being multifunctional, the upliftment of millets is necessary. Figure 9 represents the multifunctional uses of millet. There are several ways by which millet utilization in the daily diet could be uplifted which needs equal contribution from the government, researchers, and marketing agencies. Figure 10 represents the strategies for uplifting millet.

Antinutrient profile of millets

In addition to the bioactive compounds, millets also produce antinutrients which are mainly phytochemicals produced by plants for their defense. These antinutrients affect nutrient absorption, which results in reduced nutritional bioavailability and utilization. Investigators have shown that when millets are consumed, uncooked, then these antinutritional phytochemicals may become detrimental or may pose serious health issues like micronutrient malnutrition, nutritional deficiency and bloating. Majority of the plant and plant products have antinutrients like phytates, oxalates, trypsin, tannins, and chymotrypsin inhibitors.

Table 7. Millet-based dishes.

Types of food	Dish	Millets used	References
Whole grain food	Kichadi, porridge	Little millet, finger millet, kodo millet, sorghum.	[81]
Foods made from flour	Chapatis, dosa, idli, dumplings, couscous	Pearl millet, finger millet, foxtail millet, and little millet	[31,82]
Alcoholic beverages	Opaque beers, busa, chhang, katikalla	Pearl millet, finger millet, proso millet	[72,83]
Non-alcoholic beverages	Togwa, oskikundu	Finger millet, pearl millet and malted sorghum	[29,84]

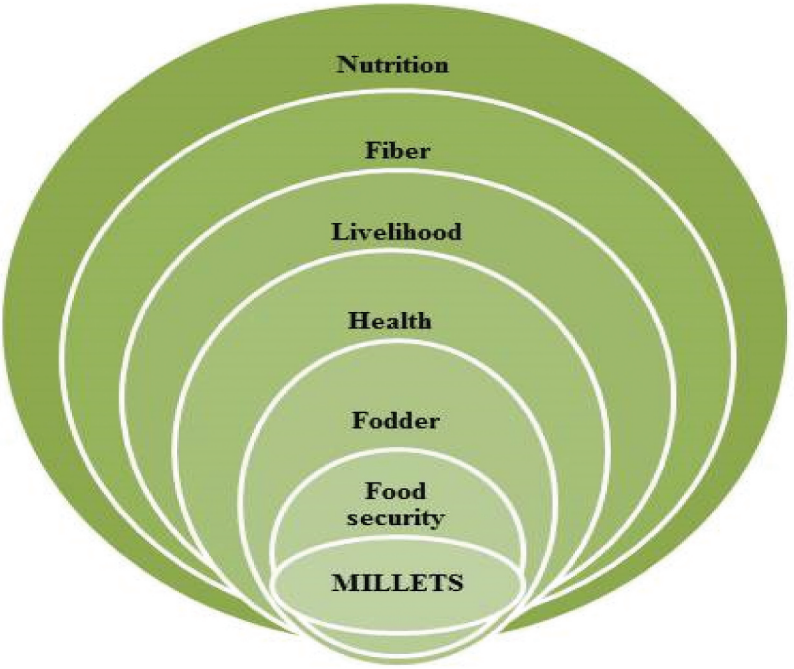

Figure 9. Represents the multifunctional uses of millet.

One of the major drawbacks of millets is that in comparison to rice and wheat millets have higher antinutrient factors. When such antinutritional factors decrease the decreased bioavailability of minerals and proteins due to metal chelation and enzyme inhibition. Finger millets were reported to have polyphenols, tannins (0.61%), phytates (0.48%), trypsin inhibitors and oxalic acid which may interfere with the bioavailability of micronutrients and protein digestibility. Several investigators reported that pearl millet has goitrogenic compounds (derivatives of phenolic flavonoids, such as C-glycosyl flavones) and their metabolites responsible for producing off odors in flours during storage.[20,85,86]

Significance of millets

The present study signifies the importance of millets in contrast to humans as well as our environment. The bioactive components such as polyphenols like vanillic acid, coumaric acid, siapic acid, flavonoids like coumaric acid, myristic acid, tannins, phytosterols like campesterol, and stigmasterol prevents inflammation, arteriosclerosis, cancer, osteomalacia, arthritis, and other degenerative diseases. Moreover, the study emphasizes the better nutritional composition of millet compared to our staple grains rice and wheat. The study also highlights the usage of millet as a savior of our environment against pollution, conserving our natural resources. Furthermore, accepting and accelerating the use of millet and millet-based food items like chapatis, idlis, chilla, sweets, and many other recipes would help in achieving stupendous health benefits.[87–89]

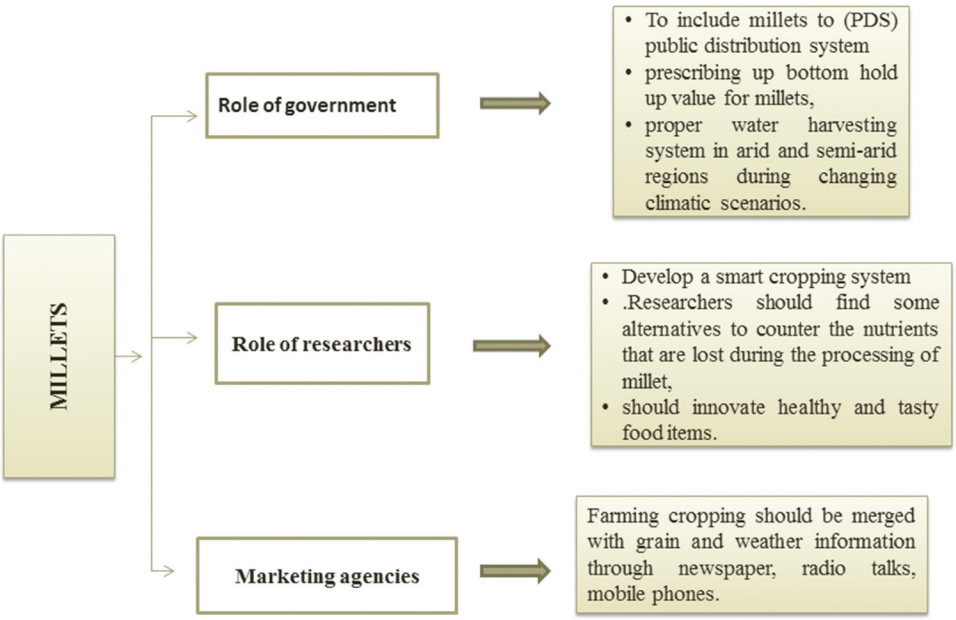

Figure 10. Represents the strategies for Uplifting millet.

Conclusion

Whilst a grain called millets has legacy honor in India, still more emphasis has been given to rice, wheat and maize production. Millets are small grain crops, cultivated on degraded poor soils. Over-reliance on cereals post-green-revolution has completely left these grains unnoticed. These grains are still regarded as orphan crops. Delinquent to the rapid sedentary habits and altering lifestyle, the necessity of healthy nutrition is missing which leads to the onset of many health ailments like diabetes, cardiovascular diseases, obesity, gastrointestinal disorders and malnutrition. Millet cultivation would provide twofold benefits. As they would help in conserving resources by limiting the use of water, and the fertility of the soil and would help in ameliorating health benefits to society. These grains are a highly rich source of carbohydrates, proteins, vitamins, fats, minerals, and antioxidants. These grains are abundant in polyphenols like coumaric acid, sinapic acid, catechins, and tocopherols which have many health benefits against many degenerative diseases. So, the addition of these grains to the daily diet will help in drawing stupendous health benefits. Furthermore, the unification of millet-based food items in international, national and state-level feeding programs will genuinely help to bridle the subsisting nutrient deficiencies in developing nations. Increasing the use of these grains for a healthy lifestyle, gluten-free substitute, farmer beneficiaries, and conservation of natural resources, there is an urgent need for developing the processing technologies that will help in upgrading the shelf life of millets. Moreover, educating the population about consuming these grains for a healthy, disease-free life. Advancement in these nutritious, high-value grains will increase the immunity, health, and socio-economic status of the population.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

Data availability statement

All the data are included within the article only.

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