Review to the Level of minerals in Teff [Eragrostis tef (Zuccagni) Trotter], grain samples

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Abstract

Tef (Eragrostis tef (Zucc.) Trotter) is a fine grain that comes in a variety of colors, from white and red to dark brown. Tef grown in Ethiopia predominantly is used to make injera, flatbread or flat pancake like fermented bread. Globally it is being found in health food stores for its long least of health benefits. Tef is leading all cereal grains by a wide margin having a high concentration of a variety of nutrients, most of which are easily absorbed by human body at most. Such as in mineral nutrients including calcium, thiamin, iron, copper, zinc, aluminum, molybdenum, barium and silicon oxide; and amino acids such as phenylalanine, tyrosine, threonine, histidine and methionine. Outside Ethiopia there is a growing interest in using tef, usually being found in health food stores either in the grain form or ground into flour, for a long list of health benefits. It is an excellent gluten-free flour alternative, and being used to make pie crusts, cookies, breads, and an assortment of other baked goods.

Key words: Teff, general information, Chemical Composition, Minerals composition.

Introduction

Teff [Eragrostis tef (Zuccagni) Trotter], is an indigenous and major food crop in Ethiopia and Eritrea, Africa. The whole grain is ground into flour that can be used as a base ingredient for leavened flatbreads such as injera, added as a thickening agent to soups and sauces, fermented to make beer and ethnic beverages, or made into porridge and puddings. Teff is a tropical cereal and it is considered a low-risk crop from the perspectives that it can be cultivated in a broad range of ecological surroundings and under tough environmental conditions where most other cereals fail. Teff belongs to the grass family, Poaceae, sub-family Chloridoideae

(Eragrostoideae), tribe Eragrostidae, subtribe Eragrostae, and genus Eragrostis. It is the only cultivated cereal in the genus Eragrostis and consists of about 350 varieties. Cultivated over approximately 2.8 million hectares, teff accounts for 28.5 percent of land area under cereal cultivation, the largest share of all staple grains in Ethiopia. The crop is preferred by both farmers and consumers due to its beneficial traits associated with its agronomy and utilization (Ketema, 1997).

Teff is a warm-season, annual, cereal crop adapted to a wide range of environmental conditions tolerant of drought-stressed, water-logged and low-fertility soils. Under native habitat and for maximum production, teff performs best with a day length of 12 hours and a temperature of 10 27°C. The recommended seeding rate is 15 kg ha^{-1} at a planting depth of 0.6 – 1.3 cm. Teff germinates rapidly, emerging within 3–7 days (Ketema, 1997). Teff is most known for its minute seed head, with nearly two million seeds per pound and diameter of only 0.7 to 1.0 mm. In fact, teff in Amharic literally means the lost seed because if dropped, it is so easily lost. In Ethiopia, teff is harvested by hand when the vegetative part of the plant turns yellow. Oxen are used to trample the grass to separate the seed from the rest of the plant (Ketema, 1997). With a population exceeding 60 million people, Ethiopia is the only country in the world where teff is intensely grown and produced for human consumption. Teff is a staple food in Ethiopia, consisting of two-thirds of their cereal diet, and is primarily used to make injera, a flat, sour, spongy, pancake-like bread. Teff can also be combined with other baking flours to produce baked products, such as muffins and cookies. Teff has also been linked to other health benefits, such as anemia, due to its exceptionally high iron content (Jennifer Marie Coleman, 2012).

Teff (Eragrostis tef(Zucc.) Totter) is a self-pollinated, annual, warm season cereal crop; believed to have originated in Ethiopia, and have been domesticated and used throughout the world due to its excellent nutritional value as grains for human consumption and as forage for livestock. Teff is a member of the millet/Poaceae/ family that is tolerant to a wide range of climatic conditions. It can grow in altitudes ranging from sea level to 2800m above sea level under different moisture, soil, temperature and rainfall regimes. It grows in dry as well as water-logged soils, can tolerate anoxic situations better than maize, wheat and sorghum; and is resistant to many pests and diseases. Its grains are milled and made to make foods and beverages for human

consumption. Although teff is grown for its grain, the straw is also used as forage for livestock as well as to reinforce mud or plasters in construction of houses both in rural and urban areas (Girma Kibatu, et al. 2017).

Teff (Eragrostis tef(Zucc.) Totter) is an important food security crop in Ethiopia and the East African Highlands. In Ethiopia the crop occupies over 2.8 million hectares equivalent to 25-30% of the total area covered by cereals. Teff is a daily food staple for about 60 million inhabitants in the country. The principal use of teff grain for human food in Ethiopia is in the form of Enjerra, a soft porous thin pancake with a sour taste. Enjerra is made from flour of Teff, water and starter fluid saved from previously fermented dough (Girma Kibatu, et al. 2017).

The study by the Ethiopian Institute Biodiversity Conservation laboratory from 114 teff variants collected from Ethiopia indicated that Teff grains contain average of 9 - 15% protein, 2% - 4% fat, 2% - 4% fiber, 68% - 74% carbohydrate, 10% - 13% of moisture and ash content between 2% and 3%. Teff contains higher amounts of a number of minerals than wheat, barley or sorghum. Previous published and unpublished studies on the levels of some essential metals in Teff flours using UV-Visible and FAAS reported higher contents of calcium, iron and zinc for Teff than other common cereals. However, information on the contents of major, minor and trace elements in the Teff flours are variable and controversial in the literature (Girma Kibatu, et al. 2017). The applications of MP-AES for soil and agricultural samples have been demonstrated, but no work has been reported the use of MP-AES for quantitative elemental analysis of Teff. Therefore, the purpose of this study is to evaluate the application of MP-AES and to determine the metal contents in Teff using the technique.

Teff is a hugely important crop to Ethiopia, both in terms of production and consumption. In terms of production, teff is the dominant cereal by area coverage and second only to maize in production and consumption. However, it has been historically neglected compared to other staple grain crops, yields are relatively low (around 1.26 tons/hectare), and some farmers under certain conditions sustain high losses which result in reduced quantity of grain available to consumers (Merga M., 2018).

Teff is one of the major and indigenous cereal crops in Ethiopia, where it is believed to have Originated (Vinning & McMahon, 2006). Nutritionally, it is an excellent source of fiber, iron, and calcium than other cereal grains and is the most valuable grain in Ethiopia (Umeta et al., 2005). Nevertheless, the high iron content of teff has been a source of controversy as some authors have estimated it to be high (Umeta et al., 2005; Saturni et al., 2010), whereas others reflect this high level to soil contamination during the traditional method of threshing and is thus of limited biological utility (Habtamu Guja, 2015).

Literature review

General information

Tef (Eragrostis tef (Zucc.) Trotter) is a fine grain that comes in a variety of colors, from white and red to dark brown. It is native and an important cereal crop to Ethiopia which is believed to be originated between 4000 and 1000 BC (Ponti, 1978). This record traces back to ancient civilizations of Abyssinia, tef as a reliable support to our early ancestors' survival. Hitherto it is grown predominantly in this country and used to make injera (flatbread or flat pancake like fermented bread). Currently it is cultivated on over 30% (3,016,063 ha) of the area used for cereals and accounts for 20% (47,506,624 quintals) of the total cereal production in this country (CSA, 2014/15).

Tef is leading all cereal grains by a wide margin having a high concentration of a variety of nutrients, most of which are easily absorbed by human body at most. Such as in mineral nutrients including calcium, thiamin, iron, copper, zinc, aluminum, molybdenum, barium and silicon oxide; and amino acids such as phenylalanine, tyrosine, threonine, histidine and methionine (Seyfu Ketma, 1997). Outside Ethiopia there is a growing interest in using tef, usually being found in health food stores either in the grain form or ground into flour, for a long list of health benefits. It frequently been ground into flour to make excellent gluten-free flour alternative, and be used to make pie crusts, cookies, breads, and an assortment of other baked goods. Similarly, being eaten whole and steamed, boiled, or baked as a side dish or a main course**.**

Teff is a grain crop endemic to Ethiopia where it has sustained people for many generations. Dating back to as early as before the birth of Christ, teff in Amharic literally means the lost seed because it is so small that if dropped, it is so easily lost. Teff is traditionally used to make a sour,spongy pancake-like bread called injera though it can also be combined with other flours to make baked products. It is the chemical composition of teff, however, that makes it such a desirable alternative to other cereal grains. High in essential amino acids, teff is higher in lysine that all other cereals except oats and rice (Ketema, 1997). Teff also has the highest iron content and more calcium, copper, zinc, aluminum, and barium than winter wheat, barley and sorghum (Ketema, 1997).

Teff [Eragrostis tef(ZUCC.) Trotter]. Eragrostis is a member of the tribe Eragrosteae, sub-family Eragrostoidae , of the poaceae (Gramineae). There are approximately 300 species in the genus Eragraostis consisting of both annuals and perennials which are found over a wide geographic range. Taxonomy of teff has been clarified by numerical taxonomy techniques, cytology and biochemistry including leaf flavanoids and seed protein electro phoreticpatterns (Bekele and Lester, 1981). Its common names include teff, love grass, annual bunch grass and warm season annual bunch grass. The word teff is thought to originate from Amharic word "teffa", meaning "Lost" and so named because of teff small size. It is the smallest grain in the world and often is lost in harvesting threshing process because of its size. It is believed that teff grains have originated in Ethiopia between 3000 and 1000 B.C. and remains an important staple food in that country. Teff , which is cheap to price and grows rapidly, is also vital to Ethiopian farmers who use it as a source of nutrient-rich fodder for strengthening livestock .The straw of the teff plant is soft and fast drying, making it perfect for many different applications, including a dobe building materials and household clay pots (Ketema, 1993 and Lovis, 2003). Teff is best suited for cultivation in a warm climate, with temperatures ranging from 10 to 27 ^{o}C and altitudes of (1,000 – 2,100 m). However, it can survive harsh environments, such as drought conditions or water-logged soil.

Teff was estimated to account for 16% of cereals grain production and cultivated on 2.7 million hectares based on Ethiopian Central Statistics Authority. In the central, northern, and western parts of the country, it is the staple food (Umeta M. et al. 2005). Teff is a high-

status cereal crop and a family who do not depend on teff as a daily food is considered poor in these parts of the country. The main reason behind such attitude is the long historical, socio-economic, and cultural values of teff developed by the society. Injera from whatever crop is the most common form of food in the central and north part of Ethiopia. Many people do not like injera made from other cereals such as wheat and barley as they lack the required organoleptic properties of injera. In a number of cases, families sell other cereals for cheaper prices and buy teff for food when they have enough cereals. Many Ethiopian people are very comfortable with the taste of teff injera than any other food. Nutritionally, teff is the most valuable grain in Ethiopia, which is considered an excellent source of fiber, iron, and calcium than other cereal grains (Umeta et al., 2005; ATA, FDRE MoA, & EIAR, 2013). Recently, there is a growing interest in teff grain utilization because of nutritional merits (whole grain) and free of the protein gluten that make teff an increasingly important dietary component for individuals who suffer from gluten intolerance or Celiac Disease (Boka et al., 2013).

Celiac Disease (CD) is a genetically based autoimmune condition that results in permanent sensitivity to the protein gluten (Alaunyte, 2013). It is characterized by chronic inflammation of the intestinal mucosa, atrophy of intestinal villi and several clinical manifestations. Its prevalence has increased in recent years. Gluten is a mixture of storage proteins (prolamins and glutenins with a high content of proline and glutamine domains) that is contained in several cereals (wheat, rye, barley and derivatives). These protein domains are resistant to degradation by gastric, pancreatic and proteases in the human intestinal brush border membrane, this results in an accumulation of relatively large peptide fragments and gluten free-diet remains the cornerstone treatment for CD patients (Saturni et al., 2010). Teff is a gluten-free cereal lacking gluten homologues, it can be used as a substitute for wheat in food applications where exclusion of gluten is required (Alaunyte, 2013).

Teff is generally accepted that the grain is highly nutritious although there is some debate about the precise nutritional value of it (Vinning & McMahon, 2006). Regarding the iron content, some authors have estimated to be high and others reflect this high level is attributed to the dust and dirt that cling to the grain (Vinning & McMahon, 2006). As per the study done by Umeta et al. (2005), to evaluate mineral contents of 36 foods consumed in rural

Ethiopia have shown teff enjera was the best source of bioavailable iron of all foods analyzed based on its high iron content and favorable phytate to iron molar ratio. Moreover, the prevalence of IDA has been reported to be lower in some regions of Ethiopia, which has been attributed to teff forming a staple part of the diet (Bokhari et al., 2012). Whereas, other studies revealed that iron content of teff vary between geographical regions possibly as a result of soil contamination (Saturni et al., 2010; Bokhari et al., 2012). With respect to soil contamination, teff is extremely exposed and complete removal of the extrinsic iron from teff is not possible (Baye et al., 2013b).

Consumption of teff in Ethiopia

In the past, a major determinant of grain consumption was its production (Berhane et al., 2011). However, with improvement in market linkages, this picture is gradually changing. In Oromia region, for instance, where regional teff production is the second highest next to Amhara region in Ethiopia, its consumption expenditure is only 8 percent (Berhane et al. 2011). In contrast, the Afar region, little known for its teff production, has comparatively higher teff consumption expenditure (10 per-cent) (Berhane et al., 2011). Today, several factors including agro-ecology (Baye et al., 2013), livelihoods, and income (Berhane et al., 2011) determine cereal consumption in Ethiopia. Findings from the analyses of a nationally representative household consumption and income survey conducted in 2004/05, suggests that teff's contribution to energy (calorie) intake in Ethiopia is only 11 percent (Figure 4.1). Maize (17 percent), sorghum (14 percent) and wheat (13 percent) are all more important sources of calories in Ethiopia (Berhane et al., 2011).

Chemical Composition of Teff

The genetic and phenotypic diversity of teff in Ethiopia is a national treasure of potentially global importance. Teff is tolerant to many extreme environmental conditions including water-logging and storage pests. Although Teff performs well on various soil types, the average grain yield in the country basis is about 0.7 mg ha^{-1}. The yield of teff is even lower in the drier part of the country. This low yield is attributed to nutrient deficiencies, mainly of nitrogen (N) and phosphorous (P), and to the susceptibility of the crop to lodging at higher N, among others, due to its low genetic yield potential. The grain proteins offer an excellent balance among the essential amino acids. Teff is rich in carbohydrates, fibre and has a complete set of essential

amino acids. Teff is also particularly high in iron and has more calcium, copper and zinc than other cereal grains. They also contain polyphenols (produced as secondary plant metabolites) which affect the nutritional properties. The demand for gluten-free foods is certainly increasing. Interest in teff has increased noticeably due to its very attractive nutritional profile and gluten-free nature of the grain, making it a suitable substitute for wheat and other cereals in their food applications as well as foods for people with celiac disease. Many gluten-free products may not meet the recommended daily intake for fiber, minerals, and vitamins (Kamila de Oliveira do Nascimento et al, 2018).

The amount of teff produced worldwide is increasing rapidly due to the plant's popularity as an especially nutritious grain and as high quality, horse hay. The grain has high nutritional values, a very high protein, carbohydrate, fat, vitamin A and C, fiber, Thiamin, Riboflavin, Niacin, and essential minerals like Calcium, Chloride, Chromium, Copper, Iron, Magnesium, Manganese, Phosphorus, Potassium, Sodium and Zinc. Teff grains contain the eight essential amino acids (isoleucine, leucine, methionine, lysine, phenylalanine, threonine, tryptophan and valine). The protein digestibility is high because the main protein fractions are the most digestible types. The main protein fractions (albumin) are rich in lysine. Teff is essentially free of gluten. Interest in Teff has increased noticeably due to its very attractive nutritional profile and gluten-free nature of the grain, making it suitable substitute for wheat, maize and other cereals in food applications especially for people with celiac disease (Girma Kibatu., et al. 2017).

Minerals

Minerals are present in foods at low but variable concentrations and in multiple chemical forms. The role of minerals in food is to provide a reliable source of essential nutrients in a balanced and bio-available form. In cases where concentration and/or bio-availabilities in food supply are low, fortification has been popular (Miller, 1996). There is a significant body of evidence that minerals by themselves and in proper balance to one another have important biochemical and nutritional functions.

I. Iron

Iron is necessary for red blood cells formation and required for oxygen transport throughout the body. According to Besrat et.al. (1980) , the iron content of 35 samples of acid washed white and red teff (also known as brown teff) grain was 3.6 to 7.8 mg/100g on dry matter bases (DM.). Lovis (2003) reported that , teff grain contains (5.8 mg Iron/100g) while wheat flour contains (4.41 mg Iron/100g). Melak (1966) reported values (19.6 and 11.5mg Iron/100g) for two teff cultivars , while values (4.00 mg Iron/100g) and (7.85 mg Iron/100g) for two wheat cultivars. According to FAO (1986) values of Iron content of teff seed ranged between (20.9 and 75.5 mg/100g) , sorghum (5.0to 15.6 mg/100g) and millet (39.0 mg/100g).

II. Phosphorus

Phosphorus works with calcium to develop and maintain strong bones and teeth . It enhances the use of other nutrients and play a key role in cell membrane integrity and intercellular communication. Phosphorus is critical for proper energy processes in the body. Melak (1966) reported values (440 and 460 mg Phsophorus/100g) for two teff cultivars, while (510 mg Phsophorus/100g and 400 mg Phsophorus/100g) for two wheat cultivars. Lovis (2003) showed that Phosphorus content of teff grain was 378 mg/100g while wheat flour (97 mg Phsophorus/100g).

III. Calcium and magnesium

Calcium is essential for developing and maintaining healthy bones and teeth, assists in blood clotting, muscle contraction, nerve transmission and oxygen transport. Optimal intakes reduce the risk of osteoporosis Magnesium activates over 100 enzymes and helps nerves and muscle functions. Lovis(2003) reported that teff grain contains 159 mg Calcium/100g and 170 mg/100g for Magnesium , while wheat flour contains (15 mg Calcium/100g)and (25 mg Magnesium/100g). Melak(1966) reported values of (180 mg Magnesium /100g) for two teff cultivars.

IV. Zinc, copper and manganese

Zinc is essential part of more than 200 enzymes included in the digestion, metabolism , reproduction and wound healing . It plays critical role in immune response and is an important

antioxidant. Melak (1966) reported that for two teff cultivars contain (6.7 and 6.8 mg Zinc/100g) while wheat (spring, winter) contains (6–3.95 mg Zinc/100g). Lovis (2003) reported that teff grain contains (2 mg Zinc/100g) but wheat flour contains (0.85 mg Zinc/100g). Copper is essential to normal red blood cells formation and connective tissue formation. It acts as a catalyst to store and release iron to help haemoglobin formation. Lovis (2003) reported that teff grain contains (0.7 mg Copper/100g)while wheat flour contains (0.182 mg Copper/100g) Melak (1966) reported values (52 mg Copper/100g and 64mg Copper/100g) for two teff cultivars while (55 mg Copper /100g) for two wheat cultivars. Manganese is a key component of enzymes systems, support brain function and is required for blood sugar regulation. Melak,(1966) reported values (2.12 mg Manganese/100g) and (3.00 mg Manganese/100g) for two teff cultivars while (1.2 mg Manganese/100g and 3.6 mg Manganese/100g) for two wheat cultivars. Lovis (2003) reported that Manganese content of teff grain was (6.4 mg/100g) and for wheat flour was (0.792 mg/100g).

V. Sodium and Potassium

Sodium and Potassium are essential nutrients, their deficiency is rare, excessive intake of Sodium may leadto hypertension . Potassium regulates heart beat , maintains fluid balance and helps muscles contraction. Lovis (2003) reported values of Sodium of teff grain as (471 mg/100g), wheat flour (2mg/100g) and values of (401 mg potassium /100g) for teff grain while wheat flour of (100 mg Potassium/100g). Melak (1966) reported values (360 mg Potassium/100g and 200 mg Potassium/100g) for two teff cultivars, while values (330 and 440mg Potassium/100g) for two wheat cultivars, also according to the same authors' values were (22.00 mg Sodium/100g) and (21.22 mg Sodium/100g) for two teff cultivars, while values (16.85mg Sodium/100g) and (39.20 mg Sodium/100g) for two wheat cultivars.

Conclusion

Teff is generally accepted that the grain is highly nutritious although there is some debate about the precise nutritional value of it (Vinning & McMahon, 2006). Regarding the iron content, some authors have estimated to be high and others reflect this high level is attributed to the dust and dirt that cling to the grain (Vinning & McMahon, 2006). Whereas, other studies revealed that iron content of teff vary between geographical regions possibly as a

result of soil contamination (Saturni et al., 2010; Bokhari et al., 2012).

According to Mariam Idreis Osman Mohammed, 2007, minerals content, bioavailability of total minerals, amino acids profile and lysine content, and anti-nutritional factors were investigated for teff grains. All these parameters were carried to evaluate the nutritional value of these grains. The results showed the protein content of teff grains flour was 10.03%, crude fiber 3.65%, ash content 2.57% and fat content 4.56% (as dry matter), but the moisture content of teff flour was 8.67%. It is observed that teff grains flour has (333.6 mg polyphenols/100g), (536.12 mg phytic acid/100g) and (0.6 mg tannin/100g). The results of total minerals and their availability showed that teff grains flour is a good source of the minerals (1813 mg P /100g) and availability 24.159%,(0.768 mg Cu /100g) and availability 73.997%, (229.917mg Mg/100g) and availability 34.59% and (44.319 mg Fe/100g) with availability 2.89%. While the result of amino acids showed that the Lysine content of teff grains flour was (5.6 g/100g protein), Histidine (6.4g/100 g protein), Leucine (18.3 g/100 g protein) and Valine (16.6 g/100 g protein), thus teff flour is a good source of amino acids specially lysine (most limited amino acid in cereals).

According to Zeleke K, 2009, the levels of nine essential elements (Na, K, Mg, Ca, Mn, Co, Cu, Zn &Fe) were determined by FAAS in the three most common and commercially available teff types (Red, Mixed and White tef) collected from four mill houses in Arada sub city of Addis Ababa. The observed average metal concentration in red, mixed and white teff respectively were: Na(22.06 ± 1.46, 25.68 ± 2.05, 22.89 ± 1.42), K (215.81 ± 8.13, 219.23 ± 8.35, 205.59 ±7.17), Mg (161.91 ± 7.76, 173.7 ± 8.89, 153.16 ± 9.45), Ca (178.54 ± 9.5, 168.64 ± 11.03, 180.7 ± 14.65), Mn (22.36 ± 0.15, 13.26 ± 0.029, 4.84 ± 0.044), Co (6.20 ± 5.38, 5.21 ± 0.29, 7.89 ± 0.75), Cu (2.51 ± 0.30, 3.79 ± 0.1, 1.08 ± 0.075), Zn (4.79 ± 10.7, 3.79 ± 0.1, 2.98 ± 0.12), and Fe (24.62 ± 1.07, 20.05 ± 1.4, 15.95 ± 1.7) mg/100g of dry weight. According to the reported values of Kamila de Oliveira do Nascimento, et al. 2018, the nutritional contents of white and brown teff varieties per 100g were 156 mg and 157mg Ca respectively. Similarly The amount of Fe was 18.9 mg and 58.9 mg for the white and brown teff varieties respectively. According to Girma Kibatu, et al. 2017, The levels of selected elements in teff flours sampled from Addis Ababa were analyzed using a portable total x-ray fluorescence spectrometer (PTXRF). The following concentrations (mean ± SD, mg/100g dry weight basis) were recorded in brown and

white teff, respectively: K (486.80 ± 8.48) and (383.70 ± 3.25); Mg (209.15 ± 2.55) and (183.38 ± 11.73); Ca (116.15 ± 0.35) and (83.85 ± 0.78); Na (2.85 ± 0.20) and (2.32 ± 0.35); Fe (22.60 ± 0.02) and (16.05 ± 1.63), Zn (3.35 ± 0.12) and (2.70 ± 0.00); Cu (0.39 ± 0.01) and (0.43 ± 0.03); Pb (0.05 ± 0.00) and (0.05 ± 0.00); Se (0.009 ± 0.00) and (0.009 ± 0.00) and As (0.0035± 0.00) and (0.0035 ± 0.00).

Thus the mineral contents of Teff flour were determined by using different techniques at different times as we can see from the above literature values. But the results reported by the different literatures are controversial and have significant differences; this may be due to sampling error. Most of the researches were done by collecting Teff flour samples from commercially available mill houses; this increases the contamination level of the sample. I recommend collecting teff grain samples and determining the mineral contents of it by using the MP-AES which is very important, cost effective, and accurate results will be obtained. Since the Agilent 4200 MP-AES operates on air, it does not require the continuous supply of flammable or expensive gases.

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