Chemical Composition of Teff (*Eragrostis tef*) Compared With That of Wheat, Barley and Grain Sorghum[1]

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The chemical composition of teff, analyzed from uncontaminated seeds, revealed the superiority of the species in mineral nutritive value. Teff's exceedingly high iron and calcium content was confirmed. The high iron content of teff reported by the Ethiopia Nutrition Survey must have been due to certain inherent factors of the species, not only a result of contamination. The magnitude of mineral absorption varied among tested teff strains which was considered an important criterion for future selection program within the species.

Ethiopia is the only country in the world that uses teff as a cereal crop. The species is cultivated for its hay in a few other places of the world, such as Kenya, South Africa and Australia. In Ethiopia, the production of teff exceeds all other cereal crops put together. Most of the fertile and best agricultural highlands in Ethiopia are annually tilled for the cultivation of teff. The best kind of "Ingera"[3] is made out of teff flour. The Ethiopion farmer has grown teff as far back as recorded history goes. The earliest use of teff seeds for human consumption is lost in antiquity.

Few and scattered reports have been published on the early history of teff. Vavilov (1957) recorded Ethiopia as the center of origin for teff. According to Ciferri and Baldrati (1939), Unger (1866) found a small quantity of teff seeds in a brick of the old Egyptian pyramid of Dassur, built in 3359 B.C. In 1867, Unger again reported that he found teff seeds in a brick taken from the ruins of the ancient Jewish town of Ranses, built in 1400–1300 B. C. He then concluded that teff was grown in Egypt before the 13th Century B.C. However, Koernicke (1885), according to Ciferri and Baldrati, thought that the seeds found by Unger were those of *Eragrostis pilosa* (L.) P.B. which apparently grows abundantly in Egypt. It is most probable that the matured plants of *E. pilosa* were then used to solidify the clay bricks. Even now, the same method of plastering and solidifying mud walls with teff straw is commonly practiced in Ethiopia.

According to Rouk and Hailu Mengesha (1963), the Biochemistry Department of Oklahoma State University reported 10 to 11% protein, 2 to 3% fat, about 81% nitrogen free extract; and about 0.2% calcium and 0.4% phosphorus from moisture free basis analysis of teff seeds. Di Maio *et al.* (1962) stated that the balance among the essential amino acids was excellent in teff, except for lysine. Chichaibelu (1965) showed experimentally that it was possible to improve the teff diet by supplementing with fenugreek (*Trigonella foenum-graecum*) and L-Lysine.

The Interdepartmental Committee on Nutrition for National Defense (Ethiopia Nutrition Survey, 1959) reported that the iron

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[3] An Amharic name for a flat, very soft, circular and slightly sour homemade bread, made only in Ethiopia from teff, wheat, barley, maize, grain sorghum or from their mixtures.

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TABLE 1

CHEMICAL COMPOSITION OF TEFF SEEDS COMPARED WITH SPRING WHEAT, WINTER BARLEY AND GRAIN SORGHUM. DIRECT READING EMISSION

Chemical element	Purple teff pure strain[a/]		Purple teff 12 mixed strains			Purple teff grand mean	White teff pure strain[b/]			White teff 12 mixed strains			White teff grand mean	Spring wheat grand mean	Winter wheat grand mean	Winter barley grand mean	Grain sorghum grand mean
	First sample	Second sample	First sample	Second sample	Third sample		First sample	Second sample	Third sample	First sample	Second sample	Third sample					
K%	.55	.59	.24	.21	.22	.36	.33	.33	.33	-1	-1	-1	.20±	.37	.33	.44	.44
P%	.41	.42	.45	.47	.44	.44	.49	.47	.48	.46	.42	.44	.46	.51	.40	.48	.52
Ca%	.13	.15	.20	.21	.21	.18	.17	.15	.16	.20	.17	.19	.17	-1	-1	-1	-1
Mg%	.15	.16	.19	.20	.18	.18	.19	.18	.18	.20	.18	.19	.19	.15	.12	.13	.18
Mn ppm	15.00	16.00	24.00	25.00	26.00	21.20	17.00	16.00	17.00	47.00	40.00	46.00	30.00	53.00	36.00	12.00	29.00
Fe ppm	116.00	138.00	230.00	238.00	241.00	196.00	110.00	95.00	113.00	132.00	110.00	132.00	115.00	78.50	40.00	35.00	66.50
B ppm	16.00	16.00	14.00	13.00	13.00	14.00	14.00	13.00	13.00	13.00	13.00	13.00	13.00	12.00	11.50	11.00	16.50
Cu ppm	46.00	47.00	61.00	58.00	57.00	53.00	23.00	22.00	24.00	49.00	48.00	50.00	36.00	20.00	11.00	14.00	23.50
Zn ppm	55.00	57.00	80.00	76.00	71.00	67.00	63.00	61.00	66.00	73.00	70.00	74.00	67.48	60.00	39.50	45.00	44.00
Al ppm	19.00	26.00	123.00	115.00	134.00	83.00	-1	-1	-1	15.00	13.00	15.00	.12±	-1	-1	-1	-1
Sr ppm	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Mo ppm	.6	.6	1.10	.8	.8	.78	.6	.6	.7	.8	.9	.8	.74	.6	.55	.4	.45
Co ppm	.5	.4	.9	.6	.2	.52	.5	.6	.4	.8	.9	.6	.64	.6	.55	.3	.3
Na ppm	247.0	257.0	209.0	197.0	196.0	220.0	218.0	246.0	217.0	194.0	209.0	189.0	212.17	195.0	168.50	392.0	141.50
Ba ppm	14.00	16.00	23.00	23.00	23.00	19.00	22.00	21.00	22.00	27.00	23.00	26.00	23.50	7.50	6.00	7.00	-1
SiO_2%	-1	.09	.15	.16	.16	.31	-1	-1	-1	.09	-1	.09	-1	-1	-1	-1	-1

In K Ca, -1 = less than 0.10%; in Al and Na, -1 = less than 10 ppm (parts per million); in Sr and Ba, -1 = less than 1 ppm; in SiO_2, -1 = trace

a/ Code No. 106 = pure line of purple teff

b/ Code No. 71 = pure line of white teff and calcium content of teff was much higher than that of wheat, barley and sorghum. This finding on high iron content of teff was challenged by Almgard (1963). According to Almgard (1963), Darby reported a low frequency of anemia in Ethiopia which he thought was the result of the high iron content of teff. It is known that anemia results when the iron intake by humans is low or when the iron is not properly assimilated by the body (Gilbert, 1953). Almgard (1963) stated that the iron content of cleaned red and white teff was 0.0052% and 0.0055%, respectively. He also reported that the iron content of cleaned teff seeds was the same as that of wheat, barley and other cereals, which is contrary to reports made by Ethiopia Nutrition Survey (1959), Darby, according to Almgard (1963) and Mengesha (1964).

Almgard (1963) concluded that the high content of iron in teff and other Ethiopian pulses was due to soil and species contamination. His work, however, does not show that he had analyzed uncontaminated teff seeds. The Ethiopia Nutrition survey stated also that the high iron content of teff may reflect some contamination. However, the committee related the fact that all samples analyzed, as well as the prepared foods, showed the high iron content of teff. No analysis has been published on previously uncontaminated teff seeds.

Materials and Methods

Twelve white and 12 purple line teff strains were randomly selected from 124 teff selections collected by the author from the major teff-producing areas of Ethiopia. The 24 strains were grown out in the field at Purdue University's Agronomy farm, West Lafayette, Indiana. The matured panicles of each strain were cut by hand with the aid of grass shears and immediately put in paper bags. The panicles in paper bags were dried at 38°C for a minimum of 72 hours. The dried panicles were then threshed by hand, and the uncontaminated

TABLE 2

Comparison of the Present Chemical Analyses with the Results Given by the National Academy of Sciences (1958). Figures are Given in Per Cent of Dry Matter

Crop	Mg		K		P		Ca		Fe	
	A[a]	B[b]	A	B	A	B	A	B	A	B
Purple teff	.176	-*	.362	-	.438	-	.18	-	.019	-
White teff	.186	-	.200	-	.460	-	.17	-	.012	-
Spring wheat	.150	.13	.375	.40	.515	.44	<.10	.09	.007	.005
Winter wheat	.125	.11	.355	.44	.405	.33	<.10	.06	.004	.005
Barley	.130	.14	.440	.60	.480	.47	<.10	.09	.004	.006
Grain sorghum	.180	.19	.440	.38	.520	.35	<.10	.05	.006	.005

a/Figures given under column A represent Mengesha's report

b/Figures given under column B represent The National Academy of Sciences' report

* Not reported by National Academy of Sciences

seeds were kept in glass containers for subsequent treatment. Soil and weed seed contamination was carefully avoided.

For comparison, clean and uncontaminated seeds of spring wheat (variety Axminister Cl 8195), winter wheat (Knox 62, Cl 13701, winter barley hull-less Purdue 5627-A-12-11) and grain sorghum (mixed strains) were obtained from the Agronomy Department, Purdue University. All seeds were ground with chromium knives and cleaned with chromium screens to avoid iron chips which might enter into the samples and influence the results. The flour samples of all the seeds were assigned random numbers and were sent in four to six replications to the Ohio State University, Agricultural Experiment Station, Wooster, Ohio, for chemical analysis. The analysis of the purple and white teff flour were from pure and mixed batches. The Direct Reading Emission Spectrography method of Ohio State University was used to determine the chemical composition of all the samples.

Results and Discussion

Table 1 shows the complete result of the chemical analyses of purple teff, white teff, spring wheat, winter wheat, winter barley and grain sorghum. In phosphorus, magnesium, boron, strontium and molybdenum content, all of the crops included in this study show relative equal amounts. Both purple and white teff yielded lower content of manganese than the other crops. But in most of the rest of the mineral elements, particularly calcium, iron, copper, zinc, aluminum (not so for white teff), sodium (except winter barley) and barium, teff had a higher content. The cereal crops seem to be uniformly low in strontium. Purple teff was higher in potassium and aluminum than white teff. White teff was slightly higher manganese than purple teff. In many of the rest of the mineral elements, purple teff was silghtly higher than white teff.

Examination of the results in Table 1 shows variation in chemical content between strains of teff. This is shown, for example, in aluminum content. When the pure strain (code No. 106) of the purple teff gave from 19 to 26 ppm of aluminum, the 12 mixed strains of purple teff together gave 115 to 134 ppm of aluminum. Apparently, there

TABLE 3
IRON CONTENT OF TEFF FROM THREE INDEPENDENT ANALYSES

Name and condition of crop	Fe content of cleaned seed recounted to % of dry matter (Almgard 1963)	Fe content of uncontaminated seed as % of dry matter (Mengesha 1964)	Fe content of cleaned seed as % of dry matter (Eth. Nut. Survey 1959)
Purple teff mixed strain	.0052	.0196	-
Purple teff pure strain	-*	.0127	-
White teff mixed strain	.0059	.0115	-
White teff pure strain	-	.0106	-
Teff, purple and white mixed	.0055	.0155	.1050

* unavailable data

were certain strains within the remaining 11 purple strains which were high in aluminum content. Strain variability was indicated also in potassium content of white teff. Such an inherent capacity of teff strains to absorb soil mineral nutrients at different rates could be a variable to consider in future selection and hybridization programs.

Table 2 shows that the present chemical analyses of wheat, barley and grain sorghum was closely related to that reported by the National Academy of Sciences (1958), which unfortunately did not include teff. The close relationship between the two results does, however, indicate the reliability of the present analysis on the crops other than teff. But, since all the crops, including teff, were prepared and analysed at the same time and in exactly the same way, there is no reason to suspect the accuracy of the present analysis on teff. Hence, the iron content of teff is much higher than the iron content of all the cereal grains tabulated in the National Academy of Sciences' Composition of Cereal Grains and Forages (1958). Therefore, Almgard's statement that the iron content of teff is of the same amount as in other cereals cannot be accepted on the basis of the present investigation. In fact, Table 1 shows that the iron content of teff is about two to three times as much as that of wheat, barley and grain sorghum.

Both the Ethiopia Nutrition Survey and Almgard analysed teff seeds collected from ordinary market places. Hence, there is a good possibility that their seeds were contaminated with soil, since the traditional threshing method in Ethiopia is by letting cattle tread on the harvested and assembled plants. Inasmuch as Almgard has stated that soil was seen on the surface of the seeds even after they had been washed, his contaminated and cleaned teff seeds should have given a higher iron content than that being reported presently from uncontaminated material: Table 3. Such an unexpectedly reversed relationship throws some doubt on the accuracy of Almgard's analysis. In view of the above, the results presently obtained from the analysis of uncontaminated teff seeds would seem to be more reliable.

The Ethiopia Nutrition Survey and later Darby (according to Almgard) reported in separate publications a low frequency of anemia in the highlands of Ethiopia. They attributed this to the high iron intake. Almgard, however, did not agree with them, since he felt that teff's iron content was not higher than the amounts found in wheat and other cereals. But now that the high iron content of teff is confirmed, it might be advisable for medical people to look closely into the true relationship between low frequency of anemia in Ethiopia and high iron content of teff.

Almgard rejected Darby's equality sign between the chemical composition of the species and that of the food. With respect to iron content of teff, however, the whole seed is ground into flour, and most of the iron found in the seed must be found in the flour and, subsequently, in the food. Therefore, it should be reasonably safe to predict a positive correlation between the iron content of teff seed and teff ingera. Such a correlation cannot be predicted in wheat, for example, since only 60 to 80% of the wheat is used in bread making (Huffnagel, 1961).

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