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Nutritional Value of African Indigenous Whole Grain Cereals Millet and Sorghum

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Abstract

Worldwide population growth expectations increase the pressure to find ways to increase agro-food production in a sustainable manner, be it by increasing production capacity, cultivating currently natural areas or changing crop consumption patterns. Cereals are staple foods and the most frequently consumed are maize, wheat and rice. However, the production of these cereals may become insufficient for the growing needs. Millet and sorghum are traditional cereal crops, able to growth in adverse drought conditions, and do not need many resources to be harvested. Furthermore, they reveal very interesting nutritional profiles, including macro and micronutrients and bioactive compounds. We would like to highlight their fiber content, since fiber inadequacy is a worldwide condition and its adverse effects on health are well described.

Over time, these indigenous cultures have become less popular than other cereals, due to their organoleptic and technological proprieties. However, techniques like bio-fortification, fortification, genetic improvement, fermentation, malting, and germination among others can be used to improve their technological properties and enhance their nutritional profile.

Keywords: Millet; Sorghum; Nutrition value; Health benefits

Introduction

According to the United Nations (2013), the medium-variant projections of world's population growth reach the values of 9.6 billion in 2050 and 10.9 billion in 2100, assuming that fertility levels will continue to decrease [1]. It is forecasted that almost all of this increase will occur in developing countries, in particular, in Sub-Saharan Africa which will be the place worldwide with the fastest growth rate, approximately 114% [2,3]. To keep up with this population growth, it is mandatory to increase food production in a sustainable manner. However, aspects such as the impacts of climate change, the increased water and land scarcity, the change in consumption patterns, mainly caused by growth in urbanization, and the increased use of cereals for fodder and fuel, hamper an effective response to current and near future food demand [4,5]. This shift in demographics and socio-economic environment leads to changes in peoples' lifestyles, causing a transition from traditional to modern and contemporary realities. Food patterns are one of the typical aspects that characterize this changeover. Although food patterns are identity factors in several communities and are difficult and slow to be changed, it has been shown that the dietary patterns have changed [6]. The THUSA study, a cross-sectional health study in South-African population, shows a transition from high carbohydrate and low fat diet to a diet associated with non-communicable diseases (NCDs), rich in sugar and fat [7]. These findings were also supported several years before by Popkin [8]. In his studies on nutritional transition in different populations worldwide, Popkin concluded that this shift in nutrition plus the reduced physical activity in both work and leisure leads to an increase of obesity and overweight [9]. In turn, this will contribute to an epidemiological transition from infectious diseases towards diet-related chronic diseases. He found that under- and over nutrition often coexist, which reinforce that a higher proportion of people might consume the types of diets associated with a number of chronic diseases [8,9]. According to World Health Organization, developing countries represent a huge cantle of the global burden of NCDs [10,11].

Cereals are a staple food for the majority of the world population, either in developed or developing countries. Globally, the consumption of maize, wheat and rice has surpassed the consumption of traditional crops such as millet and sorghum [12-14]. While wheat, maize and rice, are cereals that do not growth specifically in Africa and may be harvested in other parts of the world [15], sorghum, millets (pearl, finger), teff and African rice are traditional "small grain" crops native to Africa, that were gathered as wild grasses many centuries ago, domesticated and eventually produced by farmers in their fields in Africa, and today continue to maintain their hardy, tolerant self-reliance of their wild ancestors. One reason that justifies the increased consumption of soft cereals, like maize, rice and wheat, is the reduction on the import tariffs for these three main cereals [12]. However, these cereals do not reveal growth properties as beneficial as millets or sorghum, which are very drought-resistant, capable of growing in semi-arid and arid dry lands of sub-Saharan Africa and Asia (these areas include the five most important highest sorghum and millet-producing countries) [16], are resistant to birds damage and insects attack and do not require many resources to be harvested [5,13,14]. This replacement of indigenous cereals by maize brings some risks, associated to the increase of human population and consequently the need to produce more yet using poor quality soils for cultivation with low productive capacities, however some projects aiming to minimize this are being outlined [15]. Additionally, climate change scenarios and drought stress are harmful to crops like maize and wheat and yields are predicted to decline. Model predictions have shown that for an increase of 1^{0}C in global mean temperature, wheat yields may decrease by 6% [17]. For these reasons the importance of sorghum and millet must not be undervalued [18].

Nutritional Values of the Grains

Besides advantages related with cereal production and stress adaptation, millet and sorghum also deserve attention due to their nutritional profile, and consequently, their potential impact on human health [19-22]. As well established, cereals are generally comprised by three different parts: the outer pericarp, the germ and the endosperm. Each part is rich in different nutrients; in general, the Pericarp is rich in non-starch polysaccharides and phenolic compounds, the germ is composed mainly by lipids, vitamins (complex B and fat-soluble), minerals, few proteins and partially by non-starch polysaccharides and in the endosperm proteins, starch, water-soluble vitamins and minerals are available [13,14]. Regarding millets and sorghum, there are several varieties of each of these cereals, however this mini-review will be focused only on Finger Millet (*Eleusine coracana*), Pearl Millet (*Pennisetum glaucum*), Red and White Sorghum (*Sorghum Bicolor L.*), originating from different regions, an issue that strongly influences nutritional composition, as discussed below.

Carbohydrates

Millets, as any other cereal, have carbohydrates (between 70-78%) as their major component, from which it is possible to differentiate between starch (59%-65.5%), composed mainly by amylose and amylopectin, and non-starch polysaccharides, or dietary fibre (DF) (7-20%) [19,23]. The content of amylopectin is much higher than amylose for these cereals, in average these grains have less than 25% of amylose. Finger millet has a markedly higher amount of DF (19.1%) when compared with pearl millet (7%), and also with other common cereals such as maize (2.3-2.8% crude fibre), wheat (2.0-2.9% crude fibre) and rice (1.0-10.2% crude fibre) [19,20,23] (Table 1). Regarding sorghum, the range of carbohydrates can vary between 32%-72%, and the content of DF is about 6%-15%, where the percentage of insoluble fibre is much higher (75-90%) than soluble fibre (10-25%) [21]. The consumption of high fibre cereals has been associated with positive health effects, and various health claims are accepted by the European Food Safety Authority. Soluble fibre has demonstrated to lower blood cholesterol and to delay glucose absorption, reducing the risk of heart disease [22], diabetes [24,25] and colorectal cancer [26]. On the other hand, insoluble fibre speeds up intestinal transit, reducing disease symptoms of constipation, and improves bowel function, modifying the microbiota toward a more health-promoting profile [23].

Table 1: Nutrient composition of millets and sorghum (per 100g edible portion).

	Finger Millet	Pearl Millet	Sorghum
Energy (kcal)	328[19]-336[20]	361[19]-363[20]	329[20]
Protein (g)	7.3[19]-7.7[20]	11.6[19]-14.5[23]	10.4[20]-11[23]
Fat (g)	1.3[19]-1.5[20]	4.8[20]-5.123	3.1[20]-3.2[23]
Carbohydrates (g)	72.0[19]-72.6[20]	67.0[20]-67.5[19]	70.7[20]
Dietary Fibre (g)	11.5[19]-19.12 (crude fibre: 3.6[20])	7.0[23]-11.3[19](crude fibre: 2.3[20])	6.0[21]-15.0[21] (crude fibre: 2.0[20]-2.7[23])
Ca (mg)	330[23]-350[20]	10[23]-42[19,20]	25[20]-40[23]
K (mg)	408[19]-430[23]	307[19]-44023	289[21]-380[23]
Fe (mg)	3.9[19,20]	1.0[20]-8.0[19]	5.4[20]-6.1[21]
Thiamin (mg)	0.42[19,20]-0.48[23]	0.33[19]-0.38[20,23]	0.38[20]-0.46[23]
Riboflavin (mg)	0.12[23]-0.19[19,20]	0.21[20]-0.25[19]	0.15[23,20]
Niacin (mg)	0.3023-1.1[19,20]	2.3[19]-2.8[20]	4.6[20]-4.84[23]
Total phenol (mg/100g)	102[23]	51.4[23]	Phenolic acids: 135.5-479.40µg/g[21]

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Proteins

The cereals' content in protein is relatively low and the content of essential amino acids is not the ideal, when compared with other foods. Generally, sorghum and finger millet contain a low proportion of lysine, whereas pearl millet seems to have a higher content of this essential amino acid, which gives it a better protein quality [27]; finger millet also contains more threonine and valine than most of the other millets [17].

The protein content of pearl millet (about 11%) is higher than that of finger millet (about 7%), and the concentration in sorghum's varieties can range between 7-15% [19,21,28] (Table 1). In general, these three cereals have prolamins, followed by other type of proteins such as albumins, globulins and glutelins, in their protein profiles. Nevertheless, the prolamin types found in these cereals (finger millet's prolamins, pennisetins, and kafirins) are not harmful to gluten intolerants or celiac patients, as are the prolamins present in wheat (gliadin), rye (secalin) and barley (hordein) [23,29] and, consequently, these cereals are a safe food option for such group population. As will be deepened next, red sorghum and finger millet have a higher content of tannins, when compared to white sorghum and pearl millet, non-pigmented grains [19,21]. It has been described that tannins negatively influence protein digestibility, mainly due to a formation of aggregates that prevent the action of proteases [29-31].

Lipids

Lipids are the macronutrient with less expression within the nutritional composition of cereals, varying between 1.85%-2.10% in different varieties of millet [19] (Table 1) and 1.24%-3.07% in sorghum[21]. The fatty acid profile found in these cereals is nutritionally balanced, offering a predominance of unsaturated fatty acids. Millets have a higher content of oleic and palmitic acid than sorghum, 46%-62%19 vs. 32.2%-42.2% [21] and 20%-35% [19] vs. 12.4%-16.0% [21], respectively. In contrast, linoleic acid is present in higher amounts in sorghum, 45.6%-51.1% when compared to millets 8%-27% [19,21].

Micronutrients

Both sorghum and millets are good sources of micronutrients, especially minerals, however compositions are variable according to the production area and cultivation strategies [21,32]. Sorghum is rich in phosphorus, potassium and zinc, whereas finger millet is more recognized to be an important source of calcium, phosphorus, iron and potassium, while pearl millet is rich in iron and zinc [19,21,23,27]. In the literature there is little information to be found regarding the difference between red and white sorghums. Regarding vitamins, the contents of niacin (especially in sorghum and pearl millet), riboflavin and thiamin are important [21,23]. Although the solubility, bio-accessibility and subsequent bioavailability of some minerals are low, they can be increased by processing technologies, such as bio-fortification, fortification, genetic improvement, germination, malting, and fermentation among other [17].

Bioactive Compounds

Finger millet, in particular, and red sorghum, especially in the cereal outer layers, are very rich in phenolic compounds, namely phenolic acids such as ferulic (sorghum: 120.5-173.5μg/g; finger millet: 186μg/g), protocatechuic (sorghum: 150.3 -178.2 μg/g; finger millet: 450μg/g) and caffeic acids (sorghum: 13.6-20.8 μg/g; finger millet: 16.4μg/g), and tannins (sorghum: 0.2-48.0μg/g), but flavonoids (sorghum: 87μg/g, on average) are also present in smaller quantities [21,23,33-35] (Table 1). As mentioned above, pigmented grains have demonstrated to have more phenolics content than non-pigmented varieties. This can be due to the presence of anthocyanins, polymerized phenolics present in darker cultivars [23]. These compounds have very interesting properties such as antioxidant, anti-carcinogenic, anti-inflammatory, anti-microbial, anti-fungal and anti-diabetic, playing an important role in minimizing the incidence of some diseases and all-cause mortality. According to the antimicrobial activity, it is reported that the polyphenols are active against different microorganisms, namely *Bacillus cereus, Salmonella sp., Escherichia coli* and other [36]; the antioxidant properties of polyphenols results from their capacity of donating hydrogen atoms via hydroxyl groups on benzene rings to electron-deficient free radicals [23], supressing the excessive oxidation [23,36]; anti-diabetic properties of phenolics are due to the inhibition of amylase and alfa-glucosidase, active enzymes on the hydrolysis of complex carbohydrates, what might delay the absorption of glucose and reduce postprandial hyperglycemia [36]. However, they also act as anti-nutrients [36-38]. They are biological active molecules and if they are present in sufficient quantities, they might reduce the nutritional value of the food product as they contribute to reduce bioavailability of some nutrients. High levels of these compounds, namely phytates and oxalates can compromise the regular absorption of some minerals, protein and starch digestibility [21,23]. The main mechanisms of action involved include their action as reducing agents, metal chelators, oxygen scavengers, radical quenchers or enzyme inhibitors [23,19]. Such richness in naturally bioactive compounds may uphold the use of these whole grains, or derived fractions, in food product development with multifunctional purposes toward health promotion and chronic disease prevention. Nonetheless, biological validation thereof with animal models and human trials still need to be performed.

Current Research

There are some processes that affect both the structure and the functionality of cereals. The above cited less positive characteristics of cereals, can be improved by resorting to technology [39]. It has been studied that milling, decortication, germination, fermentation, among others alter the bioaccessibility

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and bioavailability of some minerals, protein digestibility as well as the content and bioavailability of some bioactive compounds [19,20,40]. Therefore, investments in the study of different technological processes effects on the nutritional value of whole grain cereals should be addressed.

Based on the abovementioned considerations, it is noteworthy the potential impact of these whole grain traditional cereals in human health. Mainly, the richness in DF, being gluten-free, bioactive compounds, interesting protein and fat profiles makes these cereals a very balanced food option that helps management of many disorders. People with clinical complications such as diabetes, cancer, obesity, celiac disease, lipid disorders or inflammatory and oxidative states, should consider including millets and sorghum based products in their regular diets. To ensure this, food industry must work on nutritional awareness and evolve following strategies that develop and improve those kinds of products. Although these cereals are mainly from Africa and Asia, Europe, considering the prevalence of NCDs, should wager on new products developments, including millet and sorghum whole grains.

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