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B R I E F C O M M U N I C A T I O N S

FREE SUGAR COMPOSITIONS BASED ON KERNEL TASTE IN ALMOND GENOTYPES *Prunus dulcis* FROM EASTERN TURKEY

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Recently, almonds are among fruits that are considered important for human health. Their complex carbohydrates are widely used for weight reduction in human diets [1, 2]. During recent years a remarkable increase in almond production in California has been recorded in response to consumer awareness about its healthfulness [3]. In addition, nutritional improvement of nut crops through breeding efforts has gained increasing importance for a more healthful lifestyle [4–6]. Therefore, almond genetic resources for modern breeding objectives also need nutritional identification [7] aside from morphological description [8].

In almond, kernel quality is closely related to kernel flavor. In addition to contents of protein, oil, and other components, free sugars affect industrial use of almond kernel. In almond kernel, sugar composition consisted of mainly sucrose and raffinose and lower amounts of fructose, glucose, and galactose [9–11], and they are very valuable for good flavor and taste [12]. Fruits contain sucrose, glucose, and fructose, which are the main sugars [13], depending on species, varieties, and genotypes. Kader [14] recorded that the main sugar in almond kernel is sucrose, and kernel contains 20.4% carbonhydrate and 3% sugar. Regarding the taste of sugars in the fruits, sucrose is sweeter than glucose, and fructose is sweeter than sucrose [13].

The free sugar composition of almond kernels can be influenced by varieties, genotypes, different ecological conditions, and technical and cultural practices. Karacali [15] reported that the amount and composition of sugars vary according to fruit species, varieties, and ecological conditions, and technical and cultural practices affect the flavor. In addition, irrigation, harvest time, and storage conditions also affect the sugar composition of almond kernel [12, 16, 17].

Today, although almonds are among popular fruits, studies characterizing their sugar composition are limited. The limited studies in this area have been conducted by GC methods. Nanos et al. [12] state that HPLC is a more powerful technique for sugar analyses than GC. The aim of this research was to detect by HPLC the sugar contents based on kernel taste in new almond [*Prunus dulcis* (Mill.) D.A. Webb.] genotypes from Tunceli province located in eastern Turkey, and thus to describe almond genetic resources with regard to sugar compositions.

Kernel weight was 0.77–1.38 g for sweet almond genotypes and 1.00–1.50 g for bitter almond genotypes. Eight almond genotypes had sweet kernels, and eight genotypes had bitter kernels. Genotypes with sweet kernels contained 1.27–3.70 g/100 g sucrose, 0.29–1.50 g/100 g maltose, 1.00–4.30 g/100 g glucose, and 1.42–6.50 g/100 g fructose. Genotypes with bitter kernels contained 0.99–4.35 g/100 g sucrose, 0.18–1.30 g/100 g maltose, 1.18–4.40 g/100 g glucose, and 1.60–4.46 g/100 g fructose. In both sweet genotypes and bitter genotypes, contents of sucrose, maltose, glucose, and fructose differed statistically. However, contents of sucrose, maltose, and glucose did not differ by kernel taste based on the mean values of sugars. Only fructose content differed by kernel taste statistically. According to the mean values, sweet and bitter kernelled genotypes on the average contained 2.53 g/100 g and 2.52 g/100 g sucrose, 0.92 g/100 g and 0.79 g/100 g maltose, 1.88 g/100 g and 2.24 g/100 g glucose, and 4.08 g/100 g and 2.98 g/100 g fructose (Table 1).

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TABLE 1. Sucrose, Maltose, Glucose, and Fructose Contents (g/100 g in Dry Weight) Based on Kernel Taste in Almond Genotypes from Eastern Turkey

Almond genotypes	Kernel weight, g	Sucrose	Maltose	Glucose	Fructose
		Sweet			
TA-031	1.03	3.54	0.29	1.64	5.10
TA-059	1.04	2.00	0.95	1.20	4.70
TA-005	0.77	3.20	0.97	1.01	4.00
TA-014	0.97	3.70	1.20	2.39	2.47
TA-062	0.91	2.45	0.91	1.89	2.90
TA-125	1.30	2.20	1.13	1.64	6.50
TA-129	1.35	1.90	1.50	4.30	5.52
TA-137	1.38	1.27	0.40	1.00	1.42
Mean of sweet kernelled almond selections	1.09	2.53	0.92	1.88	4.08
Significance	**	**	**	***	***
LSD (0.01)	0.42	1.03	0.57	1.08	1.41
		Bitter			
TA-010	1.50	2.20	0.90	2.95	2.30
TA-043	1.01	4.35	0.89	2.71	3.66
TA-030	1.11	2.53	0.50	1.18	3.60
TA-032	1.17	1.98	0.86	2.10	2.50
TA-097	1.15	2.36	0.85	1.24	3.32
TA-118	1.43	3.10	1.30	4.40	1.60
TA-128	1.38	0.99	0.80	1.50	2.45
TA-135	1.00	2.65	0.18	1.80	4.46
Mean of bitter kernelled almond selections	1.22	2.52	0.79	2.24	2.98
Significance	**	**	*	***	**
LSD (0.01)	0.39	1.56	0.81	0.85	1.27

*P<0.05, **P<0.01, and ***P<0.001.

TABLE 2. Relationships among Sugar Contents in Sweet and Bitter Kernelled Almond Genotypes

Sugar	Sweet			Bitter		
	Maltose	Glucose	Fructose	Maltose	Glucose	Fructose
	Correlation coefficients (r)			Correlation coefficients (r)		
Sucrose	–0.028	–0.031	0.049	0.136	0.436	0.300
Maltose		0.670	0.346		0.694	–0.853
Glucose			0.294			–0.613

In addition, the mean sugar was fructose in the majority of sweet and bitter kernelled genotypes. The findings revealed that the sucrose content is higher than the fructose content in some sweet or bitter almond genotypes.

Almond kernel contains 20.4% carbohydrate, and its total sugar content is about 3% [14]. Saura-Calixto et al. [18] reported a total sugar content of 5.5% for almond kernel. Nieddu et al. [16] recorded that almond genetic resources of Sardinia (Italy) contain a total sugar between 0.44% and 5.33%, and most genotypes had reducing sugar contents lower than 2%. In Turkey, Aslantas [19] reported a total sugar content between 2.64% and 4.17% for promising almond genotypes from Kemaliye district. Schirra et al. [20] reported that Texas almond variety contains 3.9% sugar in Italy. According to the findings of Barbera et al. [21], kernels of Ferragnes and Tuono varieties contain 3.47% and 3.19% of total sugar, respectively. Ellis et al. [22] obtained 30.1–26.0 μg/mg galactose and 147.6–157.7 μg/mg glucose in the kernels and skins of raw almonds, respectively. Nanos et al. [12] recorded that kernel soluble sugar content ranged from 1.7% to 4.3%, and sucrose content was between 68.1% and 91.0% depending on harvest times and irrigation treatments.

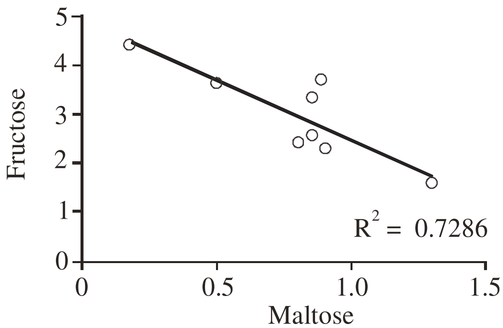

Fig. 1

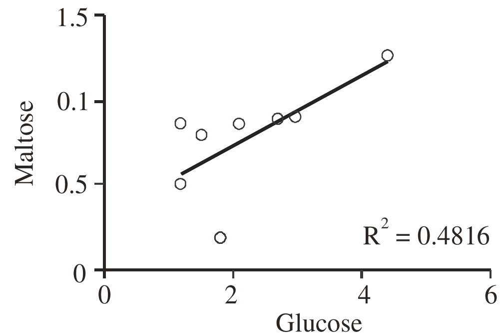

Fig. 2

Fig. 1. Relationship of fructose and maltose in bitter kernelled almonds.
Fig. 2. Relationship of glucose and maltose in bitter kernelled almonds.

Kazantzis et al. [17] reported that sucrose content ranged from 70.4% to 85.3% in early and late harvested Ferragnes variety, depending on storage conditions. Balta et al. [23] recorded that almond genotypes harvested in late August and early September in Balikesir (western Anatolia, Turkey) on the average contained 2.19–2.31 g/100 g sucrose, 0.68–0.92 g/100 g maltose, 2.09–1.82 g/100 g glucose, and 4.08–3.41 g/100 g fructose.

All the data reported in the references indicate that kernel sugar composition in almonds is influenced by genetic material, varietal differences, irrigation, early and late harvest time, and storage conditions [12, 16, 17]. On the other hand, according to compositional data of this study, the mean sugar was fructose in seven genotypes and sucrose in one genotype for sweet kernelled almonds. Similarly, the mean sugar was fructose in six genotypes and sucrose in two genotypes for bitter kernelled almonds. The existing limited references suggest that the main sugar is sucrose for almond kernels [9, 10, 11, 14]. In addition, data regarding sucrose contents of this study were similar to those by Nanos et al. [12] and Kazantzis et al. [17].

On the other hand, relationships among sugar contents were also computed based on kernel taste (Table 2). The correlation coefficients among sugar contents varied by sweet and bitter kernelled genotypes. The relationships between of maltose and glucose were similar to each other in sweet and bitter (Fig. 2) genotypes, whereas the relationships between maltose (Fig. 1), glucose, and fructose were negative in bitter genotypes and positive in sweet genotypes (Table 2). Accordingly, corelation findings indicate that inter-relationships among sugar contents vary according to kernel taste.

As is known, complex carbohydrates of almonds are widely used for human weight reduction in the diets [1–3]. Almond genetic materials should be investigated in relation to their individual nutritional values. Free sugars are important nutritional components that affect the kernel flavor of almond. Bliss [6] reported that nutritional improvement of nut crops through breeding efforts will gain increasing importance in promoting a more healthful lifestyle. Also, compositional findings of this study regarding sugar contents may contribute to nutritional improvement efforts of almond since very limited knowledge is available in the references on this subject.

Sampling. The material of this research consisted of almond [*Prunus dulcis* (Miller) D.A. Webb.] genotypes with sweet and bitter kernels selected from almond genetic resources of Tunceli (eastern Turkey). Fruits of almond genotypes were harvested in early and mid September. Fruits were removed from their shells, and they were dried in a vacuum oven at 60°C for three days. Fifty nuts representing each genotype were randomly chosen for sugar analyses.

HPLC Determination of Sugar Composition. The modified methods of [24, 25] were used for sugar (fructose, sucrose, glucose, and maltose) analyses. From kernel samples of almond genotypes, 2 g was ground into powder in liquid nitrogen and 40 mL of methanol was added. After the mixture was incubated on a magnetic stirrer at 65°C for 30 min, it was centrifuged at 4°C, 1300 rpm for 40 min. The supernatant was transferred to a clean tube and made up to 50 mL with methanol. After the methanol was removed by a rotary evaporator, the residue was dissolved in 25 mL double distilled water. Then the extract was passed through a Sep-Pak C_{18} cartridge. The filtrate of 2.5 mL was mixed with 7.5 mL acetonitrile, and it was filtered by a 0.45 μm membrane filter and injected into HPLC. The column was calibrated by using fructose, sucrose, glucose, and maltose standards. Sugar content was expressed as g/100 g.

Statistical Analysis. For statistical analysis of sugar compositional data, a completely randomized design with three replications was used. The LSD values were computed for multiple comparisons of the means. Significant differences were found at $P<0.01$. The statistical package program Minitab release 10.2 for Windows was used for the analysis of variance. Analyses of correlation and regression were done to confirm the relationships among sugar contents of almond kernels using Minitab release 10.2 for Windows and Excel package program.

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