Review Article

Millets – The Marvelous Cereals as Functional Food and Dietary Supplements for Health Disease

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ABSTRACT

Millets are cereal crops and exotic berries always viewed as a dietary staple and the main provenance of protein in most of the developing world. Millets are the minor cereals of grass family, poaceae. Due to their short burgeoning season, these can develop from seeds to ready to harvest crops in about 65 days. Millet is also an important food item for the population living in the arid parts of many other countries, especially in eastern and central Africa, and in the northern coastal countries of western Africa. Millets are nutritionally surpassing as their grains contain high amount of proteins, minerals, flavonoids, polyphenols, and vitamins. Therefore, a legitimate consumption can help to conquered malnutrition among majority of our Indian population. These have often been called the *coarse grains*; however, due to their nutritional benefactions, these are now being referred as *'nutria-millets/nutria-cereals'*. Millets are also rich in phytochemicals (polyphenols, tannins and phytosterols) and antioxidants; however, they do contain some anti-nutritional factors that can be condensed by certain processing treatments. Conventional methods of cereal processing (popping and flaking) as well as the existent ones (roller drying/extrusion cooking) can be successfully engaged for preparing different millet based ready-to-eat products. Further, the public needs to be made apprised of the benefits confabulate by millets and their role in combating the ill effects of westernized torpid lifestyle so that they can lead a healthy life. This review aims to focus on the role of millets as functional food for global use.

Keywords: Millets, Nutrition, Population, Processing, Phytochemicals, Use.

INTRODUCTION

The "Green Innovation" appears as a season of vast rural improvement, and is usually consider with preserving with lots of population from malnutrition in the advance nature. Millets are a group of highly flexible smallest turf universally developed all over the world. They are one of the primeval foodstuffs accepted by humans and perhaps the basic grain to be pre-owned for sedentary objective. They are extremely sophisticated of aridity and other utmost climate circumstances and have identical supplements to other dominant grains.[1] Food security has been exceeding interest to the terrene community that is eminently that is highly confided on cereals. Millets are traditionally preferable as they contain high amounts of proteins, minerals, flavonoids, polyphenols and vitamins that can be used as useful fodder for determent of non-communicable conditions.[2]

Figure 1: Different variations of millets

In the developing society, millets have been entrusted to be used as bird forage. However, millets in India are enjoying bloom import as it became the colossal manufacturer ensue by Africa and China.[3] Millets are in different branches of poaceae, the grasses family. Millets are also called as "miracle grains, good grains, bird food, and poor man's rice". Since from many years, millets has been growing such as the most important millets are pearl millet (*Pennisetum glaucum*), finger millet (*Eleusine coracona*), proso millet (*Panicum miliaceum*) and foxtail millet (*Stalia italica*). But according to FAO, the most important cultivated millet species are: pearl Millet *(Pennisetum typhoides),* also known as bulrush millet; proso millet (*Panicum miliaceum)*, also known as common millet; foxtail millet (*Setaria italica*); Japanese barnyard millet *(Echinochloa crusgalli* var. *Frumentacea or E. colona* (Sawa)); finger millet (*Eleusine coracona*) also known as birds food millet or African millet; and kodo millet of India (*Paspalum scorbiculatum*). Other millets include little millet (*Panicum sumatrense*), tef millet (Eargrostis *tef*) and Fonio millet (*Digitaria exilis* and *D. iburua*) that promotes millets as Nutri-cereals rather than Coarse Cereals.[4]

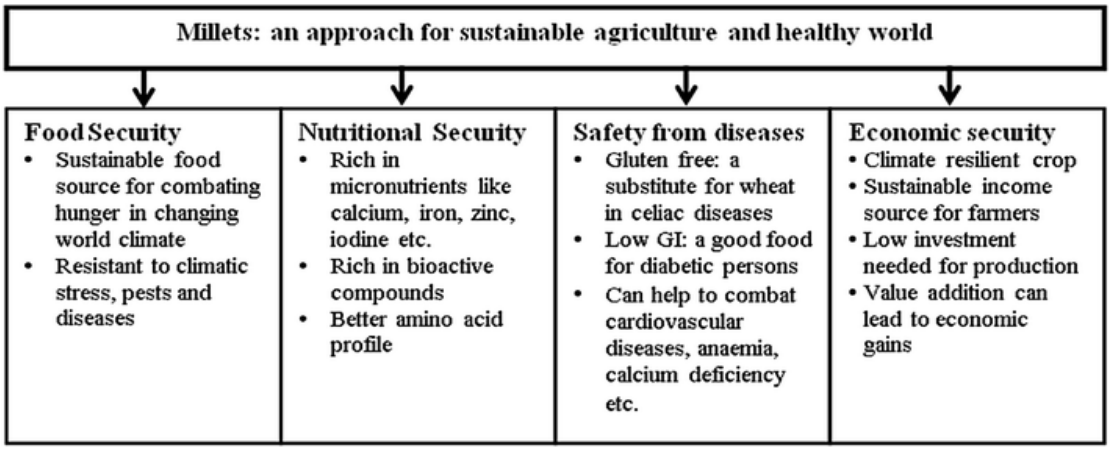

Figure 2: Millets sustaining healthy world

Millets are highly nutrient and provide protein, fiber, iron, B vitamin, manganese, phosphorus, potassium and magnesium. They are highly alkaline, making it easily digestible and soothing to the stomach. It contains around 15 % of protein and is rich in fiber. It is a rich source of Vitamin E, B complex, niacin, thiamin and riboflavin. In addition, millet also contains essential amino acids like methionine and lecithin. They are also rich in phytochemicals, including Phytic acid which is believed to lower cholesterol and Phytate, which is associated with reduced cancer risk. Today, millet continues to be a staple for a third of the world's population.[5] **They are gluten free grains and hence it can be consumed by everyone.**[6]

	Protein (g)	Carbohydrates (g)	Fat (g)	Minerals (g)	Fiber (g)	Calcium (mg)	Phosphorous (mg)	Iron (mg)	Energy (Kcal)	Thiamin (mg)	Niacin (mg)
Finger	7.3	72	1.3	2.7	3.6	344	283	3.9	336	0.42	1.1
Sorghum	10.4	70.7	3.1	1.2	2.0	25	222	5.4	329	0.38	4.3
Pearl	11.8	67.0	4.8	2.2	2.3	42	-	11.0	363	0.38	2.8
Foxtail	12.3	60.2	4.3	4.0	6.7	31	290	2.8	351	0.59	3.2
Little	7.7	67.0	4.7	1.7	7.6	17	220	9.3	329	0.3	3.2
Kodo	8.3	65.9	1.4	2.6	5.2	35	188	1.7	353	0.15	2.0
Proso	12.5	70.4	1.1	1.9	5.2	8	206	2.9	354	0.41	4.5
Barnyard	6.2	65.5	4.8	3.7	13.6	22	280	18.6	300	0.33	4.2
Paddy Rice	6.8	78.2	0.5	0.6	1.0	33	160	1.8	362	0.41	4.3
Wheat	11.8	71.2	1.5	1.5	2.0	30	306	3.5	348	0.41	5.1

Source: http://milletindia.org.[7]

Figure 3

PRODUCTION AND CULTIVATION

The millets are envisaged to have been proficient in India from archaic times. These cereals are decorous to wide range of temperatures, moisture-regimes and input conditions cater to food and hay to millions of loam farmers, particularly in the developing world. Furthermore they also form important raw material for conveyable alcohol and starch production in streamlined countries. Millets are stout and grow well in dry zones as rain-fed product, under insignificant conditions of soil fertility and moisture and are reliable yielders.[8]

Figure 4: Types of millets grown across the world

In Asia, millet is deterred almost wholly to two countries, India and China, although Myanmar, Nepal and Pakistan also yield small quantities. India is the world's largest producer, harvesting about 11 million tons per year, nearly 40 percent of the world's turnout. Pearl millet, which report for about two-thirds of India's millet production, is grown in the sapless areas of the country, mainly in the states of Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana. Finger millet is produced mainly in the state of Karnataka, but also in Orissa, Uttar Pradesh and Tamil Nadu. It is also the most important millet in Nepal and Bhutan. China produces about 3.7 million tons of millet (mainly foxtail) per year, largely in the provinces of Hebei, Shanxi and Shandong.[9]

Millet provision in Africa is distributed among a much larger number of countries, distinctly Nigeria (over 40 percent of the regional output), Niger, Burkina Faso, Mali, Senegal and Sudan. Pearl millet is grown along the southern fringe of the Sahara (i.e., the Sahelian countries and the northern parts of the coastal countries in Western Africa) and in the torrid areas of Eastern and Southern Africa. Finger millet production is robusted in Eastern and Southern Africa, where the premier manufacturers are Uganda and Tanzania.[10] As a grain crop, teff is largely bedridden to Ethiopia. Small quantities of white Fonio are grown throughout sub-Sahelian Western Africa, most importantly in Mali. Black Fonio is grown in isolated pockets in Nigeria, Togo and Benin. Guinea millet is cultivated only on the Fouta-Djallon plateau of northwestern Guinea and adjacent Sierra Leone. Foxtail and proso millets are very tacky crops in Africa, but are accomplished to a finite extent in Kenya and other upland areas in Eastern Africa. Kodo millet is commonly harvested from wild forms in Western Africa, but enlightened profiles of this "ditch millet" are only found in Asia. In Latin America, millet production is incarcerated to a small area in Argentina.[11]

Crop/ Year	Indicator	1955-56	1965-66	1975-76	1985-86	1995-96	2005-06	2008-09	2011-12
Jowar	Area	17.36	17.68	16.09	16.10	11.33	8.68	7.53	6.25
	Production	6.73	7.58	9.50	10.20	9.33	7.63	7.27	5.98
	Yield	387	429	591	633	823	880	962	962
Bajra	Area	11.34	11.97	11.57	10.65	9.32	9.58	8.75	8.78
	Production	3.43	3.75	5.74	3.66	5.38	7.68	8.88	10.27
	Yield	302	314	496	344	577	802	1015	1171
Ragi	Area	2.30	2.70	2.63	2.41	1.77	1.53	1.38	1.18
	Production	1.85	1.33	2.80	2.52	2.50	2.35	2.04	1.92
	Yield	800	492	1064	1049	1410	1534	1477	1641
Small millets	Area	5.34	4.56	4.67	3.16	1.66	1.06	0..91	0.80
	Production	2.07	1.56	1.92	1.22	0.78	0.47	0.45	0.46
	Yield	388	341	412	386	469	443	491	565
Total millets	Area	36.34	36.91	34.96	32.30	24.08	22.08	18.57	18.6
	Production	14.07	14.21	19.96	17.59	17.98	18.14	18.61	18.63
	Yield	387	385	571	545	747	870	1003	1096

Figure 5: Area, Production and Yield of millets during last 50 years

Source: Agricultural Census, Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Government of India.[12]

Among the developed countries, millet cultivation (almost entirely proso millet) is stuffed in the CIS, particularly in the Russian Federation, Kazakhstan and the Ukraine. Protraction in North America, Australia and Europe is surpassingly limited. In some countries, millet is sown as a catch crop when sowing conditions for the main crop are unfavorable. However, even in such situations the grain is sometimes left unharvested and the area simply chafe by farm animals.[13] Maximum millet agronomy happens in the kharif period, i.e. during the monsoon season. In areas that reap more than 800mm of rains, many of the millets can be cultivated in the second season, i.e. as a Rabi crop (during the post monsoon, early winter months). And in some places with the right soil and geography, a few millets can even abound in the third season, during the dark days of winter, etching on surplus moisture in the soil and the dew that precipitates.[14] Another mien that recuperates the millet crop is strewing it with fateful and appropriate spacing in lines rather than reporting. This aid in the plants getting fairly uniform access to revenue come out in a more uniform harvest, increasing the value of such grains significantly for both the market as a well as subdued processing.[15]

DESCRIPTION OF KERNEL

Millet is bitsy in size and round in shape and can be white, gray, yellow or red. The most widely accessible form of millet is the hulled variety, although doctrinal couscous made from crazed millet can also be found.[16] The term millet refers to a milenge of grains, some of which do not belong to the same genus. Cereal grain crux consists of three main parts: endosperm, bran, and germ. The multi-layered extraneous skin of the kernel is bran that assists to foster the other two parts of the kernel from sunlight, pests, water, and disease. It contains important antioxidants, iron, zinc, copper, magnesium, B vitamins, fiber, and phytonutrients.[17] The embryo, which, if mulched by pollen, will sprout into a new plant. It contains B vitamins, vitamin E, antioxidants, phytonutrients, and unsaturated fats. **Endosperm is** the germ's food supply, which, if the grain were allowed to grow would provide required energy to the young plant. As the largest portion of the kernel, the endosperm contains starchy carbohydrates, proteins, and small amounts of vitamins and minerals.[18]

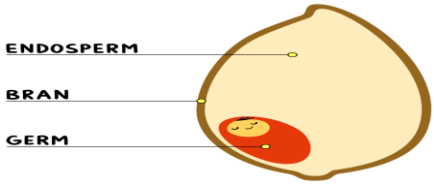

Figure 6: Whole grain kernel

NUTRITIONAL COMPOSITION OF MILLETS

Millets are exclusive among the cereals because of their richness in calcium, dietary fibre, Polyphenols and protein. Millets generally contain facund amounts of essential amino acids such as Isoleucine, Leucine, Lysine, Methionine, Phenylalanine, Threonine, Valine, Histidine, Tryptophan and Nonessential Amino Acid, Alanine, Arginine, Aspartic acid, Cystine, Glutamic Acid, Glycine, Serine, Tyrosine, Proline. Millets are also rich sources of phytochemicals and micronutrients. Phytochemicals such as phenolics (bound phenolic acid-ferulic acid, free phenolic acid-protocatechuic acid), lignans, β-glucan, inulin, resistant starch, phytates, sterols, tocopherol, dietary fiber and carotenoids are present in millets. The main polyphenols are phenolic acids and tannins, while flavonoids are present in petite quantities; they act as antioxidant and play many roles in the body immune system.[19]

HEALTH BENEFITS OF MILLETS

Millets are not only lusty but at the same time they have a exclusive taste, which can accents the taste quotient of any mess. So, here's a low down on how inclusion of millets in daily diet can mop up the health quotient and keep diseases at bay and provide voluminous nutrition.[20]

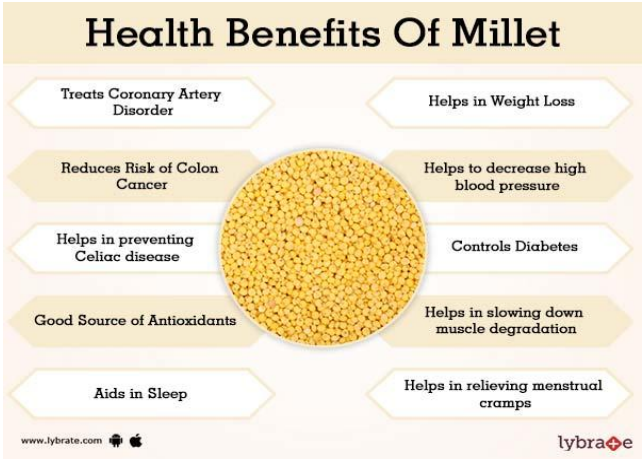

Figure 7: Health benefits of millets

I. Anti-Diabetic Activity of Millets

Lower prevalence of diabetes have been reported in millet-consuming population. Millet phenolics inhibits like alpha-glucosidase, pancreatic amylase reduce postprandial hyperglycemia by partially inhibiting the enzymatic hydrolysis of complex carbohydrates. Inhibitors like aldose reductase prevents the accumulation of sorbitol and reduce the risk of diabetes induced cataract diseases. Finger millet feeding controls blood glucose level improves antioxidant status and hastens the dermal wound healing process in diabetic rats.[21]

II. Cardio protective Activity of Millets

Millets are good sources of magnesium that is known to be adept of lessening the effects of migraine and heart attack. Millets are rich in phyto-chemicals embracing phytic acid which is known for overcastting cholesterol. Finger millet may forefend cardiovascular disease by reducing plasma triglycerides in hyperlipidemic rats.[22]

III. Role of Millets in Celiac Disease

Celiac disease is an immune-mediated enteropathy prompt by the gulp of gluten in genetically susceptible individuals. Millets are gluten-free, therefore an incomparable option for people anguish from celiac diseases and gluten-sensitive patients often irritated by the gluten content of wheat and other more prosaic cereal grains.[23]

IV. Anti-Cancer Activity of Millets

Millets are known to be rich in phenolic acids, tannins, and phytate that act as "antinutrients" However; these antinutrients curtail the fortuity for colon and breast cancer in animals. It is trot out those millet phenolics may be cogent in the interception of cancer tenderness and progression *in vitro*.[24]

V. Anti-Inflammatory Activity of Millets

Ferulic acid is very strong antioxidant, free radical scavenging and anti-inflammatory activity. Antioxidants

axiomatically prevent tissue damage and impel the wound healing process. It is reported good antioxidant effects of finger millet on the dermal wound healing process in diabetes lured rats with oxidative stress-mediated modulation of inflammation.[25]

VI. Anti-Aging of Millets

The chemical counteraction between the amino group of proteins and the aldehyde group of reducing sugars, termed as non-enzymatic glycosylation, is a main aspect responsible for the aggravations of diabetes and aging. Millets are rich in antioxidants and phenolics; like phytate, phenols and tannins which can furnish to antioxidant activity important in health, aging, and metabolic syndrome.[26]

VII. Antimicrobial Activity of Millets

Millets chunk and essence have been found to have antimicrobial activity. Seed protein extracts of pearl millet, sorghum, Japanese barnyard millet, foxtail millet, samai millet and pearl millet were evaluated *in vitro* for its ability to inhibit the growth of *Rhizoctonia solani, Macrophomina phaseolina,* and *Fusarium oxysporum.* Protein extracts of pearl millet are highly trenchant in arresting the surge of all 3 examined phytopathogenic fungi.[27]

PROCESSING TECHNOLOGIES OF MILLETS

Technical knowledge used for transforming the cereals into esculent pattern and by that exaggerating its peculiarity is known as processing. Processing of cereals and millets plays significant semblance during its fulfillment as food. Minor millets can be consumed by processing them into rice, flour, sprouting, roasted, popped, salted ready-to-eat grains, porridges and fermented products. As millet grains are compressed seed coat grains, their processing starts with the task of extermination of husk. Some food techniques are decortications, milling, soaking, cooking, germination, fermentation, malting, popping, etc.[28]

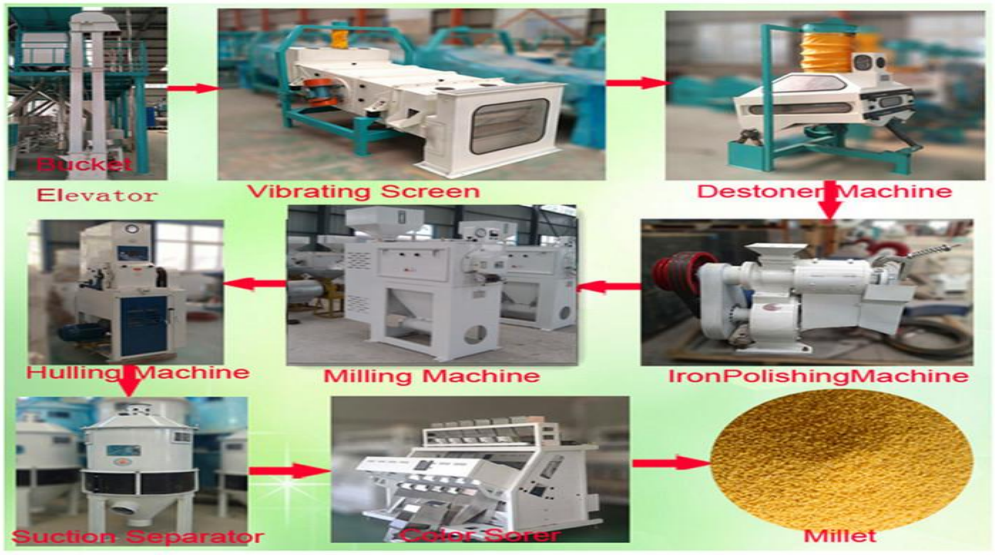

Figure 8: Millets processing pipeline

I. Decortication/ Dehulling

Millets were earlier decorticated at domiciliary level by hand malleate. Now a day these are comminuted in rice milling machinery with slight refitting of the process. Centrifugal sheller can be used to dehull the small millets. The chunk of husk in pearl millet and small millet assorted from 1.5 to 29.3%.[29] Soaking of pearl millet grain in 300 ml (w/v) 0.2 N HCL for 15 hr and washing twice with water helps in expunge the hull. Then grains are atoned in laboratory scarifier (Osawa make) for 1–3 min can remove 8.10–15.84% hull.[30]The polyphenolic pigments and phytate phosphorus were reduced to 66.9-71.3% and 60.0-74.0% respectively. Decortication ebb the total mineral contents, but surge the bio-accessibility of calcium, iron and zinc by 15, 26 and 24 g/100 g respectively.[31] It cardinally decreases total phytic acid, polyphenols, dietary fibre and the amount of tannins with coterminous increase in protein digestibility. Dehulling coupled with hydrothermal treatment perturb the phenolic content and antioxidant potential of millet grains. Antioxidant activity of phenolic extracts was in the order of hull > whole grain >dehulled grain > cooked dehulled grain.[32]

II. Milling

Most of the millets harvests in India are used as predominant food and less in ready-to-use and convenient food products due to non-availability of proper milling technology. The major impulsion for regnant utilization of millet are its coarse fibrous seed coat, coloured pigments, astringent flavour and poor keeping quality of the processed products, Pearling, debranning and chemical treatments of millets overcome some of these constraints; emend nutritional quality and consumer privilege. In milling, the milling efficiency and shelling index are the important specifications that drag the head yield and further processing.[33]

III. Composite Flour

Although millets are nutritionally finer to cereals, yet their utilization is not wide spread. One possible way of extending their utilization could be by intermixing them with wheat flour after suitable processing. On addition of millet flour there would be diversity in physico-chemical, nutritional and functional characteristics. In developed countries many avail products including extruded products are popularly consumed. Extruded products include spaghetti, macaroni, vermicelli and noodles, pasta, etc. The crops are made using subtle durum wheat flours or semolina as their main integrant.[34] Many researchers have tackle to produce composite millet flours by replacing conventional cereal flours to some extent in making the traditional foods, ready-to-use or RTE food products or in the production of pasta. Multi-grain flour by combining wheat and finger millet in the ratio of 7:3 is one of the simple semi-finished products convenient for making chapatti. It was found that swap of wheat flour with millet flours was possible from 10 to 20% level. Barnyard millet and proso millet can be added 20 and 15% respectively. The optimum level of addition of finger millet, foxtail millet and little millet was 10%. The increase in level of millets in blends increased the ash content and decreased the gluten and sedimentation value; loaf volume of dough; per cent damaged starch and protein whereas crust colour and shape of bread remained unaffected but colour of crumb bartered from creamish white to dull brown.[35]

IV. Puffed/Popped and Flaked Millets

Puffing or popping of cereals is an senile accustomed system of cooking grains to be used as snack or breakfast cereal either plain or with some spices/salt/sweeteners. Starch is the main carbohydrate in human nutrition and offers a range of desired abstruse properties. The invigorating quality of starch strongly lean on starch structure and on its processing.[36] Puffing or popping process brings about such basic changes in starch or starch-protein matrix of the millet grain or preconditioned pasta that leads to expansion of the grain or pasta pieces and produce a puffed product with high crisp and other textural aspects. The high temperature short time (HTST) treatment exploits the thermo-physical properties of starch and prepares bolster grains or flakes. During this process the Millard reaction takes place in which the sugars present in the aleurone layer echo with amino acids of the millet and gives a pleasant and highly desired aroma to the puffed product. It also recede anti-nutrients like phytate, tannins, etc., increase bio-availability of minerals, give savory essence to the product, and aggrandize protein and carbohydrate digestibility.[37]The engineering properties like moisture, porosity, bulk density, kernel size and ingredient like salt or sugar used in popping affect popping volume and ratio. Now days modern air puffing machines have been developed which can be used for mass staging of puffed or popped millet grains.[38]

V. Soaking

Soaking of grains is notorious and homely food processing approach. It is used for diminishing antinutritional compounds like phytic acid and phytase activity to perk up bioavailability of minerals. It is founded that miscellany of various processing like dehulling, soaking and cooking decreased in fecund amount of antinutrients like polyphenols, phytate and increase the protein digestibility *in vitro* and ameliorate the fallibility of minerals such as iron and zinc.[39]

VI. Germination

Germination of millets wane the levels of tannins (1.6% to 0.83%). Germination amend the *in -vitro* protein (14% to 26%) and starch (86% to 112%) digestibility in pearl millet.[40] It also led to the decrement of anti-nutrients such as phytic acid, tannins, and polyphenols, which form complexes with protein.[41] The *in vitro* extractability and bio-accessibility of minerals such as calcium, iron and zinc were increased and anti-nutritional factor such as phytic acid were decreased in pearl and finger millets by impregnation.[42] Pearl millet has higher beta-amylase activity and higher free alpha-amino nitrogen in comparison to sorghum after malting.[40] Germination and probiotic fermentation inexorably recover the innards of thiamine, niacin, total lysine, protein fractions, sugars, soluble dietary fiber.[43]

VII. Fermentation

Fermentation is widely used in food preservation, provides many stews of food products with different flavors and texture, and boosts the nutritional properties of raw food exigently.[44] Fermentation ebb the levels of antinutrients and reform the protein fling, digestibility *in vitro* and perceptible modulation in chemical content of food material.[41] Fermentation of pearl millet rally nutrient value like moisture, ash, fibre, protein and fat [45] and ineluctably condensed the mineral contents such as sodium, potassium, iron, zinc etc. and adorn flavonoids after 16 hours of fermentation.

CONCLUSIONS AND FUTURE DIRECTIONS

This study reveals that millets are used as cuisine medication. Millets can pertinently be entitled as multifaceted byproduct due to their nutritive equity, low GI and climate-change buoyant characteristics. Since times, only vitamins, minerals, essential fatty acids and fibers were aforethought to be culpable for conquering health benefits, but contemporary cogitation have determine that these factors could also act in consolidation with a number of other reactive units to wield conclusive chattels. Affirmation are there in abutment of millets playing vital role in precluding cancer and cardiovascular diseases, reducing tumor incidence, lowering blood pressure, risk of heart disease, cholesterol, and rate of fat absorption, delaying gastric emptying, and supplying gastrointestinal bulk.

Apparently, the utmost impelling field that needs to be remitted to support increased demand for millets and other antique cereals is the reinforcement of multi-culturally accustomed grain-endowment management systems. Millet-specific quality mainframe systems would convalesce the prowess of millet grain handling, the predication of millet-grains as material and succor ecumenical clientele in millets for food and other purpose.

The importance of this study undertakes to concern and developing specific agenda for these crops which must be recognized as an important food and introduce the millets as a nutritious food, fulfillment of the nutritional need of global population and to find ways to consume the millets nutritionally, effectively and to reduce the problems of malnutrition and other health problems. This study focused to reducing some anti-nutrients which diminish the acceptability, digestibility and bioavailability of nutrients and improve the nutrients of millets for nourishing the health.

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