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Quality Determination in Confectionery Sunflower

Yalcin KAYA[1*], Ufuk BAGCI[2], Necmi BESER[1], Emrah AKPINAR[1]

[1] *Trakya University Engineering Faculty, Genetic and Bioengineering Department, Edirne, Turkey*
[2] *Trakya University Engineering Faculty, Food Engineering Department, Edirne, Turkey*

✉ *Corresponding author: yalcinkaya22@gmail.com*

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ABSTRACT

Confectionery sunflower is one of the most preferred and consumed snacks both in Turkey and worldwide. Turkey's confectionery sunflower planted area is approximately 80,000 to 100,000 hectares, with seed production around 160,000 to 170,000 tons, primarily located in Denizli, Kayseri, Aksaray, Bursa, and Konya provinces, where local populations such as Inegol are generally cultivated. However, hybrid varieties with high yield, quality, and homogeneous seeds should be integrated into Turkish production to replace these local varieties. Confectionery sunflower has higher export potential but has not developed sufficiently, resulting in economic losses due to low production and poor homogeneity during processing. Furthermore, Turkey imports sunflower seeds for around 100 million dollars annually from China; these imported seeds are preferred by consumers primarily due to their taste. No detailed scientific study has been conducted in Turkey or globally regarding the properties associated with flavor in confectionery sunflower. In this study, domestic candidate hybrids, white-striped local Inegol types, and Chinese varieties were used as materials. Based on the results, the seed yield of the varieties ranged between 1,280 and 4,010 kg ha^{-1}. Seed colors varied among black, white, and striped. Protein values ranged between 17.87% and 30.05%. For fatty acids, linolenic acid varied between 0.13% and 1.27%, and oleic acid between 31.25% and 48.25%. Consumer sensory analysis was performed, with varieties ranked from lowest to highest score, and the browning index was determined. As a result, the TG 400 variety stood out in terms of multiple quality parameters and can be used as a standard variety in future evaluations of taste and other yield elements.

1. INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the most widely grown oil crops globally. However, sunflower is also cultivated for snack, birdseed, and ornamental purposes. Sunflower is one of the most preferred snacks in Turkey as well as in other countries such as Eastern Europe, USA, Canada, China, Pakistan, Iran, and Middle East countries. Except in Russia and some Slavic countries, the preferred sunflower seeds are generally white with gray stripes, and larger seeds. The main producer countries globally are China, USA, Spain, India, Ukraine, and Mexico, with China's market approximately 20 times larger than Turkey's. Worldwide, sunflower consumption preferences vary according to countries and regions. In Turkey, large sunflower types with white and gray stripes (Inegol Alaca) are preferred, while black colored sunflowers are preferred in the Balkans and Russia. In the USA, shorter grains (Dakota type) and mid longer gray and white stripe (Nevada type) varieties are consumed intensively (Gontcharov, 2011; Hladni, 2016; Hladni and Miladinović, 2019; Kaya, 2004; Velasco et al., 2014; Kaya and Beser 2018).

Confectionery sunflower yield is about 1000 kg ha^{-1} under dry conditions, but in irrigated areas such as Konya and Kayseri, the yield ranges between 2500-3000 kg ha^{-1}. Turkey's seed requirement for sunflower is around 300 tons (0.5 kg of seed per capita), while the Chinese market, which is the largest globally, is about 20 times the size of Turkey's (Kaya and Beser 2018). When examining the consumption habits of Turkish society, nuts are frequently preferred as snacks. According to statistical data, 10.8 kg of nuts are consumed per person annually in Turkey. The most preferred snack is sunflower with an 84% household consumption rate and 50% volume in the sector. Sunflower, mostly produced as oilseed for vegetable oil production, also has development potential in Turkey due to its consumption as a snack.

Turkey's snack industry has highly developed modern facilities, but production is insufficient for the current capacity, especially since local populations with low yields are generally used in confectionery sunflower. Some companies even produce by renting lands in neighboring countries such as Ukraine, Russia, and Bulgaria. In addition to intensive domestic consumption, confectionery sunflower has high export potential due to Turkey's geographical location, as the Balkans and the Middle East are the regions with the highest confectionery consumption globally. While the confectionery consumption in Turkey is 4 kg per capita, it is 11 kg in Lebanon, and similar trends exist in Greece, Iran, and Iraq. Approximately 700 industrial companies are operating in the confectionery sector in Turkey, with products delivered to consumers through approximately 7-8,000 retail outlets. The sector's turnover exceeds 1 billion dollars. The leading producer countries of confectionery sunflower globally are China, USA, Spain, Russia, Ukraine, and Turkey, with different types consumed worldwide (Beser et al., 2020).

Sunflower is one of the most widely cultivated and consumed snacks globally and in Turkey. Imports of confectionery sunflower are increasing in recent years due to problems affecting yield and quality in domestic sunflower production, processing, and marketing. The most significant issue is the lack of domestic sunflower varieties that could compete with imported sunflower seeds preferred by consumers. For new variety development studies to be successful, there is an absolute need for sufficient genetic and agronomic knowledge for selection and breeding studies focused on desired traits, especially grain quality, which is the most important element after grain yield in sunflower (Kaya and Beser, 2018). However, no study on flavor and quality criteria in confectionery sunflower has been conducted globally, either directly determining the traits or examining the relationships between them comprehensively.

In this study, all quality characteristics in confectionery sunflower grain will be examined comprehensively, and the characteristics encompassing the concept of flavor, which is the most important criterion for consumer preferences, will be determined for the first time in Turkey and globally, making this an original and novel study. The results can directly apply to a product with both intensive domestic consumption and significant export potential.

Indeed, Beser et al. (2020) emphasized that it is possible to develop domestic sunflower varieties that can compete with imported sunflower in terms of yield. However, it is critically important for the Turkish economy and the prevention of imports that the quality criteria and prominent quality characteristics of these domestic varieties be thoroughly understood and that detailed quality studies be conducted for these domestic varieties to compete with imported varieties.

Seed quality is essential in confectionery sunflower because consumers mostly prefer larger sizes, good taste, lower oil content, and longer shelf life. In this context, in addition to seed yield, 1000 grain weight and larger seed size are the most important quality traits in confectionery sunflower production. Additionally, in the sunflower sector, the homogeneity of seeds in both size and color is significant, and both the industry and consumers consistently demand larger seeds (Jovanović et al., 1998; De Figueiredo, 2015). Since high quality and homogeneous seeds can only be obtained from hybrid seeds, hybrid sunflower varieties not only yield high quality seeds but also satisfy farmers by offering high yields (Velasco et al., 2014; De Figueiredo, 2015; Demurin, 2018; Li et al., 2024).

Although Turkey has high production capacity in sunflower, unfortunately, its domestic production of confectionery sunflower cannot fully meet domestic consumption. In 2019, 75,000 tons of confectionery sunflower were imported from China. Considering consumer habits, it is important to grow confectionery sunflower to contribute to the national economy and create employment for local producers. However, the productivity values and compliance with various quality parameters of the sunflowers to be grown should be verified before local production becomes widespread. Plant breeding studies on confectionery sunflower production are ongoing, but various food-quality analyses are required to determine the chemical composition and sensory differences between imported and locally produced confectionery sunflower (Kaya and Beser, 2018). In this context, consumer preferences can be determined, and local production of confectionery sunflower can be supported. Consumer preferences for sunflower products are influenced by factors such as price, brand, and production method. For instance, consumers in Turkey prefer sunflower oil with attributes like domestic origin and organic production, which can be extrapolated to preferences for other sunflower products.

Sunflower is nutritious and healthy snack rich in fat, mostly 85% unsaturated fatty acids (14-43% oleic acid, 44-75% linoleic acid, and 0.7% linolenic acid) and 15% saturated fatty acids. It is also rich in antioxidants and various minerals, containing significant amounts of copper, zinc, iron, and fiber, and is especially rich in vitamin E (tocopherol) and selenium (Tesan et al., 2022; Rayman Ergun, 2024).

Sunflower quality is primarily related to its fatty acid composition, specifically the variability of its fatty acid content and susceptibility to oxidation. The possible oxidation process and the resulting products negatively affect the nutritional value, organoleptic properties, and shelf life of sunflower. The amount of peroxidase and hydrolytic activity in the seed cause the rancidity process. Therefore, the analysis of free fatty acids is one of the important quality criteria (Rayman Ergun, 2024). Additionally, antioxidant substances such as sterols, phenolics, and tocopherols in sunflower slow down the rancidity process by binding free radicals, making the determination of these substances' composition important for product quality. In summary, the oil composition and oxidative stability of sunflower oil are highly important quality factors (Muttagi and Joshi, 2021). Roasting is commonly used for nuts, and these process parameters may vary according to consumer expectations, affecting the color, odor, and aroma profile of the product (Zhu et al., 2015; Marzocchi et al., 2017).

Although hybrids developed by the Trakya Agricultural Research Institute (TARI), the only breeding program in Turkey for sunflower, are sold in the market, their market share is quite low because they lack the desired color and size. The market mostly demands Inegol type sunflower with white and black striped coloration. There are problems in the certified seed production of the white colored registered Inegol Alaca variety, and since it is not resistant to broomrape and some diseases, its yield is not very high. In the last few years, there has been significant demand for black types imported from China, and farmers cannot sell the white types they produce. There is an urgent need for high yielding, homogeneous, high quality hybrid varieties for producers, industrialists, and consumers. Additionally, the large, black striped sunflower variety imported from China has been highly appreciated and popular among consumers due to its large grains and flavor, leading to increased imports while demand for domestic white varieties has been declining (Kaya and Beser, 2018).

The goal of this study is to compare yield and quality traits of local and Chinese confectionery sunflower varieties widely sold and preferred in the market. Another aim is to analyze characteristics of Chinese hybrids to develop similar ones in local breeding programs, preventing imports from China by utilizing this study's data with various quality and food analyses to establish flavor criteria.

2. MATERIALS AND METHODS

A total of 25 varieties were used in the study, including 18 local candidate hybrids developed by Tragen R&D Co located in Trakya Technopark and Trakya Agricultural Research Institute (TARI), three Chinese hybrids, and four confectionery controls. TG400 (Chinese type) developed by Tragen R&D Co, Palanci and Ahmetbey sunflower hybrids developed by TARI and Denizli Beyazi cultivars, which is an open pollinated local population and still cultivated in the market were used as controls.

The experiment was conducted in Edirne in 2022 as 4 rows, 4 reps with 7.5 m plot length, 70 cm between and 50 cm above rows, according to RCBD design. The plot area was 6 m x 2.8 m = 16.80 m^2 and the harvested area was 5.4 m x 1.4 m = 7.56 m^2 by hand harvesting the middle two rows. The trial was sown on March 11, 2022, and harvested on September 22, 2022. 250 kg ha^{-1} 20-20-0 Compose fertilizer was applied to the soil at 50 kg ha^{-1} N and 50 kg ha^{-1} P2O5 dose before soil preparation in the trial.

Field observations taken in the research are as follows.

Grain yield (kg ha^{-1}): The threshed grains were cleaned and weighed. Moisture content was determined with a moisture meter and seed yields were calculated according to 10% moisture. Table Diameter (cm): 5 plants in each plot were measured at physiological maturity (R-6). Plant Height (cm): At physiological maturity (R-6), the distance from the root collar on the soil surface of five plants in each plot. Days to Flowering: It is the time when the plants in each plot reach 50% flowering (R.5.5) after emergence. Physiological Maturity: The time when the plants in each plot reached the physiological maturity stage (R.9) after emergence. Grain width and length (cm); the seeds were measured with calipers after harvesting and threshing. Grain color: the grain color was determined according to the RHS color scale. Hectoliter weight (g); the seeds was determined with a hectoliter measuring device after threshing. Oil Ratio (%); The oil ratios were determined by NMR. Thousand Grain Weight (TSW) (g); seeds were determined using grain counting machine.

Sunflower seeds were roasted in a commercial nut roaster at 145 ºC for 30 min (Guo et al., 2019). Comparative analyses were performed on raw and roasted samples. The dry matter was determined based on the method of Kashaninejad et al. (2006) as 4-5 g seeds at petri dishes dried at 105 ºC.

Total Phenolic Content

The phenolic content was determined by spectrophotometer (UV1601, Shimadzu) according to the Folin-Ciocalteu colorimetric method. Phenolic substances were extracted by taking 1 gram of ground unshelled sunflower seed samples, adding 10 mL hexane and 12 mL methanol-water (60:40 V/V) and waiting for 30 minutes. The sample was then passed through a coarse filter, and the filtrate was centrifuged at 3500 rpm for 10 minutes to separate phases. The methanol phase was taken, and Folin-Ciocalteu solution and saturated sodium carbonate solution were added to measure total phenolic content spectrophotometrically. The total phenolic content was determined according to the gallic acid standard curve (Karamac et al., 2012; Ali et al., 2023).

Dry Matter and Water Activity

The dry matter content of dehulled sunflower seeds was determined based on Kashaninejad et al. (2006). The homogenized samples (4-5 g) were placed in petri dishes and dried at 105°C until constant weight to determine moisture content. Water activity values were determined using an Aqualab 4TE device.

Protein Content

Protein content of dehulled sunflower seeds was determined using the Kjeldahl method described by Petraru (2021).

pH

After grinding the unshelled kernel samples, 9 mL of pure water was added to 1 gram of sample and homogenized. The pH values were determined using a Mettler-Toledo pH meter (Akgun et al, 2017).

Elemental Analysis

The elemental content of sunflower seeds (Ag, Ca, Cu, Fe, Mg, Mn, Na, Zn, P, Se, Cr, and Pb) was determined using Agilent 7700 ICP-MS. Unshelled sunflower seeds (1 g) were first incinerated in a microwave incinerator (CEM, MARS6) using nitric acid. Elemental matter content in the incinerated samples was determined by ICP-MS and concentrations were calculated according to standard curves (Karlsson et al., 2015).

Determination of fatty acid composition

Fatty acid profiles were determined by GC-FID (Agilent 6850). Extracted fatty acids (0.1 g) were mixed with 10 mL of hexane and 100 µL of KOH (2N) solution in methanol, mixed for 30 s, and centrifuged at 2500 g for 5 min. GC-FID analysis was performed according to Ayyildiz et al. (2015). The area under each fatty acid peak relative to the total area of all peaks was used to quantify the percentage of each fatty acid.

Textural Analysis

Hardness properties of sunflower samples were determined using a Stable Microsystems TA. HD Plus texture analyzer with P/36R probe according to Mosayebi et al. (2018).

Color Analysis

The color analysis of sunflower kernels was measured according to the CIE Lab* scale using a Minolta CM-5 colorimeter. After peeling, the seeds were placed in a petri dish for color measurement (Mosayebi et al., 2018).

Sensory Analysis

The sensory analysis of the samples (appearance, firmness, taste, aroma, and overall acceptability) was determined using a 5-point hedonic scale with 20 participants. Samples (20 g) were presented to the panelists in white plates (Mosayebi et al., 2018).

Statistical Analysis

The data were calculated with mean values and standard deviations determined from triplicate trials. All statistical analyses were performed with SPSS 17.0 (SPSS, ;2008).

Figure 1. Quality analysis in confectionery sunflower varieties in the study

3. RESULTS AND DISCUSSION

The seed yield of varieties in the experiment was statistically significant, ranging between 1280-4010 kg ha^{-1}, with the TG-400 hybrid ranking first, followed by CRZ-116, CRZ-318, CRZ-101, Affan, CRZ-213, G1, CRZ-104, and CRZ-113 hybrids respectively (Table 1). The lowest yields were obtained from Ahmetbey and Denizli Beyazi controls. The seed colors varied among black, white, and black stripe, with black stripe being most common. The earliest variety to flower was Ahmetbey (69 days), and TG-400 was earliest to reach physiological maturity (PM). The latest varieties were Palanci and IMI-CRZ-16 for flowering, and CRZ-112, CRZ-113, and CRZ-318 based on PM. TG 400 was both early maturing and high yielding as desired, CRZ-116, Affan, Stripi, and CRZ-213 varieties also had similar characteristics.

Taste evaluation of raw grains was performed with notes from three participants (5: Best, 1: Worst). The highest grade was obtained by TG 400, followed by IMI-CRZ-3, IMI-CRZ-16, IMI-CRZ-6, CRZ-19, CRZ-24, CRZ-103, and CRZ-105 (Table 1). High oleic acid ratio in confectionery sunflower is desired as it prevents oil burning during frying, prolongs shelf life, and enhances flavor. The oleic acid content measured by Spinlock NMR ranged between 54.8% and 74.4%, with the highest in Ahmetbey and lowest in CRZ-111. Higher oil content above 30% is undesirable in confectionery sunflower; oil contents ranged from 22.8-35.6%, with the highest in Palanci and lowest in CRZ-104.

Nutritional quality, including protein content and oleic acid levels, is another critical factor. High sugar content and oleic acid levels positively correlate with consumer acceptance, as they enhance taste and health benefits (Latif et al., 2024). The sensory characteristics of foods, including confectionery sunflower, are essential for consumer acceptance. Factors such as taste, texture, and appearance significantly influence consumer choices and product success in the market. While the primary focus is on seed size, nutritional content, and sensory attributes, it is important to consider the broader context of consumer acceptance.

Seed size, length, and thickness are the most significant features in confectionery sunflower, with consumers generally preferring long and large-grained varieties. Seed width ranged between 0.6-1.0 cm, with CRZ-116 and CRZ-30 having the widest seeds. Seed length varied between 1.6-2.5 cm, with CRZ-116, CRZ-30, CRZ-19, Ahmetbey, IMI-CRZ-6, G1, TG400, Affan, and CRZ-110 ranking highest. Seed thickness ranged from 0.27-0.50 cm, with CRZ-110 and CRZ-318 having the highest values. In confectionery sunflower, TSW is a critical quality determinant affecting price. Seeds weighing 150 g and above are acceptable in the market, with that 200 g and above considered large and most preferred. TSW ranged between 130.0-248.5 g, with CRZ-116 having the highest weight. CRZ-30, CRZ-19, CRZ-318, CRZ-105, and CRZ-109 candidates all exceeded 200 g (Table 1).

Based on chemical analyses, the pH values of raw sunflower seed samples ranged between 7.04-6.59 (Table 2). After roasting, this range shifted to 6.17-5.32. In sunflower seeds, pH value varies depending on roasting temperature and duration. Sen and Gokmen (2022) reported that initial pH value decreased from 7.1 to 6.25 after thermal treatment at 180°C for 45 minutes. The water activity values were below 0.6 in all samples, ranging between 0.470-0.442 (Table 2), indicating microbiological safety from spoilage. Moisture content ranged between 3.3-2.41%. Soleimanieh et al. (2015) determined that moisture content in sunflower seeds decreased from approximately 4.5% to as low as 1%, depending on roasting conditions. The same roasting parameters were used for all samples, and a decrease in moisture content of approximately 2-3% was observed after roasting.

Table 1 Seed quality characteristics of sunflower varieties, measured in the current study.

#	Variety Name	Taste	Seed Color	Seed Yield Kg ha^{-1}	Flower Period	Phy M Period	Oleic Acid (%)	Oil Cont (%)	Seed Width (cm)	Seed Length (cm)	Seed Thick (cm)	TSW (g)
1	CRZ-113	4-3-2	Black Stripe	3167 DEFG	72	110	64.52	29.79	0.8	2.0	0.4	161.5
2	CRZ-116	4-4-4	Black Stripe	3612 AB	70	105	64.28	27.88	0.9	2.2	0.4	226.0
3	CRZ-213	3-2- 2	White	3330 CDE	70	104	55.61	31.75	0.6	2.0	0.4	161.7
4	CRZ-30	4-4	Black Stripe	2052 KL	70	107	61.72	31.36	0.9	2.3	0.4	223.7
5	CRZ-19	4-4-5	Black Stripe	2566 J	70	109	62.01	30.15	0.8	2.2	0.4	205.5
6	CRZ-24	5–5	White	2870 GHI	69	105	60.34	26.77	0.7	2.2	0.4	194.3
7	CRZ-318	4–3	Black Stripe	3434 ABC	72	110	62.89	28.62	0.9	2.3	0.5	214.2
8	CRZ-103	5-4-5	Black Stripe	2998 FGH	72	107	63.23	29.93	0.8	2.0	0.4	192.8
9	CRZ-101	4–4	Black Stripe	3332 BCD	71	107	60.37	26.82	0.8	2.1	0.4	185.2
10	CRZ-110	3	Black Stripe	2895 GH	71	105	64.30	26.20	0.9	2.4	0.5	193.3
11	CRZ-112	3	White	3050 EFG	71	107	61.32	33.99	0.7	2.1	0.3	161.5
12	CRZ-104	2	Black Stripe	3140 DEFG	73	110	60.41	22.82	0.8	1.9	0.3	151.5
13	CRZ-105	4-5	Black Stripe	2161 KL	72	104	63.83	29.30	0.9	2.1	0.4	207.3
14	CRZ-111	4–4	White	2285 K	71	105	54.83	34.54	0.6	2.0	0.3	155.7
15	CRZ-109	5	Black Stripe	2607 IJ	72	105	63.29	29.94	0.9	2.2	0.3	203.7
16	STRIPI	4-4	Black Stripe	3000 FGH	70	105	66.97	32.59	0.7	2.0	0.3	138.7
17	DENIZLI B(C)	4-4	White	1715 M	71	105	60.14	31.57	0.7	1.6	0.3	140.5
18	AHMETBEY(C)	4-4	Stripe	199.0 LM	69	105	74.39	27.56	0.9	2.1	0.4	172.3
19	IMI-CRZ-6	5-4-5	Stripe	2720 HIJ	71	105	62.71	34.79	0.8	1.9	0.4	142.2
20	G1	5–4	Black Stripe	3218 CDEF	71	106	64.16	30.25	0.9	2.0	0.4	153.2
21	TG400 (C)	5-5-5	Stripe	3690 A	70	104	63.39	30.94	0.8	2.1	0.3	151.2
22	AFFAN	4-4	Black Stripe	3330 CDE	70	104	62.51	29.40	0.9	2.1	0.4	155.2
23	IMI-CRZ-3	4-5-5	Stripe	2613 IJ	73	108	64.59	34.22	0.8	2.0	0.4	143.5
24	IMI-CRZ-16	4-5-5	Stripe	2754 HIJ	74	108	65.55	30.90	0.9	1.8	0.4	170.0
25	PALANCI 1 (C)	3–3	Black Stripe	2220 KL	74	109	64.74	35.59	0.7	1.8	0.4	134.7
Average				283,0	71.2	106.4	62.9	30.3	0.8	2.1	0.4	173.6
Std Deviation				532	1.4	2.0	3.7	3.0	0.1	0.2	0.0	28.5
Maximum				3690	74	110	74.4	35.6	0.9	2.4	0.5	226.0
Minimum				1715	69	104	54.8	22.8	0.6	1.6	0.3	134.7

The peroxide value indicates the degree of oxidation in oil-containing products and generally increases with heat treatment. The peroxide values of the samples ranged between 4.5-124.5, with high values indicating significant oxidation in some samples. In confectionery seeds, high protein content is desirable from a nutritional perspective, and high-protein snacks are preferred. The protein values ranged between 17.87-30.05%, with the highest value in the Ahmetbey variety and the lowest in the Denizli Beyazi control variety (Table 2). The most preferred control variety, TG400, and some candidate lines had protein values above the average.

Under normal conditions, high phenolic content in confectionery sunflower seeds is desirable due to beneficial compounds such as antioxidants and nutrients. However, some phenolic compounds may cause bitterness or undesirable tastes and sensory perceptions for consumers. Detailed phenolic compound analyses were not conducted in this study. The total phenolic content ranged between 943-2505 mg GAE 100 g^{-1} DM (Table 2). Among the varieties, CRZ-103 had the highest phenolic content, while IMI-CRZ-16 had the lowest. Generally, the control varieties and foreign candidate lines, except for Affan, had phenolic contents below the trial average.

Nadeem et al. (2011) determined that total phenolic content ranged between 2185-2965 mg 100 g^{-1} in hulled seed samples and 3162-3614 mg GAE 100 g^{-1} in dehulled samples. Fiska et al. (2006) found the total phenolic content of hulled sunflower seed samples to be 2700 mg GAE 100 g^{-1} of dry matter. Ali et al. (2023) reported values between 1930-2310 mg GAE/100g. The total phenolic content in this study was generally consistent with literature. The macro and micro element contents in the sunflower seed samples are presented in Table 3. The heavy metal contents, such as arsenic, lead, and cadmium, were below 2 ppm in all samples. In a study conducted in Iran, the lead and cadmium contents in sunflower seed samples ranged between 10-381 ppb and 73-731 ppb, respectively (Torki et al., 2018). In all samples examined in this study, much lower amounts of cadmium and lead were detected compared to these values. No high values of heavy metals were identified in the microelement analyses of the varieties (Table 3).

The magnesium content ranged between 1181-2694 mg kg^{-1}, potassium between 3576-6855 mg kg^{-1}, and calcium between 315-803 mg kg^{-1}. In a study conducted in Argentina, the magnesium, potassium, and calcium contents in sunflower seeds were approximately 5000-6000 mg kg^{-1}, 1300-1000 mg kg^{-1}, and 1200-1600 mg kg^{-1}, respectively (Tesan et al., 2022). For confectionery sunflower seeds, high levels of certain macro elements such as Mg, K, and Ca are desirable from a nutritional perspective. However, it is difficult to interpret which of these elements influence consumers' taste preferences or play a definitive role. In terms of fatty acids, linolenic acid (Omega 3), which is highly preferred in nutrition, ranged between 0.13-1.27%, with the highest ratio in CRZ-113. Oleic acid, which significantly affects quality and extends shelf life, ranged between 31.25-48.25%, with the highest value in IMI-CRZ-3 (Table 4).

Table 2. Moisture and water activity values of hulled sunflower and total phenolic substance amounts in unhulled seed samples

Variety Name	Humidity %	Protein %	Water Activity	pH (Raw)	pH (roasted)	Peroxide # (meq O2 kg^{-1} sample)	Tot Phenolic Subst (mg GAE 100 g^{-1} DM)
CRZ-113	3.15	25.48	0.465	7.00	6.17	14.7	2262
CRZ-116	3.20	25.11	0.447	6.77	5.96	57.5	1403
CRZ-213	3.30	18.42	0.421	6.78	5.85	21.5	2207
CRZ-30	2.98	20.72	0.424	6.63	5.42	62.5	1782
CRZ-19	2.91	24.10	0.459	6.81	5.77	16.5	1536
CRZ-24	2.81	27.14	0.470	6.83	5.72	83.5	1855
CRZ-318	3.02	22.68	0.448	6.68	5.56	4.50	1701
CRZ-103	2.68	20.74	0.462	6.64	5.64	12.5	2505
CRZ-101	3.06	23.78	0.447	6.72	5.32	16.5	1230
CRZ-110	2.69	21.05	0.443	6.79	5.82	19.5	1352
CRZ-112	2.41	23.23	0.454	6.84	5.49	13.5	1768
CRZ-104	3.13	26.89	0.443	6.41	5.60	9.50	1570
CRZ-105	2.47	23.71	0.445	6.95	5.60	7.50	2212
CRZ-111	3.00	21.82	0.447	6.68	5.38	32.5	2215
CRZ-109	2.62	24.41	0.450	6.59	6.01	27.5	2112
STRIPI	3.09	22.12	0.453	6.90	5.85	26.5	1543
DENIZLI(C)	2.63	17.87	0.442	6.80	5.67	124.5	1386
A.BEY (C)	2.92	30.05	0.450	6.92	5.86	83.5	1394
IMI-CRZ-6	2.92	20.50	0.446	6.94	5.87	7.5	1317
G1	2.43	19.67	0.454	6.99	6.14	7.5	1731
TG400 (C)	2.27	24.82	0.465	6.77	6.04	8.5	1505
AFFAN	2.82	21.15	0.454	7.01	5.94	3.5	2143
IMI-CRZ-3	2.67	21.63	0.455	7.04	6.04	9.5	1219
IMI-CRZ-16	2.80	22.84	0.454	6.97	5.80	7.5	943
PALANCI(C)	2.58	19.63	0.452	7.01	5.75	8.5	1396
Average	2.82	22.78	0.45	6.82	5.77	27.5	1707.9
Std Deviation	0.27	2.86	0.01	0.16	0.23	30.8	398.0
Maximum	3.30	30.05	0.47	7.04	6.17	124.5	2505.0
Minimum	2.27	17.87	0.42	6.41	5.32	4.5	943.0

The hardness values of the sunflower seed samples were determined both with and without hulls. In all samples, the hardness values of the hulled samples were higher than those of the dehulled samples. While the hardness value in hulled samples ranged between 30-81 kg, in dehulled samples, this value ranged between 12-43 kg (Table 5). Seed hardness is an undesirable characteristic in confectionery sunflower seeds. When seeds are too hard, they are less preferred due to both excessive energy consumption during roasting and reduced ease of cracking during consumption. The seed hardness values ranged between 30.17-81.26 kg for hulled seeds and 12.86-43.07 kg for dehulled seeds. The hardest seeds, both hulled and dehulled, were found in CRZ-116, while the softest were in CRZ-112.

There appears to be a nuanced relationship when comparing instrumental hardness measurements with sensory evaluation scores, particularly for crispness. For instance, CRZ-19, which received the highest overall sensory score (4.3) and maximum crispness score (4.0), displays a relatively high hardness value (69.28 kg with shell). However, CRZ-116, which has the highest instrumental hardness value (81.26 kg), received only a moderate crispness score (3.7) and overall acceptability score (3.2).

The samples with highest consumer acceptance scores demonstrate an interesting pattern. Samples CRZ-19 and CRZ-105, which received the highest overall acceptance scores (4.3 and 4.2 respectively), show different hardness values. CRZ-19 has a relatively high hardness (69.28 kg with shell, 27.82 kg without shell), while CRZ-105 has a moderate hardness (55.71 kg with shell, 21.84 kg without shell). This suggests that consumers may prefer sunflower seeds within a specific hardness range, rather than simply favoring extremely hard or soft seeds. The data indicates that sunflower seeds with shell hardness between approximately 55-70 kg may align with higher consumer acceptance. There is generally a parallel between hulled and dehulled values in terms of seed hardness, and the control varieties mostly exhibited values close to the average in both measurements.

Table 3. Macro and micro element contents in sunflower seed samples (mg kg^{-1}).

Variety	Mo	Ag	Cd	Sn	Ba	Pb	Ni	Cu	Zn	As	Se	Li	Cr	Mn	Fe	Co	Na	Mg	Al	K
CRZ-113	8.5	1.41	1.27	2.18	1.115	0.163	7.1	64.8	269.8	0.602	0.174	0.147	0.321	62.3	179.6	0.314	9559.8	1515354	5844.6	3755460
CRZ-116	5.2	0.83	0.90	1.74	0.537	0.085	6.8	78.2	218.6	0.493	0.272	0.735	0.620	66.7	165.9	0.091	8485.7	1297360	589.1	4396577
CRZ-213	3.4	0.59	0.62	1.32	0.725	0.065	6.0	60.3	208.3	0.399	0.23	0.399	0.175	57.5	158.1	0.073	9432.1	1181626	439.1	3118582
CRZ-30	3.2	0.35	1.03	1.10	0.7	0.093	6.1	81.2	237.1	0.262	0.292	0.210	0.260	64.1	166.8	0.142	9087.9	1449102	487.9	4691641
CRZ-19	2.8	0.25	1.11	1.04	0.748	0.067	8.3	78.9	211.1	0.282	0.334	0.830	0.469	66.1	177.7	0.351	9290.1	1373562	659.3	4579551
CRZ-24	2.9	0.19	0.79	0.85	0.78	0.087	7.8	84.1	243.4	0.231	0.167	0.084	0.166	79.1	223.5	0.093	9460.1	1632988	954.5	4150464
CRZ-318	3.0	0.16	1.16	0.81	0.567	0.068	8.2	93.6	235.4	0.225	0.23	0.105	0.197	73.7	255.2	0.094	9012.0	1647868	1388.9	5685108
CRZ-103	2.1	0.16	0.99	0.58	0.438	0.122	7.9	75.2	226.7	0.191	0.271	0.231	0.048	65.5	173.3	0.131	3155.5	1427551	526.0	4214615
CRZ-101	2.3	0.11	0.98	0.55	0.583	0.104	6.6	87.7	261.9	0.172	0.272	0.457	0.040	88.3	200.8	0.080	2966.6	1731217	612.5	4807492
CRZ-110	2.1	0.07	0.97	0.55	0.314	0.110	6.5	81.6	210.5	0.193	0.209	0.200	0.080	74.3	181.2	0.084	2651.8	1288442	358.2	3909625
CRZ-112	2.0	0.07	0.99	0.52	0.931	0.146	5.7	91.7	265.6	0.159	0.272	0.851	0.154	62.7	185.2	0.139	3569.0	1418324	491.5	3576585
CRZ-104	2.6	0.05	0.87	0.39	0.497	0.109	9.2	74.7	251.8	0.137	0.195	0.672	0.036	80.9	173.8	0.119	1703.5	1600003	351.1	6855340
CRZ-105	2.5	0.04	1.63	0.37	0.569	0.150	6.7	95.9	255.1	0.115	0.091	0.021	0.041	79.5	172.5	0.111	2040.7	1489421	441.5	4915618
CRZ-111	1.7	0.04	0.85	0.44	0.653	0.131	9.9	71.1	219.3	0.142	0.202	0.336	0.110	51.5	153.7	0.106	3523.1	1279586	423.6	3710743
CRZ-109	2.3	0.03	1.30	0.34	0.77	0.126	5.9	94.7	268.0	0.2	0.056	0.168	0.047	76.3	192.7	0.112	2623.2	1381208	2363.9	4421664
STRIPI	1.3	0.02	0.92	0.28	0.615	0.113	15.2	67.1	210.8	0.162	1.086	0.200	0.125	95.9	146.4	0.196	3159.5	2694150	372.5	6176063
DENIZ B(C)	0.9	0.03	0.69	0.26	0.737	0.120	22.1	84.7	210.9	0.132	1.128	0.084	0.034	117.9	180.9	0.821	2400.4	2569147	360.6	5827747
A.BEY (C)	1.0	0.02	0.62	0.25	0.653	0.114	21.9	82.5	204.8	0.12	1.316	0.231	0.092	124.2	181.5	0.475	2233.5	2476237	276.1	5728024
IMI-CRZ-6	1.0	0.02	0.66	0.23	1.209	0.113	15.5	74.5	217.2	0.159	1.504	0.630	0.062	96.2	180.9	0.330	2856.9	2375885	229.7	5510162
G1	1.1	0.01	0.79	0.19	1.271	0.129	13.8	71.6	230.8	0.105	1.337	0.389	0.034	76.8	175.0	0.283	1933.7	2562309	197.5	6652478
TG400 (C)	1.4	0.01	0.78	0.19	1.229	0.125	13.3	86.8	247.8	0.145	1.086	0.000	0.062	97.2	190.9	0.195	1390.2	2712822	1802.0	6524797
AFFAN	1.3	0.02	0.72	0.16	1.233	0.114	12.8	72.2	218.5	0.105	1.149	0.389	0.047	70.0	157.5	0.268	2151.0	2680067	387.9	6750759
IMI-CRZ-3	0.9	0.01	0.75	0.15	1.415	0.119	14.7	76.1	241.9	0.108	1.316	0.273	0.036	96.1	178.1	0.287	3911.2	2637617	483.2	5908922
IMI-CRZ-16	0.9	0.01	0.61	0.15	2.123	0.112	14.7	72.0	215.1	0.085	0.815	0.567	0.049	95.2	175.7	0.195	3085.7	2304126	253.5	5928708
PALANCI(C)	1.1	0.00	0.85	0.15	1.396	0.175	13.3	81.0	271.0	0.164	1.107	0.021	0.046	68.2	185.7	0.305	2310.7	2750421	2577.0	6661903
Average	2.3	0.18	0.91	0.59	0.9	0.1	10.6	79.3	234.1	0.2	0.6	0.329	0.134	79.4	180.5	0.216	4479.8	1899055.8	914.9	5138345.1
Std Dev	1.6	0.32	0.24	0.53	0.4	0.0	4.8	9.4	22.1	0.1	0.5	0.256	0.147	18.1	22.1	0.166	3058.5	584102.5	1210.5	1139849.3
Maximum	8.5	1.41	1.63	2.18	2.1	0.2	22.1	95.9	271.0	0.6	1.5	0.851	0.620	124.2	255.2	0.821	9559.8	2750421.2	5844.6	6855340.2
Minimum	0.9	0.00	0.61	0.15	0.3	0.1	5.7	60.3	204.8	0.1	0.1	0.000	0.034	51.5	146.4	0.073	1390.2	1181626.1	197.5	3118581.5

When examining the overall liking scores, CRZ-19 and CRZ-105 received the highest scores from panelists. The sample with the lowest score was CRZ-30. CRZ-19 received the highest score in all sensory analysis parameters (Table 5). Among the control and candidate varieties, TG 400 received the highest score, while Palanci and Ahmetbey control varieties also scored high in all parameters except general appearance. Among the candidate lines, CRZ-105 and CRZ-111 stood out with high scores, while Stripi was notable for its strong aroma and taste, Affan for its taste, and Denizli Beyazi for its crispness.

Table 4. Fatty acid profiles of sunflower seeds from the varieties (%).

Variety	Palmitic	Stearic	Oleic	Linoleic	Linolenic	Arachidic	Eicosenoic	Behenic
CRZ-113	4.99	3.33	38.79	47.99	1.27	0.62	0.27	1.41
CRZ-116	6.27	2.66	43.24	46.42	0.27	0.08	0.19	0.63
CRZ-213	6.02	3.38	36.60	52.76	0.22	0.04	0.10	0.70
CRZ-30	6.61	2.62	39.92	49.39	0.20	0.05	0.13	0.70
CRZ-19	5.94	2.13	42.22	48.47	0.14	0.11	0.14	0.58
CRZ-24	5.98	3.80	38.43	50.26	0.25	0.12	0.12	0.81
CRZ-318	6.23	2.32	38.87	51.38	0.15	0.05	0.14	0.54
CRZ-103	5.98	2.36	43.58	44.76	0.13	0.78	0.13	0.53
CRZ-101	6.23	3.01	37.51	51.82	0.22	0.06	0.13	0.56
CRZ-110	6.21	3.21	42.77	46.36	0.22	0.11	0.14	0.58
CRZ-112	5.60	3.80	45.73	43.27	0.23	0.06	0.11	0.91
CRZ-104	7.19	2.45	31.25	57.59	0.15	0.08	0.13	0.35
CRZ-105	6.21	2.72	41.68	46.86	0.18	0.04	0.12	0.58
CRZ-111	5.47	2.93	40.09	50.18	0.17	0.01	0.15	0.77
CRZ-109	6.00	2.73	45.38	44.58	0.20	0.01	0.12	0.63
STRIPI	5.62	2.89	46.34	43.49	0.19	0.06	0.18	0.65
DENIZ B(C)	6.17	2.73	36.36	53.25	0.19	0.09	0.16	0.64
AHMETBY(C)	5.42	4.12	47.60	40.99	0.28	0.05	0.14	0.78
IMI-CRZ-6	6.01	2.60	41.25	48.25	0.21	0.06	0.16	0.89
G1	6.17	2.91	40.06	49.30	0.23	0.06	0.14	0.67
TG400 (C)	6.06	2.89	43.24	46.25	0.21	0.01	0.13	0.69
AFFAN	6.23	2.92	39.68	49.64	0.21	0.06	0.13	0.73
IMI-CRZ--3	4.96	3.10	48.25	42.00	0.22	0.04	0.15	0.86
IMI-CRZ-16	5.54	2.98	40.98	48.91	0.20	0.06	0.13	0.75
PALANCI(C)	5.48	3.12	41.47	48.57	0.21	0.05	0.14	0.61
Average (%)	5.94	2.95	41.25	48.11	0.25	0.12	0.14	0.70
Std Dev (%)	0.48	0.47	3.85	3.79	0.22	0.19	0.03	0.19
Maximum (%)	7.19	4.12	48.25	57.59	1.27	0.78	0.27	1.41
Minimum (%)	4.96	2.13	31.25	40.99	0.13	0.04	0.10	0.35

Based on correlation analysis, significant relationships were observed among measured traits in the study, as shown in blue in Figure 2. Significant positive and negative relationships were determined especially between seed width and thousand seed weight and some micro elements such as Mo, Ag, Sn, Se, and Ni, and macro elements Na, Mg, K, Al, as well as palmitic and oleic acid contents with some quality traits. Mostly negative relationships were observed between Mg, Se and Ni elements and palmitic acid with other traits. In contrast, generally positive relationships were determined between oleic acid, Ag and TSW with other traits (Figure 2).

The grain yield values of the varieties included in the study ranged between 1280 and 4010 kg ha^{-1}, with the TG-400 hybrid ranking first followed by CRZ-116, CRZ-318, CRZ-101 hybrids, etc. Since earliness is an important and desirable trait, the earliest variety in the study was Ahmetbey, while TG-400 was the earliest to reach physiological maturity. The TG-400 hybrid stood out for being both early-maturing and high-yielding, as desired. Similarly, the varieties CRZ-116, Affan, Stripi, and CRZ-213 also exhibited similar characteristics.

In the taste evaluation of raw kernels of the varieties included in the study, the TG-400 variety received the highest score, followed by IMI-CRZ-3, IMI-CRZ-16, IMI-CRZ-6 hybrids, etc. The highest oleic acid content was measured in Ahmetbey and Palanci control varieties. Kernel size, consisting of kernel width (cm), kernel length (cm), and kernel thickness (cm), is the most important desired trait in confectionery sunflowers.

The kernel size of sunflower seeds significantly influences consumer preference in the confectionery market. Larger seeds are generally preferred for direct consumption as snacks, a key market for confectionery sunflower seeds. This preference is driven by both aesthetic appeal and the ease of consumption associated with larger seeds (Reinert et al., 2020).

Consumers primarily prefer large kernels, with kernel width ranging between 0.6 and 1 cm, and the widest kernels observed in the CRZ-116 and CRZ-30 lines. Kernel length ranged between 1.6 and 2.5 cm, with the largest kernels found in CRZ-116, CRZ-30, CRZ-19, Ahmetbey (C), IMI-CRZ-6, G1, TG400 (C), Affan, CRZ-110, and CRZ-110 hybrids. Kernel thickness ranged between 0.27 and 0.50 cm, with the thickest kernels identified in CRZ-110 and CRZ-318. Another measure of kernel size is the 1000-seed weight, which ranged between 130.0 and 248.5 g, with the highest value observed in the CRZ-116 line, followed by CRZ-30, CRZ-19, CRZ-318, CRZ-105, and CRZ-109 lines.

Table 5. Sensory and Color analysis results of sunflower seed samples.

#	Variety	Color	Aroma	Taste	Crispness	General	Seed Hardness		Color Analysis			
							Hulled	Un-hulled	L*	a*	b*	Browning index
1	CRZ-113	3.0	3.9	4.0	3.0	3.3	41.2	18.1	63.35	1.36	14.65	3,83
2	CRZ-116	1.8	3.0	4.2	3.7	3.2	81.3	43.1	60.22	2.95	17.94	6,48
3	CRZ-213	1.3	4.1	4.0	3.0	3.2	30.2	16.5	61.18	2.21	14.00	4,86
4	CRZ-30	2.8	2.2	4.0	4.0	2.0	68.6	27.2	57.4	2.85	16.25	6,37
5	CRZ-19	3.0	4.4	4.2	4.0	4.3	69.3	27.8	62.08	1.54	15.62	4,28
6	CRZ-24	3.0	1.0	1.4	3.1	2.9	47.9	20.7	64.49	1.54	16.97	4,33
7	CRZ-318	1.2	2.3	1.2	3.2	1.2	68.7	24.9	60.73	2.03	15.60	4,95
8	CRZ-103	1.0	3.9	3.8	3.9	3.0	65.0	22.0	61.74	2.39	16.88	5,49
9	CRZ-101	1.3	3.3	4.1	3.1	2.9	73.0	28.8	60.97	2.19	14.89	4,99
10	CRZ-110	2.5	3.4	3.8	3.9	2.8	69.8	26.0	62.35	1.53	15.49	4,22
11	CRZ-112	3.0	3.4	3.1	3.6	2.3	30.9	12.9	60.86	3.12	13.53	5,87
12	CRZ-104	3.0	3.8	1.7	3.9	3.5	58.7	21.6	59.45	2.4	14.17	5,25
13	CRZ-105	3.0	4.1	4.2	3.9	4.2	55.7	21.8	59.00	2.84	14.68	5,92
14	CRZ-111	2.9	4.0	4.0	3.9	3.7	31.8	14.6	58.35	2.95	13.82	5,97
15	CRZ-109	3.0	3.2	4.0	3.2	2.5	51.9	21.5	59.63	1.87	12.82	4,38
16	STRIPI	2.8	4.6	4.2	1.0	3.2	59.9	20.6	61.48	3.2	16.86	6,45
17	DENIZ B(C)	2.0	1.8	1.8	4.0	2.6	55.2	26.0	63.02	2.21	16.01	5,04
18	AHMETBEY (C)	2.6	3.7	3.8	3.8	2.7	59.7	26.3	62.85	1.82	17.14	4,79
19	IMI-CRZ--6	2.5	1.5	1.8	3.0	2.2	53.2	19.5	61.02	2.19	14.73	4,97
20	G1	2.3	2.7	3.3	3.2	2.1	51.0	18.7	62.73	2.76	16.36	5,74
21	TG400 (C)	2.9	4.3	3.8	3.8	3.9	51.9	22.8	67.02	2.03	15.43	4,45
22	AFFAN	2.8	4.3	4.2	3.1	2.9	53.0	23.0	64.22	2.85	16.16	5,67
23	IMI-CRZ--3	2.9	2.5	3.8	3.2	3.8	40.8	17.9	62.10	1.35	17.85	4,41
24	IMI-CRZ--16	3.0	3.7	2.8	3.8	2.7	47.4	21.5	62.63	2.09	15.39	4,83
25	PALANCI 1 (C)	3.0	4.0	4.0	3.9	3.1	41.7	19.4	64.44	2.23	14.77	4,76
Average		3,0	3.9	4.0	3.0	3.3	54.31	22.52	61.73	15.52	2.26	5.13
Std Deviation		1,8	3.0	4.2	3.7	3.2	41.2	18.1	2.14	1.34	0.56	0.76
Maximum		1,3	4.1	4.0	3.0	3.2	81.3	43.1	67.02	17.94	3.20	6.48
Minimum		2,8	2.2	4.0	4.0	2.0	30.2	16.5	57.40	12.82	1.35	3.83

The peroxide value is an analysis indicator that reflects the degree of oxidation in oil-containing products, generally increasing with the application of heat treatment. In our study, the peroxide values of the samples ranged considerably between 4.5 and 124.5 meq O_2 kg^{-1} sample, with high peroxide values indicating that some samples were exposed to significant oxidation levels. This wide range of peroxide values provided an opportunity to evaluate the relationship between oxidative status and consumer acceptance.

The results of the sensory evaluation showed an inverse relationship between peroxide value and overall acceptability scores. Samples with lower peroxide values generally received higher scores in taste, aroma, and overall acceptability parameters. For instance, Affan, TG400, CRZ-318, and CRZ-105 varieties, which had comparatively lower peroxide values (3.5, 8.5, 4.5, and 7.5 meq O_2 kg^{-1}, respectively), received higher sensory scores. In contrast, varieties such as CRZ-24 and Denizli Beyazi, with significantly higher peroxide values (83.5 and 124.5 meq O_2 kg^{-1}, respectively), were rated lower in sensory evaluations, particularly in taste attributes.

The relationship between peroxide value and off-flavor development is well-established in the literature. Peroxide value measures the concentration of peroxides formed during the initial stages of lipid oxidation, which are unstable and can decompose into various volatile compounds that contribute to off-flavors, particularly rancidity (Muresan et al., 2010; Manzocco et al., 2020). In sunflower seeds, the lipid fraction is rich in polyunsaturated fatty acids, which are highly susceptible to oxidation due to their multiple double bonds, making sunflower oil and its derivatives prone to oxidative deterioration.

	SY	Flow	PM	OA	Oil C	SW	SL	ST	TSW	Hum	Prot	WA	pHR	pHC	PV	TPS	Mo	Ag	Cd	Sn	Ba	Pb	Ni	Cu	Zn	As	Se	Li	Cr	Mn	Fe	Co	Na	Mg	Al	K	PA	SA	OA	LA	LLA	AA	EA	BA	BRI
SY	1,00
Flow	-0,10	1,00
PM	0,05	0,59	1,00
OA	-0,14	0,01	0,06	1,00
Oil C	-0,30	0,17	-0,09	-0,13	1,00
SW	0,09	0,09	0,08	0,58	-0,45	1,00
SL	0,29	-0,44	-0,09	0,08	-0,38	0,42	1,00
ST	0,13	0,04	0,21	0,22	-0,24	0,46	0,44	1,00
TSW	0,05	-0,22	0,03	0,02	-0,45	0,51	0,73	0,44	1,00
Hum	-0,24	0,43	0,27	0,11	0,36	-0,22	-0,30	0,07	-0,28	1,00
Prot	0,12	-0,22	0,12	0,43	-0,56	0,27	0,33	-0,09	0,29	-0,23	1,00
WA	0,23	0,06	0,17	0,31	-0,03	0,05	-0,03	-0,08	-0,14	0,04	0,41	1,00
pHR	-0,11	0,05	-0,12	0,42	0,45	0,05	-0,25	0,26	-0,39	0,25	-0,16	0,31	1,00
pHC	0,28	-0,02	-0,13	0,42	0,05	0,26	-0,07	0,06	-0,26	-0,02	0,06	0,35	0,49	1,00
PV	-0,24	0,43	0,27	0,11	0,36	-0,22	-0,30	0,07	-0,28	1,00	-0,23	0,04	0,25	-0,02	1,00
TPS	0,07	-0,15	-0,17	-0,36	0,00	-0,18	0,18	-0,11	0,19	-0,15	-0,07	0,01	-0,20	-0,04	-0,15	1,00
Mo	0,32	-0,08	0,31	-0,12	-0,29	0,05	0,29	0,19	0,40	-0,15	0,29	0,04	-0,12	0,16	-0,15	0,39	1,00
Ag	0,29	-0,12	0,24	-0,08	-0,13	-0,03	0,14	0,20	0,26	-0,11	0,15	-0,01	0,04	0,28	-0,11	0,31	0,95	1,00
Cd	-0,05	0,18	0,20	0,00	-0,18	0,29	0,42	0,09	0,55	-0,05	0,18	0,07	-0,19	-0,16	-0,05	0,44	0,46	0,24	1,00
Sn	0,29	-0,24	0,24	-0,19	-0,21	-0,04	0,33	0,26	0,47	-0,17	0,17	-0,10	-0,13	0,09	-0,17	0,32	0,94	0,95	0,31	1,00
Ba	0,01	0,42	0,16	0,17	0,47	0,07	-0,46	-0,03	-0,47	0,27	-0,17	0,29	0,62	0,42	0,27	-0,34	-0,25	-0,10	-0,39	-0,29	1,00
Pb	-0,27	0,47	0,06	0,22	0,36	-0,07	-0,41	-0,31	-0,46	0,46	-0,05	0,32	0,37	0,14	0,46	0,14	-0,05	-0,06	0,22	-0,27	0,32	1,00
Ni	-0,40	-0,02	-0,16	0,46	0,25	-0,03	-0,61	-0,20	-0,61	0,11	-0,07	0,13	0,43	0,27	0,11	-0,47	-0,57	-0,40	-0,60	-0,55	0,38	0,17	1,00
Cu	-0,19	0,03	-0,04	0,13	-0,17	0,33	0,34	0,01	0,45	0,04	0,26	0,09	-0,23	-0,35	0,04	-0,11	-0,18	-0,38	0,48	-0,25	-0,25	0,08	-0,16	1,00
Zn	0,11	0,43	0,38	-0,08	0,00	0,01	0,04	-0,19	0,02	0,35	0,22	0,26	-0,09	-0,08	0,35	0,18	0,29	0,13	0,52	0,07	0,11	0,55	-0,42	0,43	1,00
As	0,32	-0,19	0,19	-0,13	-0,13	-0,08	0,24	0,21	0,34	-0,07	0,13	-0,06	-0,06	0,25	-0,07	0,29	0,93	0,96	0,25	0,97	-0,22	-0,19	-0,48	-0,31	0,09	1,00
Se	-0,15	-0,01	-0,18	0,45	0,42	0,05	-0,49	-0,08	-0,67	0,21	-0,23	0,15	0,60	0,44	0,21	-0,48	-0,59	-0,40	-0,62	-0,57	0,55	0,21	0,87	-0,24	-0,31	-0,46	1,00
Li	0,26	-0,05	0,19	-0,16	-0,04	0,00	-0,01	-0,10	0,04	-0,25	0,09	-0,09	-0,11	-0,11	-0,25	-0,24	0,04	0,07	-0,21	0,14	0,07	-0,30	-0,17	-0,22	-0,20	0,10	-0,08	1,00
Cr	0,22	-0,36	0,17	-0,03	-0,11	0,07	0,39	0,19	0,53	-0,13	0,24	-0,01	-0,08	0,10	-0,13	0,03	0,67	0,69	0,20	0,81	-0,23	-0,42	-0,37	-0,12	-0,15	0,77	-0,37	0,39	1,00
Mn	-0,30	-0,07	-0,19	0,56	-0,09	0,19	-0,37	-0,15	-0,33	-0,13	0,21	0,12	0,23	0,18	-0,13	-0,60	-0,49	-0,42	-0,38	-0,51	0,18	0,03	0,81	0,19	-0,25	-0,47	0,64	-0,21	-0,40	1,00
Fe	0,16	0,09	0,34	0,05	-0,27	0,19	0,29	0,38	0,32	0,05	0,26	0,29	-0,15	-0,15	0,05	-0,15	0,07	-0,08	0,19	0,02	-0,06	-0,21	-0,14	0,61	0,35	-0,02	-0,19	-0,25	-0,04	0,12	1,00
Co	-0,53	-0,04	0,00	0,28	0,24	-0,07	-0,59	-0,19	-0,45	0,11	-0,17	0,08	0,37	0,24	0,11	-0,28	-0,24	-0,09	-0,33	-0,21	0,23	0,20	0,80	-0,06	-0,27	-0,16	0,62	-0,12	-0,12	0,61	-0,10	1,00
Na	0,17	-0,30	0,27	-0,26	-0,08	-0,11	0,40	0,37	0,51	-0,15	0,09	-0,11	-0,10	-0,02	-0,15	0,21	0,69	0,70	0,17	0,84	-0,18	-0,55	-0,47	-0,18	-0,06	0,77	-0,47	0,10	0,76	-0,46	0,24	-0,21	1,00
Mg	-0,11	0,10	-0,10	0,46	0,33	0,05	-0,51	-0,15	-0,68	0,30	-0,16	0,27	0,57	0,39	0,30	-0,46	-0,58	-0,44	-0,51	-0,62	0,59	0,31	0,83	-0,12	-0,11	-0,52	0,93	-0,26	-0,46	0,66	-0,07	0,57	-0,53	1,00
Al	0,13	0,25	0,39	0,09	0,05	-0,02	-0,01	0,01	-0,04	0,29	0,20	0,36	0,14	0,37	0,29	0,28	0,68	0,64	0,40	0,50	0,17	0,44	-0,22	-0,05	0,59	0,59	-0,20	-0,35	0,20	-0,24	0,22	0,04	0,29	-0,08	1,00
K	-0,01	0,26	0,13	0,40	-0,02	0,29	-0,39	-0,11	-0,45	0,28	-0,02	0,17	0,22	0,24	0,28	-0,45	-0,52	-0,49	-0,31	-0,62	0,42	0,17	0,64	0,01	-0,02	-0,56	0,71	-0,14	-0,41	0,54	0,02	0,37	-0,54	0,83	-0,15	1,00
PA	0,19	-0,16	-0,10	-0,30	-0,58	0,27	0,21	0,01	0,36	-0,20	-0,03	-0,42	-0,65	-0,33	-0,20	0,03	-0,05	-0,18	0,10	-0,03	-0,45	-0,42	-0,27	0,23	-0,06	-0,11	-0,28	0,16	0,00	-0,08	0,08	-0,23	-0,04	-0,26	-0,40	0,17	1,00
SA	-0,08	-0,27	-0,26	0,25	0,04	-0,24	0,02	-0,02	-0,26	0,08	0,31	0,12	0,39	0,13	0,08	-0,05	0,00	0,07	-0,31	0,00	0,14	0,25	0,16	-0,04	0,09	0,01	0,12	-0,13	-0,16	0,19	0,03	0,05	-0,03	0,12	0,11	-0,23	-0,48	1,00
OA	-0,13	-0,11	-0,23	0,59	0,40	0,19	0,25	-0,01	0,05	0,01	0,14	0,30	0,39	0,31	0,01	-0,12	-0,25	-0,19	0,06	-0,22	0,12	0,21	0,18	0,19	-0,07	-0,15	0,29	-0,06	0,04	0,20	-0,12	0,02	-0,19	0,22	-0,05	-0,06	-0,59	0,25	1,00
LA	0,11	0,13	0,23	-0,64	-0,33	-0,21	-0,26	-0,01	-0,05	0,03	-0,21	-0,35	-0,41	-0,34	0,03	0,03	0,13	0,08	-0,11	0,13	-0,09	-0,29	-0,14	-0,16	0,01	0,08	-0,25	0,10	-0,04	-0,20	0,13	-0,02	0,17	-0,18	-0,05	0,11	0,60	-0,34	-0,98	1,00
LLA	0,14	0,06	0,29	0,15	-0,04	0,01	-0,04	0,09	-0,10	-0,03	0,24	0,28	0,31	0,41	-0,03	0,24	0,77	0,80	0,24	0,63	0,15	0,37	-0,12	-0,32	0,33	0,68	-0,13	-0,14	0,28	-0,15	-0,01	0,13	0,34	-0,10	0,83	-0,26	-0,45	0,29	-0,08	-0,06	1,00
AA	0,13	0,15	0,31	0,08	-0,11	0,00	-0,08	0,16	0,09	-0,07	0,02	0,38	-0,03	0,12	-0,07	0,47	0,49	0,50	0,22	0,42	-0,13	0,22	-0,19	-0,28	0,11	0,42	-0,24	-0,11	0,12	-0,24	-0,04	0,02	0,19	-0,24	0,44	-0,30	-0,20	-0,10	-0,02	-0,11	0,52	1,00
EA	0,08	0,05	0,28	0,25	0,05	0,03	-0,15	0,04	-0,14	-0,02	0,13	0,28	0,29	0,41	-0,02	-0,01	0,62	0,68	0,15	0,52	0,06	0,27	0,13	-0,38	0,04	0,59	0,09	-0,07	0,42	0,01	-0,14	0,29	0,25	0,08	0,63	-0,04	-0,40	-0,04	0,03	-0,11	0,80	0,45	1,00
BA	0,00	-0,07	0,06	0,11	0,37	-0,15	-0,09	0,00	-0,25	-0,10	0,11	0,30	0,54	0,39	-0,10	0,15	0,46	0,56	-0,03	0,40	0,40	0,36	0,06	-0,31	0,18	0,44	0,13	-0,04	0,17	-0,06	-0,06	0,20	0,29	0,07	0,59	-0,31	-0,69	0,50	0,20	-0,31	0,81	0,31	0,60	1,00
BRI	-0,01	-0,19	-0,28	-0,09	0,14	0,01	0,00	-0,25	0,11	-0,10	-0,21	-0,35	-0,13	-0,37	-0,10	0,16	-0,14	-0,13	0,04	-0,07	-0,23	-0,01	-0,05	-0,06	-0,19	-0,14	0,00	0,22	0,13	-0,19	-0,46	-0,19	-0,11	-0,04	-0,49	0,07	0,31	-0,21	0,04	-0,01	-0,36	-0,17	-0,10	-0,28	1,00

Figure 2. Correlation analysis of measured traits

Several volatile compounds resulting from lipid oxidation contribute to off-flavors in sunflower seeds, including hexanal (associated with rancid flavor), pentane (linked to rancidity), and deca-2,4-dienals (contributing to a deep-fried or painty flavor). Our findings align with other research showing that higher peroxide values correlate with increased consumer detection of off-flavors and reduced acceptability (Villiere et al., 2007).

Multiple factors, including fatty acid composition influence the oxidative stability of sunflower seeds. Interestingly, varieties with higher oleic acid content in our study, such as AHMETBEY (74.39%) and IMI-CRZ-3 (64.59%), demonstrated better sensory scores despite having moderate peroxide values. This observation is consistent with research suggesting that high-oleic sunflower varieties, with their higher proportion of monounsaturated fatty acids, are more resistant to oxidation and subsequent off-flavor development compared to varieties with higher polyunsaturated fatty acid content (Sabolová et al., 2017; Marmesat et al., 2009).

The total phenolic content of the varieties may also play a role in oxidative stability and consumer acceptance. Phenolic compounds act as natural antioxidants, potentially reducing peroxide formation and delaying the development of off-flavors. In our study, CRZ-103, which had the highest phenolic content (2505 mg GAE 100 g^{-1}), exhibited a relatively low peroxide value (12.5 meq O_2 kg^{-1}) and received favorable sensory scores. This observation supports previous findings that natural antioxidants can mitigate lipid oxidation and improve consumer acceptance (Athanasiadis et al., 2023). Storage conditions, though not specifically measured in this study, also significantly impact the rate of lipid oxidation and the formation of off-flavors. Higher temperatures and light exposure accelerate the oxidation process, leading to faster increases in peroxide value and the formation of volatile compounds (Sadeghi et al., 2020). This factor should be considered when interpreting our results, as variations in storage conditions prior to analysis could have influenced the peroxide values observed.

From a practical perspective, understanding the relationship between peroxide value and consumer acceptance is essential for the confectionery sunflower industry. Our findings suggest that maintaining low peroxide values through appropriate selection of varieties with favorable fatty acid compositions (higher oleic acid content), higher phenolic content, and implementing proper storage conditions could significantly improve consumer acceptance of confectionery sunflower products.

The TG 400 variety, which stood out in our study for its overall performance, demonstrated a favorable balance between peroxide value (8.5 meq O_2 kg^{-1}), oleic acid content (63.39%), and phenolic content (1505 mg GAE/100g DM), resulting in high consumer acceptance scores. This variety could serve as a benchmark for developing new confectionery sunflower varieties with improved oxidative stability and consumer acceptability.

Soil pH, organic matter content, and the presence of other elements can significantly influence the accumulation of heavy metals and microelements in sunflower seeds. For example, lower soil pH has been associated with higher accumulation of Cu and Zn in sunflower seeds (Sabudak et al., 2007). In this study, heavy metal contents such as Ar, Pb, and Cd in the samples were found below 0.002 mg kg^{-1}. Cadmium is one of the most studied heavy metals in sunflower seeds. Research indicates that sunflowers have a high capacity to accumulate Cd, particularly in their seeds. Studies have shown that Cd concentrations in sunflower seeds can range from 0.052 to 0.234 mg kg^{-1}, with some samples exceeding the maximum permissible levels (Sorour et al., 2024). The bioaccumulation of Pb in sunflower seeds is relatively low compared to other heavy metals, suggesting that sunflowers may not be as efficient at accumulating Pb as they are for Cd or Zn (Chaves et al., 2011).

Sunflowers have been shown to accumulate Zn efficiently, with higher concentrations in seeds compared to other plant parts. This makes sunflowers a good candidate for Zn biofortification. In this study, the highest microelement found in samples was also Zn, with concentrations ranging between 201-271 mg kg^{-1}. Copper is an essential microelement for plant growth, but excessive levels can be toxic. The second highest microelement found in samples was Cu, with concentrations ranging between 67-95 mg kg^{-1}. Sunflower seeds have been found to accumulate Cu, with concentrations ranging from 1.21 to 42.9 mg kg^{-1} (Gul and Kul, 2021).

The micronutrients in sunflower seeds also affect the fatty acid profile of the seed. The concentrations of oleic acid were primarily influenced positively by manganese, phosphorus, and nitrogen. This indicates that these nutrients play a vital role in enhancing the quality of oil in terms of its fatty acid composition. The findings emphasize the importance of balanced nutrient management in sunflower cultivation to optimize oil quality and fatty acid composition. Understanding these relationships can help farmers and agronomists make informed decisions regarding fertilization practices to enhance oil yield and quality (Bozkurt and Karaca, 2001).

The pH values of raw sunflower kernel samples ranged between 7.04 and 6.59, water activity values between 0.470 and 0.442, and moisture content between 3.3% and 2.41%, with no significant impact on kernel quality. Another critical factor is the moisture content of the seeds. Maintaining optimal moisture levels is essential, as excessive moisture can lead to spoilage, while insufficient moisture can result in undesirable texture. Moisture content significantly affects the texture of roasted sunflower seeds. Roasting at specific temperatures and times reduces moisture, enhancing crispiness. For instance, roasting at 125°C for 45 minutes yields seeds with optimal texture and minimal off-flavors (Guo et al., 2019). High protein content is a desirable trait in confectionery sunflowers, and the protein values of the varieties ranged between 17.87% and 30.05%, with the highest value observed in the Ahmetbey variety. Protein content is a key factor in the texture of sunflower seeds. Varieties with higher protein content (18.82-29.81%) tend to have a firmer texture, which is desirable for snacking and culinary uses (Ozcan et al., 2024).

The total phenolic content of hulled sunflower kernel samples ranged between 943 and 2505. Among the varieties, the CRZ-103 candidate line had the highest phenolic content, while the lowest value was observed in the IMI-CRZ-16 candidate line. Control and foreign candidates, except for the Affan variety, generally had phenolic content below the trial average. Numerous studies have investigated the phenolic compounds in sunflower seeds, highlighting their strong antioxidant properties. The primary phenolic components in sunflower seeds include chlorogenic acid, caffeic acid (in smaller amounts), as well as cinnamic, coumaric, syringic, and hydroxy-benzoic acids. These phenolic compounds exhibit high antioxidant potential and technofunctional properties that may offer biofunctional benefits (Rayman Ergun, 2024).

The differences in the total phenolic content of sunflower kernels are likely influenced by factors such as variety, location, growing and climatic conditions, and harvest time. Nadeem et al. (2011), in their study with sunflower seeds, found that the total phenolic matter content of the samples varied between 2185-2965 mg/100g in shelled seed samples and 3162-3614 mg GAE100 g^{-1} in unshelled seed samples. Fiska et al. (2006) determined the total phenolic matter content of unshelled sunflower samples as 2700 mg GAE100 g^{-1} dry matter. Ali et al. (2023) found the total phenolic matter content of unshelled sunflower seed samples between 1930-2310 mg GAE100 g^{-1}. The total phenolic matter content was found to be generally compatible with the literature. In another study, Ozcan et al. (2024) found that total phenolic content of the seeds varied between 99.64-130.75 GAE 100 g^{-1} sample.

No direct correlation was found between the total phenolic content in the samples and the results obtained from sensory analysis regarding taste, aroma, and color. Phenolic compounds in olive oil and other plant-based foods contribute to their aroma and flavor profiles, which are critical for consumer acceptance. For example, lower molecular weight phenolic acids, such as ferulic and vanillic acids, tend to have a sourer and bitter taste, whereas larger polymeric phenols are associated with astringency (Duizer & Langfried, 2016). Phenolic compounds can contribute to the color of nuts and seeds. For example, chlorogenic acid, a phenolic compound found in sunflower seeds, can react with proteins to form green-colored complexes, which may affect the appearance of sunflower-based food products (Wildermuth et al., 2016). Some phenolic compounds, such as tannins, can impart a bitter or astringent taste to nuts and seeds, which may be undesirable to some consumers (Ozcan et al., 2024). Detailed research should be carried out on which phenolic components affect consumers' appreciation of sunflower seeds.

The fatty acid composition of confectionery sunflower seeds plays a crucial role in determining their consumer acceptance, not only affecting nutritional value but also significantly influencing flavor, texture, oxidative stability, and shelf life (Yin et al., 2022; Li et al., 2024). In our study, the fatty acid profiles of the different varieties showed considerable variation (Table 4), with palmitic acid ranging from 4.96-7.19%, stearic acid from 2.13-4.12%, oleic acid from 31.25-48.25%, linoleic acid from 40.99-57.59%, and linolenic acid from 0.13-1.27%. These variations have important implications for consumer acceptance of confectionery sunflower varieties.

The relationship between fatty acid composition and sensory characteristics is particularly notable in confectionery sunflower seeds. High-oleic varieties, with their lower polyunsaturated fatty acid content, are more resistant to oxidation and less prone to developing rancidity and off-flavors (Sabolová et al., 2017). Our study showed that varieties with higher oleic acid content generally received higher sensory scores and had lower peroxide values, indicating better oxidative stability. Varieties with higher oleic acid content, such as IMI-CRZ-3 (48.25%), Ahmetbey (47.60%), and Stripi (46.34%), generally received favorable scores in taste and overall acceptability. This correlation can be attributed to the enhanced oxidative stability and improved flavor profile associated with high-oleic varieties. The moderate oleic acid content of TG 400 (43.24%), combined with its balanced fatty acid profile, contributed to its high consumer acceptance ratings, making it a promising variety for confectionery applications.

Notably, the ratio of saturated to unsaturated fatty acids also had a significant impact on consumer acceptance in the present study. Varieties exhibiting moderate concentrations of saturated fatty acids—specifically palmitic and stearic acids—alongside elevated levels of oleic acid, appeared to offer an optimal balance, aligning well with consumer preferences. For example, CRZ-19, which received high sensory scores (4.3 overall acceptability), had a balanced fatty acid profile with 5.94% palmitic acid, 2.13% stearic acid, and 42.22% oleic acid. This balance provides improved oxidative stability while maintaining desirable sensory properties. The linolenic acid content varied significantly among the varieties in our study, with CRZ-113 showing the highest content (1.27%). While linolenic acid is nutritionally beneficial, its high degree of unsaturation makes it susceptible to oxidation, potentially affecting flavor stability and shelf life. This may explain why CRZ-113 received moderate rather than exceptional sensory scores despite having the highest linolenic acid content.

The aroma of sunflower seeds is significantly influenced by their fatty acid composition, with variations in oleic acid content being particularly impactful on the sensory experience and consumer acceptance. Our findings demonstrate that the aroma profile of confectionery sunflower seeds is closely tied to both the underlying fatty acid composition and the oxidative processes that occur during storage and processing. Higher oleic acid content in sunflower seeds is consistently associated with a more desirable aroma profile, particularly following thermal treatment such as roasting (Yin et al., 2022). As evidenced in our analysis, varieties with higher oleic acid content, such as IMI-CRZ-3 (48.25%) and Ahmetbey (47.60%), received higher sensory scores for aroma (2.5 and 3.7, respectively).

Our data align with previous research indicating that the volatile compounds present in sunflower oil are significantly influenced by its fatty acid composition. High oleic sunflower varieties tend to have fewer volatile aldehydes associated with rancidity and off-flavors, such as E-2-heptenal, compared to traditional varieties with higher linoleic acid content (Xu et al., 2017). The CRZ-104 variety in our study, with the lowest oleic acid content (31.25%), received a relatively lower aroma score (3.8) compared to varieties with higher oleic acid content.

This extended shelf-life is vital for maintaining product quality and consumer satisfaction, as it allows for longer storage without degradation (Pajin et al., 2011). Among fatty acids, linolenic acid (Omega 3), which is highly preferred in nutrition, showed the highest rate in CRZ-113, as well as oleic acid, which extends shelf-life quality and taste, with the highest value measured in IMI-CRZ-3. Regarding kernel hardness, the CRZ-116 line showed the highest hardness in both measurements, while the CRZ-112 line had the lowest. Fatty acid composition is a critical quality parameter. High oleic sunflower seeds have higher oleic acid (C18:1) and lower linoleic acid (C18:2) content, which improves oxidative stability and shelf life. Processing methods like roasting and microwave pretreatment can influence fatty acid profiles, with high-oleic varieties being more resistant to oxidation (Soleimanieh et al., 2015; Yin et al., 2022). The taste of sunflower seeds is largely determined by volatile compounds formed during processing. Roasting generates terpenes, pyrazines, and aldehydes, which contribute to nutty and roasted flavors. Key compounds include 2,5-dimethylpyrazine and 2,3-dimethylpyrazine, which are enhanced by higher roasting temperatures and times (Guo et al., 2019; Yin et al., 2022). During storage, sunflower seeds can develop off-flavors due to lipid oxidation. The formation of compounds like hexanal and octanal contributes to rancidity. Proper processing and storage conditions are essential to minimize these changes (Yin et al., 2022).

Our findings revealed a positive correlation between oleic acid content and consumer acceptability scores. Varieties with higher oleic acid content, such as IMI-CRZ-3 (48.25%), Ahmetbey (47.60%), and Stripi (46.34%), generally received favorable scores in taste and overall acceptability. This correlation can be attributed to the enhanced oxidative stability and improved flavor profile associated with high-oleic varieties. The moderate oleic acid content of TG 400 (43.24%), combined with its balanced fatty acid profile, contributed to its high consumer acceptance ratings, making it a promising variety for confectionery applications.

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The fatty acid composition of sunflower seeds significantly influences their acceptance as a confectionery food, both in terms of overall and sensory acceptance. Sunflower seeds with modified fatty acid profiles, such as high oleic and high stearic varieties, offer distinct physical properties that enhance their functionality in confectionery applications. These modifications affect the texture, melting behavior, and sensory characteristics of the final product, which are crucial for consumer acceptance. Interestingly, the ratio of saturated to unsaturated fatty acids also influenced consumer acceptance in our study. Varieties with moderate levels of saturated fatty acids (palmitic and stearic acids) combined with high levels of oleic acid seemed to achieve the best balance for consumer preference. For example, CRZ-19, which received high sensory scores (4.3 overall acceptability), had a balanced fatty acid profile with 5.94% palmitic acid, 2.13% stearic acid, and 42.22% oleic acid. This balance provides improved oxidative stability while maintaining desirable sensory properties.

The application of sunflower seeds in confectionery products is further enhanced by specific fatty acid compositions. High stearic sunflower oils have been developed to improve the physical properties of sunflower oil, making it suitable for confectionery applications. These oils have a higher content of solid fats, which are essential for creating the desired texture and stability in confectionery products. Several varieties in our study, particularly Ahmetbey with 4.12% stearic acid, show potential for such applications due to their relatively higher stearic acid content. In our sensory evaluations, this characteristic may have contributed to the higher acceptability of varieties with balanced fatty acid profiles, such as TG 400 and CRZ-19.

The linolenic acid (Omega-3) content varied significantly among the varieties in our study, with CRZ-113 showing the highest content (1.27%). While linolenic acid is nutritionally beneficial, its high degree of unsaturation makes it susceptible to oxidation, potentially affecting flavor stability and shelf life. This may explain why CRZ-113 received moderate rather than exceptional sensory scores despite having the highest linolenic acid content. However, from a nutritional perspective, moderate levels of linolenic acid are desirable and could be promoted as a health benefit in marketing confectionery sunflower seeds. While the modification of fatty acid composition in sunflower seeds can enhance their application in confectionery products, it is important to consider the nutritional implications. High levels of saturated fats, although beneficial for texture and stability, may pose health risks if consumed in excess. Therefore, balancing the functional benefits with health considerations is crucial for the overall acceptance of sunflower seed-based confectionery products.

According to sensory analyses of the varieties, the CRZ-19 line received the highest score, while among control and foreign candidate varieties, the TG-400 variety received the highest score. Among control varieties, Palanci and Ahmetbey, and among candidate varieties, CRZ-105 and CRZ-111 lines also received high scores. The CRZ-113 line had the lowest browning index among the varieties, while the TG-400 variety had the lowest among control varieties. In general, samples with lower peroxide values had higher sensory acceptability.

4. CONCLUSION

In summary, from the producer's perspective, grain yield and earliness are important. In terms of yield, the TG-400 hybrid and, respectively, CRZ-116, CRZ-318, CRZ-101, Affan, and CRZ-213 varieties stood out. For earliness and high yield, TG-400, CRZ-116, AFFAN, and CRZ-213 varieties were prominent. From the consumer's perspective, based on raw taste evaluation, TG-400 and IMI-CRZ-3, IMI-CRZ-16, IMI-CRZ-6, CRZ-19, and CRZ-24 lines were notable. For kernel size, CRZ-116 and CRZ-30 lines, as well as TG400, CRZ-110, CRZ-318, and CRZ-19 lines, were prominent. According to sensory analyses, the CRZ-19 line stood out, and the TG-400 variety, along with CRZ-105 and CRZ-111 lines, were among the most preferred. In conclusion, when evaluated from the perspectives of consumers, industry, and producers together, it is preferred that newly developed varieties be high-yielding and early maturing like the TG-400 hybrid, with high oleic and linolenic acid and protein content, but low browning index and hardness.

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