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ANNEX 2.5 NUTRITIONAL COMPARISON OF MILLETS WITH OTHER SUPER FOODS

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Nutritional Comparison of Millets with other Superfoods

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Abstract

Nutrient-rich natural foods, which have balanced amounts of macro and micronutrients, are now called superfoods. They also contain significant amounts of polyphenols, phytonutrients and other minor components that can promote health and well-being. These superfoods can vary depending on the geographical location but few of them are commonly available all around the world which includes kale, blueberry and quinoa. In this review, we will assess the nutritional profile of various millets to compare them with generally accepted superfoods. It was observed that most of the millets are highly nutritious and can be considered as superfoods. They also contain considerable amounts of antioxidants and bioactive compounds that promote cardiovascular health and hypoglycemia. Furthermore, millets possess various non-nutritional benefits as they have the least global warming potential and are not resource-intensive like rice and wheat for their cultivation. With a wide range of advantages, millets can genuinely be the cereal superfood that the world needs to reduce the agricultural impacts on climate change and achieve food security, especially in arid and semi-arid regions of the world.

Keywords: millets; superfoods; food security; nutritional security; health benefits;

1. Introduction

Milletts, also known as minor cereals, are an indispensable source of energy for populations living in the arid and semi-arid regions of the world, especially in Africa and Asia. They are primarily cultivated in marginal lands which have adverse agricultural conditions where the major cereals would fail to produce sizable yields [1, 2]. They are classified within the grass sub-family *Panicoideae*. The popularity and the use of millets in these regions is due to their drought resistance character and their extended shelf life compared to other major cereals like corn, wheat and rice [1]. Hence, they became a vital source of energy and major nutrients, principally carbohydrates and protein, in regions susceptible to low rainfall. There are many varieties of millets that are in turn classified into major and minor millets based on the importance of their production (Table 1). However, despite the advantages of cultivating millets, the production rates around the world did not keep up with the other cereal crops. The total area in which the millets are harvested around the world has decreased from 36.2 million hectares in 2010 to 31.4 million hectares in 2014 which is a 15% fall. During the same period (2010 and 2014), the area in which maize (corn) and wheat are cultivated has increased by 11.3% and 2% respectively. The total millet production around the world reduced by 15.7% while the production of corn, rice and wheat grew by 18%, 5.4% and 12% respectively. In 2014, the top five nations producing millets were India (11.42 MT), Niger (3.32 MT), China (2.34 MT), Mali (1.71 MT) and Nigeria (1.38 MT) and these countries combined production accounts for 71% of the world production [3].

In recent years, there has been an increased emphasis on ‘superfoods’ which is the term used to define foods that are nutrient-rich, natural, dense and balanced along with providing an abundant source of antioxidants and bioavailable compounds. It is believed that the consumption of these foods leads to better health as it can help to regulate cholesterol and blood pressure and can help

1 in preventing certain cancers and cardiovascular diseases [4]. Though the term is mostly used in
2 marketing and advertisement, consumers look at superfoods as products that are between food
3 and medicines and many of them are primarily exotic or coming indigenous cuisines [4, 5]. The
4 products considered as superfoods vary widely depending on the country/region and the local
5 markets and local demand for such products. However, there are few food ingredients that are
6 considered as superfoods in most regions around the world, which include chia seeds (*Salvia*
7 *hispanica*), quinoa (*Chenopodium quinoa*), buckwheat (*Fagopyrum esculentum*), flaxseed
8 (*Linum usitatissimum*), kale (*Brassica oleracea* var. *sabellica*), broccoli (*Brassica oleracea*),
9 spinach (*Spinacia oleracea*) and various berries like goji (*Lycium barbarum*), açai
10 (*Euterpeoleraea Martius*) and blueberries (genus: *Vaccinium*) [6-8].

11 The emphasis of this paper will be on comparing the nutritional aspects of millets with various
12 known superfoods, especially grains and cereal-based superfoods. Further, we also provide an
13 overview of the health benefits reported in multiple studies with the consumption of millets.

14 **Table 1:** List of all commonly available millet varieties

Millets	Biological name
<u>Major millets:</u>	
Finger millet	<i>Eleusine coracana</i>
Proso millet	<i>Panicum miliaceum</i>
Pearl millet	<i>Pennisetum glaucum</i>
Foxtail millet	<i>Setaria italica</i>
<u>Minor millets:</u>	
Adlay millet (Job's tears)	<i>Coix lacryma-jobi</i>
Polish millet (Fonio)	<i>Digitaria sanguinalis</i>
Indian barnyard millet	<i>Echinochloa frumentacea</i>
Japanese barnyard millet	<i>Echinochloa esculenta</i>
Little millet	<i>Panicum sumatrense</i>
Kodo millet	<i>Paspalum scrobiculatum</i>
Browntop millet	<i>Urochloa ramosa</i>

Table 2(a): Nutritional Chart for Millets (% dry-weight basis)

Source: [9-15]

Millet	Carbohydrates	Fiber	Protein	Fats	Ash	Vitamins (mg/100g)				Minerals (mg/100g)	
						A	B1	B2	B3	Ca	Fe
Finger millet	82.3	3.4	8.7	1.8	2.8	6	0.3	0.1	1.4	350	5.0 – 9.9
Proso millet (dehulled)	80.1	0.7	12.5	4.9	0.8	-	0.41	0.28	4.54	8	2.9
Pearl millet	75.6	2.3	11.6	4.8	2.2	22	0.3	0.15	2.0	25	3.0 – 9.8
Foxtail millet	66.9	4.1	11.8	4.1	3.3	-	0.6	0.1	0.99	20	4.9
Adlay millet	85.9	15.1	6.7	2.5	-	-	-	-	-	-	-
Polish millet	73.6	8.5	8.7	3.5	3.8	0	0.24	0.14	2	44	8.5
Indian barnyard millet	74.0	2.0	15	5.2	1.3	-	0.3	0.09	-	210	7.6
Japanese barnyard millet	55.7	13.9	11.3	4.0	4.6	-	-	-	-	22	18.6
Little millet	66.3	7.0	10.7	6.0	5.9	-	0.41	0.28	-	17	-
Kodo millet	73.5	8.4	10.2	3.9	3.6	-	0.2	0.10	-	35	1.7

Table 2(b): Essential amino acids in Millets (mg/100g)

Source: [12, 15-21]

Millet	Isoleucine	Leucine	Lysine	Methionine	Phenylalanine	Histidine	Threonine	Tryptophan	Valine	Total
Finger millet	275	594	181	194	325	170	263	191	413	2606
Proso millet	405	762	189	160	307	340	147	49	407	2766
Pearl millet	256	598	214	154	301	150	241	122	345	2381
Foxtail millet	475	1044	138	175	419	20	194	61	431	2957
Barnyard millet	288	725	106	133	362	140	231	63	388	2436
Little millet	416	679	114	142	297	200	212	35	379	2474
Kodo millet	188	419	188	94	375	90	194	38	238	1824

2. Nutritional comparison with millets

2.1 Carbohydrates

Although emphasis on millet research around the world is limited, there has been significant increasing interest in millet research over the past few years due to their advantageous nutritional attributes. Table 2(a) outlines the nutritional content of various millets. From this table, it is clear that carbohydrates are the primary component present in millets (over 65%) with the exception of Japanese Barnyard millet which has only about 56% carbohydrates. Annor et al., (2017) have assessed the quality of both the starch and protein present in various millets. They concluded that the starch present in millets has a higher resistance to digestion compared to other grains and cereals. Though various factors are contributing for their lower hypoglycemic property, the interactions between the major nutritive components, i.e. carbohydrates – proteins – fats, due to the significant amounts in which they are present, has been cited as a critical factor. Further, the high fibre content in millets and the resulting matrix could also contribute to the slower carbohydrate digestion rate [22, 23]. The fibre content was found to vary from 3% - 15% depending on the millet variety [22, 23].

Table 3 summarizes the nutritional composition of various superfoods that are being consumed widely around the world. Their moisture content has also been included in the table to show that the nutritional information included is not greatly influenced by the water content. Table 3 shows that the carbohydrate content of most of the superfoods varies between 65 – 77% which is similar to the carbohydrates in millets with the exception of Finger millets and Adlay millets whose carbohydrates content extends into the mid-80%. Only flaxseed and chia seeds have lower carbohydrates due to the presence of fats and fibre in higher quantities. Research has shown that some superfoods such as Quinoa, Buckwheat and Oats, can help regulate the insulin release into

the blood by lowering the glucose released from the digestion process. Further, there is also evidence which suggests that appropriate processing conditions can increase the resistant starch present in these superfoods and thus regulate the overall digestion rate of carbohydrates in the body [24-29]. Similar research on the starch digestibility and the factors that influence these rates require to be further studied for all superfoods.

2.2 Proteins

The protein content is also high in millets ranging between 8.5% – 12.5% except for Adlay millet (6.7%), which is one of the minor millets (Table 2(a)). However, the protein digestibility studies showed that the polyphenols and the tannins present in the millets could result in lower rates of *in-vitro* protein digestibility (IVPD). However, processing methods including thermal processing have potential to increase the digestibility of proteins [22]. Thermal processing methods like cooking millets have been reported to increase the IVPD in the case of Foxtail millet, Finger millet and Proso millet through removal of the anti-nutritional factors [30]. Similar results were also observed in the case of soybean where the trypsin inhibitor, an anti-nutrient, reduced the IVPD significantly [31, 32]. Recent studies showed that wet-thermal processing methods, like boiling and pressure-cooking, did not improve the IVPD of Pearl millet, but dry roasting significantly improved the digestibility [33]. Nazari et al., (2017) studied the effects of ultrasonication of millet protein concentrate which showed significant changes in the functional properties and the secondary structure conformations. However, the ultrasonication effect on the digestibility of the millet protein was not reported [34].

Table 2(b) lists the essential amino acids that are present in various major and minor millets. All the millets were found to have the minimal quantity of essential amino acids; however, their availability ranges widely. Foxtail millet was found to have the highest amounts of essential

amino acids which are estimated to be almost 3g/100g with leucine alone amounting to nearly 1g/100g. Kodo millet was found to have the least amount of essential amino acids (1.8 g/100g). However, it has higher quantities of phenylalanine and lysine compared to other millet varieties.

2.3 Fats

The fat content in various superfoods varies widely depending on the origin and the group to which the food belongs to. Goji berry was found to have the least amount of fats with less than 1% of the total nutritive value. Flaxseed was found to contain the highest quantity of fats (42%) followed by Chia seeds which contain an average of 30.7% fat. However, despite the presence of higher quantities of lipids in flaxseed, flaxseed oil is a highly beneficial food product due to its favorable fatty acid profile and phytonutrient content with health benefits. Xu et al. (2017) observed that the combination of flaxseed oil and astaxanthin could reduce the lipid accumulation in liver and oxidative stress caused due to high-fat diets [35]. Further, flaxseed oil was also found to reduce body weight gain, plasma cholesterol and low-density lipoprotein-cholesterol in rats [36]. It is also a vital plant-based source of omega-3 fatty acids that promote cardiovascular health [37]. Similar to flaxseed, the fats present in chia seeds were also found to be rich in polyunsaturated fatty acids and omega-3 fatty acids which provide various health benefits [38] and thus are classified as superfoods.

In the case of millets, none of the varieties have such high quantities of fat which varies only between 2 – 6% with over 80% being unsaturated fatty acids [39, 40]. Little millet has the highest fat content and finger millet has the lowest as reported in Table 2(a). This amount of fat content is similar to the quantities present in Quinoa, Buckwheat and Oats which are 6.1%, 3.4% and 6.9% fat respectively. Research has shown that the fat digestibility of millets is much higher compared to traditional cereals [41]. Furthermore, the various health benefits have been

associated with consumption of oils from these sources which include lowering blood cholesterol, lowering blood pressure and cancer prevention [40, 42, 43].

2.4 Dietary fiber

It is well known that intake of dietary fiber in appropriate amounts can provide numerous health benefits. Although the recommended dietary fiber intake can vary widely depending on gender and age, the accepted recommendation is around 14g/1000 kcal [44]. With an estimated average calorie intake of 2000 – 2500 kcal/ day, the adequate dietary intake of fiber would be about 28 – 35 g/day [45]. Multiple studies have reported that consuming sufficient amounts of dietary fiber daily can reduce the risk of cardiovascular disease, diabetes, obesity and gastrointestinal diseases [46, 47]. Chia seeds were found to have the highest fiber content of around 34.4% followed by flaxseeds (27%). Other superfoods also contain a considerable amount of dietary fiber which varies between 6 – 10% as reported in Table 3. Millets are also known for their dietary fiber content and the health benefits that it provides with regular consumption. The fiber is especially high when the millets are consumed in the form of grain which could lead to reduction in the risk of cardiovascular diseases [48]. The fiber content was found to be highest in Adlay millet (15%) and Barnyard millet (13.9%). Kodo millet and Polish millet were also found to have high quantities of fiber.

2.5 Minor nutrients, polyphenols and Health benefits

Millets are a staple food for large sections of the population in Asian and African countries. Millets provide them with a nutritious and calorie-rich diet with significant amounts of micronutrients (vitamins and minerals) and polyphenols that contribute to numerous health benefits. Finger millets have significantly high levels of calcium and are primarily concentrated

1 in the seed coat and its removal can lead to loss of calcium [49]. Millets are found to be rich in B
2 vitamins similar to other cereals and superfoods (Table 3) [15]. Researchers have shown that
3 millets contain high levels of phenolic phytochemicals primarily in the form of flavonoids and
4 phenolic acids [50]. However, Finger millet was also found to contain significant amounts of
5 tannins especially in the brown millet varieties [51]. Some of the typical phenolics present in
6 millets include *trans*-ferulic acid, catechins, luteolin, kaempferol, apigenin and quercetin [15,
7 52]. However, the data available is still limited. Hence, further research in identifying the
8 primary polyphenolic compounds which are present in various millets is warranted [53].

9 The beneficial role of consuming millet grains has been reported in multiple studies. Rajasekaran
10 et al.(2004), showed that feeding Finger millets for four weeks could significantly improve the
11 wound healing process and control glucose levels in diabetic rats [54]. Finger millets were also
12 found to reduce the plasma glucose levels in patients who have diabetes (non-insulin dependent).
13 Similar hyperglycemic effect was also observed in Wistar rats on consumption of Finger millets
14 and Kodo millet grains [55, 56]. Shobana et al. (2009), also reported that a hypoglycemic effect
15 along with nephroprotective and hypocholesterolemic properties were observed in
16 streptozotocin-induced diabetic rats when they were fed with 20% Finger millet seed coat [53,
17 57]. The presence of various phenolic compounds and flavonoids also contributes to their
18 hypolipidemic, anti-inflammatory and goitrogenic properties [15, 52]. Furthermore, millets are
19 gluten-free and are an excellent option for people suffering from gluten allergy, wheat allergy
20 and celiac disease [58].

Table 3: Nutritional chart for different superfoods (% dry-weight basis)

Source: [7, 26, 27, 59-62]

Food	Moisture (%)	Carbohydrates	Fiber	Protein	Fats	Ash	Vitamins (mg/100g)				Minerals (mg/100g)	
							A	B1	B2	B3	Ca	Fe
Quinoa	13	64.6	7.0	14.12	6.1	2.8	0	0.36	0.32	1.5	47	4.57
Buckwheat	10	71.5	10.0	13.25	3.4	2.1	0	0.1	0.43	7.02	18	2.2
Flaxseed	7	28.9	27.3	18.29	42.2	-	0	1.64	0.16	3.1	255	5.73
Chia seeds	6	42.12	34.4	16.54	30.74	-	-	0.62	0.17	8.83	631	7.73
Amaranth	11	65.25	6.7	13.56	7.02	2.9	0	0.12	0.2	0.92	159	7.61
Goji berry	7.5	77.06 (45.61)	13.0	14.26	0.39	-	15.2	-	-	-	190	6.8
Wild rice	8	74.9	6.2	14.7	1.1	-	0	0.12	0.26	6.73	21	1.96
Oats	8	66.27	10.6	16.89	6.9	-	0	0.76	0.14	0.96	54	4.72

3. Non-nutritional benefits of millets

Apart from being wholesome and nutritious foods, that are reflective of being a superfood, the promotion of the cultivation of millets can have various other benefits. We know the wide range of challenges faced in this 21st century, such as climate change, water scarcity and population explosion which can have a detrimental effect on agriculture and food security, especially for the population living below the poverty line in Asia and Africa. However, millets present the ability to grow in poor soils with just 200 – 400 mm of annual rainfall [63]. With proper support and encouragement of governments, millets can be grown on a large scale in lands least suitable for agriculture of major cereals like rice, wheat and maize. Furthermore, the crop duration is short and roughly varies between 60 – 100 days depending on the variety [64]. Jain et al. (2016), evaluated the greenhouse gases released during cultivation of various cereal crops and reported that millets have the least global warming potential among all the cereals tested (rice, maize, wheat, sorghum and millets) [65].

4. Conclusion

The nutritional comparison with recognized superfoods such as flax, quinoa and chia seeds, showed that a variety of millets have comparable quantities of macro and micronutrients and hence can be considered as superfoods in the nutritional sense. Further, the presence of health-promoting flavonoids and phenolic compounds boosts their position in this regard. In addition, millets also have various non-nutritional advantages that further makes a case for their status as cereal superfoods we need will need to nurture for the future. The ability of millets to grow in marginal lands with no irrigation facilities could help the world in achieving the targets of food security. With the current challenges of soil erosion and water scarcity in mind and our food

security targets set at providing safe and nutritious food to everyone, millets could become the superfood that we need to truly achieve our objectives.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper

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