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Mineral Composition of Grain and Straw of Tef *(Eragrostis tef)* Grown on Vertisols

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በኢትዮጵያ ጤፍ ለሰው ምግብነት እና ለእንስሳት መኖ ጥቅም ላይ ይውላል፡፡ በመካከለኛው እና ሰሜን ኢትዮጵያ ጤፍ በሚመረትባቸው አካባቢዎች የጤፍ እህል (ቅንጣት) እና ገለባ ናሙና ተወስዶ የኬሚካል ምርመራ በአውስትራሊያ ተደርጓል፡፡ ናሙና በተወሰደባቸው በሶስቱም አካባቢዎች የተለያየ የኬሚካላዊ ንጥረ ነገር ክምችት እንዳለ ተረጋግጧል፡፡ የአየር ንብረት እና የአፈር ንጥረ ነገር ክምችት መለያየት ለውጤቱ መለያያት እንደምክንያት መጥቀስ ይቻላል፡፡ ይህም ሆኖ ናሙና በተወሰደባቸው ሶስቱም ኣካባቢዎች የተገኘው ውጤት ከምላ ጎደል ተመሳሳይነት ኣለው ማለት ይቻላል፡፡ ይህ ጥናት የጤፍ ቅንጣት እና ገለባ የኬሚካላዊ ንጥረ-ነገር ክምችት ለተመራማሪዎች እና ሞያተኞች እንደ መሰረታዊ መረጃ ያገለግላል፡፡ የተሻሻለ እና ከፍተኛ የንጥረ ነገር ክምችት ያለው የጤፍ ምርት እንዲኖረን ተጨማሪ ጥናቶች በተለያዩ የጤፍ ዝርያዎች እና የኣፈር ኣይነቶች ሊሞከር ይገባል፡፡

Abstract

Tef grain and straw are important food and feed resources, respectively, in Ethiopia. Chemical analysis was carried out on tef grain and straw grown on Vertisols of three areas of the central and northern districts in Ethiopia in 2008. The grain and straw samples were analyzed from nitric acid- hydrogen peroxide digest using Inductively Coupled Plasma Atomic Emission Spectrometry (ICPAES) in Australia. Variability among districts in trends and concentrations of different elements of tef grain and straw were observed. The variability could be due to the differences in agro-ecology and soil mineral composition in the different districts. Even though there were some inconsistencies, chemical composition of tef grown in different agro-ecologies was similar. The current study serves to give basic information on the elemental concentration of tef grain and straw to researchers and professionals in tef mineral element composition and nutrition. Additional studies may require across soil types and using different varieties of tef to strengthen the quality of tef in terms of nutrient composition, and to give indications for further research on nutrients that are deficient in soils and plants.

Introduction

Relative to cereals like wheat, rice, and maize, little is known about the nutritional composition and potential health benefits of tef. This, along with technological limitations in processing tef, has for long restricted its more widespread consumption from its center of origin, Ethiopia. Although tef is the preferred grain for making the staple *Injera* (Senayit *et al.,* 2005), the limited information available to the general public and the lack of global interest in tef, has prolonged thinking by Ethiopians that their grain is of inferior nutritional quality. However over the past decade, the recognition that tef is gluten-free has spurred global research interest by nutritionists and food scientists. Consequently, studies on the nutritional composition of tef and its processing qualities have grown, and the development of new tef-based products has accelerated (Baye *et al.,* 2014).

Mengesha (1966) had studied mineral composition of tef grain and the iron content of tef grain was reported as 115 and 196 mg/kg grain for white and red types, respectively. The difference in mineral content between and within tef varieties is wide ranging. Red tef has a higher iron and calcium content than mixed or white tef (Abebe *et al.*, 2007). On the other hand, white tef has a higher copper content than red and mixed tef. Kabaja and Little (1989) reported that tef straw is unlikely to supply adequate sodium and is marginal to deficient in phosphorous, copper and possibly zinc.

Comparing uncontaminated tef to barley, wheat, maize and sorghum, Mengesha (1966) reported that tef is superior in its mineral content, particularly in calcium and iron. More recently, Baye *et al.* (2014) examined the content of iron, zinc and calcium in tef, barley, wheat, and sorghum before and after washing with de-ionized water. As tef grain and straw are the very important food and feed source to Ethiopian human and livestock, respectively, detailed and up-to-date information on the chemical (mineral) composition of tef is beneficial. Hence, the aim of this research was to determine some chemical composition of tef grain and straw grown on Vertisols of three different agro ecologies in Ethiopia.

Methodology

Sampling

Tef grain and straw samples were collected from three tef growing districts in Ethiopia. The samples were collected from thirty-four tef growing Vertisol fields. Sample tef varieties were Dz-Cr-387 and Dz-Cr-196 in Ada Liben and La’elay Michew districts, respectively, but local variety in the case of Alamata district. The general characteristics of sampling districts and selected soil properties partly adapted from Bereket *et al.* (2011) are depicted in Tables 1 and 2.

Table 1. Description of the study areas

Site	Altitude (m)	Rain fall average (mm)	Rainfall 2008 (June-Nov), mm	Agro-ecological Zone (AEZ)	Major crop types	Farming system
Eude, Ada liben, Oromiya	1886	867.70	811.20 (709.4)	Tepid to cool sub-moist mountains and plateau (SM2-5)	Tef, wheat, chickpea, faba bean, grass pea, lentil	Cereal-legume-livestock
Hateseb, La'elay Michew, Tigray	2083	768.72	620.30 (442.2)	Tepid to cool sub-moist mountains and plateau (SM2-5)	Tef, wheat, barley, chickpea, faba bean, grass pea, fenugreek, field pea and lentil	Cereal-legume-livestock
Selam Bikalisi, Alamata, Tigray	1525	706.80	499.00(424)	Hot to warm sub-moist lowland plains (SM1-3)	Sorghum and Tef	Sorghum/Tef-livestock

Table 2: Selected soil properties of Tef fields on Vertisols

Soil parameter	Site		
	Ude (n=12)	Hatsebo (n=12)	Selam Bikalisi (n=10)
pH $_{water}$ (1:2.5)	6.71 ± 0.08	7.84 ± 0.10	7.96 ± 0.05
EC $_{water}$ ((1:2.5) ds m^{-1})	0.05 ± 0.01	0.44 ± 0.13	0.21 ± 0.02
Organic carbon (%)	1.26 ± 0.07	0.84 ± 0.05	1.15 ± 0.05
CEC (meq100g $^{-1}$)	44.0 ± 0.93	55.4 ± 1.45	52.1 ± 0.83
Calcium carbonate (%)	1.29 ± 0.12	2.14 ± 0.30	4.17 ± 0.43
Sand (%)	15.2 ± 0.95	14.4 ± 1.10	24.2 ± 1.17
Silt (%)	27.0 ± 0.95	27.5 ± 0.97	35.1 ± 1.17
Clay (%)	57.9 ± 0.78	58.2 ± 1.11	40.8 ± 1.60

Data represent means ± standard error. † Figure in parenthesis indicated the number of farmers' fields sampled. Soil pH, electrical conductivity (EC) and organic carbon (Jackson 1967); Cation exchange capacity (Chapman 1965); $CaCO_3$ (Allison and Moodie 1965) and Soil texture (Day, 1965).

Preparation of Grain and Straw Samples and Analysis

Straw samples were washed with deionized water and finally in distilled water until the foreign materials were completely removed. The extra moisture was wiped out and the samples were placed in paper bags and dried in an oven at 70°C for 24 hours. Straw samples were ground in a stainless steel grinder. Grain samples were cleaned from any dust and oven dried. After receiving phytosanitary certificate and material export permit from the Ministry of Agriculture and Rural Development, and Institute of Biodiversity in Ethiopia, the grain and straw samples were shipped to Waite Analytical Services, University of Adelaide, Australia for analysis. The grain and straw samples were analyzed for the different elemental concentration from nitric acid- hydrogen peroxide digest using Inductively Coupled Plasma Atomic Emission Spectrometry (ICPAES).

Data Analysis

Data analysis was performed using SPSS software Version 20 for windows (International Business Machine (IBM), 2011) to compile the mineral elemental composition of tef grain and straw and some selected soil properties.

Results and Discussion

Tef Grain Mineral Element Composition

Table 3 presents mineral composition of tef grain grown on Vertisols of Ethiopia. The major elemental composition of tef grain followed the order of P >K > Mg > S >Ca > Fe > Mn >Al > Zn >Na > Cu in Ada Liben district, K > P > Mg > S >Ca > Mn > Fe >Na > Zn > Cu > Al in La'elay Michew district and P > K > Mg > S >Ca > Fe > Mn > Al > Na > Zn > Cu in the district of Alamata. The variability among the districts in the trend and elemental concentration could be due to differences in agro-ecology and growing potential of tef in the different districts (Bereket *et al.*, 2011). In the present study tef grain P concentration was comparable while K content which was higher than earlier studies (Mengesha, 1966) and lower than that of Tekalign and Parsons (1987).

Tef grain Mg concentration was higher than the previous studies while the Ca concentration was in between the results of these two studies (Mengesha, 1966, and Tekalign and Parsons, 1987). Mean Fe concentration of tef grain samples collected from La'elay Michew district was lower than the previous studies whereas the samples collected from Ada Liben and Alamata districts were in between the results of the previous studies (Mengesha, 1966, and Tekalign and Parsons ,1987). Considering the mean Fe tef grain concentrations of the three districts, the assumption of the richness of tef grain in Fe content did not correspond with the results of this study. However, very high Fe concentrations were recorded from one tef grain sample in Ada Liben (150 mg/kg grain) and two samples in Alamata (152 and 200 mg/kg grain) districts. These samples might not represent the inherent characteristics of Tef. The concentration of Mn in tef grain was higher and tef grain concentrations of Zn, Cu and Na were lower than the previous studies (Mengesha, 1966; Tekalign and Parsons, 1987). In contrast, in the present study the concentrations of Cu, Zn, and Ca were higher than the study reported by Abebe *et al*. (2007). The grain Zn concentration in all the study sites was lower compared with the recommended target Zn concentration in grains (40-60 mg kg^{-1}) for human nutrition (HarvestPlus, 2014; Graham *et al*., 2007). However, results from the present study indicated tef grain tremendously contribute P, K, Mg, Ca, Fe, Mn and Zn in the daily human food requirement (Table 3). While its contribution for Na, Se, Mo and Cr in the daily human requirement is small.

Tef Straw Mineral Concentration

Minerals, both macro and micro minerals, are required for the normal functioning of all metabolic processes in ruminants. Dietary deficiencies or excesses of certain minerals and vitamins can result in sever health consequences and substantial economic losses in animal productivity (Spears and Weiss, 2014). Different minerals though are required in trace amount enhances the metabolism of ruminant animals thereby feed intake. A study by Lai *et al.* (2009) reported cows supplemented with Cr manifested higher blood glucose, which is attributed to higher Dry Matter Intake and gluconeogenesis. Table 4 presents elemental concentrations of tef straw grown on Vertisols of Ethiopia. Samples of K, Ca, P, S, Mg, Fe, Al, Mn, B, and Ti concentrations of tef straw followed the order of Alamata > La'elay Michew > Ada Liben. The highest Zn concentration of tef straw was recorded in the district of Alamata. The concentrations of Zn tef straw samples collected from Ada Liben and La'elay Michew were comparable. Tef straw Na concentration was the highest in the district of La'elay Michew followed by Alamata and Ada Liben. Copper and Cr concentrations of tef straw were comparable in all the three districts. The concentrations of K, P, Ca, Na and Zn tef straw of the present study were lower than the previous study by Kabaja and Little (1989). Magnesium and Mn concentrations of tef straw collected from the district of Alamata were higher and samples collected from the districts of Ada Liben and La'elay Michew were lower than the previous study by Kabaja and Little (1989). The Fe concentration of tef straw was the highest in Alamata district followed by La'elay Michew and Ada Liben.

Table 3. Mineral element composition of tef grain grown on Vertisols of three districts in Ethiopia

Elemental content ($mg\ kg^{-1}$)	Site			
	Ude (12)†	Hatsebo (12)	Selam Bikalisi (10)	Human requirement (mg/day)#
P	4375 ± 109	4400 ± 110	4340 ± 86	1500
K	3950 ± 61	4892 ± 69	4290 ± 111	4700
Mg	1978 ± 34	2073 ± 31	2023 ± 46	310-420
S	1510 ± 23	1676 ± 33	1708 ± 34	
Ca	1361 ± 25	1449 ± 40	1545 ± 60	1000-1200
Fe	76.4 ± 8.8	47.3 ± 2.6	78.1 ± 17.1	8-18
Mn	70.4 ± 7.9	60.00 ± 5.6	65.5 ± 4.9	1.8
Al	42.5 ± 9.8	6.7 ± 2	42.9 ± 19.0	
Zn	27.6 ± 0.6	28.8 ± 0.5	31.0 ± 1.5	8
Na	20.5 ± 1	43.9 ± 4.1	36.3 ± ±3.3	1500
Cu	7.7 ± 0.2	7.3 ± 0.2	8 ± 0.4	
B	1.5 ± 0.04	2.1 ± 0.1	2.1 ± 0.1	
Ni	1.5 ± 0.1	1.2 ± 0.04	5.56 ± 0.2	
Ti	0.6 ± 0.1	0.2 ± 0.05	1.6 ± 0.5	
Se	< 10	< 10	< 10	55
Pb	< 3	< 3	< 3	
Mo	< 1	< 1	< 1	45
Co	< 1	< 1	< 1	
Cr	< 0.6	< 0.6	< 1	30-35
Cd	< 0.3	< 0.3	< 0.3	

Data represent means ± standard error † Figure in parenthesis indicate the number of Tef farmers' fields sampled
http://healthyeating.sfgate.com#

Relatively higher Fe in Tef than a legume grass pea content was observed in a study by Lemma and Smit (2005). Exceptionally the K content of the straw across all the locations exhibited higher values than the K grain content and the requirement for both sheep and cattle. Sheep are sensitive to Cu and the current result lies exactly to the requirement for all the locations. The results from the present study indicated tef straw tremendously contribute P, S, Mg, Ca and Zn in the daily feed requirement of sheep and cattle (Table 4). While its contribution for Na was small and for K, Fe and Mn were high.

Table 4. Straw mineral composition of tef grown on Vertisols

Elemental content (mg kg^{-1})	Site			Requirement*	
	Ude (12) †	Hatsebo (12)	Selam Bikalisi (10)	Sheep**	Cattle **
K	8908 ± 354	9725 ± 497	10120 ± 524	5000	5000
Ca	2229 ± 94	2957 ± 165	3660 ± 130	1400-7000	2000-11000
P	969 ± 70	1224 ± 206	1291 ± 180	900-3000	1000-3800
S	959 ± 53	1603 ± 79	1722 ± 85	2000	1500
Mg	755 ± 47	1680 ± 70	2202 ± 147	900-1200	1300-2200
Fe	108 ± 9	175 ± 12	247 ± 28	40	40
Al	74 ± 8	133 ± 11	171 ± 20		
Na	49 ± 9	211 ± 77	92 ± 16	700-1000	800-1200
Mn	48 ± 3.3	51 ± 7	80 ± 6.6	20-25	20-25
Zn	16 ± 0.8	15 ± 1.4	19 ± 2.6	9-20	9-20
Cu	4.4 ± 0.2	4.2 ± 0.2	4.4 ± 0.3	4.0-14	4-14
Mo	3.3 ± 0.5	1.5 ± 0.2	1.8 ± 0.5		
Ti	3.3 ± 0.3	4.6 ± 0.3	13 ± 2		
B	2.6 ± 0.2	4 ± 0.3	4.2 ± 0.3		
Ni	2.3 ± 0.1	2.0 ± 0.11	3.7 ± 0.2		
Cr	3 ± 0.3	2.9 ± 0.2	3 ± 0.2		
Se	< 10	< 10	< 10	0.05	0.04
Pb	< 3	< 3	< 3		
Co	< 1	< 1	< 1	0.11- 0.15	0.07- 0.15
Cd	< 0.3	< 0.3	< 0.3		

*Data represent means ± standard error † Figure in parenthesis indicate the number of Tef farmer fields sampled *lower values show maintenance requirement and higher values for pregnancy or productivity ** NRC (National Research Council), (1996)*

Conclusion

Tef is a good source of essential fatty acids, fiber, minerals (especially calcium and iron), and phytochemicals, such as polyphenols and phytates. Relative to wheat, rice, and maize, little is known about the nutritional composition and potential health benefits of tef. Even though there were some inconsistencies, chemical composition of tef grown in the three different agroecologies (Adaliben, Alamata and Laelay maichew) was similar. Potassium, calcium, and iron concentrations were higher in straw than grain in the study areas while P and Cu were higher in tef grain than straw. The current study is up-to-date, informative on the elemental composition of tef grain, and straw. The information generated from this study can be beneficial to researchers and professionals working on tef production and nutrition both for human food and livestock feed.

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