Asian Journal of Chemistry Vol. 20, No. 1 (2008), 723-730

Mineral Composition of Some Sweet Corn (*Zea mays* L. *saccharata* Sturt.) Genotypes Under Semi Arid Region

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In this study, mineral contents of some sweet corn genotypes are determined. The research was carried out during 2003 and 2004 in Sanliurfa, Turkey. Eight hybrid and two open-pollinated sweet corn genotypes were grown in the field and kernel samples analyzed by an atomic absorption spectrometry. Some minerals such as K, Ca, Mg, Na, Fe, Mn, Cu and Zn were determined in kernel of sweet corn genotypes. Genotypes were statistically significant (**$p < 0.01$) for all minerals in both years. K and Ca content of open-pollinated genotypes were higher than hybrid values whereas Fe, Mn and Cu contents were lower than hybrid values. Mg, Na and Zn values were similar for hybrids and open-pollinated genotypes. Mineral composition of some genotypes such as Reward, Jubilee, Merit and Secerac were higher than other genotypes. According to correlation analysis, K and Ca were negative correlated with some micronutrients like Fe, Mn and Cu. Correlations among Fe, Mn and Cu were positive and significant.

Key Words: Metals, Minerals, Sweet corn, Microwave digestion, Atomic absorption spectrometry.

INTRODUCTION

In contrast to dent and flint corns, sweet corn is used primarily for human consumption. Sweet corn consumption has increased considerably over the past 30 years world-wide. Sweet corn is an important export crop and acreage fluctuates from year to year in response to variable export market demand and market price. Sweet corn is produced for human consumption as either a fresh or a processed product. Fresh-market sweet corn is a high value crop and become an attractive option for consumers due to its delicious taste, delicate crust, tender and high sugary texture compared to other corn varieties[1].

Sweet corn is used as one of the major sources of protein and energy in the preparation of different types of human foods in many parts of the world. The consumers prefer canned sweet corn or mixtures of sweet corn with other foods. It is used as an appetizer or in salads. It is also consumed

as frozen sweet corn and can be kept fresh for a long time. Dough made from dry kernels of sweet corn is used for baby food, chips, dough products, pasta and cakes[2].

Sweet corn can be an excellent source of both vitamins C and E and some minerals such as Ca and P are required as structural components of the skeleton and others like Na and K function in acid-base balance. Cu and Fe are also required for the activity of enzymes[3]. Zinc is an essential element for all living organisms. Zinc deficiency has been shown to be the cause of dwarfism and hypogonadism among adolescents from low social classes. On the other hand, toxic heavy metal contamination in soils and crop plants is of major importance due to their health effects on humans and other animals[4]. Therefore, mineral composition of sweet corn for human health is important.

Mineral compositions are also important in physiological and biochemical functions in plants. Several metabolic processes, *i.e.* photosynthesis, cellular respiration, nutrient uptake and photolysis of water, may be affected by presence of trace elements[5] such as Ca, Zn, Cu, Fe, Mn and Mo.

Mineral composition of sweet corn for human diet is very important. Thus, this study aimed to determine the macro and micro nutrient composition of sweet corn genotypes, to compare hybrids and open-pollinated genotypes for mineral composition.

EXPERIMENTAL

This study was conducted during 2003 and 2004 years in the Field Research Facility of the Faculty of Agriculture at Harran University, Sanliurfa, Turkey. The experimental field is located in Harran Plain (altitude: 465 m; 37º 08' north and 38º 46' east) where the climate varies from arid to semi-arid. The weather is hot and dry from May to September where temperatures can reach up to 46 ºC and relative humidity was below 50 %. On the other hand, the weather is usually warm during winter months and rainfall is rare. The soil of the research field was clay, slightly alkaline, high in lime content and low in salt content. Field capacity of the soil was 33.8 % in dry basis, permanent wilting point was 22.6 % and bulk density of the soil was 1.41 g cm^{-3}.

Land was ploughed and cultivated then prepared for planting with a single pass of a disk-harrow. The experiment was set up as a randomized complete block experimental design with three replications. Each plot area was 14 m^2 (5 m × 2.8 m) and consisted of 4 rows. Distance between rows was 70 cm and intra row spaces were 20 cm. At sowing, 100 kg ha^{-1} pure N, P and K (15-15-15 composite) was applied to each plot and this was followed by 150 kg ha^{-1} N as urea (46 % N) at the 6 leaf stage. The fertilizer was placed 5 cm (2") to the side of the seed row at a depth of 4 cm (1.75").

Eight single cross (F1) hybrid and two open-pollinated sweet corn (*Zea mays* L. *saccharata* Sturt.) genotypes were used as the crop material. The seeds were sown at a 50-60 mm depth on the 28th of June 2003 and the 24th of June 2004. In both years, irrigation water was first applied to all plots using a sprinkler irrigation system. After the emergence of plants, plots were irrigated equally to fresh harvest of sweet corn by the furrow irrigation system. When the kernel moisture was about 72 %[6] and from 2 rows in the centre of each plot were harvested manually. Kernel moisture was determined using a microwave drying method[7]. Cobs were stripped of their husks and weighed. The cobs chosen for evaluation contained distinctly developed kernels taken to the laboratory for analysis.

Kernel samples washed with distilled water, put in paper bags and oven dried to constant weight[8] at 65°C for at least 4 d. Dried samples were homogenized and stored in polyethylene bottles until analysis. Metal tools were not used in any stage of sample preparation. Double deionized water was used for all dilutions. HNO_3 and H_2O_2 were of suprapure quality (Merck). Samples (1.0 g) were digested with 6 mL of HNO_3 (65 %), 2 mL of H_2O_2 (30 %) in microwave digestion system for 31 min and diluted to 10 mL with deionized water. A blank digest was carried out in the same way. Due to higher accuracy with respect to both time and recovery values, this procedure preferred. The recovery values were nearly quantitative (> 95 %) for above mentioned digestion method. An atomic absorption spectrometer with deuterium background corrector was used for elemental analysis. All measurements were carried out in an air/acetylene flame.

Analysis-of-variance (Anova) was conducted on the data for both 2003 and 2004 years. A correlation analysis was performed to determine relationships among tested minerals.

RESULTS AND DISCUSSION

According to variance analyses, genotypes were statistically significant (**$p < 0.01$) for all minerals in both years. Macronutrients like potassium, calcium, magnesium and sodium content of kernel of sweet corn genotypes are given in Table-1. Based on hybrids, K content of kernel was ranged from 10.8 (Merit) to 15.4 g kg^{-1} (Secerac) in 2003 and 11.3 (GH-2547) to 14.5 g kg^{-1} (Secerac) in 2004. As seen from Table-1 that other genotypes varied between these values. K content of Secerac, Lincoln, Martha and Jubilee genotypes were high in both years. The lowest K contents were seen at Merit, GH-2547 and Reward genotypes. K content of open-pollinated genotypes was higher than hybrids. K content of Sanliurfa and Adana genotypes were 16.8-19.2 and 18.1-15.9 g kg^{-1} in 2003 and 2004, respectively. Maddonni *et al.*[9] stated that genotypic difference might affect kernel biomass accumulation in each phase.

Among hybrids, Merit genotype gave the highest Mg values whereas the lowest Mg values were obtained from Reward genotype in both years. Mg content ranged from 0.97 (Reward) to 1.86 g kg^{-1} (Merit), 0.88 (Reward) to 1.78 g kg^{-1} (Merit) in 2003 and 2004, respectively. Mg content of Merit, Jubilee and Martha genotypes were high. Reward, Secerac and GH-2547 genotypes gave the lowest Mg content (Table-1). Variations for K and Mg content among genotypes were lower than other macronutrients (Ca and Na). Mg content of open-pollinated genotypes were 0.94-1.17 g kg^{-1} (Sanliurfa) and 1.41-1.09 g kg^{-1} (Adana) in 2003 and 2004 years, respectively. Quality and chemical composition of grain may be influenced by growing conditions[10,11], cultivars[12] and agricultural practices[13].

Based on hybrids, Ca contents were the lowest at Secerac genotype (66.4 and 78.6 mg kg^{-1}) while the highest values found at Reward genotype (151.4 and 124.1 mg kg^{-1}) in 2003 and 2004 year (Table-1). Ca contents were high at Reward, Jubilee and Martha genotypes. Lower Ca contents were seen at Secerac, Vega and Lincoln genotypes. Ca content of open-pollinated genotypes was higher than hybrids due to thicker shell that contain more Ca content. Ca content of open-pollinated genotypes was 153.4-171.4 mg kg^{-1} (Sanliurfa) and 138.7-161.2 mg kg^{-1} (Adana) in 2003 and 2004 years, respectively. Lower kernel K, Ca and Mg content values than our findings were reported in popcorn genotypes[14]. It is recognized that the mineral concentrations of crops are influenced by the mineral composition of the soil and environment in which plants grow[5,15].

Na content of hybrid genotypes varied between 30.9 (Vega) and 95.6 mg kg^{-1} (Secerac), between 42.8 (Merit) and 96.4 mg kg^{-1} (Jubilee) in 2003 and 2004 years, respectively (Table-1). Similar findings for popcorn genotypes were reported[14]. Na content was the lowest at Vega and Merit genotypes. Secerac, Jubilee and Reward genotypes had the highest Na content in both years.

Micronutrients like iron, manganese, copper and zinc content of kernel of sweet corn genotypes are given in Table-1. Micronutrients such as Fe, Mn and Cu content of open-pollinated genotypes were lower than hybrids (Table-1). Variation level for Fe, Mn and Cu content among genotypes was high. Fe content was 7.1-6.2 mg kg^{-1} for Sanliurfa and 5.3-4.9 mg kg^{-1} for Adana open-pollinated genotype in 2003 and 2004, respectively. Genotypes was different each other for Fe content. Fe content of hybrid genotypes were between 12.2 (Martha) and 20.6 mg kg^{-1} (Vega) in 2003 whereas 12.2 (Secerac) and 21.2 mg kg^{-1} (Vega) in 2004 year. Present results are supported by Oikeh *et al.*[16] who stated Fe content was 15.5-19.1 mg kg^{-1} and genetic component accounted for 11 % of the total variation in kernel-Fe levels.

TABLE-1
MACRONUTRIENT CONTENT OF SOME SWEET CORN GENOTYPES IN 2003 AND 2004 UNDER SEMI ARID REGION

Genotypes	[a]K (g kg^{-1})		Mg (g kg^{-1})		Ca (mg kg^{-1})		Na (mg kg^{-1})	
	2003*	2004*	2003*	2004*	2003*	2004*	2003*	2004*
Jubilee	13.9 ± 0.35	13.5 ± 0.53	1.57 ± 0.05	1.62 ± 0.04	131.0 ± 2.0	113.0 ± 3.05	80.0 ± 1.13	96.4 ± 1.85
GH-2547	12.6 ± 0.56	11.3 ± 1.53	1.10 ± 0.04	1.05 ± 0.04	109.6 ± 2.75	122.4 ± 4.10	66.8 ± 2.01	75.3 ± 1.10
Lincoln	14.6 ± 0.55	13.6 ± 0.70	1.19 ± 0.04	1.36 ± 0.06	83.6 ± 1.77	81.6 ± 4.50	54.7 ± 1.10	66.7 ± 2.33
Martha	13.7 ± 0.79	14.4 ± 0.82	1.48 ± 0.07	1.63 ± 0.05	133.4 ± 2.75	110.5 ± 2.62	49.6 ± 2.80	57.1 ± 1.87
Merit	10.8 ± 0.56	11.6 ± 0.44	1.86 ± 0.10	1.78 ± 0.06	96.4 ± 1.85	104.6 ± 2.46	35.6 ± 1.35	42.8 ± 1.65
Reward	12.6 ± 0.44	13.4 ± 1.22	0.97 ± 0.05	0.88 ± 0.05	151.4 ± 6.41	124.1 ± 6.68	76.4 ± 2.95	84.3 ± 2.07
Secerac	15.4 ± 0.20	14.5 ± 0.82	1.11 ± 0.08	0.96 ± 0.04	66.4 ± 2.50	78.6 ± 0.70	95.6 ± 2.51	83.6 ± 2.17
Vega	11.6 ± 0.20	12.3 ± 0.87	1.33 ± 0.13	1.56 ± 0.08	78.9 ± 1.04	91.5 ± 0.85	30.9 ± 1.61	48.7 ± 1.14
Sanliurfa†	16.8 ± 1.68	19.2 ± 1.47	0.94 ± 0.10	1.17 ± 0.07	153.4 ± 4.29	171.4 ± 6.26	42.5 ± 1.83	65.3 ± 1.57
Adana†	18.1 ± 1.39	15.9 ± 1.40	1.41 ± 0.04	1.09 ± 0.06	138.7 ± 4.14	161.2 ± 6.27	46.7 ± 1.23	58.3 ± 1.42
	[a]Fe (mg kg^{-1})		Mn (mg kg^{-1})		Cu (mg kg^{-1})		Zn (mg kg^{-1})	
Jubilee	17.6 ± 0.79	19.1 ± 0.95	6.7 ± 0.53	6.3 ± 0.67	4.2 ± 0.30	5.8 ± 0.46	19.4 ± 0.76	21.5 ± 0.76
GH-2547	18.1 ± 0.70	15.2 ± 1.08	4.9 ± 0.35	4.4 ± 0.30	8.8 ± 0.44	8.1 ± 0.30	16.7 ± 0.27	17.6 ± 0.82
Lincoln	13.4 ± 1.02	14.6 ± 0.95	6.1 ± 0.20	5.2 ± 0.44	5.7 ± 0.35	4.9 ± 0.20	23.2 ± 0.56	23.4 ± 0.46
Martha	12.2 ± 1.04	13.6 ± 0.92	13.1 ± 0.67	10.6 ± 0.56	5.9 ± 0.27	6.2 ± 0.27	16.6 ± 0.46	16.4 ± 1.05
Merit	15.6 ± 1.00	16.7 ± 1.21	12.8 ± 0.66	14.1 ± 0.70	4.4 ± 0.27	3.9 ± 0.17	32.8 ± 0.27	35.6 ± 0.62
Reward	16.3 ± 0.70	17.4 ± 0.80	13.6 ± 0.17	11.4 ± 0.27	6.8 ± 0.36	7.4 ± 0.35	20.9 ± 1.14	22.4 ± 1.74
Secerac	14.1 ± 0.79	12.2 ± 0.56	12.4 ± 0.78	12.8 ± 0.46	5.6 ± 0.27	5.8 ± 0.36	24.7 ± 0.76	25.6 ± 0.99
Vega	20.6 ± 1.38	21.2 ± 0.95	9.3 ± 0.44	8.8 ± 0.35	6.2 ± 0.36	6.4 ± 0.20	17.9 ± 0.40	19.8 ± 0.61
Sanliurfa†	7.1 ± 0.61	6.2 ± 0.40	3.1 ± 0.30	4.4 ± 0.66	2.3 ± 0.27	3.1 ± 0.70	18.5 ± 1.90	24.2 ± 3.02
Adana†	5.3 ± 0.44	4.9 ± 0.27	3.9 ± 0.27	3.5 ± 0.96	2.8 ± 0.27	2.4 ± 0.44	21.8 ± 2.86	20.4 ± 2.52

†Open-pollinated genotypes; *Denotes significant difference among genotypes $p < 0.01$; [a]Values are mean ± SD.

The highest Mn contents were found at Reward (13.6 mg kg^{-1}) genotype in 2003 and Merit (14.1 mg kg^{-1}) genotype in 2004 year (Table-1). GH-2547 genotype gave the lowest Mn values (4.9 and 4.4 mg kg^{-1}) among hybrids in both years. Reward, Merit, Martha and Secerac genotypes gave higher Mn content than others. Mn content of open-pollinated genotypes were the lower than hybrids. Mineral element uptake by plants may influence by both soil and genetic factors[17].

Based on hybrids, Cu content was the highest at GH-2547 (8.8 and 8.1 mg kg^{-1}) genotype in both years. Cu contents of Jubilee (4.2 mg kg^{-1}) and Merit (3.9 mg kg^{-1}) were the lowest. Cu content of Sanliurfa open-pollinated genotype was 2.3 mg kg^{-1} for 2003 and 3.1 mg kg^{-1} for 2004 year. Adana open-pollinated genotype gave 2.8 and 2.4 mg kg^{-1} in 2003 and 2004 year, respectively (Table-1). Similar results was reported in popcorn[14]. Mineral element uptake by plants may influence by both soil and plant factors. These factors are quantity and mobility of elements in the soil solution and around the plant roots, source and chemical form of elements in soil, pH, organic material and plant species[11].

Zn content of genotypes was ranged from 16.6 to 32.8 and 16.4 to 35.6 mg kg^{-1} in 2003 and 2004 year, respectively. The lowest and highest Zn content values were obtained from Martha and Merit genotypes, respectively. Oikeh *et al.*[16] stated that Zn content varied from 16.5 to 20.5 mg kg^{-1} and reported that genetic component accounted for 34 % of the total variation in the kernel-Zn levels.

Higher Fe, Mn, Mg and Zn content values than present findings were reported in pop corn genotypes[14]. Popcorn pericarp is the thickest among other corn types (dent, flint and sweet corn) is very rich for mineral nutrients[14].

Reward genotype had the richest mineral composition among other genotypes. Ca, Na, Fe, Mn, Cu and Zn contents of Reward genotype were high level. K, Mg, Ca, Na and Fe content of Jubilee genotype, Mg, Ca, Mn and Zn content of Merit genotype, K, Na, Mn and Zn content of Secerac genotype, K, Mg, Ca and Mn content of Martha genotype were found at high level. GH-2547 genotype was found a rich genotype for Ca, Fe and Cu content. K and Zn content of Lincoln genotype and Mg and Zn content of Vega genotype were found at high level. Reward genotype was rich about both macro (Ca and Na) and micronutrients (Fe, Mn, Cu and Zn) whereas Jubilee (K, Mg, Ca, Na) and Martha (K, Mg, Ca) genotypes were richer about macronutrients. Differences in grain mineral element contents among varieties could be associated with differences in adaptation ability of genotypes, genotypic structure and reacted differently to soil and climate conditions. Vyn and Tollenaar[10] reported that lower macro and micronutrient amount than our findings in dent corn. Reason of this may depend on the contents of mineral nutrients and their combinations in soil and species.

K and Ca contents of open-pollinated genotypes were higher than hybrids values whereas Fe, Mn and Cu contents were lower than hybrids values. Mg, Na and Zn values were similar for hybrids and open-pollinated genotypes. Mineral composition of some genotypes such as Reward, Jubilee, Merit and Secerac were higher than other genotypes.

Correlation coefficients of kernel nutrients were given in Table-2. There was positive correlation between K and Ca (0.440**) whereas negative correlation was seen between K and Fe (-0.707**), K and Cu (-0.590**). Between K and Mn correlation was negative (-0.284*). A negative relationships were found between Mg and Na (-0.375**). Between Mg and Zn (0.328*) and between Mg and Fe (0.287*) positive correlation were seen. Ca was negative correlated with Fe (-0.565**), Mn (-0.376**) and Cu (-0.393**). A positive correlation was seen between Na and Cu (0.342**). Fe was correlated positively with Mn (0.411**) and Cu (0.684**). Relationship between Mn and Cu (0.285*), between Mn and Zn (0.414**) were positive. A negative correlation was seen between Cu and Zn as -0.325*. Correlations among Fe, Mn and Cu were positive and significant. K and Ca were negative correlated with some micronutrients like as Fe, Mn and Cu.

TABLE-2
CORRELATION COEFFICIENTS OF KERNEL NUTRIENTS†

Minerals	Mg	Ca	Na	Fe	Mn	Cu	Zn
K	-0.108ns	0.440**	0.101ns	-0.707**	-0.284*	-0.590**	0.167ns
Mg	1	-0.225ns	-0.375**	0.287*	0.234ns	-0.189ns	0.328*
Ca		1	-0.045ns	-0.565**	-0.376**	-0.393**	-0.236ns
Na			1	0.144ns	0.033ns	0.342**	-0.105ns
Fe				1	0.411**	0.684**	0.001ns
Mn					1	0.285*	0.414**
Cu						1	-0.325*

†Two years data was used for correlation analyses. *,**Significant at 0.05 and 0.01 level, respectively. ns: no significant.

In light of the data obtained from present studies, it is indicated that macro and micro nutrient content of sweet corn genotypes was different from each other. Reason of differences was genotypes and genotypic structure (hybrid or open pollinated). K and Ca content of open-pollinated genotypes were higher than hybrid values, whereas Fe, Mn and Cu contents were lower than hybrid values. Mg, Na and Zn values were similar for hybrids and open-pollinated genotypes. According to correlation analysis, K and Ca were negative correlated with some micronutrients like as Fe, Mn and Cu. Correlations among Fe, Mn and Cu were positive and significant.

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(*Received*: 6 January 2007; *Accepted*: 18 September 2007) AJC-5881