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Akansha
Department of Food Science and Nutrition, Banasthali Vidyapith, Rajasthan, India

Kriti Sharma
Department of Food Science and Nutrition, Banasthali Vidyapith, Rajasthan, India

Ekta Singh Chauhan
Department of Food Science and Nutrition, Banasthali Vidyapith, Rajasthan, India

Correspondence
Ekta Singh Chauhan
Department of Food Science and Nutrition, Banasthali Vidyapith, Rajasthan, India

Nutritional composition, physical characteristics and health benefits of teff grain for human consumption: A review

Akansha, Kriti Sharma and Ekta Singh Chauhan

Abstract
Current study aimed to understand the need for improving nutritional content of gluten-free diets by incorporating alternative gluten-free grains that are naturally abundant in nutrients. Teff (*Eragrostis tef*) has been grown and consumed by humans for centuries in Ethiopia. However, teff's global use for human consumption has been restrained partly due to limited knowledge about its nutrient composition and the processing challenges faced in making teff-based food products. A review on published research on nutritional, physical characteristics and health benefits of teff grain has been done by revisiting the respective literature, to identify gaps in our knowledge and outlining future research directions. Numerous gaps in our knowledge of nutritional status and health benefits of teff grain were identified. Over the past decade, the recognition that teff is gluten-free has raised global interest. The existing literature suggests that teff is composed of complex carbohydrates with slowly digestible starch. Teff has similar protein content to other more common cereals like wheat, but is relatively richer than other cereals in the essential amino acid, lysine. Teff is also a good source of essential fatty acids, fiber, minerals (especially calcium and iron) and phytochemicals (polyphenols and phytates). Existing studies of the nutrition and health benefits of teff are limited since they fail to take into account difference in teff varieties and growing conditions. Nevertheless, the studies undertaken so far confirms teff's excellent nutrient profile and suggests that it has considerable potential globally to be a functional food for health promotion and disease prevention.

Keywords: Teff, functional food, amino acid, minerals

Introduction
Nutritional quality of food is the most important parameter for maintaining human health and complete physical well-being. Since nutritional well-being is the driving force for development and maximization of human genetic potential [1]. Dietary quality of food should be taken into consideration for maintaining human health and fitness to solve the problem of deep rooted malnutrition. Diversification of food production must be encouraged both at national and household level with their increasing yields and techniques [2]. Due to lack of knowledge or unawareness in society about millets do not allow agriculture foods to be used for human. Millets are used as animal and bird feed, it also contain nutritious and therapeutic potential which has been reported by [3]. These are underutilized and neglected crop because of little knowledge in people and some critical problems like lower cooking quality, taste and low bioavailability of millets. These problems can be solved by making them valuable as food for poor families to combat malnutrition and it plays an important role in source of income. Millet is known to be a drought-resistant crop, resistance to pests and diseases, short growing season as compared to other major cereals [4]. Due to above mentioned advantageous characteristics; millet grains are receiving specific attention in developing countries (like India, China and some countries from Africa Continent) in terms of utilization as food. Some developed countries are also giving due attention to millet grains in terms of its good potential in the manufacturing of bioethanol and biofilms [5]. This study emphasized on teff millet, recognized as high-energy nutritious food that helps in reducing malnutrition, nourishing the common population and in treatment of diseases like obesity, diabetes and cardiovascular diseases. Millet is a gluten-free food and can be a substitute for celiac patients.

Teff (*Eragrostis tef*) is a grain commonly used in Ethiopia. Its small size (1-1.5 mm) prevents the separation of the germ from the endosperm in teff flour [6]. It is reported to have a higher content of iron, calcium, phosphorus, copper, and thiamine compared to other grains like

wheat, barley, and sorghum [7]. It is also reported to be free of gliadin [8, 9] and could be suitable for use in the diet of patients suffering with celiac disease [10, 11]. Teff proteins are non-gluten in nature. It has high nutritional content including all essential amino acid composition especially lysine, more mineral content (mainly iron, calcium, phosphorus and copper) than other cereal grains. It contains B_1 vitamin and is rich in fibre [12].

In this review, the nutrient composition, physiochemical characteristics and potential health benefits that could be associated with higher consumption of teff are highlighted.

Physical Characteristics of Teff Grain

Teff is probably the smallest cereal grain with an average length of ~1 mm[13]. The minuteness of teff grains has nutritional and technological implications. For instance, as teff grains are difficult to decorticate so, wholegrain cereals helps to improve nutritional quality for consumers.

The color of teff can vary from white (ivory) to dark brown (black) depending on the variety. In Ethiopia, three major categories can be identified: white (*nech*), red (*quey*) and mixed (*sergegna*). It is also common for wholesalers to further sub-divide white teff into very white (*magna*) and white (*nech*). White teff generally grows only in the Ethiopian highlands and require relatively good growing conditions. However, in recent years, red teff, which is believed to be more nutritious, is also gaining popularity among health conscious consumers in Ethiopia.

Taxonomical classification

Kingdom	Plantae
Order	Poales
Family	Poaceae
Subfamily	Chloridoideae
Genus	Eragrostis
Species	*E. tef*

Small millets can be grown even in poor soil and climatic conditions. They have short growing season and can be very well fitted into multiple cropping systems both under irrigated as well as dry farming conditions. They can provide nutritious grain and fodder in a short span of time. Their long storability under ordinary conditions has made them "famine reserves". This aspect is very important as Indian agriculture suffers from vagaries of monsoon. The most important minor millets cultivated in India are finger millet (ragi), proso millet, barnyard millet, italian millet, kodo millet, little millet and teff [14].

Chemical Composition of Teff

The chemical composition of cereals varies widely and depends on the environmental conditions, soil, variety and fertilizer. The importance of teff is mainly due to the fact that it has attractive nutritional profile and has no gluten found in other common cereals such as wheat, barley and rye. Now days the demand for gluten-free foods is growing among the people are which diagnosed with celiac disease and other types of gluten sensitivity [10].

Table 1: Nutritional and Microelement Composition of Teff Grain [15-17]

Nutrients	Amount
Crude protein (g/100 g)	11.0
Crude fat (g/100 g)	2.5
Moisture (g/100 g)	10.5
Ash (g/100 g)	2.8
Crude fibre (g/100 g)	3.0
Carbohydrate (g/100 g)	70.2
Calcium (mg/100 g)	165.2
Copper (mg/100 g)	2.6
Iron (mg/100 g)	15.7
Magnesium (mg/100 g)	181.0
Manganese (mg/100 g	3.8
Phosphorus (mg/100 g)	425.4
Potassium	380.0
Sodium (mg/100 g)	15.9
Zinc (mg/100 g)	4.8

Carbohydrates

Carbohydrates are the major source of energy for humans and play an important role in metabolism and homeostasis. Based on the molecular size and degree of polymerization, carbohydrates can be classified into sugars, oligosaccharides, starch (amylose, amylopectin and non-starch polysaccharides) [18]. reported that complex carbohydrates make up 80 percent of teff grain. It has a starch content of approximately 73 percent making teff a starchy cereal. The amylose content of 13 teff varieties tested that ranged between 20 to 26 percent, comparable to other grains such as sorghum. [19] and the [20] reported that carbohydrate content are found to be 73g/100g in teff flour, which is similar to other cereal grains, such as white wheat flour-75g/100g, rye flour- 76g/100g but lower than maize flour (92g/100g) and higher than soya flour-(28g/100g) and brown wheat flour (69g/100g). The difference in carbohydrate content in teff and other cereal grains flour could be explained by different levels of protein and fibre. Soya flour has high amount of protein (37g/100g) and fibre (11g/100g) by [21] as compared to teff flour. White wheat flour has lower fibre content than brown wheat flour. Therefore, white wheat flour has similar carbohydrate amount as teff flour.

Lower Glycemic Index of teff may be explained by its amylose content, lower starch damage, and the possible formation of amylose-lipid complexes that can hinder the enzymatic access and starch digestibility [22]. In addition, the high (68-80 °C) gelatinization temperature of teff [18, 22] can hinder the gelatinization and decrease susceptibility to enzymatic attack by α-amylase [23].

Protein

The average crude protein content of teff is in the range of 8 to 11 percent, similar to wheat. Teff's fractional protein composition suggests that glutelins (45 percent) and albumins (37 percent) are the major protein storages while prolamins

are a minor constituent (~ 12 percent) [24]. In contrast, more recent studies reported that prolamins are the major protein storages in teff. By examining, the profile of amino acid in teff contains higher amount of glutamine, alanine, leucine and proline as compare to lysine [13]. Teff's amino acid composition is well-balanced as shown in Table 2. A relatively high concentration of lysine amino acid is found in teff. Similarly, compared to other cereals, higher contents of isoleucine, leucine, valine, tyrosine, threonine, methionine, phenylalanine, arginine, alanine and histidine are found in teff.

Fat

Cereals are not the best source of fat but as they are consumed in large quantities. It can contribute a significant amount of essential fatty acids to the diet [25]. The crude fat content of teff is higher than that of wheat and rice, but lower than maize and sorghum (Table 1). Rice, wheat and maize contains negligible amount of linoleic acid (LA) and traces of α-linoleic acid (ALA). Furthermore, these widespread cereals are consumed after decortications and further refining which reduces their amount of crude fat and poly-unsaturated fatty acids. Teff grains are rich in unsaturated fatty acids, predominantly oleic acid (32.4%) and linoleic acids (23.8%) [26].

Crude fiber

The crude fibre content in teff (3.0 g/100 g) is far higher than the other gluten containing and gluten-free cereals. Consumption of dietary fiber provides many health benefits. The dietary fiber content of teff (8.0 g/100 g) is high when compared to some fruits, nuts, pulses and cereals such as corn and rice [17]. Studies revealed that high fiber diets prevent many human diseases like colon cancer, coronary heart disease and diabetes [27].

Table 2: Macro, amino acid composition of teff [22, 25]

Amino acid (g/16 g N)	Teff
Lysine	3.7
Isoleucine	4.1
Leucine	8.5
Valine	5.5
Phenylalanine	5.7
Tyrosine	3.8
Tryptophan	1.3
Threonine	4.3
Histidine	3.2
Arginine	5.2
Methionine	4.1
Cystine	2.5
Asparagine	6.4
Serine	4.1
Glutamine + Glutamic Acid	21.8
Proline	8.2
Glycine	3.1
Alanine	10.1

Minerals

The difference in mineral content between and within teff varieties is wide ranging. Red teff has a higher iron and calcium content than mixed or white teff. On the other hand, white teff has a higher copper content than red and mixed teff (Table 3). The most recent study investigated iron content in selected teff grains. Their findings showed that teff contained almost 38mg/100g and more than 150mg/100g of iron in locally purchased white and red teff grains varieties respectively [28].

Table 3: Mineral content of teff grain [29, 30]

Minerals (mg/100 g)	White teff	Red teff	Mixed teff
Iron	9.5-37.7	11.6- > 150	11.5- > 150
Zinc	2.4-6.8	2.3-6.7	3.8-3.9
Calcium	17-124	18-178	78.8-147
Copper	2.5-5.3	1.1-3.6	1.6

Teff has a higher iron, calcium and copper content than other common cereals. The zinc content of teff is also higher than that of sorghum and wheat. The zinc content of teff grains reported by the researchers varies from 2.00 mg/100g to 6.77mg/100g. The zinc content of teff is similar to other cereal grains, such as barley, wheat and maize [19]. However, the high iron content of teff has been contested and in many instances attributed to soil contaminations [28]. Recently [29] examined the content of iron, zinc and calcium in teff, barley, wheat, and sorghum before and after washing with de-ionized water. Teff is notably higher in calcium than other cereals. Teff grains contain between 147- 180mg/100g of calcium whereas wheat grains contain 3.33mg/100g [19], barley-46mg/100g and maize- 16mg/100g of calcium [8].

The mineral contamination of teff is probably due to its small size and suggests increased contact with soil over a larger area. Recently [31] compared the iron content of the same variety of teff after laboratory (manually) and traditional threshing. Traditional threshing leads to 30 to 38 percent increase in iron content due to soil contamination. Teff is still a better source of iron than other cereals like wheat, barley, sorghum, and maize. In contrast to iron [29] showed that under the same conditions, the values reported for calcium and zinc are consistent and are less affected by washing. This suggests that soil contamination contributes little to the content of these minerals in teff.

Total Phenol compounds

The other most important health-promoting aspects of teff as a food is like other millets. It is generally assumed to contain substantial amounts of phenolics [32]. Research findings revealed that ferulic acid (285.9µg/g) is the major phenolic compound in teff. Some other phenolic compounds such as protocatechuic (25.5 µg/g), gentisic (15 µg/g), vanillic (54.8 µg/g), syringic (14.9 µg/g), coumaric (36.9 µg/g), and cinnamic (46 µg/g) acids are also present in teff in considerable amounts [33]. Phenolics are notable for their antioxidant activity which appears to be beneficial in terms of prevention of cardiovascular diseases and cancer [34]. They also act as natural antioxidants for the food industry. At the same time, they might inhibit digestive enzymes and reduce food digestibility [35].

Table 4: Phytochemical composition of teff grain [28, 29]

Phytate (mg/100 g dry matter)	682-1374
Tannin (mg CE/100 g dry matter)	16
Total polyphenols (mg gallic acid equivalent/100 g dry matter)	140
Iron-binding phenolics	
Galloyls (mg tannic acid equivalent/100 g dry matter)	210
Catechols (mg catechin equivalent/100 g dry matter)	200
Phenolic acids (µg/mg)	
Protocatechuic	25.5
Gentisic	15
p-0OH Benzoic	-
Vanillic	54.8
Caffeic	3.9
Syringic	14.9
Coumaric	36.9
Ferulic	285.9
Cinnamic	46

Opportunities

Teff has an excellent nutritional profile [36] and also a gluten-free cereal [10]. It contains all essential amino acid that makes it comparable to egg [37]. Thus, highly nutritionally improved gluten free foods can be made with it.

It is naturally higher in nutritional profile as compared to other grains and doesn't need to be fortified. Major problems are allied with gluten-free products such as their inferior taste and structure [38]. However, use of teff grain with falling number higher than 250 seconds at the moment of grinding solves these problems [39].

Due to the higher amount of fiber content [18] and having a gluten free property, teff is getting acceptance as medicinal ingredient [10]. In connection to its medicinal values interests are growing in many countries to utilize teff for the production of gluten free foods.

It is a tropical low risk grain that grows in a wider ecology and can tolerate harsh environmental conditions where most other cereals are less feasible. Thus, it has the potential of growing in every part of the world.

Conclusions

Teff is a reliable and low risk cereal that grows on a wider ecology under moisture stress and waterlogged areas with few plant diseases and grain storage pest problems. Processing of teff for different foods is usually done by traditional ways and is mostly limited to the household level. Processing of the grain for different commercial foods is needed to promote worldwide teff utilization. Teff grain nutrients are promising and it is also an excellent gluten free alternative for people with celiac disease and other gluten allergy. The search for new gluten-free brewing materials is still in its infancy and researchers in this field of study are continuously researching on the malting, mashing, fermentation conditions and other aspects of teff so as to use it as a raw material for gluten-free beer, functional beverages and other gluten-free foods.

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