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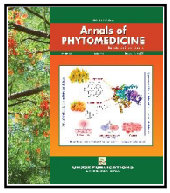

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Characterization of teff (*Eragrostis tef* (Zucc.) Trotter) grains for nutritional efficacy and cooking quality

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Abstract

Teff [*Eragrostis tef* (Zucc.) Trotter], a minor millet belonging to the Poaceae family, is a gluten-free grain with potential applications in various food and beverage products. Hence, the study was conducted to analyze the nutritional efficacy and cooking quality of teff grains. Moisture, protein, fat, ash, crude fibre, and total carbohydrate, were 11.30 g, 14.22 g, 2.2 g, 3.03 g, 8.07 g, and 72.35 g which contributed 321 kcal per 100 g. Teff grain has 165.96, 8.01, 4.70, 182.66, 3.70, and 1.09 mg of calcium, iron, zinc, magnesium, manganese and copper per 100 g. Teff grains were rich in nutraceuticals, *i.e.*, dietary fibre, polyphenols, vitamin E, and antioxidant activity. The antinutrients such as tannin (19.66 mg CE), phytic acid (684 mg), and oxalates (99.66 mg) per 100 g were observed. The *in vitro* protein digestibility of teff grains was 72.65 per cent and *in vitro* starch digestibility at 30, 60, 90, and 120 min of hydrolysis were 57.22, 78.47, 97.73, and 103.53 mg of glucose per min, respectively. High levels of rapidly digestible starch (51.49) and less per cent of slowly digestible starch (41.67) were recorded. The glycemic index of teff grains was predicted to be 47.05 which is grouped as food with low glycemic index. Teff cultivation is a labor-intensive process, and the small seed size poses a significant challenge in handling and transportation, as it can lead to considerable seed loss. The Central Food and Technological Research Institute (CFTRI), Mysore has introduced teff to India as a potential "superfood" particularly in dryland areas. Teff is highly resistant to diverse climatic conditions and highly resilient to diseases, can be cultivated during both kharif and rabi seasons, offering farmers flexibility. Hence, the utilization of teff grains can be promoted in different food products, especially for those with digestive disorders.

1. Introduction

Teff [*Eragrostis tef* (Zucc.) Trotter] belongs to the Poaceae family, subfamily Eragrostoidae, tribe Eragrosteae, and genus Eragrostis, with diploid chromosome number, 2n = 40. Eragrostoidae of teff is referred to as chloridoideae (Costanza *et al.,* 1980). It is commonly known as teff or Williams love grass or annual bunch grass. Teff was one of the first domesticated plants and it is thought to have originated between 4000 and 1000 B.C. in Eritrea and Ethiopia. Teff is said to be derived from the Amharic term *teffa,* which means “to be lost”. Among the 300 species known in the genus Eragrostis, teff is the only cultivated species. In Ethiopia, teff is the primary indigenous cereal crop, serving as a staple food for over 85 per cent of the country’s 85 million people. In Ethiopia, teff is cultivated on approximately 3.01 million hectares, yielding an annual production of 5.01 million tonnes and an average productivity of 1.664 tonnes per hectare. Teff grains are packed with nutrition and are free from gluten and straw has high palatability when fed to milch animals.

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Simultaneously, the benefits of teff farming are dispersing to various localities of the world. The Central Food and Technological Research Institute (CFTRI), Mysore has launched teff to India as a potential “superfood” and a lucrative option for farmers, particularly in dryland areas of Karnataka. Teff cultivation is currently limited to a few hundred hectares in selected districts of Karnataka state. Teff, known for its resilience to diverse climatic conditions and resistance to diseases, can be grown during both kharif and rabi seasons, offering farmers flexibility. Its small grain size reduces post-harvest losses, making it economically viable for farmers. *E. tef* is an annual cereal grass that is self-pollinated and tetraploid. Teff is a C_4 plant, which means it can fix carbon more efficiently under drought and hot temperatures. It is produced for its edible seeds as well as straw for cow feed. The grain is oval and measures about 0.9-1.7 mm and 0.7-1.0 mm in length in width. Each grain weighs about 0.2-0.4 mg, making them one of the tiny kernels abundant in carbohydrates (Belay *et al.,* 2009; Bultosa, 2007). Teff grain ranges in hue from white to deep reddish brown. Culinarily, teff is similar to millet and quinoa, but it has a significantly smaller seed size, which enables faster cooking time and lower energy consumption.

Uncooked teff has 9, 73, 13, and 2 per cent moisture, carbohydrate, protein, and fat content, respectively. Cooked teff has modest levels of thiamine, phosphorus, iron, magnesium, and zinc, and offers 101 kcal of energy per 100 g. Teff also has a greater fibre level than most

of the other cereals. Teff grain is rich in minerals compared to cereal grains, *viz.,* wheat, barley, and sorghum when eaten whole (Abebe *et al*., 2007). Teff is gluten-free and rich in micronutrients such as calcium, zinc, iron, and potassium along with dietary fibre. It is as nutritious as or better than the major staple grains such as wheat, rice, oats, and barley (Gebremariam *et al.,* 2014). It is exceptionally rich in vitamins and considered a superb food, boasting an impressive array of vital amino acids, with nearly three times the amount found in wheat and barley (Sirawdink and Ramaswamy, 2011). Teff grain proteins provide a perfect mix of vital amino acids (Yu *et al.,* 2006). Teff has increasingly gained international notice as a "healthy food" that may be used in innovative meals like infant foods and gluten-free products (Dekking *et al*., 2005). Teff grain is gluten-free, hence can be included in a variety of food and beverage items to help persons with celiac disease, diabetes, hypertension, cardiovascular diseases, and obesity (Gebremariam *et al*., 2014). However, much of studies have not been done on teff grains, nutritional efficacy, and cooking quality of teff grains have not been well documented. Hence, the present investigation was formulated to determine the nutritional efficacy and cooking quality of teff grains.

2. Materials and Methods

2.1 Authentication ofplant

The plant material was authenticated by Dr. P. Ashoka, Senior Scientist and Head, Department of Agronomy, KVK, Hanumanamatti, Haveri, University of Agricultural Sciences, Dharwad, Karnataka, India. Teff (Brown teff) had been adopted by the Central Food and Technological Research Institute (CFTRI), Mysore, Karnataka from Ethiopia, and the sample was handed over to the Agriculture Research Station, Hanumanamatti, Karnataka to carry out the research. The herbarium of the same has been deposited in the Agriculture Research Station, Hanumanamatti, Karnataka, India for future reference.

2.2 Procurement of teff grains

Teff grains (Figure 1) were procured from ICAR, KVK, Haveri during the Kharif 2020-2021. Dehulled whole grains were subjected to cleaning, sieving, washing and drying, and manual cleaning. The cleaned whole grains were used to study quality parameters.

Figure 1: Teff grain.

2.3 Composition of teff grains

The composition including proximate principles, minerals, antinutrients, and nutraceuticals in teff grains were analyzed.

2.3.1 Proximate principles

The proximate composition including moisture, fat, protein, crudefibre, ash, carbohydrate, and energy in teff grains were analyzed.

2.3.1.1 Moisture

A sample of known quantity was weighed and transferred to previously weighed moisture cups. Later it was dried in a hot air oven at 100 ± 2°C till constant weight was attained. Every time moisture cup was cooled in a desiccator before weighing. Then, the obtained result was expressed in percent and calculated using the following formula (AOAC, 2005):

$$\text{Moisture content (\%)} = \frac{\text{Initial weight (g)} - \text{Final weight (g)}}{\text{Weight of sample (g)}} \times 100$$

2.3.1.2 Fat

The principle of crude ether extraction of dry material was involved in crude fat estimation. The dehydrated sample (2 g) was accurately measured and packed in small pouches of filter paper (Whatman No. 1). Then, pouches were inserted into a thimble. Later thimble was placed in a Soxhlet apparatus (Socs Plus- Pelican) and extracted with petroleum ether (60 - 80°C) for two h. Then, was evaporated after extraction and the flask with residue was dried in a hot air oven at 80-100°C, finally cooled in desiccators, and weighed (AOAC, 2005). The total crude fat was expressed in percent and calculated by using the following formula:

Fat content (%)

$$= \frac{\text{Final weight of beaker (g)} - \text{Initial weight of beaker (g)}}{\text{Sample weight (g)}} \times 100$$

2.3.1.3 Protein

The quantity of protein in dehydrated and defatted samples was analyzed using the Micro Kjeldhal method (AOAC, 2005). Separate digestion and distillation of the sample were carried out automatically in the Kelplus - Classic Dx (Pelican equipment) unit. Thereafter, total nitrogen content was estimated using the formula:

Nitrogen content (%)

$$= \frac{14 \times \text{normality of acid} \times \text{titrant value (burette reading)}}{\text{Weight of sample (g)}} \times 100$$

The total amount of nitrogen was converted to total protein content by multiplying with the conversion factor of 6.25.

Protein content (%) = 6.25 × Nitrogen content (%)

2.3.1.4 Crudefibre

Crude fibre estimation was done using a moisture and fat-free sample. Digestion of the sample was carried out using 1.25 % sulphuric acid and 1.25 % sodium hydroxide solution and the obtained residue was dried in the crucible. Complete ashing of the residue was done and weighed again. The difference obtained in the weight of the crucible before and after ignition depicted the weight of the crude fiber (AOAC, 2005) in the following formula:

Crude fibre (%)

$$= \frac{\text{Reduction in weight on ignition } (W_2 - W_1) - (W_3 - W_1)}{\text{Sample weight (g)}} \times 100$$

where

W_1 = Weight of the crucible (g)

W_2 = Residue weight after drying (g)

W_3 = Residue weight after ignition (g)

2.3.1.5 Ash

A known quantity of sample (5 g) was incinerated at a high temperature to eliminate all the organic matter and the ash content was determined based on weight loss. The sample present in the crucible was completely decarbonized by placing it on a heating mantle until all the fumes were emitted. Then the crucible was ignited in a muffle furnace for 6 h at 600°C. Further, the crucible was cooled in desiccators and weighed again (AOAC, 2005). The total ash content was expressed in percent and calculated using the following formula:

$$\text{Total ash (\%)} = \frac{\text{Weight of the crucible after ignition (g)} - \text{weight of the crucible (g)}}{\text{Sample weight}} \times 100$$

2.3.1.6 Carbohydrates

The total carbohydrate percentage was calculated by subtracting the combined values of moisture, protein, fat, crude fibre and ash from 100 percent. Similarly, the available carbohydrate fraction was determined by subtracting the combined values of moisture, protein, fat and ash from 100 per cent (AOAC, 2005).

2.3.1.7 Total energy

The Atwater factor of protein, fat, and carbohydrate was used to compute the total calorific value (AOAC, 2005).

Energy (kcal) = (Protein × 4) + (Carbohydrate × 4) + (Fat × 9)

2.3.2 Mineral estimation

2.3.2.1 Preparation of mineral solution

The mineral solution of the samplewas prepared using the standard wet ash method (AOAC, 2005). To facilitate rapid decomposition,the sample was treated with a mixture of mineral acids (tri-acids) and heated, causing the volatile components to evaporate, leaving the non-volatile mineral elements in the solution. Heating was continued until the contents were reduced to a small volume of clear, yellow residue. This residue was then dissolved in 6 N hydrochloric acid (HCL), filtered, and diluted to a known volume with triple-distilled water yielding a solution for further elemental analysis.

2.3.2.2 Calcium

The calcium content was estimated using the titrimetric method (AOAC, 2005). This involved precipitatingcalcium as calcium oxalate, which was then dissolved in hot, dilute sulphuric acid. The resulting solution was subsequently titrated with standard potassium permanganate.

2.3.2.3 Trace minerals

Atomic absorption spectrophotometer (AOAC, 2005) was used to analyze different trace minerals such as iron, zinc, copper, and manganese present in the sample solution.

2.3.3 Nutraceuticals

2.3.3.1 Vitamin E

The vitamin E content was estimated using a method involving saponification under reflux,followed by hexane extraction and injection onto a normal-phase HPLC column coupled with a fluorescence detector, Ex λ = 290 nm, Em λ = 330 nm (ÁOAC, 2005).

2.3.3.2 Dietary fibre

Soluble, insoluble, and total dietary fibre fractions in teff grains were determined by the rapid enzymatic method as mentioned in AOAC (2005). The defatted flour was gelatinized, and further protein and starch were removed using α-amylase, pepsin, and pancreatin enzymes. Filtrate was collected and treated with 95 per cent ethanol which was precipitated. Further soluble and insoluble fibre were separated by filtration. The residue obtained after filtration was washed with ethanol and acetone, oven-dried, weighed, and ignited to ash. The soluble and insoluble content was calculated using the formula:

Soluble/Insoluble dietary fibre

$$= \frac{\text{Weight of residue} - \text{Weight of ash}}{\text{Weight of the sample}} \times 100$$

Total dietary is the sum of insoluble and soluble dietary fibre.

2.3.3.3 Total polyphenols

Total polyphenol content was determined using the Folin-ùiocalteau reagent. The reaction involves the formation of a blue-colored complex in an alkaline medium, resulting from the interaction between polyphenols and phosphomolybdic acid in the presence of the Folin-Ciocalteau reagent. The absorbance of this complex was measured at 650 nm, with gallic acid serving as the standard (Sadashivam and Manikam, 2008).

2.3.3.4 Antioxidant activity

The antioxidant activity was evaluated using DPPH (2, 2-diphenyl-1-picryl-hydrazyl) free radical scavenging assay, which is based on electron transfer and yields a violet-colored methanol solution. Here, one g of defatted sample was refluxed in 10 ml of methanol for 30 min, followed by centrifugation to obtain the supernatant. This supernatant was then mixed with one ml of 0.05 mg/ml DPPH solution, vortexed, and allowed to stand at room temperature for 30 min. The absorbance was subsequently measured at 517nm (Hsu *et al.,* 2003).

2.3.3.5 Tannin

The tannin content of teff grains was analyzed by the modified vanillin- assay (Price *et al.,* 1978) using catechin as the standard

2.3.4 Antinutrients

Antinutrients such as oxalates and phytic acid content of teff grains were analyzed.

2.3.4.1 Phytic acid

Phytic acid of teff grains was estimated by phytic-phosphorus as outlined by Thompson and Erdman (1982). Phytic acid contents were computed by multiplying the phytic phosphorus value by 3.55 (Rusydi and Azrina, 2012).

2.3.4.2 Oxalates

Following acid treatment, the sample was subjected to defatting with ether, after which it was extracted with a mixture of NaOH and water. The aqueous layer was then adjusted to pH 4.5 with calcium chloride buffer and centrifuged. The resulting pellet was subsequently treated with calcium oxalate saturated acetic acid, centrifuged again and the residual material was dissolved in sulphuric acid. Finally, the extract was titrated with a standardized 0.02 N potassium permanganate solution, allowing for the calculation of oxalic acid content (Thimmaiah *et al.,* 1999).

2.4 Nutritional quality of teff grains

The nutritional quality of teff grains was assessed in terms of *in vitro* protein digestibility, *in vitro* starch digestibility, and predicted glycemic index.

2.4.1 *In vitro* protein digestibility

The procedure outlined by Moulishwar *et al.* (1993) was employed to estimate the *in vitro* protein digestibility. A sample containing 100 mg of protein was treated with 0.1 N HCl containing 12.5 mg of pepsin at 37°C for 3 h. Thereafter, 0.5 N sodium hydroxide and 25 ml of phosphate buffer containing 6 mg of pancreatin were added to neutralize the mixture. Then, the mixture was incubated at 37°C for 24 h. The volume was adjusted to 100 ml with distilled water and 50 ml of aliquot was treated with 10 per cent trichloroacetic acid, left overnight to allow protein precipitation. The resulting suspension was centrifuged and the residue was analyzed for protein content using the Micro Kjeldahl method. The amount of protein digested was calculated using the formula:

$$\text{Digested protein (\%)} = \frac{\text{Total protein} - \text{Undigested protein}}{\text{Total protein}} \times 100$$

Resultant values of digested protein were expressed in percentage.

2.4.2 *In vitro* starch digestibility

A 500 mg sample was dissolved in 25 ml of distilled water followed by heating in a boiling water bath for 15 min and subsequently allowed to cool. After cooling, 0.2 N sodium hydroxide was added, and the volume was adjusted to 100 ml. From this solution, 10 ml of aliquot was mixed with 0.05 M phosphate buffer containing 7.5 mg each of pancreatin and amyloglucosidase, then incubated at 37!. Samples were withdrawn at 30, 60, 90, and 120 min of incubation, and the released reducing sugars were measured using Nelson Somogy's method. Glucose was used as standard and the degree of hydrolysis was expressed as mg of glucose liberated from the food sample after correction for blank values. The starch equivalent was calculated by multiplying the obtained value by 0.9 (Moulishwar *et al.,* 1993).

Amount of rapidly digestible starch (RDS), slowly digestible starch (SDS) and resistant starch (RS) was derived using following formulae (Annor *et al.,* 2013).

RDS = Glucose released at 30 min × 0.9

SDS = (Glucose released at 120 min – Glucose released at 30 min) ×0.9

2.4.3 Predicted glycemic index (pGI)

The hydrolysis at the end of 90 min (H_{90}) was used to calculate predicted glycemic index using the formula given by (Goni *et al.,* 1997).

$$pGI = [39.21 + 0.803(H_{90})]$$

Foods are accordingly classified into three categories of glycemic index (Allen *et al.,* 2012);

1. Low GI ≤ 55,
2. Medium GI = 55-69, and
3. High GI ≥ 70

2.5 Cooking quality of teff grains

Ten grams of teff grains were subjected to boiling and pressure cooking. The cooking quality of grains was assessed by measuring the cooked weight and volume, cooking time, the percentage increase in weight and volume, and the percentage of solid matter leached after cooking (Amerine *et al.,* 1965).

2.5.1 Cooking time

Cooking time was determined following the procedure outlined by Amerine *et al.* (1965). A 10 gsample was placed in a beaker and cooked in 200 ml of distilled water on a hot plate. The cooking time was determined by removing a few grains at different intervals during cooking and pressing them in between two glass slides. The time required for the grains to cook was then recorded.

2.5.2 Weight of cooked grains

Soon after cooking followed by cooling, the weight of grains was recorded using an electronic weighing balance with a sensitivity of 0.01 mg (Amerine *et al.,* 1965).

2.5.3 Volume of cooked grains

The water displacement method was used to measure the volume of cooked grains in triplicates. Cooked grains were added to a measuring cylinder containing a known volume of distilled water and thereafter the volume change was recorded in ml (Amerine *et al.,* 1965). The average volume was expressed as ml per 100 grains.

2.5.4 Volume expansion ratio

The volume expansion ratio soon after cooking was calculated as per the protocol suggested by Bhonsle and Sellappan (2010). The volume expansion ratio wasobtained by dividing the volume of cooked teff grains by volume of raw grains.

2.5.5 Water uptake ratio

The supernatant obtained after boiling teff grains for forty-five min at 80°C was measured and later water uptake ratio was calculated as 100/2g × actual water absorbed (Bhonsle and Sellappan, 2010).

2.6 Statistical analysis

All the results were statistically analyzedin SPSS statistical packages (16.0) softwareto test the significance using percentage, mean, standard deviation, and analysis of variance (ANOVA) technique.

3. Results

3.1 Composition of teff grains

3.1.1 Proximate content of teff grains

The moisture, protein, fat, ash, crude fibre, total carbohydrate, available carbohydrate and energy values of teff grains were (Table 1) 11.30 g, 14.22 g, 2.2 g, 3.03 g, 8.07 g, 72.35 g and 61.16 g and 321kcal per 100 g, respectively.

Table 1: Proximate composition of teff grains

Parameters	Quantity (g/100 g)
Moisture	11.30 ± 0.15
Protein	14.22 ± 0.98
Fat	2.20 ± 0.15
Ash	3.03 ± 0.00
Crude fiber	8.07 ± 0.21
Total carbohydrate	72.35 ± 4.81
Available carbohydrate	61.16 ± 0.86
Energy (kcal)	321.00 ± 1.56

Note: Values are the mean of three replications.

3.1.2 Mineral content teff grains

The mineral content of teff grains (Table 2) shows that 100 g of teff contained 165.96 mg of calcium, 8.01 mg of iron, 4.70 mg of zinc, 182.66 mg of magnesium, 3.70 mg of manganese and 1.09 mg of copper.

Table 2: Mineral content of teff grains

Minerals	Quantity (mg/100 g)
Calcium	165.96 ± 0.75
Iron	8.01 ± 0.44
Zinc	3.70 ± 0.26
Magnesium	182.66 ± 1.52
Manganese	3.70 ± 0.10
Copper	1.09 ± 0.01

Note: Values are the mean of three replications.

3.1.3 Nutraceutical content of teff grains

Nutraceutical contents,*viz.,* dietary fibre, total polyphenols, antioxidant activity and vitamin E content of teff grains are depicted in Table 3. Teff grains had 1.3 g of soluble dietary fibre, 5.05 g of insoluble dietary fibre and 6.34 g of total dietary fibre per 100 g. The total polyphenol was found to be 233.1 mg GAE per 100 g. Antioxidant activity and vitamin E content of teff grains were noted to be 140.33 µ mol TE per g and 0.08 mgper 100 g, respectively.

Table 3: Nutraceutical content of teff grains

Parameters		Quantity
Dietary fibre (g/100 g)	Soluble	1.3 ± 0.00
	Insoluble	5.05 ± 0.00
	Total dietary fibre	6.34 ± 0.00
Total polyphenols (mg GAE/100 g)		233.1 ± 4.34
Antioxidant activity (DPPH) (µ mol TE/g)		140.33 ± 1.52
Vitamin E (mg/100 g)		0.08 ± 0.01

Note: Values are the mean of three replications, GAE-gallic acid equivalents, TE-Trolox equivalent, DPPH-2,2-diphenyl-1-picrylhydrazyl.

3.1.4 Antinutrient content of teff grains

Antinutrients, *viz.,* tannins, phytic acid and oxalates were found to be 19.66 mg CE, 684 mg and 99.66 mg per 100 g, respectively, in teff grains.

Table 4: Antinutrient components of teff grains

Parameters	Values
Tannin (mg CE/100 g)	19.66 ± 0.05
Phytic acid (mg/100 g)	684 ± 1.00
Oxalates (mg/100 g)	99.66 ± 0.57

Note: Values are the mean of three replications, CE- Catechin equivalents.

3.2 Nutritional efficacy of teff grains

Nutritional efficacy, *viz., n vitro* protein digestibility, starch, *in vitro* starch digestibility, and predicted glycemic index were analyzed. The nutritional efficacy of teff grain is shown in Table 5. Teff grain had an *in vitro* protein digestibility of 72.65 per cent. About different types of starch, higher levels of rapidly digestible starch (51.49 %) and less percent of slowly digestible starch (41.67 %) were recorded. *In vitro* starch digestibility of teff grain at 30, 60, 90 and 120 min of hydrolysis were 57.22, 78.47, 97.73, and 103.53 mg of glucose per min, respectively. The predicted glycemic index of teff grain was 47.05.

Table 5: Nutritional efficacy of teff grains

Parameters		Quantity
In vitro protein digestibility (%)		72.65 ± 0.00
Types of starch (%)	Rapid digestible starch	51.49 ± 0.01
	Slow digestible starch	41.67 ± 0.00
In vitro starch digestibility (mg glucose/min)	30 min	57.22 ± 0.01
	60 min	78.47 ± 0.00
	90 min	97.73 ± 0.00
	120 min	103.53 ± 0.00
Predicted glycemic index		47.05

Note: Values are the mean of three replications.

3.3 Cooking quality of teff grains on boiling and pressure cooking

The cooking quality of teff grains was analyzed in terms of traditional processing methods including boiling and pressure cooking of teff grains. Cooking parameters are judged w.r.t per cent increase in weight, volume, cooking time, water uptake ratio, and volume expansion ratio are presented in Table 5. The percent increase in weight in boiled and pressure-cooked teff grain was 327.18 g and 329.42 g, respectively. Among the traditional processing methods, the teff grains increased their weight and volume to the extent of 4-5 times after boiling (Table 6) and pressure cooking. Non-significant difference was observed in percent increase in weight (327.18 g, 329.42 g) and volume (188.10 ml, 183.08 ml) for boiling and pressure-cooking methods. Upon boiling and pressure cooking the teff grain was cooked for 11 and 9 min, respectively. Significant difference (p<0.05) was observed in cooking time with a 't' value of 3.53. The volume expansion ratio and water uptake ratio of teff grain were noted to be 0.36 and 8.50, respectively.

Table 6: Cooking quality of boiled and pressure cooked teff grains

Parameters		Teff grains		't' value
		Boiling	Pressure cooking	
Weight (g)	Initial	10.00	10.00	0.90NS
	After cooking	43.00 ± 1.00	43.66 ± 1.52	0.63NS
	Percent increase	327.18 ± 11.12	329.42 ± 8.61	0.27NS
Volume (ml)	Initial	10.00	10.00	0.90NS
	After cooking	29.00 ± 1.00	28.66 ± 1.15	0.00NS
	Percent increase	188.10 ± 10.52	183.08 ± 7.14	0.68NS
Cooking time (min)		11.00 ± 0.57	9.00 ± 0.57	3.53*
Volume expansion ratio	0.36 ± 0.03	-		
Water uptake ratio	8.50 ± 0.10	-		

Note: Values are the mean of three replications, NS- Not Significant, *Significant @ 5%

4. Discussion

The composition of grain influences grain quality, which distinguishes it from other types. All foods are made up of proximate principles such as moisture, fat, protein, crude fibre, ash, and carbohydrate content, all of which serve diverse purposes. The moisture content of food crops represents the degree of maturity and accumulation of various nutrients. It is an essential criterion that contributes to crop harvest attractiveness. The ash content of a foodstuff indicates the inorganic residue that remains after the breakdown of organic materials. Carbohydrates are a readily available and important source of biological energy, as well as perform a variety of structural and metabolic functions in the body (Potter *et al.,* 1996). The dissimilarity in the proximate composition may be linked to differences in agronomical practices, varietal characteristics, and fertilizer application. Moreover, seed composition can differ based on genetic and environmental factors, source of seed material, seed processing methods, laboratory conditions, reagents, pesticides used, modification of the methods, *etc.* (Jindal, 2016).

The difference in mineral content of teff grains might be due to varietal differences, composition of teff grains, and agronomical practices such as fertilizer application and irrigation which significantly affect the concentration of macro minerals and micro minerals. Washing significantly lowered the iron content of teff by more than 50 per cent, representing that some of the minerals may have originated from soil or processing contamination (Baye *et al.,* 2014). The mineral contamination of teff is likely attributed to its small size which increases its contact with soil over a larger surface area. The traditional threshing method results in a 30 to 38 per cent increase in iron content due to soil contamination (Akansha *et al.,* 2018).

Nutraceuticals, also known as functional foods, are foods that provide health benefits by reducing the risk of chronic diseases, while also supplying essential nutrients. Examples of nutraceuticals include antioxidants, dietary supplements, fortified dairy products, citrus fruits, vitamins, minerals, herbal products, milk, and cereals, all of which are naturally occurring or derived from natural sources. This difference in the dietary fibre content might be due to varietal differences, analytical methods, chemical composition of teff grains, properties of teff bran, and cell wall material which is a major part of dietary fibre (Forsido *et al.,* 2013). Catechin, ferulic, and rosmarinic acids are the major polyphenols in the soluble fraction of teff, whereas ferulic, rosmarinic, and p-coumaric acids are seen inbound fractions (Shumoy and Raes, 2016). The trans-p-coumaric, proto-catechuic, ferulic, and gallic acids are the major free phenolics in brown teff, whereas rutin, ferulic, and proto-catechuic acids are the major ones in white teff (Kotaskova *et al.,* 2016). The differences in antioxidant capacity and total polyphenol content are attributed to genetic variations, the amount of quercetin and luteolin are bound to the cell wall material of teff, which resulted from the hydrolysis of covalent bonds in alkaline conditions (Salawu *et al.,* 2014).

Antinutrients can be present in minimum amounts in almost all diets for a variety of reasons. In present crops, however, their levels are reduced, most likely as a result of the domestication process. Phytate is a key antinutrient that chelates calcium and other micronutrients including iron, copper, and zinc affecting their bioavailability. Other antinutrients, such as polyphenols and oxalates form complexes and tend to decrease the absorption and availability of minerals from meals (Kaushik *et al.,* 2018). In the small intestine and stomach, phytic acid inhibits the action of enzymes that are required for protein breakdown (Kies *et al.,* 2006). The bran is the primary

location in legumes where tannins tend to accumulate in higher concentrations. When ingested, complexes combined with tannins and proteins are formed, which causes the inactivation of many digestive enzymes and slows down protein digestibility (Joye, 2019). The presence of antinutritional components that reduce the nutritional quality of foods, can be significantly decreased by employing traditional processing methods such as fermentation, cooking, soaking, and puffing. Such processing techniques not only reduce antinutritional factors but also enhance the digestibility of protein and improve the biological value of grains (Handa *et al.,* 2017; Jaybhaye and Srivastav, 2015). The differences might be due to varietal differences, composition, environmental factors, type of grains, *etc.*

The ability of specific proteins to be enzymatically hydrolyzed into particular amino acids is called protein digestibility (Culetu *et al.,* 2021). This can be influenced by several factors such as protein quality, processing methods, and the presence of antinutritional compounds, including polyphenols or phytic acid, in addition to protease inhibitors. Phytic acid and polyphenols can form complexes along with proteins, decreasing protein solubility and limiting protease access to vulnerable peptide bonds. Additionally, digestibility of protein may also be affected by its globular structure and conformation, which can change during processing (Carbonaro *et al.,* 1997). *In vitro* measurements play a key role in assessing the release of free sugars from foods during enzymatic digestion. Sampling at regular intervals enables the identification of rapidly available carbohydrate components, offering a measure of glycemic potency. A glycemic response takes place when the absorption of rapidly available carbohydrates surpasses the body's ability to remove glucose from the blood, leading to a temporary buildup of glucose in the bloodstream. Based on the rate of hydrolysis, starch is classified as rapidly digestible, slowly digestible, and resistant starch (Englyst *et al.,* 1996). The higher the non-resistant starch content, the higher the glycemic index (GI). However, foods with higher slowly digestible starch content contribute to a moderate release of glucose in the bloodstream, because slowly digestible starch is less subjected to hydrolysis. Slowly digestible starch (SDS) is fully digested in the small intestine, but at a slower rate, helping to reduce postprandial plasma glucose and insulin levels. It is typically considered the most beneficial form of dietary starch (Jenkins *et al.,* 1981). The glycemic index (GI) is derived from the hydrolysis index (HI) which is referred to as the percentage of the corresponding area under the curve followed by administering an equal portion of carbohydrate from the reference product (Jenkins *et al.,* 1983). Teff grains were expected to have a glycemic index of 47.05, putting them in the low glycemic index category (Allen *et al.,* 2012). The differences could be due to the presence of other factors affecting the digestibility of starch such as high amylose or amylopectin ratios, presence of various antinutrients such as polyphenols, phytic acid, and oxalates (Deshpande and Cheryan, 1984; Thomson and Yoon, 1984). The predicted glycemic index (pGI) is influenced not only by starch composition but also by the presence of specific compounds that may impact hydrolytic enzymes. For instance, some of the phenolic compounds can potentially slow down the action of the α-amylase enzyme resulting in lower GI.

The acceptability of any food grain or product is determined by its cooking quality, which influences its final use in daily life. Parrish and Kumar (2006) reported that cooking time (15 min) for boiling of teff grains which was higher than reported in the present investigation. This might be attributed to varietal variations, quantity of grains, types and amount of water used in cooking.

5. Conclusion

Gluten-free teff grains had better nutritional as well as cooking quality. They are rich in protein, carbohydrates, energy, micro and macro minerals, and nutraceuticals with better *in vitro* properties. Teff grains have better cooking properties which aid in their utilization in different food products like cookies, malt, beverages, and bread. Teff is grouped as a food grain with a low glycemic index. The cooking quality of teff grains revealed that the boiling method took more time to cook (11 min) than the pressure-cooking method (9 min). Teff grains have better cooking properties which aid in its utilization in different food products like cookies, malt, beverages, bread, porridge, dosa, and so on. The future scope of the study can be focused on the effect of processing on the composition and development of therapeutic foods from teff grains.

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Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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