

A Review On Nutritional Values And Health Benefits Of Teff (*Eragrostis Tef*) And Its Product (Injera): Evidence From Ethiopian Context

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Abstract: The main objective of this paper is to review the nutritional values and health benefits of teff and its product (injera). Tef (*Eragrostis tef*) is a very tiny and interesting cereal crop widely cultivated in Ethiopia (where it originated from) mainly to process its grain flour into injera (a traditional fermented Ethiopian pancake, the staple food for the majority of Ethiopians). The nutritional content of teff grain contains high levels of proteins, like grain, wheat, maize, and pearl millet, and higher than rye, brown rice, and sorghum. Teff grain has higher fat content than wheat, rye, and brown rice but less than that of grain, maize, sorghum, and pearl millet. Apart from giving protein and calories, it has high dietary content, including better amino acid composition, predominantly lysine, more mineral content (mostly iron, calcium, phosphorus, and copper) than other cereal grains, contain B1 vitamin, phytochemicals (such as polyphenols and phytates) and it is rich in fiber. Because of these properties, teff has many health benefits in preventing anemia, diabetes, osteoporosis, and celiac diseases. The worldwide usage of teff and its products for human consumption has been restrained partially because of minimal knowledge and pieces of information about its nutritional values and the complex processing challenges faced in making teff-based food products. Over the past period, the finding that teff does not contain gluten has raised interest across the globe. As a result, the number of researches and different studies on the nutritional composition, and potential health benefits of teff has increased considerably. Many recent works of the literature suggest that teff contains complex carbohydrates with slowly digestible starch. Current studies about the detailed nutritional value and health benefits of teff are limited. However, the studies were undertaken so far suggest teff has substantial importance to be a functional food for health promotion and disease prevention. On the other hand, further research and deep studies are needed to determine potential health benefits and alternative uses of teff.

Keywords: Teff, Injera/Engera, nutritional value, health benefit, Ethiopia

1. INTRODUCTION

Africa is rich in a wide variety of less explored grain species, including teff and other distinctive sorts of millets. Tef (*Eragrostis tef*) is a cereal crop widely cultivated in Ethiopia mainly to process its grain flour into injera (a traditional fermented Ethiopian pancake, a staple food for the majority of Ethiopians) [1].

There are around 350 species of *Eragrostis* comprising of annuals and perennials, which are found over a wide geographic extend. Teff is a fine stemmed, tufted yearly grass characterized by a huge crown, numerous shoots, and a shallow stringy different root framework. The plants grow rapidly and adapted to environments extending from drought stress to waterlogged soil types [2]. Teff has the a huge share of area coverage (23.42%, 2.6 million hectares) under cereal crop cultivation and ranked third (after maize and wheat) in terms of grain production (18.57%, 29.9 million quintals) in Ethiopia [3].

Bergamo [4] expressed that teff injera is a gluten-free product and being fermented food from entirety grain flour mixture by lactic corrosive microscopic organisms and yeast has pre- and probiotic potential. In many respects, it favors complete

nutrient supply with functional food character for consumers, especially for celiac patients.

Some studies on the nutritional content of E. teff grains have indicated it contains high levels of proteins, like grain, wheat, maize, and pearl millet, and higher than rye, brown rice, and sorghum [5]. E. teff grain has higher fat content than wheat, rye, and brown rice but less than that of grain, maize, sorghum, and pearl millet [5]. Apart from giving protein and calories, it has high dietary content, including better amino acid composition, predominantly lysine, more mineral content (mostly iron, calcium, phosphorus, and copper) than other cereal grains, contain B1 vitamin and is rich in fiber [3, 6].

The physical appearance of teff grain is hull-less (naked) and comes during a range of colors from milky-white to just about dark brown. The foremost common colors are white, creamy-white, brown, and dark brown. It is assumed that the word teff has been derived from the Amharic word teffa,, which suggests, "lost" because of the minute size of the grain and the way simply it's lost just in case dropped. The grain is oval-shaped with an estimate of 0.9–1.7 mm (length) and 0.7–1.0 mm (diameter). It's going to be the smallest among carbohydrate-rich parts, as its individual grain mass measure ranges from 0.2- 0.4 mg [7, 8].

The principal use of teff grain for human food is that the Ethiopian bread (Injera). It's wont to wrap all quite foods.

Teff is ground into flour, fermented for 3 days then made into Injera. Injera is a sourdough type flatbread. It's described as a soft, porous, thin pancake, which features a sour taste [2]. Teff is free in gluten and thus, the bread remains quite flat. Research studies on the techniques went to make Injera have indicated that the yeast, *Candida guilliermondii* (Cast.), is that the micro-organism that primarily liable for the fermentation process [2, 9]. Injera may be a major food staple and provides approximately two-thirds of the diet in Ethiopia [2, 9].

Dijkstra [2] mentioned that teff has also lots of fanatic consumers, just like the top well known Ethiopians Athletes Haile Gebrelassie and Kenisse Bekele, they assert that the teff products aren't only gluten-free but might help consumers to regulate their weight. Different then the amazing grains teff helps the body to be fit life. Both athletes think that products made from teff, including Injera, helps them break international records over and once again. This is often possible because teff contains a high amount of iron. This made that the hemoglobin within the blood is higher, so more oxygen is often transmitted, and therefore the sportsmen can reach better sports results.

Nowadays, nutritionists and also the general public have come to take cereals as quite sources of energy and essential nutrients. Certain minor components of foods are now recognized as public health-promoting properties, especially for their roles in preventing or alleviating the consequences of a number of chronic diseases like cardiovascular disease and certain cancers. Vegetables and fruits are the foremost important sources of those antioxidants. However, grains have largely been ignored as important contributors of dietary antioxidants, despite the very fact that they're a staple dietary component for many of the world's population. Antioxidants found in whole grain foods are polyphenols including phenolic acids and flavonoids, which are liable for the high antioxidant activity [10]. Although, many studies are finished other cereals nutritive value and health benefits they provide to consumers every a part of the planet, little or no information is out there about tef. Thus, the most objective of this short review paper is to review researches on teff and its major product Injera to explain its nutritional value and potential health benefits that could be associated with consumption.

2. FORMS OF CONSUMPTION OF TEFF AND ITS PRODUCT (INGERA) IN ETHIOPIA

Teff is primarily used for the making of injera. Injera is made by mixing cereal flour with water to make the dough and then triggering the fermentation process by adding ersho (yeast) a starter taken from previous fermentations [11]. The fermentation complete on average two to three days, after that the dough is thinned into a batter prior to steam baking. The grain of teff is best for making injera, due to its attractive sensory attributes (for example, flavor, color, smell) and shelf life [12, 13]. Besides, the capability to easily roll (softness) injera is characteristic quality since this lets easy wrapping of the sauces (wot) consumed with it. In this regard, the

superiority of teff was demonstrated by the minimal force required bending fresh, 24- hour, and 48- hour stored injera comparative to injera made from other grain [12]. Likewise, incorporating teff flour into the sorghum flour has been shown to enhance the sensory attributes of sorghum injera [12]. Moreover, combining teff with wheat, as is often seen in less privileged households [14], has been found to be nutritionally advantageous, as it allows higher phytate degradation because of the higher endogenous phytase activity in wheat [15]. Although used to a much lesser level than for injera, teff can also be used for the making of porridges, unleavened bread (kitta), gruels (atmit), and cultural alcoholic beverages, like tella and arake [5].



Figure 1 Appearance of injera from: <https://www.almy.com>



Figure 2 injera and several kinds of wet (stew or sauce) From; <https://en.wikipedia.org/wiki/Injera>

3. CHARACTERISTICS OF TEFF

An average length of teff grain is about ~ 1 mm, thus it could be the smallest amongst cereal grains [8, 16, 17]. The average thousand-kernel weight of 12 teff diversities verified by was 0.264 g [8]. The minuteness of teff grains has dietary and technological implications. For instance, decorticating teff grains are very difficult, the cereal is consumed as a whole grain, improving nutrient intake for consumers. Teff color can vary from white (ivory) to dark brown (black) counting on the

variability. Three major categories are often identified in Ethiopia: white (nech), red (quey), and mixed (sergegna), it's also common for wholesalers to further subdivide white teff into very white (magna) and white (nech). However, as long as these classifications are imprecise and subjective, for example: what some people called Magna, the same variety by some others it's going to be considered as nech.

White teff usually grows only in the highlands of Ethiopia and need relatively suitable growing conditions. This, alongside its higher consumer preference, may explain why white teff is that the costliest sort of teff. However, currently, the red teff, which is known to be highly nutritious, is additionally it attaining acceptance amongst health-conscious consumers in Ethiopia and Eritrea.



Figure 3 teff at early stage of development. From: <https://www.dreamstime.com>



Figure 4 teff at harvesting stage. From: <https://www.dreamstime.com>



Figure 5 Tiny grains of teff (*Eragrostis tef*), From: <https://www.britannica.com>

4. NUTRITIONAL COMPOSITION OF TEFF GRAIN

a. Carbohydrates

Carbohydrates are the main source of energy for human nutrition and play a crucial role in metabolism and homeostasis. Carbohydrates can be classified into sugars, oligosaccharides, starch (amylose, amylopectin), and non-starch polysaccharides based on the molecular size and degree of polymerization. Complex carbohydrates structure 80 percent of the teff grain. It's a starch content of roughly 73 percent, making teff a starchy cereal. Bultosa [8] stated on his work that amylose content of 13 teff varieties tested ranged from 20 to 26 percent, equivalent to other grains, like sorghum.

Carbohydrate digestion and absorption extent in the intestine determines the health effect of an individual. Rapidly digested and absorbed carbohydrates such as glycemic carbohydrates have a greater impact on blood sugar levels, as they cause greater metabolic perturbation [18]. Such perturbations are related to metabolic diseases like type-II diabetes and CVD [19]. Hence, from a health perspective, slowly digesting carbohydrates are better than rapidly digesting ones. The speed of carbohydrate digestion of food is often characterized by its glycemic index (GI) [20].

The GI of a diet mainly depends on endogenous factors of the food matrix-such as starch susceptibility to enzyme α -amylase, protein and lipid content, and thus the macroscopic makeup of the food [21]. Starch susceptibility to α -amylase is successively determined by its structure, encapsulation, crystal structure, degree of gelatinization, the proportion of damaged granules also because of the retrogradation of the starch granules [21]. Employing a scanning microscope (SEM), the dimensions of teff starch was found to be 2-6 μm [22]. Such peculiar characteristics make teff starch granules smaller than those of wheat (A type 20-35 μm), sorghum (20

µm), and maize (20 µm) [23]. Tester, Karkalas, and Qi [24] mentioned given their larger area, smaller starch granules are more vulnerable to enzymatic attack. Nonetheless, as compared to wheat, which has larger starch granules, the in vitro starch digestibility of teff was found to be significantly lower [25]. In line with this, the anticipated glycemic index of teff (74) was considerably less than that of white wheat (100) but like that of sorghum (72) and oats (71) [25]. This somewhat lower GI for teff than expected could also be explained by its amylose content, lower starch damage, and therefore the possible makeup of amylose-lipid complexes which will delay enzymatic access and thus starch digestibility [26]. Additionally, the high (68-80 °C) gelatinization temperature of teff can hinder gelatinization and thus reduce exposure to enzymatic attack by α -amylase [21].

b. Protein

The mean crude protein substance of teff is within the range of 8 to 11 %, nearly like other more common cereals like wheat. Teff's grain fragmentary protein composition shows that glutelins (45 %) and albumins (37 %) are the maximum protein storages, whereas prolamins are a minor constituent (~ 12 percent) [27, 28]. In contrast, more up to date studies report that prolamins are the most protein storages in teff [16]. The shifted strategies of extraction between these ponders may explain the contradictory discoveries. By analyzing the amino corrosive profile, the higher contents of glutamine, alanine, leucine, and proline and hence the relatively lower content of lysine advance suggests that prolamins are the most capacity proteins [16]. The amino acid composition of Teff is well balanced. Generally, a huge concentration of lysine, a noteworthy constraining amino acid in cereals, is found in teff. Hopman in his work states that teff grains compared with other cereal grains, it contains a better amount of isoleucine, leucine, valine, threonine, methionine, phenylalanine, arginine, and histidine composition". Another important characteristic of teff is that it has no gluten [29]. Tested the presence or absence of gluten in pepsin and trypsin digests of 14 teff varieties were tested by [30]. The digests were examined for the presence of T-cell-stimulatory epitopes. No T-cell stimulatory epitopes were recognized in the protein digests of all the teff grain varieties, In contrast to known other gluten-containing cereal grains. This condition confirming that teff is gluten free. This makes teff an important ingredient for useful diet destined for celiac patients who are gluten intolerant.

c. Lipids

Cereals don't seem to be specified lipid sources but maybe a good essential fatty acid supplier when considering daily consumption. The lipid content of teff (3.7%) was above a variety of other Ethiopian staple grains like maize and wheat [31]. Another comparative study showed that the lipid content of teff (4.4%) was higher than that of wheat (3.6%), rice (0.9%), sorghum (3.5%), and maize (2.5%) flours, and but lower than that of oat (6.7%) and quinoa (8.6%) [32]. Fatty

acids have important effects on growth, development, and future health problems. For instance, the intake of omega-3 fatty acids (a-linoleic acid) has been found to minimize biological markers related to the disorder, cancer, inflammatory, and autoimmune diseases [33]. Teff's lipid content is above wheat and rice, but less than corn. Additionally, the intake of omega-3 and omega-6 fatty acids are decreasing because of the refining processes of those widely consumed grains. The raw grain is richer than those refined in terms of fatty acids. Teff predominantly contains oleic fatty acid (32.4%) and linoleic fatty acids (23.8%). The optimal ratio between linoleic acid and a-linoleic acid isn't exactly clear, but the ratio of 5:15 is suggested for formulas used for infants. This ratio is 7:1 in teff, which is suitable compared to legumes, an interesting carboxylic acid source [34].

d. Minerals

Teff contains a wide range of mineral content among its different varieties. Higher Fe and Ca content found in red teff than mixed or white teff. On the opposite, white teff features a higher copper content than red and mixed [35]. Minerals of contents of different varieties of tee grain (1 variety, uncooked) including Calcium (180 mg/100 g), Iron (7.63 mg/100 g), Magnesium (184 mg/100 g), Phosphorous (429 mg/100 g), Potassium (427 mg/100 g), sodium (12 mg/100 g), and Zink (3.63 mg/100 g) (wet basis) were reported. Baye stated that the Fe, Zn, and Ca contents of the teff grain were 31.6, 2.31, and 78.8-mg/100 g (dry basis), respectively [36]. In some studies, 12 differing types of teff and 5 sorts of it grown in sericulture were reviewed and it's indicated that genetic and environmental factors affected the Fe content of teff. When different ecological environments are unnoticed, teff contains a higher content of Fe, Ca, and Cu than other grains. Moreover, the Zn content of teff is more than that of wheat and sorghum [37].

e. Vitamins

Vitamins found in teff comprise that niacin: 3.363 mg/100 g, vit B6: 0.482 mg/100 g, thiamin: 0.39 mg/100 g, riboflavin: 0.27 mg/100 g, vit K: 1.9 mg/100 g, vit A: 9 IU, and a-tocopherol: 0.08 mg per 100 g [38]. The amount variation may be due to analytical techniques and genotypes of teff.

f. Polyphenols

Polyphenols are secondary metabolites that participate in the protection of plants from different pathogens or ultraviolet radiation [39]. Polyphenols protect cell components against oxidative harm and minimize oxidative stress-related disease hazards [40]. The amount of teff polyphenol content is moderate when compared to other grains. Ferrulic acid is the principal component of phenolic acid in teff. Phenolic acids in teff lack galloyl and catechol functional groups and are therefore less inclined to inhibiting iron absorption. Hence, this suggests that it may be possible to utilize teff anti-oxidative properties. Generally, the polyphenol content of teff doesn't inhibit Fe bioavailability [41].

5. HEALTH BENEFITS OF TEFF AND ITS PRODUCTS

Gambola and Eriks [2] on their work stated that most Ethiopians hardly suffer from diseases like anemia, osteoporosis, and diabetes. Some scientists relate this to the consumption of teff as a daily diet. Some researchers suppose that the bioavailability of iron in injera provides more than the iron content of teff for the minimum existence of anemia in Ethiopia [42]. Teff injera was found to be the top bioavailable source of iron because of low phytate: iron ratio rather than its high iron content among Ethiopian foods [43]. Iron and zinc are the two most often deficient micronutrients in developing countries. Iron deficiency is triggered not only by phytate but also by tannins in the diet or low iron content of foods, which are the essential causes of nutritional anemia that originates from the low bioavailability of non-haem iron [44]. This indicates that teff injera principally fermented injera plays a great role in diminishing nutritional anemia.

We can conclude that teff contains a high level of iron; this means that most people in Ethiopia eat their daily-recommended nutrient intake of iron. In contrast this does not mean that the people in Ethiopia do not have anemia, this is probably caused by a lack of foods which are rich in ascorbic acid, that improve the absorption of iron [45].

Gluten-free and nutritious cereals can be a good substitute diet for celiac disease patients though it was thought that wheat treatment was the best probability to be considered. Clinical studies are needed to prove the safety of other cereals, which otherwise may be unsafe [2]. The argument continues on the suitability of other cereals such as buckwheat, amaranth, quinoa, and teff [46]. According to Gambola and Eriks [2], This issue can be considered largely in food processing, diet, and health projects. A lot of opposition may arise by people affiliated to the wheat flour industry on the use of teff and other grains such as quinoa, buckwheat, amaranth, and oats for various food products. Many gluten-free cereal foods can be made from these crops without requiring supplementation. Teff is a nutrient-dense crop, which can thus be a good substitute for nutritious food for people with celiac disease [2].

The high mineral content of teff shows its importance in numerous metabolic and body functions, as some of them are cofactors of enzymes and important for bone development and resistance to osteoporosis. Osteoporosis is a disease condition characterized by low bone mass and structural deformity of bone tissue, leading to bone brittleness or fragility and an enhanced risk of fractures of the hip, spine, and wrist [47]. Teff possibly has a positive effect on osteoporosis, because it is high in calcium content, which prevents osteoporosis. Calcium makes the bones stronger. There is done research to found information about osteoporosis in relation to teff, but there is not found any relevant information [2].

Teff is denser when compared to other gluten-free cereals [48]. Additionally, there is a high incidence of diabetes in people with celiac disease and teff may help in keeping

glycemic control in such cases because of its low glycemic index [49].

Celiac disease (CD) is an inflammatory disease condition of the upper small intestine triggered by the ingestion of wheat, rye, barley, and possibly oat products. The clinical feature of celiac disease is characterized by the destruction of the microscopic finger-like projections of the small intestine (villi) [50]. Subsequently, large proline and glutamine-rich peptides are stored in the SI and reach the subepithelial lymphatic tissue, results in mal-absorption of nutrients. These features may vary from patient to patient, depending on the severity and degree of the disease [51]. The only treatment for those with celiac disease accessible to date is to follow a strict gluten-free diet [52]. So, some recent studies on teff conclude that it has a good influence on the healthiness of CD patients. The CD patients who are using teff reported a meaningful reduction in symptoms. This is perhaps related to a reduction in gluten intake or a rise in fiber intake. Hence, teff can be an important addition to the GFD of celiac disease patients [51].

6. CONCLUSION

Teff is one of the ancient indigenous cereal crops cultivated in Ethiopia. There are numerous teff varieties, with special qualities for production in different agro-ecological clusters. Ethiopians have a long history and many cultural practices associated with teff production and feeding. Regarding the nutritional value white variety (kunchu) and the red variety (key-teff) showed that the nutrient composition of red varieties (key-teff) is better especially in minerals and essential amino acids.

Various teff-based food products have been developed, the majority of which are gluten-free. These include injera, porridges, unleavened bread (kitta), gruels (atmit), and cultural alcoholic beverages, like tella and arake. These food products tend to have desired nutritional quality such as gluten-free, high dietary fiber contents, and low glycaemic index. It has a balanced amino acid composition. Teff is also a good source of unsaturated fatty acids and has a balanced linoleic: alpha-linolenic acid ratio. In addition, it has a high content of iron and calcium minerals. Also, it is rich in dietary fiber and phytochemicals. Because of these properties, teff has many health benefits in preventing anemia, diabetes, osteoporosis, and celiac diseases. However, it is low in productivity than other cereals and its production is laborious at all stages. This negatively affects its futurability as a primary or secondary cereal in the country. Despite teff have great nutrient content, its consumption is limited to Ethiopia and Eritrea. The limited understanding of teff's physical and chemical characteristics, nutrient composition along with processing difficulties faced in making teff-based food products adapted for worldwide consumers has restrained its global use for human consumption. Advanced research and studies should investigate the variation in nutrient composition across teff varieties, the role of teff consumption on the controlling and prevention of diabetes, and the human adsorption (bioavailability) of Fe in teff and how it can contribute to the prevention of iron deficiency disorders.

Along with the potential health benefits in managing CD, and a possible solution in managing iron deficiency and diabetes, these all indicate the potential of teff to be a future international useful food for health promotion and disease prevention.

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