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Kernel Quality of Some Sweet Corn Varieties in Relation to Processing

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Abstract

The quality characteristics (dry matter content, soluble solid concentration, kernel colour, sugar, starch and protein content) of fresh, frozen and canned kernels of seven sweet corn varieties ('Lumina', 'Merit', 'Sunshine', 'Jubilee', 'Challenger', 'Yellow Baby' and '2201') were studied. The present research was conducted during 2009 and 2010 in Eskisehir, Midwestern Turkey. The trials were set up in randomised complete block design, with four replications. Ears were harvested and randomly selected for analysis as fresh, frozen and canned. Dry matter content ranged from 34.2% ('2201') to 39.5% ('Yellow Baby'), soluble solid concentration from 16.3% ('2201') to 27.4% ('Yellow Baby'). The sugar content of fresh kernels was higher than other treatments (frozen and canned) for all varieties. The starch content of the varieties was decreased after processing, except in 'Yellow Baby'. Fresh, frozen and canned sweet corn kernels had similar protein contents; the highest protein content was obtained, for all treatments, from 'Challenger', and it maintained its higher protein content after processing. '2201' had the highest sugar and the lowest starch content for fresh, frozen and canned varieties. When compared on a kernel basis, sweet corn marketed as fresh, frozen or canned, it may be feasible to select varieties for different sweet corn markets.

Keywords: canned, fresh, frozen, starch, sugar, *Zea mays* L. var. *saccharata*

Introduction

Sweet corn (*Zea mays* L. var. *saccharata*) is a cultivated plant grown fresh for human consumption and is a raw or processed material of the food industry throughout the world. It is an important source of fibre, minerals and certain vitamins (Lertrat and Pulam, 2007). Sweet corn differs from other corns (field, pop corn etc.). The primary difference is gene expression that determines endosperm carbohydrate content as well as many other genes that affect maize growth (Znidarcic, 2012). It is produced for three distinct markets; fresh, frozen and canned. Production within these markets is largely independent of each other (Kleinhenz, 2008). Both the total production and the value of processed sweet corn have increased 60% over the last 25 years in the world (Williams, 2006). The reasons for the boost in popularity are the domestic consumption, export development and import replacement (Najeeb *et al.*, 2011).

One of the goals of sweet corn producers is to produce sweet corn with a high quality. The quality of fresh, or processed whole kernels, canned or frozen, is determined by its unique combination of flavour, texture and aroma (Lertrat and Pulam, 2007). Sweetness is the major component of flavour and affected by the amounts of sugar and starch in the endosperm (Flora and Wiley, 1974; Azanza *et al.*, 1994). It has been reported that selection for more tender and crispy genotypes with higher sugar and lower starch concentration and an increased sweet corn aroma would increase the eating quality of the product (Azanza *et al.*, 1996).

Based on the nature of kernel sweetness, sweet corns can also be classified into three main genetic groups: standard or sugary (*su*), super sweet or shrunken (sh_2), sugary enhanced (*se*) (Hale *et al.*, 2005). Sugary varieties accumulate less sugar compared with other sweet corn types. They have a creamy texture and good corn flavour and are known for their good germination and seedling vigour. But sugary varieties can lose their kernel quality rapidly after harvest due to the convertion of sugars to starch and moisture loss (Carey *et al.*, 1982, 1984). Shrunken varieties are characterised by kernels that have two to three times more sugar content at typical harvest maturity and have less starch than sugary varieties. The fresh market shelf life is extended because of the slower conversion of sugars to starch after harvest (Azanza *et al.*, 1996). Sugary enhanced varieties have a sugar content twice as much as sugary varieties, extremely tender kernels, creamy texture and good corn flavor. The sweet taste of their kernels is retained longer after harvest. Despite the desirable attributes of shrunken and sugar enhanced varieties, their production has been hindered by reduced field emergence, seedling vigour and standard uniformity (Styer *et al.*, 1980; Andrew, 1982; Douglass *et al.*, 1993).

Sweetness is determined not only by genetics, but also by the way the respective varieties are managed and harvested. Each year, seed companies apply a great number of new sweet corn varieties to variety lists. Primary differences among the hybrid varieties include the duration of their vegetation period, content of sugars, and suitability for various uses (Szymanek, 2012).

In Turkey, no information is available regarding the acreage of sweet corn grown. Despite the above-mentioned knowledge, interest in sweet corn has grown in recent years. Frozen sweet corn kernels are in the first rank among the fresh vegetables for import and frozen sweet corn export value was 36 tons in Turkey in 2010 (Aydın, 2011). This is mainly due to the fact that today more and more farmers are looking for a new alternative to traditional vegetable growing, which is threatened by various cultivation and economic problems. Several studies have been reported in sweet corn kernel quality. Still, studies of quality traits on numerous sweet corn varieties are resource-demanding and rare, including in Turkey. Besides this, many sweet corn varieties are developed under environments which differ from those in target production areas. Therefore, assessing the consistency of variety performance across locations and/or time is important to farmers. Yet, such studies are needed to assist in selecting a variety, maintaining consumer satisfaction and improving our understanding of the relative contributions of variety and environment to variability in quality traits. The objective of this research was to evaluate available commercial sweet corn varieties for their kernels quality. In this way, a wide assortment of varieties (which differ in soluble solids and colour, sugar content and other kernel characteristics) were documented to assist in selecting varieties for different sweet corn markets and increasing the efficiency of future evaluations.

Materials and methods

The field experiments were carried out in the experimental fields of Faculty of Agriculture, Eskişehir Osmangazi University, Eskişehir (39°46'N; 30°33'E; 801 m above sea level), during 2009 and 2010. The soil was sandy clay (44% sand; 20% clay) with 1% organic matter, 0.05% total salt, 5% lime and pH 7.6. Seven sweet corn varieties ('Lumina', 'Merit', 'Sunshine', 'Jubilee', 'Challenger', 'Yellow Baby' and '2201') were used as materials. Each cultivar was sown in randomised complete block with four replications and each experimental plot was 29.4 m^2. Seeds were sown on April 29 in 2009 and on May 19 in 2010 in a spacing of 70 cm x 25 cm. Plants were fertilised with the equivalent of 280 kg N, 110 kg P_2O_5 and 110 kg K_2O per hectare (Turgut, 2000) during the growing season. The drip irrigation was applied as needed and weeds were controlled mechanically by hand. No fungicide or insecticide was applied during cultivation.

When the sweet corn reached harvest maturity (juice consistency of kernels) fifty ears from the centre of each replication were harvested randomly by hand in the morning. Then, the ears were taken to the processing lab and husked, sorted, inspected and divided into the following categories for analysis: twenty ears for fresh kernel measurements, ten ears for frozen kernel measurements and ten ears for canned kernel measurements. Within an hour after harvest, kernels were cut from the ear with machine and the following experiments were conducted.

Freezing kernels

After the water comes to a boil, the cut kernels were blanched 3-5 minutes and cooled. Then, the kernels were put into freezer bags to a level of 3 to 4 inches from the top and the air was squeezed out, leaving 1-inch of head space, labelled, and frozen at –20 °C. The frozen kernels were stored for 6 months. After storage time, the kernels were evaluated according to their sugar, starch and protein content.

Canning kernels

After the water comes to a boil, the cut kernels were blanched 3-5 minutes and then put into clean jars with hot corn and cooking liquid leaving 1-inch of head space. The sealing surfaces of the jars were wiped with a clean damp paper towel and the lids were added and processed in an autoclave at 115 °C for fifty minutes. The canned kernels were stored for 6 months. After storage time, the kernels were evaluated according to their sugar, starch and protein content.

Dry matter content (DMC %)

Kernels were dried in an oven at 65 °C and the weight loss between measurements was < 0.05 g. The percentage difference between the fresh and dry weights was used to calculate the dry matter content of the kernel. This procedure was done for fresh kernels.

Soluble solid concentration (SSC %)

Kernels were cut from the centre section of ten ears from each plot, after a 2-inch section was removed from each end of each ear. Fifteen grams from each ear were placed on a double layer square of cheesecloth. Extract was collected and placed on the ATAGO Mark Digital Refractometer for analysis. This procedure was done for fresh kernels.

Kernel colour

Kernel colour was measured with a colorimeter at the CIE (Commission Internationale De L'eclairage) L*a*b*. Kernels were measured for each replicate, and the colour was characterised by lightness (L*), hue angle ($H^\circ = \tan^{-1}(b^*/a^*)$) and chroma($\sqrt{a^{*2}+b^{*2}}$) (Tuncay *et al.*, 2005). This procedure was done for fresh kernels.

Sugar content (%)

Kernel sugar content was determined by the Lane-Eynon method (Horwitz, 2000). This procedure was done for fresh, frozen and canned kernels.

Starch content (%)

Kernel starch content was determinated by the polarimetric method (Earle and Milmer, 1944). This procedure was done for fresh, frozen and canned kernels.

Protein content (%)

Kernel protein content was determined by the Kjeldahl method (Kirk and Sawyer, 1991). Nitrogen content in the sample was converted to total protein content by multiplying the N percentage by the standard corn conversion factor (6.25). This procedure was done for fresh, frozen and canned kernels.

Data evaluation

Analysis of variance (SAS, 1996) was performed on DMC, SSC and color characteristics for each year. A factorial design was used to analyse for sugar, starch and protein content, with treatments (fresh, frozen and canned) as main factors. Mean differences were determined by an LSD test.

Results and discussion

Dry matter, soluble solid concentration and color characteristics of fresh sweet corn kernels

Dry matter content (DMC) and soluble solid concentration (SSC) of fresh kernels are presented in Tab. 1. DMC was affected significantly by variety in both years ($p<0.01$ and $p<0.05$, respectively). DMC was slightly higher in the second year of the experiment. The 'Yellow Baby' variety had a DMC of 39.1% (2009) and 39.9% (2010), which was significantly higher than other varieties. In the first year of the experiment, the lowest DMC were obtained from 'Merit' and '2201' with a percent of 33.9 while '2201' (34.7%) and 'Challenger' (34.9%) had the lowest DMC in 2010, which was in the range reported for sweet corn previously by Bozokalfa *et al.* (2004).

The effect of variety on SSC was found significant ($p<0.01$) in both years (Tab. 1). SSC was slightly higher in the second year of the experiment. SSC changed between 15.2% and 27.2% in 2009; and between 12.4% and 27.7% in 2010. In general, fresh kernels had higher SSC in 2010 compared to 2009. 'Yellow Baby' had the highest SSC while 'Challenger' had the lowest SSC in both years. SSC data reported here are similar to those found by Kleinhenz (2003) and Hale *et al.* (2005). Many authors stated that the refractometer, which measures SSC, has been utilised as a rapid, preharvest method to determine sweet corn sugar content (Kleinhenz, 2003; Randle *et al.*, 1984). Kumari *et al.* (2006) also reported total sugar, reducing sugar and non-reducing sugar content were positively and significantly correlated with SSC. On the other hand, Zhu *et al.* (1992) reported that an overall R^2 of -0.99 between SSC and total sugars; SSC cannot be used as a reliable indicator of sweet

Tab. 1. Dry matter content - DMC (%) and soluble solid concentration - SSC (%) of fresh sweet corn kernels

Varieties	DMC (%)			SSC (%)		
	2009	2010	Mean	2009	2010	Mean
'Lumina'	34.3 ^{cd}	35.4 ^{bc}	34.9 ^{cd}	23.7^{bc}	24.1 ^{b}	23.9^{b}
'Merit'	33.6 ^{d}	36.7^{abc}	35.2 ^{cd}	22.5^{cd}	24.8 ^{b}	23.7 ^{b}
'Sunshine'	35.7 ^{bc}	38.9 ^{ab}	37.3^{b}	21.3 ^{d}	26.2 ^{ab}	23.8^{b}
'Jubilee'	36.2 ^{bc}	36.0 ^{bc}	36.1 ^{bc}	24.3^{b}	25.4 ^{ab}	24.8 ^{b}
'Challenger'	35.9 ^{bc}	34.9 ^{c}	35.4^{bcd}	15.2^{f}	12.4^{d}	13.8 ^{d}
'Yellow Baby'	39.1^{a}	39.9 ^{a}	39.5 ^{a}	27.2 ^{a}	27.7^{a}	27.4^{a}
'2201'	33.6 ^{d}	34.7^{c}	34.2 ^{d}	17.6^{e}	15.0^{c}	16.3 ^{c}
Mean	35.5	36.7		21.7	22.2	
LSD (%5) Year			n.s.			n.s.
LSD (%5) Variety	1.72^{**}	3.51^{*}	1.89^{**}	1.53^{**}	2.33^{**}	1.34^{**}
LSD (%5) Year*Variety			n.s.			1.90^{**}

*: $p<0.05$; **: $p<0.01$ n.s.: not significant; Within each column, different letters denote significant differences (LSD test)

Tab. 2. Colour characteristics of fresh sweet corn kernels

Varieties	Lightness			Hue			Chroma		
	2009	2010	Mean	2009	2010	Mean	2009	2010	Mean
'Lumina'	73.4	75.5	74.4	83.3	83.6 ^{bc}	83.4 ^{bc}	27.8 ^{a}	27.2 ^{cd}	27.5 ^{ab}
'Merit'	71.3	73.6	72.5	87.6	87.9^{a}	87.8 ^{a}	22.5 ^{c}	22.5^{e}	22.5 ^{c}
'Sunshine'	72.5	74.5	73.5	85.9	85.9 ^{ab}	85.9 ^{ab}	23.7 ^{bc}	23.7 ^{de}	23.7 ^{c}
'Jubilee'	71.0	68.9	69.9	82.6	81.3 ^{c}	81.9^{c}	27.6^{a}	29. 1 ^{bc}	28.4 ^{ab}
'Challenger'	75.5	77.9	76.7	85.0	86.2 ^{ab}	85.6 ^{ab}	23.5 ^{bc}	31.4^{ab}	27.5 ^{ab}
'Yellow Baby'	76.4	79.1	77.7	86.7	87.4^{a}	87.1 ^{a}	23.7 ^{bc}	29.4 ^{bc}	26.5 ^{b}
'2201'	69.9	71.3	70.6	83.2	84.7 ^{abc}	83.9 ^{bc}	24.9 ^{b}	33.6^{a}	29.3 ^{a}
Mean	72.9^{b}	74.4 ^{a}		84.9	85.3		24.8^{b}	28.1 ^{a}	
LSD (%5) Year			1.31^{*}			n.s.			1.45^{**}
LSD (%5) Variety	n.s.	n.s.	n.s.	n.s.	3.81^{*}	3.03^{**}	1.73^{**}	3.85^{**}	2.04^{**}
LSD (%5) Year*Variety			n.s.			n.s.			2.88^{**}

* : $p<0.05$; **: $p<0.01$, n.s.: not significant; Different letters, small in line and each column, denote significant differences (LSD test)

corn total sugar concentrations (Hale *et al.*, 2005).

Colour characteristics of fresh kernels are presented in Tab. 2. Kernel lightness values were not significantly affected by varieties in both years. Mean values ranged from 69.9 to 77.7. Lightness values were significantly higher in the second year of the experiment. This indicates that kernels grown in 2010 had lighter coloured kernels compared to those grown in 2009. In the first year of the experiment, non-significant differences in kernel hue values were found but in 2010, hue values were significantly ($p<0.05$) affected by variety. The lightest yellow kernels were obtained from 'Merit' (87.9) and 'Yellow Baby' (87.4), while 'Jubilee' (81.3) had the darkest kernels. Significant differences ($p<0.01$) were found in kernel chroma values between varieties in both years. 'Merit' had the lowest chroma value with 22.5 when compared to the other varieties. The highest chroma values were obtained from 'Lumina' (27.8) and 'Jubilee' (28.4) in 2009 and from '2201' (33.6) in 2010. Colour characteristics values are in close agreement with earlier report of Tuncay *et al.* (2005). Also, this trait was influenced by genotype, genotype x environment interactions and in-field management (Esiyok *et al.*, *2004*; Esiyok and Bozokalfa, 2005).

Sugar, starch and protein content of fresh, frozen and canned sweet corn kernels

The sugar, starch and protein content of fresh, frozen and canned sweet corn kernels are presented in Tab. 3. In both years, treatment, variety and the interaction between treatment and variety had a statistically significant ($p<0.01$) effect on sugar content.

In 2009, the highest sugar content was obtained from fresh kernels of '2201' (9.5%) and the lowest sugar content was found in canned kernels of 'Merit' (1.6%) and 'Lumina' (2.1%). In the second year of the experiment, fresh kernels of 'Yellow Baby' and frozen kernels of '2201' had similar values and higher sugar contents than all others (7.7% and 7.6%, respectively). The lowest sugar contents were obtained from canned kernels of 'Merit' (1.5%), 'Sunshine' (1.6%), 'Lumina' (1.7%) and 'Jubilee' (1.8%). According to the average results from the two years, the sugar content from fresh kernels was higher than other treatments for all varieties and the sugar content of all varieties decreased after processing, except '2201'. The highest sugar content was obtained, for all treatments, from '2201' (Fig. 1). The presented results revealed that the varieties differed significantly for sugar content and there were differences among the varieties compliance processes. Similar findings were reported by Lertrat and Pulam (2007).

Tab. 3. Sugar, starch and protein content (%) of fresh, frozen and canned sweet corn kernels

			Varieties							
		Treatments	'Lumina'	'Merit'	'Sunshine'	'Jubilee'	'Challenger'	'Yellow Baby'	'2201'	Mean
Sugar content (%)	2009	Fresh	4.1	4.6	3.9	3.5	6.1	6.2	9.5	5.4^{a}
		Frozen	2.8	2.0	2.5	3.3	5.3	3.9	8.4	4.0^{b}
		Canned	2.1	1.6	2.6	2.2	3.6	2.8	5.1	2.7^{c}
		Mean	3.0^{d}	2.7^{d}	3.0^{d}	3.0^{d}	5.0^{b}	4.3^{c}	7.7^{a}	
		LSD(%5) T:0.22** V:0.33** T*V:0.58**								
	2010	Fresh	3.4	3.3	3.7	3.5	5.7	7.7	6.6	4.9^{a}
		Frozen	3.2	2.3	3.0	3.1	5.6	3.9	7.6	4.1^{b}
		Canned	1.7	1.5	1.6	1.8	3.0	2.0	5.2	2.4^{c}
		Mean	2.8^{d}	2.4^{e}	2.8^{d}	2.8^{d}	4.8^{d}	4.5^{c}	6.5^{a}	
		LSD(%5) T: 0.17** V:0.25** T*V:0.44**								
Starch content (%)	2009	Fresh	18.0	19.3	18.3	19.3	13.6	17.7	16.3	17.^{a}
		Frozen	17.4	14.9	15.8	18.5	12.3	17.9	9.1	15.^{b}
		Canned	12.7	13.4	13.9	14.2	7.9	13.4	4.1	11.^{c}
		Mean	16.0^{b}	15.9^{b}	16.0^{b}	17.3^{a}	11.4^{c}	16.4^{b}	9.8^{d}	
		LSD(%5) T:0.62** V:0.94** T*V:1.63**								
	2010	Fresh	17.8	16.9	17.0	18.2	12.2	14.5	14.4	15.^{a}
		Frozen	17.6	18.9	18.1	18.1	11.3	19.4	6.4	15.^{b}
		Canned	13.8	13.5	16.3	15.5	6.1	14.9	5.4	12^{c}
		Mean	16.4^{c}	16.5^{bc}	17.1^{ab}	17.3^{a}	8.3^{d}	16.2^{c}	8.7^{d}	
		LSD(%5) T: 0.45** V:0.69** T*V:1.20**								
Protein content (%)	2009	Fresh	10.6	10.3	10.9	9.9	13.0	10.5	12.5	11.1
		Frozen	10.6	9.9	11.2	10.0	12.9	10.9	10.9	11.2
		Canned	10.4	10.1	10.5	10.0	12.8	10.0	12.9	11.0
		Mean	10.5^{c}	10.1^{d}	10.9^{b}	10.0^{d}	12.9^{a}	10.5^{c}	12.8^{a}	
		LSD(%5) T:n.s. V:0.29** T*V:n.s.								
	2010	Fresh	10.7	10.7	11.2	9.7	13.3	10.4	11.6	11.1
		Frozen	10.2	9.5	10.1	9.8	14.5	9.5	12.7	10.9
		Canned	10.8	10.6	9.8	11.0	14.3	9.7	12.2	11.2
		Mean	10.6^{c}	10.3^{cd}	10.4^{c}	10.2^{cd}	14.0^{a}	9.8^{d}	12.1^{b}	
		LSD(%5) T: n.s. V:0.47** T*V:0.82								

**: $p<0.01$; n.s.: not significant. T: Treatment; V: Variety; T*V: Treatment*Variety; Different letters, small in each line and each column, denote significant differences (LSD test)

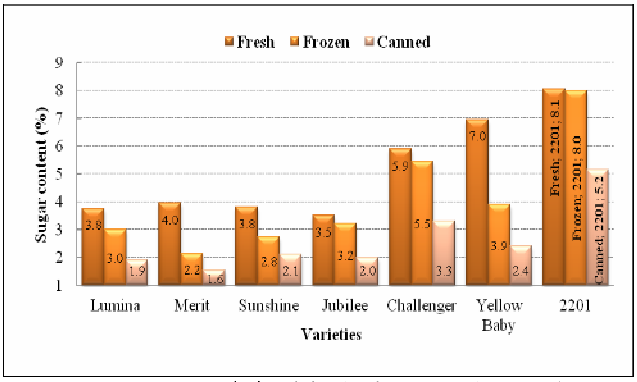

Fig. 1. Sugar content (%) of fresh, frozen and canned sweet corn kernels, as average values for two years

Both main effects and the interaction between the experimental factors on starch content were found to be statistically significant ($p<0.01$) in 2009 and 2010 (Tab. 3). In 2009, canned kernels of '2201' (4.1%) had the lowest starch content while fresh kernels of 'Jubilee' and 'Merit' with 19.3% gave the highest starch contents. In 2010, the lowest starch content was found in canned kernels of '2201' (5.3%), followed by canned kernels of 'Challenger' (6.1%) and frozen kernels of '2201' (6.4%). The highest starch content was obtained from frozen kernels of 'Yellow Baby' (19.4%), followed by frozen kernels of 'Merit' (18.9%) and fresh kernels of 'Jubilee' (18.2%). According to the average results from the two years, the starch content of the varieties was decreased after processing, except in 'Yellow Baby'. The lowest starch content, for all treatments was different according to varieties. The lowest starch content was obtained from 'Challenger' for fresh kernels whereas '2201' had the lowest starch content for frozen and canned kernels (Fig. 2). This indicates that the varieties differed significantly for starch content and there were differences among the varieties compliance processes. These results are in close agreement with earlier report of Lertrat and Pulam (2007). Also, the starch content values for fresh kernels reported here are similar to those found by Szymanek (2009).

In the first year of the experiment, the protein content was only affected significantly ($p<0.01$) by variety (Tab. 3). The highest protein content was attained, for all treatments, from 'Challenger' and '2201' with a mean content of 12.9% and 12.8%, respectively. 'Jubilee' (10.0%) and 'Merit' (10.1%) had the lowest protein content. In

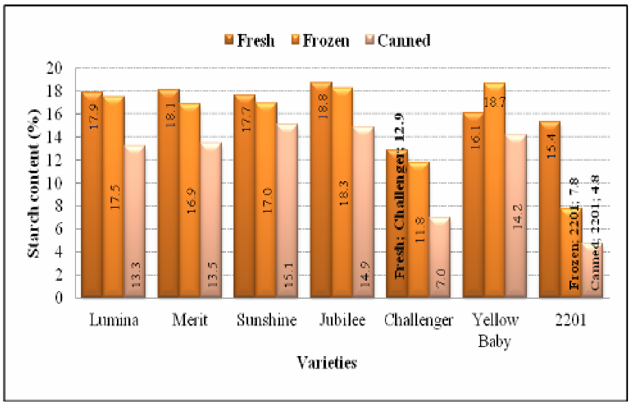

Fig. 2. Starch content (%) of fresh, frozen and canned sweet corn kernels, as average values for two years

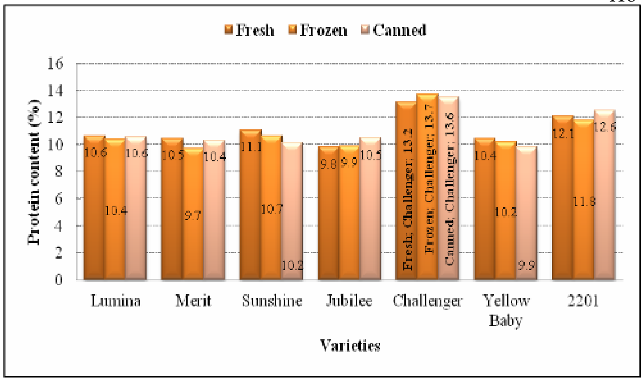

Fig. 3. Protein content (%) of fresh, frozen and canned sweet corn kernels, as average values for two years

2010, the effects of variety and 'treatment*variety' interaction on protein content were found significant ($p<0.01$). Protein contents changed between 9.8% ('Yellow Baby') and 14.0% ('Challenger'). According to the average results over the two years, fresh, frozen and canned sweet corn kernels had similar protein contents; the highest protein content was obtained, for all treatments, from 'Challenger', and it maintained its higher protein content after processing (Fig. 3). It has been reported that sweet corn is one of the most important sources of dietary protein among vegetables because of its relatively high protein concentration (3.5 g/100 g edible portion) (Goldman and Tracy, 1994). Our protein content results are similar to the results of Sanderson *et al.* (1979) and Goldman and Tracy (1994).

Conclusions

It can be concluded that kernel quality can be changed both among the varieties and treatments (fresh, frozen and canned). Sugar content of fresh kernels was higher than other treatments for all varieties. '2201' had the highest sugar and the lowest starch content for fresh, frozen and canned treatments. It could be suggested as suitable variety both for fresh consumption and processing. Fresh, frozen and canned sweet corn kernels had similar protein contents. Also, 'Yellow Baby' and 'Challenger' varieties can be advised for fresh consumption with moderate sugar and lower starch content. It has been reported that kernel quality is determined not only by varieties, but also by genetic groups (sugary, shrunken or sugary enhanced). Therefore, when compared on a kernel basis, sweet corn marketed as fresh, frozen or canned may be identified and it may be feasible to select varieties and genetic groups for different sweet corn markets.

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