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Influence of variety and location on fatty acid composition and protein content of peanuts (*Arachis hypogaea* L.) in two locations of Türkiye*

Yerfıstığının (*Arachis hypogaea* L.) yağ asidi kompozisyonu ve protein içeriği üzerine çeşit ve lokasyonun etkisi

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ABSTRACT

Objective: This study aimed to evaluate the fatty acid compositions, oil quality factors (such as oleic/linoleic acid ratio and iodine value), and protein content of four peanut varieties (Masal, NC-7, Halisbey, and Rigel) grown during the main season in two different locations (Şırnak and Osmaniye).

Material and Methods: Field experiments were conducted using a randomized complete block design with three replications at each location. It was determined that the oil and protein contents of peanut seeds, as well as oil quality parameters, including fatty acid composition, the oleic/linoleic acid ratio, and iodine value.

Results: The effect of variety was significant (p<0.05) for all quality parameters measured, except for oil content. The composition of oleic, palmitic, and stearic acids was significantly influenced by location (p<0.05). The Halisbey variety exhibited the highest protein content (22.17%).

Conclusion: The study revealed a significant genotype × environment interaction, highlighting that location is a decisive factor in varietal performance. The Masal variety was identified as the most stable and superior genotype across both locations, characterized by its high oleic acid content (approx. 50% higher than others), a superior O/L ratio, and the lowest iodine value. It was concluded that the Masal variety is a promising candidate for cultivation in both Şırnak and Osmaniye conditions to achieve premium oil quality and extended shelf life.

Keywords: Fatty acid compositions, locations, oil content, protein content

ÖZ

Amaç: Bu çalışma, iki farklı lokasyonda (Şırnak ve Osmaniye) ana ürün koşullarında yetiştiriciliği yapılan dört farklı yerfıstığı çeşidinin (Masal, NC-7, Halisbey ve Rigel) yağ asitleri kompozisyonu, yağ kalite faktörleri (oleik/linoleik asit oranı ve iyot değeri gibi) ve protein oranını belirlemeyi amaçlamıştır.

Materyal ve Yöntem: Araştırma, her iki lokasyonda tesadüf blokları deneme desenine göre üç yinelemeli olarak yürütülmüştür. Yağ ve protein içerikleri ile yağ kalite parametreleri arasında yağ asidi kompozisyonu, oleik/linoleik asit oranı ve iyot değeri incelenmiştir.

Araştırma Bulguları: Çeşidin yağ içeriği dışındaki tüm özelliklerde (p<0,05) önemli etkisi bulunmuştur. Oleik asit, palmitik asit ve stearik asit ise lokasyondan önemli (p<0,05) seviyede etkilenmiştir. En yüksek protein içeriği Halisbey çeşidinde (%22,17) gözlenmiştir.

Sonuç: Çalışma, önemli bir genotip x çevre etkileşimi ortaya koymuş olup, lokasyonun çeşit performansında belirleyici bir faktör olduğunu vurgulamaktadır. Masal çeşidi, her iki lokasyonda da en stabil ve üstün genotip olarak belirlenmiştir. Yaklaşık %50 daha yüksek oleik asit içeriği, üstün O/L oranı ve en düşük iyot değeri ile karakterize edilmiştir. Masal çeşidinin, üstün yağ kalitesi ve uzun raf ömrüne ulaşmak için hem Şırnak hem de Osmaniye koşullarında yetiştiricilik için umut verici bir aday olduğu sonucuna varılmıştır.

Anahtar sözcükler: Yağ asidi bileşimleri, lokasyonlar, yağ içeriği, protein içeriği

INTRODUCTION

Peanut (*Arachis hypogaea* L.), also known as groundnut and earthnut, is a major oil-bearing crop worldwide. The specific use of peanuts is largely determined by their oil content, shape, size, and flavor. Along with oil, peanuts are mainly used for peanut butter, roasted peanuts, snacks, confections, and soups (Tillman & Stalker, 2009; Bertioli et al., 2011; Arya et al., 2016; Mingrou et al., 2022). Globally, peanut ranks fifth in oil production after soybean, cotton, rapeseed, and sunflower, and its seeds are essential sources of protein and oil for human nutrition (Mokgehle et al., 2014; Bemova et al., 2023). Peanut seeds are composed of 44-56% oil, 22-30% protein, and 9.5-19% carbohydrate; therefore, they are an important source of vitamins E, K, and B, and minerals such as magnesium, potassium, calcium, and phosphorus (Njoroge, 2018; Zahran & Tawfeuk, 2019).

In 2023, peanuts were cultivated across 30.9 million hectares in 114 countries, yielding a global production of 54.3 million metric tons with an average yield of 1.8 tons per hectare (FAO, 2025). China emerged as the top producer, accounting for 62% of total output, while Nigeria and Argentina contributed 33.3% and 13.9%, respectively. The same year, Türkiye harvested approximately 185.137 tons of peanuts from 46.000 hectares, achieving a yield of 4 tons per hectare, which is higher than the average. The Mediterranean provinces of Adana and Osmaniye dominated domestic production, collectively responsible for 71.9% of the country's total output, followed by Şırnak with the ratio of 13% (TUIK, 2025).

Peanut oil contains rich fatty acids such as oleic, linoleic, palmitic, and stearic acids (Akhtar et al., 2014; Lee et al., 2016; Liu et al., 2019). Oil quality is largely determined by its fatty acid profile, with oleic (C18:1) and linoleic (C18:2) acids constituting approximately 80% of the total composition (Yol & Uzun, 2018). Consequently, a high oleic/linoleic acid (O/L) ratio is a key commercial trait that enhances the oil quality by improving the shelf life and flavor stability of peanut-based products (Campos-Mondragon et al., 2009; Singkham et al., 2010). For this reason, high oil content and elevated oleic acid levels are major selection criteria alongside high yield. Furthermore, consuming high-oleic peanuts offers health advantages, as they help reduce blood cholesterol levels, particularly LDL (low-density lipoprotein) cholesterol, in individuals and are associated with other benefits such as lower blood pressure (Wang et al., 2023). Among the saturated fatty acids, palmitic acid (C16:0) is the primary one in peanut oil, and its content is often found to be lower in genotypes with high oleic acid content (Yol & Uzun, 2018). The other important oil quality parameter, iodine value (IV), which is intrinsically linked to the fatty acid profile, is also associated with shelf life; lower IV values generally indicate higher oil stability (Akhtar et al., 2014).

Peanut yield and quality traits are dynamic and known to be influenced by three primary determinants: genetic characteristics, environmental conditions (location), and cultivation techniques. The plant is highly sensitive to its growing conditions (Yol & Uzun, 2018; Wang et al., 2023). This environmental variability complicates the identification of suitable varieties for specific ecological regions, especially since the Genotype × Environment (G × E) interaction has a strong and significant effect on yield (Narh et al., 2014; Kebede & Getahun, 2017; Pail et al., 2018). Studies have shown that genotype and environment interactions are significant for pod yield, mineral composition, and quality traits. For instance, the G × E interaction can mask the genetic contribution to seed mineral composition (Phan-Thien, 2010; Huang et al., 2015; Kebede & Getahun, 2017). Furthermore, significant differences among genotypes have been recorded for important fatty acid contents, such as palmitic, oleic, and linoleic acids (Yol & Uzun, 2018). Among the quality components, a strong negative correlation (e.g., $r = -0.80$) has been found between seed oil content (OC) and protein content (PC). Additionally, some high-oleic varieties exhibit notable stability for this content across different environments, suggesting the presence of genetic mechanisms that buffer against environmental variations (Wang et al., 2023).

The complex interplay of these factors highlights the need for location- and climate-optimized solutions to minimize the Genotype × Environment × Management (G × E × M) interaction (Hajjarpoor et al., 2025). Therefore, it is of great importance to investigate the variability and stability of peanut varieties in terms of yield, oil and protein content, and fatty acid composition across different ecological regions. Such a study will provide valuable information for breeding programs and farmers, enabling them to make informed decisions based on varietal performance in specific ecological zones (Yol & Uzun, 2018; Wang et al., 2023).

This study was conducted to determine the variations in fatty acid compositions, key oil quality parameters (including the O/L ratio and iodine value), and protein content of four peanut varieties (Masal, NC-7, Halisbey, and Rigel) cultivated in two distinct ecological locations of Türkiye, Osmaniye and Şırnak. A primary focus was to assess the genotype × environment (G × E) interaction and identify stable, high-quality varieties suited for each specific region.

MATERIALS and METHODS

Materials

The peanut varieties Masal, NC-7, Halisbey, and Rigel, which were obtained from the Oil Seed Research Institute, were used as plant materials in the study. The study was carried out at the locations in Türkiye: *i*. Silopi, Şırnak, Türkiye, *ii*. Cevdetiye, Osmaniye, Türkiye (Figure 1).

Figure 1. Location of the provinces of Şırnak and Osmaniye on the map of Türkiye

Şekil 1. *Şırnak ve Osmaniye illerinin Türkiye haritasındaki konumu.*

Soil analysis revealed distinct chemical characteristics for each location (Table 1). The soils in both experimental locations, Şırnak and Osmaniye, had a clayey-loam texture. The soil in Şırnak was slightly alkaline (pH 8.01), with low levels of organic matter (1.26%), phosphorus (6.33 kg da^{-1}), and potassium (66.35 kg da^{-1}), while its lime content was moderate (6.23%). In contrast, the soil in Osmaniye was also slightly alkaline but had a higher pH (8.25). It contained higher amounts of organic matter (1.73%), phosphorus (8.25 kg da^{-1}), and potassium (75.32 kg da^{-1}), with a moderate lime content of 9.22%.

Table 1. Soil properties of the experimental areas

Çizelge 1. *Çalışmanın yapıldığı lokasyonların toprak özellikleri*

	pH	O.M. (%)	P (kg da^{-1})	K (kg da^{-1})	Lime (%)	Structure
Şırnak	8.01	1.26	6.33	66.35	6.23	Clayey-Loam
Osmaniye	8.25	1.73	8.25	75.32	9.22	

O.M.:Organic Matter

The climatic conditions during the growing season (May-October 2021) exhibited significant differences between Şırnak and Osmaniye, particularly in precipitation and relative humidity. Şırnak experienced an extreme drought, with a total seasonal precipitation of only 3.8 mm, which was drastically lower than the long-term average of 56.24 mm for the region. In stark contrast, Osmaniye received 65.0 mm of rainfall, which, while still below its long-term average of 248.7 mm, was over 17 times higher than the total precipitation in Şırnak. This disparity in humidity was equally notable; the average relative humidity in the arid climate of Şırnak was 26.7%, whereas in Osmaniye, it was more than twice as high, at 60.5%. In terms of temperature, Şırnak was slightly warmer, with a seasonal average of 30.2°C compared to 25.6°C in Osmaniye (Table 2).

Table 2. Climate data of the experimental areas based on long-term averages and the study year *

Çizelge 2. *Çalışmanın yapıldığı yıl ve uzun yıllar ortalamasına göre lokasyonların iklim verileri**

	Total precipitation (mm)		Average temperature (°C)		Average relative humidity (%)	
	2021	LT	2021	LT	2021	LT
Şırnak						
May	0.80	27.10	27.6	23.9	30.9	42.9
June	0.00	4.13	31.4	30.8	21.7	16.4
July	0.00	0.44	35.7	35.0	21.8	14.4
August	0.30	2.17	34.8	34.5	23.1	15.8
September	0.00	0.50	28.9	30.2	27.6	17.5
October	2.70	21.90	22.7	23.1	35.2	29.3
Sum/Average	*3.80*	*56.24*	*30.2*	*29.6*	*26.7*	*22.7*
Osmaniye						
May	4.60	72.60	22.9	21.3	59.8	63.2
June	1.80	42.40	25.0	25.2	65.9	62.7
July	15.70	19.80	28.9	27.9	64.6	66.4
August	19.70	10.70	29.3	28.6	62.8	64.9
September	14.00	34.50	25.9	25.7	60.8	60.7
October	9.20	68.70	21.5	21.1	49.1	58.4
Sum/Average	*65.00*	*248.70*	*25.6*	*25.0*	*60.5*	*62.7*

* MEVBIS, 2025; LT: Long-term.

Methods

Peanuts were planted on May 15, 2021, in Şırnak and May 10, 2021, in Osmaniye with 70 cm apart rows and 15 cm spacing between each two plants per row. The experimental layout was a randomized complete block design (RCBD) with three replications. In both experiments, 25 kg da^{-1} of diammonium phosphate (DAP) was applied prior to sowing. Before the first irrigation, 20 kg da^{-1} of urea was applied, and an additional 20 kg da^{-1} of urea was applied prior to the third irrigation. Weed control was performed manually when necessary. Irrigation was carried out using a sprinkler system to prevent the plants from drought stress, with a total of six irrigation events applied. The harvest timing was determined primarily by the estimated number of days to maturity for each variety. Physiological maturity was confirmed using the standard hull scrape method (Williams & Drexler, 1981). In this method, the outer mesocarp of the peanut shell is scraped off, and maturity is assessed based on the color of the underlying endocarp: a dark color indicates immaturity, while a brown/black color signifies physiological maturity. Accordingly, manual harvesting was performed once the majority of pods for each variety reached this stage. Harvests were carried out on October 27, 2021, in Şırnak and on October 25, 2021, in Osmaniye. To minimize edge effects and ensure sampling accuracy, plants were harvested from the two inner rows of each plot.

The Kjeldahl method was used for determining the nitrogen content, and the conversion factor was 5.46 for peanut (Liu & Li, 2023). The oil extraction was performed using the conventional Soxhlet extraction method with diethyl ether. The fatty acid composition program was operated according to the method reported by Nagy et al. (2024). The ratios of oleic and linoleic acids and the iodine values were calculated using the formulas given below by Chowdhury et al. (2015).

$$\text{Iodine Values (IV)} = [(\%\ \text{oleic acid} \times 0.8601) + (\%\ \text{linoleic acid} \times 1.7321)]$$

$$\text{Oleic Acid/Linoleic Acid (O/L) Ratio} = \frac{\%\ \text{oleic acid}}{\%\ \text{linoleic acid}}$$

Statistical analyses

The combined data from both locations were subjected to an analysis of variance (ANOVA) according to a Randomized Complete Block Design (RCBD). The ANOVA tested the significance of the main effects of variety and location, as well as their interaction (variety × location). The significance of the variety × location interaction indicated that the performance of the varieties was not consistent across the two environments. Therefore, to understand the stability and specific adaptation of each genotype, the data were also analyzed separately for each location. For the combined and individual location analyses, means were compared using Duncan's Multiple Range Test at a 5% significance level (Steel & Torrie, 1980). All statistical analyses were performed using IBM SPSS Statistics software, version 27.

RESULTS and DISCUSSION

The study was subjected to analysis of variance (ANOVA) according to the RCBD by including the locations (Table 3 and 4). The oil content was found to be insignificant (p>0.05) for locations, varieties, and their interaction (Table 3). It ranged from 52.66% to 53.29% in Şırnak, while it varied between 51.26% and 53.22% in Osmaniye. Although NC-7 had the maximum value in Şırnak, Masal came to the forefront with its highest value in Osmaniye. Additionally, the oil content varied between 51.96% and 53.07% for the mean values, with the highest value observed in Masal, followed by NC-7 and Rigel with the values of 52.61% and 52.38%, respectively. The mean oil content was 52.51%. Shad et al. (2012) stated that the oil content, which was an important quality parameter, varied according to the varieties and the location where they were grown, and the oil ratio varied between 45.09% and 51.63%. Similarly, Mora-Escobedo et al. (2015) also found that the oil content of peanut ranged from 37.90% to 56.31% in terms of genotypes. In a study conducted in the Mediterranean region of Türkiye, oil content was also reported to be insignificant for genotypes and locations, with values of 50.71% for Adana and 50.82% for Antalya (Yol & Uzun, 2018), which aligns with the non-significant findings of the present study. In contrast, Wang et al. (2023) emphasized a significant impact of environmental conditions on peanut traits, suggesting that the stability of oil content can be context-dependent.

The major unsaturated fatty acids in peanuts are oleic acid and linoleic acid, which account for approximately 75-85% of the total fatty acids (Mingrou et al., 2022; Shin et al., 2010). Among these, the oleic acid content is a critical quality trait, shaped by the complex interaction of genetic (variety) and environmental (location) factors (Yol & Uzun, 2018). A high oleic acid content, typically exceeding 80%, is therefore a commercially desirable trait as it significantly extends product shelf life by enhancing oil stability and offers substantiated health benefits, particularly for cardiovascular wellness (Yol & Uzun, 2018; Wang et al., 2023).

Oleic acid, a monounsaturated fatty acid, was found to be significant (p>0.05) for locations, varieties, and their interaction (Table 3). It varied between 49.47% and 77.75% in Şırnak while it ranged from 51.89% to 77.03% in Osmaniye. Moreover, the oleic acid varied between 51.49% and 77.39% for mean values, and the highest value was observed in Masal, followed by Rigel with the value of 54.85%. Masal had approximately 35-40% higher oleic acid content than other varieties. The mean oleic acid was 59.11%. These findings align with the known variability, as oleic acid content has been reported to range from 49.96% to 79.41% among different varieties (Shin et al., 2010). The significant genotype-by-location interaction observed in our study is further supported by research from China, where oleic and linoleic acid contents were also found to differ across locations. Notably, in the Chengdu location, high-oleic varieties Zhonghua 215 and Zhonghua 24 exhibited a remarkable increase in oleic acid content, demonstrating a similar genotype-specific response to a distinct environment (Wang et al., 2023).

There is a well-established negative correlation between oleic and linoleic acids in peanuts (Mora-Escobedo et al., 2015; Wang et al., 2023), and linoleic acid is a dominant unsaturated acid for peanuts (Mingrou et al., 2022). Linoleic acid was found to be significant (p<0.05) for varieties and V x L interaction, but not for locations (Table 3). It ranged from 6.66% to 31.30% in Şırnak, while it varied between 6.87% and 29.56% in Osmaniye. Besides, linoleic acid varied between 6.77% and 29.82% for mean values, and the lowest value was observed in Masal since it had a higher oleic acid content. The mean linoleic acid was 23.30%. It was reported that the oleic acid content varied between varieties, ranging from 49.96% to 79.41%. This inverse relationship and the reported range for linoleic acid (4.65% to 30.30%) are consistent with previous literature (Shin et al., 2010).

Table 3. Mean values for oil content, oleic acid, linoleic acid, oleic/linoleic acid ratio (O/L Ratio), and iodine value (IV) of peanut varieties grown in Şırnak and Osmaniye

Çizelge 3. *Şırnak ve Osmaniye'de yetiştirilen yer fıstığı çeşitlerinin yağ içeriği, oleik asit, linoleik asit, oleik/linoleik asit oranı (O/L oranı) ve iyot değeri (IV) özelliklerine ait ortalama değerler*

Locations	Varieties	Oil content (%)	Oleic acid (%)	Linoleic acid (%)	O/L Ratio	IV
Şırnak	Masal	52.91±0.14	77.75±0.28	6.66±0.32	11.74±0.62	79.19±0.42
	NC-7	53.29±0.36	53.35±0.73	28.25±0.55	1.89±0.06	95.35±0.34
	Halisbey	52.67±0.25	49.47±0.61	31.30±0.58	1.58±0.05	97.27±0.51
	Rigel	52.66±0.03	57.80±0.62	26.67±0.49	2.17±0.06	96.49±0.32
	Mean	52.88±0.13	59.60±3.29 A	23.22±2.93	4.34±1.30	92.07±2.26
Osmaniye	Masal	53.22±0.48	77.03±0.62	6.87±0.64	11.42±1.16	78.93±0.57
	NC-7	51.94±1.57	52.05±0.75	29.02±0.67	1.80±0.07	95.55±0.53
	Halisbey	51.26±0.65	53.50±0.71	28.34±0.55	1.89±0.06	95.63±0.35
	Rigel	52.10±0.77	51.89±0.28	29.56±0.36	1.77±0.03	95.83±0.38
	Mean	52.13±0.46	58.62±3.22 B	23.45±2.88	4.22±1.28	91.49±2.19
Mean	Masal	53.07±0.23	77.39±0.34 a	6.77±0.32 c	11.58±0.59 a	79.06±0.32 c
	NC-7	52.61±0.78	52.70±0.55 c	28.63±0.43 ab	1.85±0.05 b	95.45±0.28 b
	Halisbey	51.96±0.44	51.49±0.99 c	29.82±0.75 a	1.74±0.08 b	96.45±0.46 a
	Rigel	52.38±0.37	54.85±1.36 b	27.97±0.64 b	1.97±0.09 b	96.16±0.27 ab
Total	Mean	52.51±0.25	59.11±2.26	23.30±2.01	4.28±0.89	91.78±1.54
p-value	Locations	0.328	0.028*	0.648	0.736	0.134
	Varieties	0.346	0.000**	0.000**	0.000**	0.000**
	L x V	0.456	0.000**	0.003**	0.872	0.231

The values are presented as mean±standard error of the mean. Letters show different groups in each column: A and B for locations, and a, b, c, and d for varieties. * Significant at level of 0.05 and ** Significant at level of 0.01.

The oleic/linoleic acid (O/L) ratio is a major focus in peanut breeding because a high ratio, indicative of elevated oleic acid content, directly confers superior oxidative stability and a longer shelf life to the product, alongside associated health benefits (Pandey et al., 2014; Toomer et al., 2019). Therefore, the O/L ratio is an index of stability for the storage of the product (Mora-Escobedo et al., 2015). The O/L ratio was found to be significant ($p < 0.05$) for varieties (Table 3). It was observed that the peanut oil varied from 1.58 to 11.74 in Şırnak and from 1.77 to 11.42 in Osmaniye. Additionally, the O/L ratio for mean values ranged from 1.74 to 11.58, and Masal showed the highest value, with its six times higher value compared to other varieties. This significant genotypic variation aligns with findings from other regions; for instance, studies in different locations of China have also reported considerable variation in fatty acid profiles and, consequently, in the O/L ratio across environments (Wang et al., 2023). The stability of a high O/L ratio in a variety like Masal across both Turkish locations in our study is a valuable finding for regional breeding programs. Due to the high O/L ratio and low IV of the oil, varieties possess better oil stability and desirable nutritional composition (Shad et al., 2012). Consistent with the current study, it was indicated that the O/L ratio ranged from 2.31 to 3.22 (Zahran & Tawfeuk, 2019) and varied between 2.09 and 18.33 (Shin et al., 2010). Besides, Shad et al. (2012) noted that the O/L ratio, a key quality parameter, varied according to the variety and the location where it was grown, with a range of 3.53 to 19.79.

Table 4. Mean values for protein content, linolenic acid, palmitic acid, and stearic acid of peanut varieties grown in Şırnak and Osmaniye

Çizelge 4. *Şırnak ve Osmaniye'de yetiştirilen yer fıstığı çeşitlerinin protein içeriği, linolenik asit, palmitik asit ve stearik asit özelliklerine ait ortalama değerler*

Locations	Varieties	Protein content (%)	Linolenic acid (%)	Palmitic acid (%)	Stearic acid (%)
Şırnak	Masal	20.68±0.16	1.65±0.07	5.46±0.09	3.07±0.16
	NC-7	17.83±0.48	1.26±0.04	9.76±0.06	3.38±0.07
	Halisbey	21.85±0.19	1.38±0.09	9.74±0.06	2.57±0.06
	Rigel	20.24±0.22	1.75±0.06	5.53±0.06	3.01±0.05
	Mean	20.15±0.46	1.51±0.07	7.62±0.64 B	3.01±0.10 A
Osmaniye	Masal	19.77±0.65	1.67±0.05	6.36±0.18	2.75±0.06
	NC-7	21.71±1.92	1.50±0.08	9.57±0.08	3.43±0.04
	Halisbey	22.50±1.04	1.43±0.05	9.38±0.17	2.38±0.06
	Rigel	20.34±0.82	1.28±0.04	9.60±0.08	2.53±0.14
	Mean	21.08±0.61	1.47±0.05	8.73±0.42 A	2.77±0.13 B
Mean	Masal	20.23±0.36 b	1.66±0.04 a	5.91±0.22 c	2.91±0.11 b
	NC-7	19.77±1.24 b	1.38±0.07 c	9.66±0.06 a	3.41±0.04 a
	Halisbey	22.17±0.49 a	1.41±0.05 bc	9.56±0.11 a	2.48±0.06 c
	Rigel	20.29±0.38 b	1.52±0.11 b	7.56±0.91 b	2.77±0.13 b
Total	Mean	20.62±0.39	1.49±0.04	8.17±0.39	2.89±0.08
p-value	Locations	0.357	0.505	0.000**	0.025*
	Varieties	0.024*	0.001**	0.000**	0.000**
	L x V	0.028*	0.000**	0.000**	0.064

The values are presented as mean±standard error of the mean. Letters show different groups in each column: A and B for locations, and a, b, c, and d for varieties. * Significant at level of 0.05 and ** Significant at level of 0.01.

IV was found to be significant ($p < 0.05$) for varieties (Table 3). The IV ranged from 79.19 to 97.27 and from 78.93 to 95.83 in Şırnak and Osmaniye, respectively. Additionally, IV varied between 79.06 and 96.45 for the mean values, with the highest value observed in Halisbey, followed by Rigel and NC-7, with the values of 96.16 and 95.45, respectively. The mean of IV was 91.78. The observed variation in IV is intrinsically linked to the fatty acid composition. A high oleic acid content, being monounsaturated (one double bond), reduces the overall degree of unsaturation compared to polyunsaturated fatty acids like linoleic acid (two double bonds), thereby resulting in a lower IV (Pandey et al., 2014; Huang et al., 2015; Wang et al., 2023). Consequently, varieties with high and stable oleic acid content are expected to maintain a more stable IV across different environments. This biochemical relationship is reflected in the literature. It was reported that the O/L ratio varied depending on the content of oleic acid and linoleic acid, and that IV differed between varieties. It was reported that the O/L ratio varied depending on the content of oleic acid and linoleic acid, and that IV differed between varieties. The IV varied between 78.08 and 91.65 (Shin et al., 2010) and ranged from 86.71 to 90.90 (Zahran & Tawfeuk, 2019). Similarly, Shad et al. (2012) also reported that IV ranged from 70.16 to 86.02 in varieties.

Protein content in peanut seeds is a critical quality trait that is closely associated with oil content and fatty acid composition, and is strongly influenced by both genotype (variety) and location (environment). In this study, the protein content was found to be significant ($p<0.05$) for varieties and L x V interaction, but not for location (Table 4). It ranged from 17.83% to 21.85% in Şırnak, while it varied between 19.77% and 22.50% in Osmaniye. Moreover, the protein content varied between 19.77% and 22.17% for the mean values, with the highest value observed in Halisbey, followed by Rigel, Masal, and NC-7 with values of 20.29%, 20.23%, and 19.77%, respectively. The mean protein content was 20.62%.

Peanuts are a rich source of both protein and oil. In contrast to the present study, it was reported that protein content in peanut seed was affected by environmental conditions (Patil et al., 2018). The values reported here are consistent with the known range, as protein content has been shown to vary between 27.54% and 32.85% depending on the genotype (Mora-Escobedo et al., 2015).

Linolenic acid, a polyunsaturated fatty acid, was found to be significant ($p < 0.05$) for varieties and L x V interaction, but not for location (Table 4). It varied between 1.26% and 1.75% in Şırnak, while it ranged from 1.28% to 1.67% in Osmaniye. Besides, linolenic acid varied between 1.38% and 1.66% for mean values, and the highest value was observed in Masal, followed by Rigel with the value of 1.52%. The mean linolenic acid was 1.49%. While literature on peanut oil quality predominantly focuses on the two main unsaturated fatty acids, oleic and linoleic, which constitute approximately 80% of the composition, the minor component linolenic acid receives less attention. Its very low concentration often leads to its omission in some studies, and its variation due to genotype and location is rarely discussed. The findings of the present study address this gap. The peanut contains linolenic acid in minor proportions, in contrast to oleic and linoleic acids (Toomer et al., 2019), a fact confirmed by these results. The levels it was observed align with the reported range of 1.25% to 1.33% (Zahran & Tawfeuk, 2019), however, it was demonstrated that its content was significantly influenced by genotype and the genotype-by-environment interaction.

Palmitic and stearic acids are two of the most important saturated fatty acid compositions (Shin et al., 2010, Mingrou et al., 2022). Palmitic acid was found to be significant ($p < 0.05$) for locations, varieties, and their interaction (Table 4). It varied between 5.46% and 9.76% in Şırnak, while it ranged from 6.36% to 9.60% in Osmaniye. Moreover, palmitic acid varied between 5.91% and 9.66% for mean values, and the highest value was observed in NC-7 and Halisbey, followed by Rigel with the value of 7.56%. Masal had the minimum value for palmitic acid owing to its higher unsaturated fatty acid contents. The mean palmitic acid was 8.17%. Stearic acid was found to be significant ($p < 0.05$) for varieties and locations, but not for V x L interaction (Table 4). It ranged from 2.57% to 3.38% in Şırnak, while it varied between 2.38% and 3.43% in Osmaniye. Besides, stearic acid varied between 2.48% and 3.41% for mean values, and the maximum value was observed in NC-7. The mean stearic acid was 2.89%. The content of palmitic and stearic acid is largely controlled by genetic factors, but location-based differences have also been reported, with varying conclusions across studies. For instance, a study in China confirmed that palmitic and stearic acid contents changed depending on genotype and location (Wang et al., 2023), which aligns with our findings of a significant location effect. In contrast, a study conducted in Türkiye reported that the location effect was statistically insignificant for these traits (Yol & Uzun, 2018), highlighting the context-dependent nature of environmental influence. This is consistent with other reports indicating that palmitic and stearic acids are affected by genotypes and environmental conditions, with palmitic acid varying between 12.01% and 15.00% (Zahran & Tawfeuk, 2019). Besides, Mora-Escobedo et al. (2015) indicated that palmitic acid ranged from 11.9% to 13.1%, while stearic acid varied between 2.5% and 3.8% in terms of genotypes.

CONCLUSION

This study demonstrates that the expression of key quality traits in peanut—oil content, fatty acid composition, and protein content—is not solely governed by genetics but is profoundly shaped by the genotype × environment (G × E) interaction. The cultivation of four peanut varieties across the contrasting ecological zones of Şırnak and Osmaniye provided critical insights for location-specific variety recommendations. The most significant finding was the exceptional stability and superiority of the Masal variety. Despite oil content showing no significant variation overall, Masal consistently yielded the highest mean oil content. More notably, it exhibited remarkably high oleic acid content (approximately 50% higher than other varieties) and a consequently superior O/L ratio (about tenfold higher) across both locations. This biochemical profile resulted in the lowest iodine value, positioning Masal as an ideal candidate for producing stable, long-shelf-life peanut products in both arid and temperate Mediterranean environments. In contrast, the Halisbey variety emerged as the best performer for protein content. However, the significant G × E interaction for this trait indicates that its high protein yield is more dependent on the specific growing conditions, necessitating further evaluation for stable production. In conclusion, the location-specific environmental factors were decisive in modulating varietal performance. For breeders and farmers, our results underscore the critical importance of multi-environment testing. We conclusively recommend the Masal variety for reliable cultivation in both Şırnak and Osmaniye to achieve premium oil quality, while Halisbey presents a valuable, though location-sensitive, option for high protein yield.

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Data Availability

Data will be made available upon reasonable request.

Author Contributions

Conception and design of the study: MY, CBS; sample collection: MY, CBS; analysis and interpretation of data: CBS, MY; statistical analysis: CBS, MY; visualization: MY, CBS; writing manuscript: MY, CBS.

Conflict of Interest

There is no conflict of interest between the authors in this study.

Ethical Statement

We declare that there is no need for an ethics committee for this research.

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