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Review Article

Nutritional importance of Teff (*Eragrostis tef* (Zucc.) Trotter) and human health: A critical review

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Consumer concern about health via nutrition has grown in recent years and the majority of the population is attempting to live a healthy lifestyle by eating a balanced diet. Pseudo cereals are gaining popularity among consumers and experts due to their nutritional value and deliciousness. Teff (*Eragrostis tef* [Zucc.] Trotter) (*Poaceae*) is an annual crop with a very tiny grain. The crop is mainly cultivated in Ethiopia and Eritrea, where it is used in preparing a pancake-like staple food called injera. Teff can be cultivated in any climatic condition as it is resistant to drought and waterlogging. Teff is thought to be made up of complex carbohydrates and slowly digestible starch. Teff has a similar protein composition to other common cereals like wheat. However, it is higher in the vital amino acid lysine than other cereals. Teff is also high in fiber, minerals (particularly calcium and iron) and phytochemicals (polyphenols and phytates). Over the past decade, the recognition that teff is gluten-free has raised global interest. Several health advantages have been associated with the grain, including the prevention and treatment of illnesses including celiac disease, diabetes and anemia. The principal objective of this review is to know the nutritional importance, human health benefits and anti-nutritional properties of the teff.

Key words: Teff, pseudo cereals, pancake, injera, phytochemicals, gluten-free, celiac disease, anemia

INTRODUCTION

Teff (*Eragrostis* tef) is a fascinating grain that is ancient, small and high in nutrients. Williums love grass, teffa and annual bunch grass are all popular names for teff. It is said to have originated in Ethiopia between 4000 and 1000 BC (Melak-Hail, 1966; Tadesse, 1969; Costanza, et al. 1979; Seyfu, 1997). Teff signifies the modern re-discovery of an ancient civilization's crop (Stallknecht, 1993). Teff is a member of the *Poaceae* family, subfamily *Eragrostidae* and the genus *Eragrostis*, with a diploid chromosome number of 2n=40. There are 350 species in this genus and it is the only domesticated cereal species. The word teff is thought to have been derived from the Amharic word teffa, which means "lost," due to the small size of the grain and how easily it is lost if dropped. It is the world's tiniest grain, measuring 1-1.7 mm in length and 0.6-1 mm in diameter, with an average seed weight of 0.3-0.4 g for 1000 seeds and 150 grains required to equal one grain of wheat (Umeta, et al. 1996; Lacey, et al. 2005; Adebowale, et al. 2011; Bultosa and Geremew, 2007).

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Teff is intermediate between tropical and temperate grass. It is grown on 3.01 million hectares in Ethiopia, with a yield of 5.01 million tonnes and productivity of 1.664 tonnes per hectare (Lee, 2018). Depending on the type, teff grains can be white, light tan to deep brown or dark reddish-brown purple (Eba, 1975; Roseberg, et al. 2005; Gamboa and van Ekris, 2008). In Ethiopia, the market price of teff grain is directly linked to the production area and soil type, which is strongly correlated with grain colour (Minten, et al. 2013; Assefa, et al. 2015; Abewa, et al. 2019). Teff has a mellow, nutty flavour with a hint of molasses sweetness. The white teff has a chestnut flavour, while the darker types have a more earthy hazelnut flavour. The grain has a mucilaginous texture. Surprisingly, papers from the late 1800s show that the upper cast ate the lighter grains. It is perhaps an area of growing concern for scientists such as nutritionists, chemists, food engineers and traders to rediscover this appealing tiny grain that is old but new to emerging countries. It is of tiny size but with a giant nutritional content.

Teff's nutritional worth and health advantages and its quality value as a gluten-free grain have piqued attention throughout

the world (Baye, 2014; Spaenij-Dekking, et al. 2005; Hopman, et al. 2008; Bergamo, et al. 2011). According to Akansha et al. (2018), 100 g teff grains contain 11.0 per cent protein, 2.5 per cent fat, 70.2 per cent carbohydrate, 3.0 per cent fiber, 10.5 per cent moisture, 2.8 per cent ash, calcium (165.2 mg), iron (15.7 mg), copper (2.6 mg), magnesium (181.0 mg), manganese (3.8 mg), phosphorous (425.4 mg), potassium (380.0 mg), sodium (15.9 mg), potassium (380.0 mg) and sodium (15.9 mg (4.8 mg). Due to the continuous ingestion of wheat protein, i.e., gluten, celiac disease is quite common in Western nations. As a result, teff is gluten-free and can be used to avoid celiac disease when used as a substitute for wheat (Hopman, et al. 2008; Mamo and Parsons, 1987). It has a higher nutritional content than other cereal grains, containing all necessary amino acid composition, notably lysine and greater mineral content (mostly iron, calcium, phosphorus and copper). It is high in fiber and includes the B1 vitamin (Umeta, et al. 1996).

Teff is richer in lysine than most other cereals (Gebremariam, et al. 2012) and can reduce iron deficiency which causes anaemia diseases (Abebe, et al. 2007; Urga, et al. 1998; Umeta, et al. 2005). It also has a complete set of essential amino acids with excellent composition (Umeta, et al. 2005; Jansen, et al. 1962; Campo, et al. 2016).

REVIEW OF LITERATURE

Many developing nations have thoroughly investigated the lack of anemia, osteoporosis, celiac disease and diabetes in the Ethiopian population. They strive to provide new goods to customers and meet their nutritional demands. Ethiopian athletes' resilience and overall fitness are likewise widely recognized on a global scale. That is why modern scientists are curious about the content of teff, its nutritional characteristics and the changes that occur during grain fermentation and also which occurs during the manufacture of injera, a flatbread that feeds roughly 70% of Ethiopians. Universities carried out this study in Ethiopia and also in other countries as well as commercial firms working with this crop to turn it into a "golden grain."

Its flour is mainly used to make "Injera," a fermented sourdough flatbread. It's also used in porridge and is a key ingredient in many traditional alcoholic drinks. Its flour is used to make the majority of bread items, either entirely or partially substituting for other baking flours (Stewart and Getachew, 1962). Teff intake has several health advantages, including the development of strong bones and teeth, reduction of premenstrual syndrome, blood sugar regulation, long-lasting energy and weight loss. A daily dose of 100 g of teff suffices to make up for the iron deficiency in the diet. Teff straw is best utilized as animal feed because it has more crude protein (9-14%), acid detergent fiber (32-38%), neutral detergent fiber (53-65%), total digestible minerals (55-64%) and has a more excellent relative feed value (80-120) than other minor millets straw (Miller, 2007).

Agronomic practices

Teff is a warm-season annual grass crop (Stallknecht, 1993). Teff is a chasmogamous self-pollinating plant. Teff is a tufted annual grass with fine stems, numerous shoots and a shallow fibrous varied root structure. When planted at an average depth of 1.2 cm, teff germinates quickly. However, unless a strong root system is formed, early development is sluggish. The seedlings sprout fast and are adaptable to a variety of circumstances, including dryness and waterlogged soil. At elevations of 1800-2100 m, rainfall of 450–550 mm (Ketema, 1997) throughout the growing season and temperatures ranging from 10-27°C maximum teff production occurs. Teff planting, like alfalfa planting, needs a solid wet seedbed. Due to the incredibly tiny seed size, excellent soil moisture-seed contact is a must. Seeding rates range from 2.3 to 9 kg/ha, with 5 to 8 kg/ha being the most common. Teff should be seeded 1.2-1.5 cm deep either broadcast or in narrow rows (Stallknecht, 1993).

It's frequently seen as a rescue crop during seasons when early-planted crops like maize fail due to a lack of rainfall. Teff thrives in heavy black to light red soils and is chemically suited to acidic to alkaline soils, although it performs better agronomically in light sandy to heavy clay soils and mild acidic to low alkaline environments (Takelel, 2001). Different varieties take different numbers of days to mature and most cultivars finish their life cycle in 60-180 days, depending on the agro-ecology, but the optimal time to produce the crop is 90-130 days (Deckers, et al. 2001). It is suitable for a wide range of environmental conditions due to its adaptability it is grown as major cereal crop in 10 of the 18 broad agro-ecologies found in Ethiopia (Forum for Environment, 2010).

To avoid lodging, use a moderate amount of nitrogen and phosphorus fertilizer. Teff is a day length sensitive crop that blooms best when there are 12 hours of daylight. Light is one of the most important factors influencing many vital plant processes like seed germination, leaf expansion, growth of stem and shoot, production of tillers, branches, flowering, fruiting, root development, growth movements in plants. It's a low-risk crop that may be sown in late May, much like millets. Teff is an inferior competitor with weeds during the early development phases. Therefore, late plantings benefit from controlling emerging weeds by tillage prior to planting, which can be important. Teff germinates quickly and the broadcast and narrow row planting methods allow for better weed control competition (Stallknecht, 1993). Teff is adapted to environments ranging from drought stress to waterlogged soil conditions.

The inflorescence is a tiny seed-producing open panicle (1000 weigh 0.3 to 0.4 g). A lemma, three stamens, two stigmas and two lodicules make up the florets. Florets come in a range of colours from white to dark brown. Teff plant height ranges between 25 and 135 cm, depending on cultivar and growth conditions. Panicle length ranges from 11 to 63 cm, with 190 to 1410 spikelets per panicle. Panicles come in various shapes and sizes, including loose, lax, compact, numerous branching multi-lateral and unilateral loose to compact. The time it takes for a plant to reach maturity ranges between 93 and 130 days (Stallknecht, 1993).

Teff grain yields in the United States range from 700 kg/ha on dry soil to 1400 kg/ha in irrigated fields in Montana (Stallknecht, et al. 1993). Depending on the moisture levels during the growing season, forage yields range from 9.0 to 13.5

Mg/ha (Boe, et al. 1991; Stallknecht, et al. 1993). Ethiopians thresh teff by stomping the chopped crop collected on a level surface with oxen. Teff grain is separated by tossing the grain and material out of the grain mix in the air and exploiting the difference in aerodynamic characteristics to separate them. The grain chaff mix is cleaned by physically blowing air over it with a dried firm leather strap (Zewdu, 2007).

Structural property of teff grain

Teff grain is hull less (naked) and occurs in a variety of hues ranging from milky white to practically black. White, creamy white, light brown and dark brown are the most frequent hues (Tefera, et al. 1995). The teff kernel is a tiny oval-shaped grain with a mean length of 0.61-1.17 mm and a mean width of 0.13-0.59 mm, resulting in a thousand kernel weight of 0.264 g (Bultosa, 2007), 2500–3000 grains weighing about 1 g (Babatunde and Manyasa, 2002). Different researchers used Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), and light microscopy to investigate the anatomy of the teff kernel (LM) (Parker et al., 1989; Kreitschitz, et al. 2009). Teff grain outer thin and membranous structure of the kernel is termed pericarp, containing some starch granules, equivalent to the bran of wheat, beneath the cuticle toward the nuclear epidermis, teff grain is known to bear slime layer (slime layer to absorb and maintain moisture around the grain is implicated as a contributor to teff adaptive features to moisture stress) rich in pectins (Arendt and Emanuele, 2013). A pigmented substance was found surrounding the testa of the brown-seeded teff in light microscopy research. This layer is thought to contain tannins or polyphenolic chemicals that give the seed its brown colour (Parker, et al. 1989). However, no coloured substance was found in white-seeded teff. Review (Bultosa and Taylor, 2004) indicate that teff grain bears an insignificant level of condensed tannins.

In teff seeds, the endosperm is the main component of the grain and is divided into outer and inner layers. The outer layer is vitreous and includes most of the endosperm's protein reserves and a few starch granules. The inner layer is mealy, with thin-walled cells largely made up of starch granules and a few protein structures. The endosperm is the essential part of the grain, and it has an exterior vitreous coating. This includes the majority of the kernel's protein as well as a few starch granules, with an inner floury portion containing mostly starch granules and a few protein structures (Babatunde and Manyasa, 2002; Arendt and Emanuele, 2013; Bultosa and Taylor, 2004).

NUTRITIONAL IMPORTANCE OF TEFF

Carbohydrates

Carbohydrates are the most important energy source in the human diet and play a crucial role in metabolism and homeostasis. Carbohydrates are categorized as sugars, oligosaccharides, starch (amylose, amylopectin) and non-starch polysaccharides based on their molecular size and degree of polymerization. Bultosa (2007) revealed that complex carbohydrates account for 80% of the teff grain in his experiment. Teff is a starchy grain with a starch content of around 73%. The amylose percentage of 13 teff varieties examined ranged from 20% to 26%, equivalent to other cereals like sorghum.

Teff grain has an 85.6% total carbohydrate content, with starch levels ranging from 74 to 75.5% (Wolter, et al. 2013). As shown in Table 1. Teff flour has a carbohydrate content of 73 g/100 g, which is similar to other cereal grains such as white wheat flour (75 g/100 g) and rye flour (76 g/100 g), but lower than maize flour (92 g/100 g) and higher than soya flour (28 g/100 g) and brown wheat flour (69 g/100 g), according to the (National Research Council).

Table 1. Carbohydrate content of teff grain

	Quantity (%)	Reference
Carbohydrates	85.6	Wolter et al., 2013
	73	Bultosa and Taylor, 2004
	74-75.5	National Research Council (NRC), 1996
	85.6	Abebe and Ronda, 2014
	73.33	Zhu, 2018
	70.2	Gebremariam et al., 2014; Awadalkarem et al., 2008 and Saturni et al., 2010
	61.6	Tadessa Daba, 2017

In the case of the teff, the amylopectin reported around 83% (Tari, et al. 2003). Teff grains have a high amylopectin content, which is comparatively higher than certain rice type's varieties (Tukomane and Saiyavit, 2008). Teff starch pastes at a comparable temperature to maize starch, but it takes longer to reach maximal viscosity. The viscosities of peak, breakdown and setback are lower than maize starch (Bultose and Taylor, 2004). Teff starch functions well as a flavour and fragrance transporter or fat replacer since its granules are smooth, small, and consistent in size.

Teff starch granules are composed of numerous simple polygonal granules and they are very small (2-6 μm in diameter) (Bultose, et al. 2002). They are, however, bigger than amaranth and quinoa and resemble the granules of rice starch (Bultose, et al. 2002). Like those of other cereal grains, teff's starch granules are mostly made up of a branching fraction called amylopectin and a linear fraction called amylose, which accounts for about 25-30% of total starch.

Bultose, et al. 2002; Wolter, et al. 2013 reported that teff starch was measured to be 2-6 m in diameter using a Scanning Electron Microscope (SEM). This makes teff starch granules smaller than those of wheat (A type 20-35 μm), sorghum (20 μm) and maize (20 μm) (Delcour, et al. 2010). The A-type starches are well-known for their high digestibility. The delayed retrogradation characteristic of tef starches is linked to the high digestion and keeping quality of teff injera, such as dirqoosha (dried-form of injera, shelf-stable) (Bultose, et al. 2008). Smaller starch granules are more vulnerable to enzyme attack because of their greater surface area (Tester, et al. 2004). Despite this, teff's in vitro starch digestibility was substantially lower than wheat, containing bigger starch granules (Wolter, et al. 2013).

The Glycemic Index (GI) of a food can determine the rate of carbohydrate digestion (Harris and Raymond, 2009). The GI of a food is determined by endogenous food matrix variables, including starch sensitivity to α - amylase, protein

and fat content and the food's microscopic structure (Fardet, et al. 2006). The structure, encapsulation, crystal structure, degree of gelatinization, the proportion of damaged granules and retrogradation of the starch granules all influence starch sensitivity to α - amylase (Fardet, et al. 2006). Teff had a projected glycemic index of 74%, which was lower than white wheat (100%) but equivalent to sorghum (72%) and oats (71%) but higher than quinoa (71%) (Bultose, et al. 2002).

Protein

Plants store proteins in the embryo to provide nutrients for growth and development (Herman and Larkins, 1999). Proteins in seeds are the protein source eaten directly by humans in plant meals (Shewry, 2009). A food's nutritional value is defined by its protein quality, determined by amino acid quantity, digestibility, anti-nutritional factors, and tryptophan ratio to large neutral amino acids ratio (Comai, et al. 2007). Amino acids are a primary source of nitrogen for the body and a minor quantity of sulphur compounds. They carry various compounds in lipoproteins (triglycerides, cholesterol, phospholipids and fat-soluble vitamins). The majority of the diet is derived from animal sources, high quality protein is a big issue. Thus, it is advised that animal diets be replaced with protein-rich plant sources. This strategy may be helpful for the prevalence of malnutrition by contributing essential amino acids to the diet.

Teff has an average crude protein level of 8 to 11 per cent, similar to other popular cereals like wheat (Table 2). Glutamine (45%) and albumins (37%) are the primary protein storages in Teff, whereas prolamins (12%) are a minor element (Bekele, et al. 1995; Tatham et al., 1996). Adebowale, et al. 2011 reported that prolamins, on the other hand, are the primary protein storages in teff, according to current studies. The different methods of extraction between these studies may explain the contradictory findings. By studying the amino acid profile, the greater glutamine, alanine, leucine and proline levels, as well as the lower lysine content, it's clear that prolamins are the primary storage proteins (Adebowale, et al. 2011).

Table 2. Protein content of teff grain

	Quantity (%)	Reference
Protein	8-11	Bekel et al., 1995
	8.7-11.1	Bultosa, 2007
	11	Bultosa and Taylor, 2004
	10.7	Sadik et al., 2013
	13.3	Zhu, 2018
	10-12	Gamboa et al., 2008
	12.8	Tadessa Daba, 2017
	11	Gebremariam et al., 2014; Awadalkarem et al., 2008; Saturrni et al., 2010
	8-10.8	Seyfu, 1997
	8-11	Tatham et al., 1996
	12.8-20	Zhu, 2018; El-Alfy et al., 2012

Another vital feature of teff is that it has no gluten (Hopman, et al. 2008). Spaenij-Dekking et al. (2005) investigated the presence or absence of gluten in pepsin and trypsin digests of 14 teff varieties. T-cell–stimulatory epitopes were searched for in the digests. In contrast to recognised gluten-containing cereals, no T-cell stimulatory epitopes were found in the protein digests of any of the teff types tested, proving that teff is gluten-free. As a result, teff is an excellent component for gluten-free functional meals aimed at celiac sufferers.

Fiber

Whole grains offer more fiber than decorticated grains and tiny grains have a large amount of bran, which is high in fiber (Tefera, et al. 1995). As a result, increasing consumption of teff is predicted to result in higher dietary fiber intake and the accompanying health advantages. Teff has more excellent fiber content since it is always ingested whole grain (bran and germ intact), as fractionation during the milling process is difficult owing to the tiny size of teff grains (Bultosa and Taylor, 2004).

The crude fiber, total and soluble dietary fiber content of teff (3%, 4.5% and 0.9%,) respectively is several folds higher than that found in wheat (2%), sorghum (0.6%) and rice (0.6-1.0%) (Gebremariam, et al. 2012). In contrast to most common cereals, the amount of uronic acid in tef grain is high (Umeta, 1986).

The intake of gluten-free dietary fiber is considered inadequate, so experts recommend a higher intake of whole grains rich in fiber, unlike grains and refined products in the diet of patients with celiac disease, relieving, at least partially, the deficit of fiber intake by that portion of the population (Alvarez, et al. 2010). According to studies, many human diseases, such as colon cancer, coronary heart disease, and diabetes, are prevented by high fiber diets, according to studies (Abebe, et al. 2007). Fiber content of teff grain is showed in Table 3.

Table 3. Fiber content of teff grain

	Quantity (%)	Reference
	3	Gebremariam et al., 2014; Awadalkarem et al., 2008 and Saturrni et al., 2010
Fiber	2.6 - 3.8	Bultosa, 2007
	3	Obilana, 2003
	1.9 - 3.5	Bultosa and Taylor, 2004

Fat

Cereals are not the best form of fat, but since they are so widely consumed by people, they may provide a considerable quantity of necessary fatty acids to the diet (Michaelsen, et al. 2011). Fatty acids may help with long-term health, growth and development. As a result, there has been a lot of buzz about including them in people's diets in recent years. Increased consumption of n-3 fatty acids (α-linoleic acid), for example, has been reported to lower biological markers linked to cardiovascular disease, cancer, inflammatory and autoimmune disorders (Simopoulos and Artemis, 2001).

Teff, the grain contains lower levels of lipids (approximately 2.0-3.0% of total grain weight) and other cereals such as maize, oats (6.9%), millet (4.2%) and sorghum (3.4%) as compared to quinoa. Teff grains are high in unsaturated fatty acids (72.46%),

with polyunsaturated fatty acids accounting for 39.91 per cent and saturated fatty acids accounting for 20.06 per cent (El-Alfy, et al. 2012). Teff lipids were found to be mostly unsaturated, with linoleic and oleic acids contributing for 50% and 29%, respectively (Hager et al., 2013). The limited available information (Fuf Hundera, 1998) indicates that the major fatty acids [linoleic (C18:2)>oleic (C18:1)>palmitic (C16:0)] were found similar to other small cereal grains. Fat percent of teff grain determined by different scientist is listed in Table 4.

Table 4. Fat content of teff grain

	Quantity (%)	Reference
	2-3.1	Bultosa and Taylor, 2004
	3.2	Tadessa Daba, 2017
Fat	2.5	Gebremariam et al., 2014; Awadalkarem et al., 2008 and Saturrni et al., 2010
	2-3	El-Alfy et al., 2012
	2.38	Zhu, 2018
	2-3	Bultosa, 2007
	4.4	Hager et al., 2013

Minerals

Unlike carbohydrates, lipids, and proteins, Minerals are inorganic and cannot be synthesized by living organisms that perform vital activities in the body. Low intake or reduced bioavailability can lead to physiological imbalances and impaired essential processes. Among the best known are calcium, phosphorus, iron, potassium, sulfur, sodium, magnesium, zinc, copper, selenium and chromium (Vega et al., 2010). The Fe and Ca content of brown teff variants was greater than that of white teff types. On the other hand, white teff cultivars have a greater Cu content than brown teff types (Gujral, et al. 2012). Teff has a mineral concentration that is two to three times that of wheat, barley and sorghum, especially Fe (16 mg 100 g1) (Mengesha, 1966). Teff eaters have more haemoglobin in their blood than non-teff eaters, according to studies. Even when infected, they do not get hookworm anaemia; nevertheless, non-teff eaters acquire hookworm anaemia if they are infected with hookworm. In Ethiopia, the lack of anaemia appears to be linked to teff intake, which is thought to be owing to the grain's high iron concentration. According to the same study, malaria is often seen in people with lower haemoglobin levels (Molineaux and Biru, 1965; Tadesse, 1969).

Teff also contains high levels of Ca, P, Cu, Zn and Mg (Bultosa and Taylor, 2004a; Seyfu Ketema, 1997). Teff has a high calcium content (147 mg per 100 g), considerably surpassing other cereals such as maize (16 mg per 100 g), sorghum (5.8 mg per 100 g), wheat (39.5 mg per 100 g) and rice (23 mg per 100 g). Mineral content of teff grain is listed in Table 5.

Table 5. Mineral content of teff grain

Minerals	Quantity (mg/100 g)	Reference
Iron	16	Mengesh, 1966
	7.63	USDA., 2017
	7.63	Zhu, 2018
	15.7	Gebremariam et al., 2014; Awadalkarem et al., 2008 and Saturrni et al., 2010
	18.7	Tadessa Daba, 2017
	15.7	Bultosa and Taylor, 2004
Calcium	180	USDA., 2017; Zhu, 2018
	165.2	Bultosa and Taylor, 2004; Seyfu ketem, 1997
	117	Tadessa Daba, 2017
	165.2	Gebremariam et al., 2014; Awadalkarem et al., 2008 and Saturrni et al., 2010
Copper	2.6	Gebremariam et al., 2014; Awadalkarem et al., 2008 and Saturrni et al., 2010
	1.01	Tadessa Daba, 2017
	2.6	Bultosa and Taylor, 2004; Seyfu ketem, 1997
Zinc	3.63	USDA., 2017; Zhu, 2018
	4.9	Gebremariam et al., 2014; Awadalkarem et al., 2008 and Saturrni et al., 2010
	4.05	Tadessa Daba, 2017
Phosphorus	425.4	Gebremariam et al., 2014; Awadalkarem et al., 2008 and Saturrni et al., 2010
	270	Tadessa Daba, 2017
	425.4	Bultosa and Taylor, 2004
	429	USDA., 2017; Zhu, 2018
Magnesium	184	Alvarez-Jabete wijngaard, 2010a
	181	Mengesha, 1966
	184	USDA., 2017; Zhu, 2018
	158	Tadessa Daba, 2017
	380	Bultosa and Taylor, 2004
Potassium	427	USDA., 2017; Zhu, 2018
	438	Tadessa Daba, 2017
Sodium	11.9	Tadessa Daba, 2017
	15.9	Gebremariam et al., 2014; Awadalkarem et al., 2008 and Saturrni et al., 2010
	15.9	Bultosa and Taylor, 2004
	12	USDA., 2017; Zhu, 2018

Vitamins

Vitamins aid in the prevention and treatment of a variety of ailments, including heart disease, excessive cholesterol, eye issues, and skin conditions. The majority of vitamins aid the body's mechanisms and perform activities that no other nutrients can (WHO, 2003). In comparison to other whole cereal grains like sorghum (0.24 mg/100 g, 2.9 mg/100 g) and maize (0.25 mg/100 g, 1.9 mg/100 g), the vitamin B (thiamine and niacin) contents in teff grain (0.39 mg/100 g and 3.4 mg/100 g) are high. Teff has a higher amount of riboflavin (0.27 mg/100 g) than sorghum (0.14 mg/100 g), maize (0.08 mg/100 g), wheat (0.17 mg/100 g) and millet (0.07 mg/100 g) (Bultosa and Tylor, 2004a). In the injera, somewhat an increase in the riboflavin and a decrease in the niacin levels are observed compared to the content in the teff grain.

Teff is higher in B-vitamins than cereals like wheat and

maize because the vitamins B are concentrated in the bran section of the grain and it is taken as a whole grain, whereas in wheat and maize, the bran position is removed during processing. An adult female and man need to take 344 g and 377 g of dry injera, respectively, to meet their daily thiamine requirement, whereas around 100 g of dry injera meets their daily riboflavin requirement.

The respective figures for niacin for an adult female and male are 1077 g and 1231 g of dry injera, respectively. USDA Food Composition Databases (USDA, 2017) included the contents of some vitamins. Raw teff has niacin (3.363 mg/100 g), vitamin B6 (0.482 mg/100 g), thiamin (0.39 mg/100 g), riboflavin (0.27 mg/100 g), vitamin K (phylloquinone) (1.9 µg/100 g), vitamin A (9 IU) and α-tocopherol (0.08 mg/100 g) (Table 6).

Table 6. Vitamin content of teff grain

Vitamins	Quantity (mg/100 g)	Reference
Thiamin (B1)	0.39	Bultosa, 2007; Zhu, 2018
	0.39	USDA, 2017
	0.83	Tadessa Daba, 2017
	0.30	NRC., 1996
Riboflavin (B2)	0.30	Bultosa and Taylor, 2004
	0.27	Bultosa, 2007; Zhu, 2018
	0.27	USDA, 2017
	0.11	Tadessa Daba, 2017
	0.20	NRC., 1996
Niacin (B3)	0.20	Bultosa and Taylor, 2004
	3.4	Bultosa, 2007
	3.36	USDA, 2017; Zhu, 2018
	2.5	NRC., 1996
	2.5	Bultosa and Taylor, 2004

PHYTO CHEMICALS IN TEFF

Minerals must be absorbed by the small intestine in order to be utilised for regular metabolic processes (bioavailability) (Fairweather, 2002). Mineral bioavailability is influenced by factors such as the subject/host and the food (Hurrell, et al. 2010). Phytochemicals, such as polyphenols and phytates, are important mineral absorption inhibitors and were thus referred to as anti-nutritional factors for a long time. However, in recent years, recognizing their health-promoting effects, including anti-diabetic, anti-cancer and anti-oxidative properties (Shamsuddin and Abulkalam, 1995) made the term anti-nutritional factor obsolete (Schlemmer, et al. 2009).

Phytates

Phytates are a common constituent of cereals and legumes (Schlemmer, et al. 2009). It's the most common way for seeds to store phosphorus, accounting for 60-90 per cent of total phosphorus. It can make up to 1.5 per cent of the dry weight of grains (Loewus, 2002; Bohn, et al. 2008). Teff contains a lot of phytates, although the amount varies a lot depending on the variety and growing circumstances (Schlemmer, et al. 2009). The development of insoluble phytate-mineral or peptide-mineral-phytate complexes in the gastrointestinal system is the mechanism by which phytate limits mineral absorption (Weaver and Kannan, 2002). Furthermore, phytates form complexes with endogenously secreted minerals such as zinc (Sandstrom, 1997; Manary, et al. 2002) and calcium (Morris and Ellis, 1985), making these minerals unavailable for reabsorption into the body.

Endogenous phytases can breakdown phytate, which can be triggered by food processing procedures such as soaking, fermentation and germination and, to a lesser extent, heating. For example, injera fermentation has been found to activate endogenous phytases, resulting in phytate breakdown (Umeta, et al. 2005; Baye, et al. 2013; Baye, et al. 2014). On the other hand, exogenous commercial enzymes may be more efficient in Phytate degradation (Troesch, et al. 2009; Baye, et al. 2013). On the plus side, phytates have been found to reduce the risk of kidney stones by acting as calcium salt crystallisation inhibitors in biological fluids (Curhan, et al. 2004). They also have glucose-lowering (Lee, et al. 2006; Lee, et al. 2005) and anti-cancer properties (Singh, et al. 2003). Given these favourable benefits of phytates, it is unclear if there is an optimum phytate concentration at which the beneficial effects may be enjoyed with little or no compromise in mineral bioavailability. Further investigations are needed to find more conclusive results.

Polyphenols

Polyphenols are secondary plant metabolites that help to protect plants from diseases and UV radiation (Manach et al., 2004). Polyphenols also protect cell components from oxidative damage, reducing the incidence of oxidative stress-related illnesses (Scalbert, et al. 2005). Baye, 2013 reported the total polyphenol content of teff, wheat, barley and sorghum whole grains using the modified Folin-Ciocalteu's method. Total polyphenols per 100 g gallic acid equivalents (GAE) of flour are highest in red sorghum (1,607 mg), followed by barley (310 mg), wheat (143 mg), teff (140 mg) and white sorghum (140 mg) (81 mg). However, because only one kind of teff, sergegna, was studied, it is unclear to what degree varietal variations in teff impact polyphenol content.

Polyphenols can hamper iron absorption from plant-based foods (Hurrell, et al. 2010). Consequently, reducing polyphenol contents in predominantly plant-based diets has been encouraged (Matuschek, et al. 2002). The catechol (ortho-dihydroxy benzene) and galloyl (trihydroxy-benzene) functional groups, on the other hand, are related with the iron-binding characteristics of polyphenols. Hence, not all polyphenols possess inhibitory effects (Brune, et al. 1989).

Teff had galloyl levels equivalent to wheat, white sorghum and barley, but greater catechol levels than wheat and white sorghum (Baye, et al. 2013). The polyphenol profile of teff was reported by Mc Donough, et al. (2000). Teff's main phenolic acid component is ferulic acid. Phenolic acids also contain vanillic, cinnamic and coumaric acids.

Teff's main phenolic acid components lack galloyl and catechol functional groups, making them less likely to obstruct iron absorption. This implies that benefiting from the anti-oxidative effects of the polyphenols in teff without sacrificing iron bioavailability may be achievable. Indeed, Alaunyte, et al. (2014) demonstrated that adding 30 percent teff flour to wheat bread increased the overall anti-oxidant capacity from 1.4 to 2.4 mM trolox equivalent anti-oxidant capacity (TEAC) per 100 g substantially.

ANTI OXIDANT PROPERTIES OF TEFF

Anti-oxidants are well-known for their ability to initiate anti-oxidation chain reactions in many parts of the human body. According to Vega, et al. 2010, anti-oxidants are used as a food preservative (it stops rancidity, toxic product formation and maintains nutritional quality and shelf life). Natural anti-oxidants have recently received a lot of attention for their demonstrated efficacy in improving brain functioning and lowering the risk of numerous degenerative illnesses, cancer, cardiovascular disease and osteoporosis (Alvarez, et al. 2009; Vega, et al. 2010; Yawadio, et al. 2008). Fruits, vegetables, whole grains and pseudocereals, which are high in antioxidants, may contribute to excellent health. Cereals and pseudocereals are crucial among these foods (Calderelli, et al. 2016; Shela, et al. 2008).

In the brown teff from the United States (Kotaskova, et al. 2016) reported the various polyphenols in teff, as ferulic acid is the main phenolic component in teff and reported 160.0 μg g^{-1} as the free and 290.0 μg g^{-1} as the bounded form. Other phenolic compounds found in significant levels in teff include protocatechuic (25.5 μg g^{-1}), Gentisic (15 μg g^{-1}), vanillic (54.8 μg g^{-1}), syringic (14.9 μg g^{-1}), coumaric (36.9 μg g^{-1}), and cinnamic (46 μg g^{-1}) acids (Blandino et al., 2003). Anti-oxidative chemicals of teff grain are listed in Table 7.

Table 7. Anti-oxidative components of teff grain

Phytochemicals	Quantity (mg/100 g)	Reference
Ferulic acid	285.9	Mc Donough et al., 2000; Abebe et al., 2007; Baye et al., 2014
Protocatechuic	25.5	Mc Donough et al., 2000; Abebe et al., 2007; Baye et al., 2014
Gentisic	15	Mc Donough et al., 2000; Abebe et al., 2007; Baye et al., 2014
Vanillic	54.8	Mc Donough et al., 2000; Abebe et al., 2007; Baye et al., 2014
Syringic	14.9	Mc Donough et al., 2000; Abebe et al., 2007; Baye et al., 2014
Coumaric	36.9	Mc Donough et al., 2000; Abebe et al., 2007; Baye et al., 2014
Cinnamic	46	Mc Donough et al., 2000; Abebe et al., 2007; Baye et al., 2014

BENEFICIARY EFFECT OF TEFF ON HUMAN HEALTH

Celiac disease

Teff grain products are gaining popularity across the world, owing to the absence of gluten, the cause of the celiac disease (CD) (Spaenij-Dekking, et al. 2005; Hopman, et al. 2008 and Bergamo, et al. 2011), which affects around 1% of the population in the United States and Europe (Engleson and Atwell, 2008; See and Murray, 2006). The following is a list of the disease's prevalence among persons at risk of CD: 3 to 6 per cent in type 1 diabetic patients, up to 20 per cent in first-degree relatives, 10 to 15 per cent in those with symptomatic iron-deficiency anemia (IDA), 3 to 6 per cent in those with asymptomatic IDA and 1 to 3 per cent in individuals with osteoporosis (Dube et al., 2005). Abnormal T-cell responses to glutens and gluten-like proteins present in wheat, barley, rye and perhaps oats cause CD (Vader, et al. 2003; Arentz, et al. 2004).

Gluten (from wheat, barley and rye) destroys the lining of the small intestine and inhibits normal digestion and nutritional absorption in CD patients, resulting in chronic nutrient deficiency illnesses such as anaemia, diarrhoea and weight loss (See and Murray, 2006). Too far, the only therapy for CD patients is to adhere to a rigorous gluten-free diet (Fasano, et al. 2001). Teff is more nutrient-dense than gluten-free cereals and pseudocereals including quinoa, amaranth, buckwheat, maize, brown rice and sorghum (Arentz, et al. 2004; Gebremariam, et al. 2012).

Diabetes

Diabetes mellitus, or diabetes, is a metabolic disease marked by high blood glucose levels and improper insulin control. The contemporary world's new tendencies toward a high-fat diet, obesity prevalence, and a more sedentary lifestyle have increased diabetes incidence worldwide (Guariguata, et al. 2013). The quantity and quality of carbohydrates in one's diet are the major determinants of blood glucose levels and insulin responses in the body (Wolever, 2000).

The postprandial glucose response of carbohydrate-containing foods is reflected by the glycemic index (GI). Its impact is thought to be strongly connected to the fiber content of the foods ingested (Gutschall, et al. 2009; Wolever, 1990). Compared to other popular grains, teff has more excellent crude fiber content and a lower GI (Wolter, et al. 2013). Teff-based foods are expected to have outstanding contributions to the prevention and amelioration of diabetes. Furthermore, the grain's high calcium content can help to avoid weight gain, fat buildup and osteoporosis, all of which can contribute to diabetes. Future study is needed because there is no empirical data on the impact of a teff-based diet on diabetes.

Anemia

Anemia is a disease in which the number of red blood cells, which represents the quantity of haemoglobin in the blood, diminishes, causing the blood's ability to carry oxygen throughout the body to be reduced. Dietary iron deficiency is the leading cause of anaemia all over the world. In poor and middle-income nations, iron deficiency is widespread, especially in babies and young children and pregnant women (Gibson, et al. 2010; Clark and Susan, 2008). Iron deficiency can be prevented through food fortification and nutritional supplements (Stoltzfus and Rebecca, 2011). Teff can be a good alternative (Gebre-Medhin, et al. 1976; Adish, et al. 1999). The iron content of wheat bread was more than double when supplemented with 30% teff flour (Alaunyte, et al. 2014). It is feasible to meet between 42% and 81% and 72% and 138% of daily iron intake needs in women and men, respectively, by assuming an average daily consumption of 200 g of teff-enriched bread (Ieva, et al. 2012).

Iron bioavailability in teff is expected to vary according to the processing method. Significant reductions in phytate concentration, for example, result in an optimum phytate to iron molar ratio during injera fermentation (Umeta, et al. 2005; Baye, et al. 2014). Given that soil contamination is responsible for a portion of the iron in teff, it's been questioned whether

molar ratios can properly predict iron bioavailability (Baye, et al. 2014). However, Bokhari et al. (2012) found that eating 30% teff-enriched wheat bread can assist pregnant women in maintaining their blood iron levels. The findings also showed that phytate breakdown might improve iron bioavailability.

Further research on the iron bioavailability of teff is needed, given its high iron content and potential contribution to food-based initiatives to enhance nutrition. Indeed, suppose the bioavailability of iron in teff can be confirmed. In that case, teff can be an excellent ingredient for celiac patients due to the absence of gluten and its high iron content.

CONCLUSION

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. It is a small-seeded crop packed with high nutrient content compared to other cereal crops like rice, wheat and maize. The nutrient point of view contains a high amount of protein, fiber and carbohydrates compared to rice and wheat. It also has a balanced number of amino acids and phytochemicals, such as polyphenols and phytates. It is reported that teff contains anti-nutritional factors such as tannic acid and phytic acid. Teff also contains anti-oxidant property, which is beneficial to human health, like reducing the risk of several degenerative diseases, cancer, cardiovascular disease and osteoporosis.

It is majorly grown and consumed in Ethiopia hence; people in this region are less susceptible to celiac disease because of gluten free nature of seeds. The popularity of this crop is increasing majorly in European countries because people in these countries mainly have celiac disease due to continuous consumption of wheat (contains gluten) and wheat containing products, so their preferences are being changed to gluten-free products where teff is a naturally gluten free product. It also has a high amount of minerals, mainly iron. It supplies a good amount of iron, so people suffering from anemia (deficiency of iron) prefer teff and its products and diabetic patients also prefer it and all these indicate the potential of teff to be a future global functional food for health promotion and disease prevention.

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