FIXED OIL POTENTIAL OF WESTERN BLACK SEA LAUREL (*LAURUS NOBILIS* L.) SEEDS: MORPHOLOGICAL, BIOCHEMICAL AND PHYSIOLOGICAL APPROACHES

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Abstract. Contemporary forestry prioritizes functional planning approaches for non-wood forest products to meet the changing demands of society and enhance welfare. In this context, bay laurel (*Laurus nobilis* L.), which grows naturally in the Western Black Sea Region, holds strategic importance for its seeds used in fixed oil production. İntended aims to evaluate the fixed oil yield and chemical composition of bay laurel seeds by examining their morphological, physical, and organoleptic properties. The bay laurel plant has multifaceted importance for the Western Black Sea Region. This importance can be assessed in terms of economic, ecological, socio-cultural, and export potential Seed samples were collected from different elevations (0, 150, and 400 m), and their morphological (seed-to-shell ratio, seed weight), physical, and organoleptic properties were determined. Seed fixed oil was extracted with hexane., and acid and saponification numbers and fatty acid composition were analyzed. Analysis revealed that the seed-to-shell ratio ranged from 67.6% to 70.2%, with the seed predominating by weight. The fixed oil ratio decreased with increasing elevation. The acid number exhibited regional variation; The acid number showed regional differences and the highest value was found in Sinop. (14.30), and the lowest in Zonguldak (11.57). The high saponification number demonstrates the importance of the importance of oil to the soap and detergent industry. Saturated fatty acids (29.40–32.06%) and unsaturated fatty acids (67.94–70.60%) were detected in the oils obtained with hexane, with oleic and lauric acids being the primary components. Laurel (Laurus nobilis L.) seeds grown in the Western Black Sea Region represent a strategic biological resource for the production of high-value fixed oils thanks to their morphological, biochemical, and physiological properties. The findings indicate that the fixed oil from the Western Black Sea laurel seed is particularly rich in unsaturated fatty acids and has significant functional potential for the food, cosmetics, and pharmaceutical sectors. Overall, the study demonstrates that laurel seed fixed oil can be utilized industrially and commercially as a high-value-added natural product.
Keywords: *Laurus nobilis L., seed morphology, fixed oil, fatty acids, organoleptic properties, industrial utilization*

Introduction

Natural plant resources are a focal point of scientific research today due to their biochemical properties and versatile applications. Turkey, with high quality products and widespread distribution, is among the leading countries in the production of bay laurel (*Laurus nobilis* L.) leaves and fruit. The Western Black Sea Region stands out with its natural populations and high yield capacity.

Soap is produced from bay laurel seed fixed oil by cold process method and activated carbon is produced from the seed kernel. The study supports the usability of bay laurel seed fixed oil as a carrier oil in cosmetics (Yagmur et al., 2024). This study aims to determine the morphological and biochemical properties of bay laurel fruits growing naturally in the Western Black Sea Region and to scientifically evaluate the industrial, food and pharmaceutical potential of the obtained fixed oil.

The composition of Turkish bay laurel fruit seed oil was investigated by gas chromatography and mass spectrometry. Of the 20 fatty acids present in the acidic fraction, lauric acid (54.2%), oleic acid (15.1%) and linoleic acid (17.2%) were found to

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be the main dominant components (Hafızoğlu and Reunanen, 1993). Bay laurel fruit seeds are a strategic resource for the production of fixed oil and seedlings. The resulting fixed oil is rich in saturated and unsaturated fatty acids, particularly lauric acid, sterols, tocopherols, and phenolic compounds.

Studies conducted in the Hatay region of southern Turkey reported that bay laurel seed oil is yellow in color and has a viscous structure; its density is 0.9374 g/cm³, its freezing point is 26.4°C, its melting point is 32°C, its acidity index is 1.82, its saponification index is 232, its unsaponifiable matter content is 2.1%, and its iodine index is 44.4 (Özcan and Chalchat, 2005). In another study from Hatay, it was determined that the seed fixed oil consists of lauric (12.7–31.2%), palmitic (12.4–19.9%), oleic (30.4–44.4%), and linoleic (15.9–26.8%) acids (Ayanoğlu et al., 2018).

Comparison of cold-pressed and Soxhlet fractions for seed kernels and seed coats; fatty acid profiles with GC-FID. While the saturated fraction increases in Soxhlet, the unsaturated fraction in the shell is higher due to cold-pressing; the selection of fraction and method is a determining factor on yield and profile. However, in particular applications, a comparison of cold-pressed and Soxhlet fractions was made for seed kernels and seed coats; fatty acid profiles with GC-FID; While the saturated fraction increases in Soxhlet, the unsaturated fraction in the shell is higher due to cold-pressing; the selection of fraction and method is a determining factor on yield and profile (Şentürk et al., 2022)

The extraction method plays a decisive role in oil quality. Cold pressing (≤50°C) preserves heat-sensitive components (tocopherols, phenolics), reducing oxidative degradation and allowing for continued biological activity. The effects of different extraction methods (cold press, Soxhlet, supercritical CO_2) and regional differences on fixed oil yield and component distribution are presented in *Table 1*.

Table 1. *Fixed oil yield of bay laurel seeds according to different extraction methods*

Source/year	Method	Yield/major Fa	Recommended use
Türkmen and Koçer (2021)	Cold Press, Soxhlet	18–26 / Oleic 45, Linoleic 22	Cosmetics, food carrier oil
Şentürk et al. (2022)	Cold Press, Soxhlet	17–25 / Oleik 48, Palmitic 15	Food additives, soap production
Yağmur et al. (2024)	Cold Press	22 / Oleic 43, Linoleic 20	Cosmetic soap, activated carbon by-product
Awada et al. (2023)	Supercritical CO_2	28 / Oleic 49, Linoleic 23	Biofuel, cosmetic formulation
Fantasma et al. (2024)	Chemometric EO-SC Comparison	— / Oleic-Linoleic based profile	Food aroma, functional analysis

The extraction method plays a decisive role in the quality of the oil. Cold pressing (≤50°C) preserves heat-sensitive components (tocopherols, phenolics), reducing oxidative degradation and allowing for the maintenance of biological activity. Fatty acids in laurel seed oil obtained by supercritical CO_2 (SC-CO_2) extraction were determined as lauric (27.7%), oleic (27.2%), linoleic (21.5%), and palmitic (17.1%) (Marzouki et al., 2018). It is emphasized in the literature that lauric acid is the dominant component and that process parameters play a critical role in yield (Beis and Dunford, 2006). Furthermore, trans-β-ocimene and germacrene D are prominent in the volatile fraction,

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which constitutes approximately 10% of the oil. In the neutral lipid fraction, oleic (30%) and linoleic (20%) are reported as the main unsaturated fatty acids, while lauric (18%) and palmitic (22.5%) are reported as the main saturated fatty acids (Castilho et al., 2005). Bay laurel fruit seed oil content reaches a maximum of 23.76% on day 140 after flowering, with lipid accumulation decreasing thereafter. The main fatty acid is oleic acid, and among phytosterols, β-sitosterol is the dominant component at 84.02%. Other sterols such as campesterol and stigmasterol have also been identified (Sebei and Zouhir, 2022). In the unsaponifiable fraction, hydroxy ketones derived from fatty acid esters are the prominent components (Garg et al., 1992).

Thanks to its antimicrobial properties, bay leaf fixed oil has natural preservative properties and extends shelf life for food safety. Used as a base oil in cosmetics and pharmaceuticals, it is utilized in soap, cream, lotion, and shampoo formulations for its skin-softening, anti-inflammatory, and antiseptic properties. Bay laurel fixed oil comes to the forefront in terms of its use in cosmetics (carrier oil, soap) and food (flavor carrier/antioxidant additive) areas and the use of natural products with the trend that has developed in recent years Lauric acid increases lathering and cleansing capacity in soaps, while oleic and linoleic acids provide moisturizing and restorative effects. Furthermore, the pulp resulting from fixed oil production can be used as animal feed due to its high energy and fiber content.

In Turkey, bay laurel oil and soap production is a high-value-added economic activity, particularly concentrated in the coastal villages of Hatay, Osmaniye, and Adana. Small-scale production initiatives also exist in the Mediterranean belt (Mersin, Antalya) and, to a lesser extent, in the Aegean region. The growing demand for natural cosmetic products strengthens the export potential of bay laurel oil and its derivatives. Organoleptic analyses (taste, odor, color, texture) of vegetable oils play a critical role in determining product freshness, purity, and potential spoilage. These tests are recognized as an integral part of quality control in the Food Codex, Pharmacopoeia, and industry standards.

Materials and methods

The study material consisted of bay laurel (*Laurus nobilis* L.) fruits naturally distributed in the Western Black Sea Region (Sinop, Kastamonu, Bartın, Zonguldak). The research material was formed from laurel plant (*Laurus nobilis* L.) seeds, which are naturally distributed in the forest ecosystem, obtained from the Bartın, Sinop, Kastamonu and Zonguldak regions of the Western Black Sea region.

Seeds were harvested at maturity (September–November), and samples were collected from 36 experimental plots, three for each region and at each elevation. Samples of laurel plants containing seeds were collected and mixed evenly across the plots to best represent the area. Approximately 2000 g of fruit from each plot were placed in bags and individually numbered. Standard-scale test samples were collected from these bags and analyzed. The oil samples obtained were stored at 4–8°C, protected from light and oxygen.

Morphological, physical, organoleptic, and chemical analyses were conducted according to standard laboratory protocols. Thirty-seven 400 m² sample plots were established in the Bartın region for inventory studies and were found to be adequate at a 95% confidence level. Furthermore, to examine the effect of elevation on oil yield and fatty acid composition, 12 sub-regions were identified in four provinces, as shown in *Figure 1*. A total of 36 sample plots were established at elevations of 0, 150, and 400 m. These plots represent areas where laurel populations are dense and continuously distributed.

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Figure 1. *Sampling areas of materials in West Black Sea Region of Turkey*

Sample plots were selected to represent the region's topographical units, elevational ranges, and habitat diversity. Mature laurel seeds were collected by hand or with telescopic shears from ≥ 30 trees of varying ages and heights, up to 5 m high, mixed homogeneously by site, and transported to the laboratory in polyethylene bags, protected from the sun. The seeds were cleaned of foreign material and aerated for 48 h to remove surface moisture.

Fruit samples were collected between October and November 2022 and 2024, with sampling conducted at elevations of 0, 150, and 400 m in each sub-region. Approximately 2 kg of fruit were collected from each of the 36 sample plots.

To determine physical properties, weight, length, and width measurements were taken on 1000 fruits from each region, and the flesh, peel, and seed ratios were calculated. Additionally, the number and size of berries in 500-g fruit groups were examined to determine the peel-to-seed ratio. Moisture content was determined by drying to a constant weight at 103 ± 2°C.

For oil analyses, samples collected from the same elevations in each region were blended to create representative samples. Fixed oil content was determined using a multistage extraction method with hexane from the dry matter; the solvent was removed by rotary evaporation under nitrogen, and the yield was calculated as a percentage.

For the essential oil content, 50 g of ground seed sample from each sub-region was subjected to hydrodistillation with 500 ml of water in a neo-Clevenger apparatus for 3 h; the oil ratio according to dry matter was calculated and the components were analyzed by GC–MS.

The density of bay laurel seed fixed oil was determined by pycnometry, acid number by direct titration, saponification number by back titration, and unsaponifiable matter by the petroleum ether method. Fatty acid components were identified by GC analysis after saponification of triglycerides and their conversion to methyl esters, and the results were calculated as percentage composition.

For morphological measurements, length and width of 300 randomly selected seeds from each region were examined using a digital caliper (0.01 mm), weight using a precision scale (0.001 g), humidity rate using oven drying (103 ± 2°C, 17 h), shell thickness using a microtome and stereomicroscope, and embryo structure under a microscope.

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The seed fixed oil content was determined by Soxhlet extraction (petroleum ether); oil samples were analyzed by gas chromatography (GC-FID) to evaluate fatty acid composition.

All measurements were made in three replicates, the data were evaluated using variance analysis (ANOVA) in the SPSS 25.0 package program, and the differences between the means were compared using the Tukey test ($p < 0.05$).

Sensory analyses were conducted by 12 trained panelists at 21 ± 1°C in an odorless, color-neutral environment. Coded samples were presented in 15 mL glass containers, and color, odor, taste, and texture parameters were evaluated using a 9-point hedonic scale. Inter-panel consistency was determined using Cronbach's alpha. Mean sensory scores were visualized on a 1–8 scale using a radar chart, providing a holistic view of the product's sensory quality profile.

Results

Determination of bay leaf inventory quantity

In inventory studies conducted in the Western Black Sea Region, data from 400 m² trial plots were extrapolated to hectares to calculate fruit yield. In the Bartın region, an average fruit yield of 2117 kg/ha was determined. Considering the total area of laurel in the region, which covers 573 ha, the annual potential production is estimated at approximately 1,213,041 kg.

It is anticipated that approximately 20% of the fruit can be processed in modern facilities to yield a fixed oil. This yield corresponds to approximately 242,608 kg of oil from total production. Detailed statistics on fruit yield (mean, minimum, maximum, and standard deviation) are summarized in *Table 2.*

Table 2. *Average, minimum and maximum fruit amount in Bartın Province Sub-Regions*

Region	N (number of sampling)	Min (kg)	Max (kg)	Mean ± std
Bartın-Kurucaşile	9	60	98	78.9 ± 12.4
Bartın-Amasra	9	55	121	90.3 ± 18.7
Bartın-Gürgenpınarı	9	52	109	79.1 ± 18.2
Bartın-Karaçaydere	9	55	123	93.4 ± 20.1

In the measurements made in four different sub-regions of Bartın province (Kurucaşile, Amasra, Gürgenpınarı and Karaçaydere), the amount of fresh fruit varied between 52 and 123 kg and the regional average was found to be 84.69 kg. Multiple variance analysis of the effects of collection region, altitude and residues on the amount of fixed oil in bay laurel fruit is given in *Table 3*.

When *Table 2* was examined, the differences between collection region, altitude, and residues in terms of their effects on the amount of fixed oil in bay laurel fruit were found to be statistically significant ($P < 0.05$). The results of the Duncan test, which was conducted to determine which groups the difference was significant between, are given in *Tables 4* and *5*.

According to *Table 4*, the highest fixed oil content in bay laurel fruit was obtained at an altitude of 0 m above sea level, while the lowest value was obtained at an altitude of 450 m above sea level. It can be said that microclimate characteristics and the aspect have

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a high effect on generative growth in bay laurel trees, thus contributing to the high fixed oil content in the fruit.

Table 3. *Multiple analysis of variance regarding the effects of collection region, altitude and residues on the amount of fixed oil in bay laurel fruit*

Variance source	Sum of squares	Degrees of freedom	Mean squares	F Value	Level of importance
Region	99.094	3	33.031	15.382	0.000
Elevation	164.796	2	82.398	38.371	0.000
Residues	219.036	102	2.147	-	0.000
Total	482.927	107	-	-	

Table 4. *Duncan test results between bay leaf fixed oil amount and altitude*

Elevation	Sample number	Mean	Homogenous groups
400	36	14.133	X
150	36	16.075	X
0	36	17.114	X
Interactions			Differences
0-150			1.039
0-400			2.981
150-400			1.942

Table 5. *Duncan test results between the amount of fixed oil in bay leaves and the collection region*

Collection area	Sample number	Average	Homogeneous groups
Zonguldak	27	14.322	X
Kastamonu	27	15.548	X
Bartın	27	16.385	X
Sinop	27	16.840	X
Interactions			Differences
Sinop-Kastamonu			1.292
Sinop-Bartın			0.455
Sinop-Zonguldak			2.518
Kastamonu-Bartın			0.837
Kastamonu-Zonguldak			1.225
Bartın-Zonguldak			2.062

An examination of *Table 4* reveals that the highest fixed oil content of bay laurel fruit was obtained in the Sinop region, followed by Bartın, Kasyamonu, and Zonguldak. Sinop, Bartın, and Sinop regions exhibit similar characteristics within the same range, but there are differences between Kastamonu and Zonguldak. This is likely due to edaphic and genotypic differences between the regions. Bartın and Sinop regions, on the other hand, appear to be similar in terms of microclimate characteristics, particularly regarding the growing environment for bay laurel fruit.

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Using the average values f measurements obtained in different regions and elevations was preferred to reveal the general trend in seed fixed oil yield at each elevation level by reducing the effect of individual differences, and the average values are given in *Table 5*. The results demonstrate the effect of region and elevation factors on fixed oil accumulation from a more holistic perspective.

Bay fruit physical properties, moisture and total ash content

Physical properties of bay laurel fruits obtained from the Western Black Sea Region are given in *Table 6*. Physical parameters are important indicators in evaluating fruit seed quality, oil yield and industrial use potential.

Table 6. *Physical properties of bay laurel fruit according to regions in the Western Black Sea region*

Properties	Sinop	Kastamonu	Bartın	Zonguldak
1000-grain weight (g)	1250	1094	1110	1045
Grain lenght (mm)	15.8	14.1	15.3	13.9
Grain width (mm)	12.2	10.6	11.1	10.3
Seed (%)	69.2	67.6	68.9	67.8
Shell (%)	30.2	29.8	32.0	31.3
Moisture (%)	72	74	72	70
Ash (%)	2.0	1.8	1.9	1.7

As shown in *Table 6*, the basic physical properties of bay laurel berries in the Western Black Sea region varied among provinces. The highest 1000-seed weight was found in Sinop at 1250 g, and the lowest in Zonguldak at 1045 g. Morphological measurements ranged from 13.9 to 15.8 mm in length and 10.3 to 12.2 mm in width, with Sinop samples being more substantial.

The seed ratio ranged from 67.6% to 69.2%, and the shell ratio ranged from 29.8% to 32.0%, with the shell ratio being relatively higher in the Bartın samples. Moisture content ranged from 70% to 74%, with the highest value found in the Kastamonu (74%). Ash content ranged from 1.7% to 2.0%, with the highest value found in the Sinop samples. These results indicate that the seed ratio supports the fixed oil potential, while moisture and ash contents are important for the fruit's storage, processability, and mineral composition.

Morphological characteristics of bay laurel (Laurus nobilis L.) fruit seeds

Morphological characteristics of bay laurel (*Laurus nobilis* L.) seeds are a determining parameter for oil yield. *Table 7* shows the morphological characteristics of bay laurel seeds from the Western Black Sea Region, which are used to select high-quality seeds and determine raw material quality for industrial oil production.

Morphological traits of bay laurel (*Laurus nobilis* L.) seeds collected from the Western Black Sea region showed limited but significant differences among the provinces. The highest seed length, width, and single seed weight were determined in Bartın (11.4 × 7.5 mm; 0.50 g), while the lowest were determined in Sinop (11.0 × 7.2 mm; 0.47 g). Seed coat thickness was 0.84–0.85 mm in Kastamonu and Bartın, decreasing to 0.76 mm in Sinop. Moisture content was found to be highest (30.5%) in Bartın and lowest (28.8%)

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in Sinop. These findings suggest that ecological conditions and genetic differences affect morphological traits.

Table 7. *Morphological characteristics of bay laurel (Laurus nobilis L.) seeds*

Region	Length (mm)	Width (mm)	Seed weigth (g)	Moisture (%)	Shell thickness (mm)
Kastamonu	11.1	7.3	0.46	29.0	0.84
Bartın	11.4	7.5	0.50	30.5	0.85
Zonguldak	11.3	7.4	0.49	30.2	0.83
Sinop	11.0	7.2	0.47	28.8	0.76

In general, the length of Western Black Sea seeds was measured as 11.4 ± 0.3 mm, width as 7.5 ± 0.3 mm, and individual seed weight as 0.50 ± 0.03 g. Differences within the region are compared in *Figure 2*. Individual seed weight was found to be statistically significantly higher in the Bartın and Zonguldak samples. Moisture content varied between 28.8% and 30.5%.

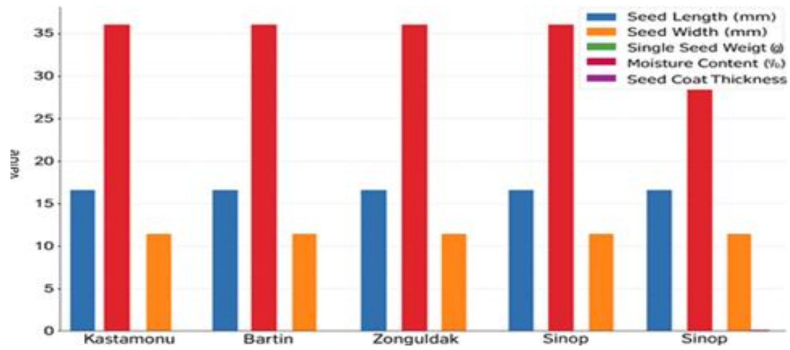

Figure 2. *Comparative morphological features in the western Black Sea region*

Morphological parameters varied significantly among regions. Bartın samples had the highest values for seed length, width, single seed weight (0.50 g), and moisture content (30.5%), while Sinop samples exhibited the lowest values (0.47 g; 28.8%). Seed coat thickness was 0.84–0.85 mm in Kastamonu and Bartın, decreasing to 0.76 mm in Sinop.

The study demonstrates that bay laurel seeds from the Western Black Sea Region are of high morphological quality and offer significant potential for both production and industrial use. Regional differences can be explained by intraspecific genetic diversity and the influence of environmental conditions.

Effect of elevation on fruit seed fixed oil yield of laurel (Laurus nobilis L.) in the Western Black Sea Region.

Fixed oil yields of laurel plant fruit seeds at different elevations (0, 150 and 400 m) in four regions (Sinop, Kastamonu, Bartın and Zonguldak) in the Western Black Sea Region are given in *Table 8*. In the study carried out in the Western Black Sea Region, it was determined that different elevation levels (0, 150 and 400 m) had significant effects on the fixed oil yield of laurel (*Laurus nobilis* L.) fruit seeds.

While the Sinop and Bartın samples reached the highest values (~18%) at sea level, this ratio decreased to 13–16% at 400 m. Kastamonu had the lowest ratios (12.5–16.5%)

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at intermediate levels and Zonguldak at all elevations. The findings indicate that local ecological conditions and elevation play a decisive role in fixed oil accumulation.

Table 8. *Fixed oil contents (%) of laurel (Laurus nobilis L.) fruit seeds at different elevations in the Western Black Sea Region*

Region	0 m	150 m	400 m
Sinop – Akliman	18.2	17.8	15.9
Sinop – Gerze	18.0	17.8	15.6
Sinop – Çatalzeytin	17.4	15.7	15.2
Kastamonu – Cide	15.4	14.7	12.1
Kastamonu – İnebolu	17.3	16.9	14.3
Kastamonu – Abana	18.2	16.9	14.0
Bartın – Kurucaşile	18.2	17.7	14.5
Bartın – Amasra	18.6	17.1	15.8
Bartın – Mugada	17.6	15.0	13.0
Zonguldak – Merkez	14.5	13.4	12.5
Zonguldak – Ereğli	16.5	15.3	13.5
Zonguldak – Suludere	15.6	14.4	13.2

Using the average values of measurements obtained in different regions and altitudes was preferred in order to reveal the general trend of seed fixed oil yield at each altitude by reducing the effect of individual differences, and the average values are given in *Table 9*. Thus, the results show the effect of the altitude factor on fixed oil accumulation from a more holistic perspective, while taking into account the variation between regions.

Table 9. *Average values of fixed oil yields from laurel (Laurus nobilis L.) fruit seeds at different altitudes (0, 150 and 400 m) in the Western Black Sea Region (%)*

Altitude (m)	Sinop	Kastamonu	Bartın	Zonguldak
0	17.85	16.97	18.11	15.51
150	17.11	16.16	16.62	14.40
400	15.55	13.50	14.42	13.05
Mean	16.82	15.54	16.38	14.32

According to average values, fixed oil yield decreased with increasing altitude in all provinces. Bartın (18.11%) and Sinop (17.85%) had the highest yields at sea level, while Zonguldak (13.05%) had the lowest at 400 m. An examination of the overall averages revealed the highest yield at 16.82% and the lowest at 14.32% in Zonguldak. Bartın and Sinop showed high values, Kastamonu showed medium values, and Zonguldak showed low values. These results suggest that elevation is an important determinant of fixed oil production from bay laurel. Differences in yield are thought to be due to regional microclimatic conditions (temperature, humidity, proximity to the sea) and edaphic characteristics (soil structure, drainage). At lower altitudes, favorable microclimate and aspect conditions enhance generative development and support fixed oil accumulation. *Figure 3* visualizes regional average values for the region to facilitate interpretation of both differences between provinces and changes due to elevation. The relationship

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between fixed oil ratios and elevation is presented comparatively. It is clearly seen that fixed oil ratios decrease with increasing elevation in all regions. While the Sinop and Bartın samples reached the highest values (~18%) at sea level, this ratio decreased to 13–16% at 400 m. Sinop and Bartın reached the highest values at lower elevations, while Zonguldak had the lowest values (12.5–15.5%) at all elevations (*Fig. 3*). These results indicate that elevation is a determining environmental factor in fixed oil accumulation, suggesting that lower elevation areas are more advantageous for fixed oil production. The Sinop and Bartın regions were generally found to exhibit the highest fixed oil ratios, suggesting that coastal ecosystems at lower elevations provide more favorable growing conditions for laurel, and that microclimate and soil conditions enhance fixed oil accumulation.

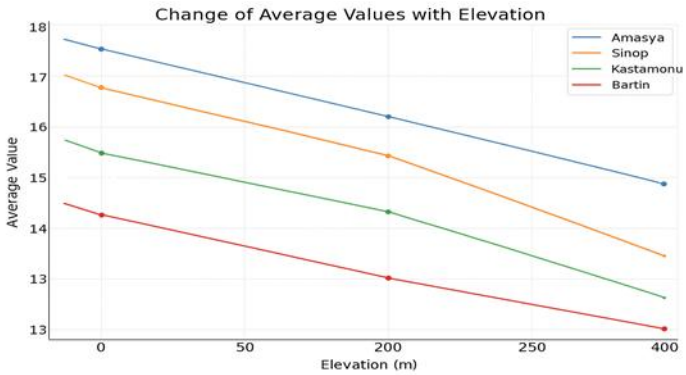

***Figure 3.** Average change (%) in fixed oil content of laurel (Laurus nobilis L.) fruit seeds depending on different altitudes (0, 150 and 400 m) in the Western Black Sea region*

Organoleptic properties of bay laurel (Laurus nobilis L.) seed fixed oil

Determining organoleptic properties is essential for evaluating the sensory quality and potential applications (food, cosmetics, pharmaceuticals) of vegetable oils. Parameters such as color, appearance, odor, and taste play a critical role in understanding the product's consumer acceptance and compliance with industrial standards. The organoleptic properties of bay laurel fixed oil were evaluated based on odor, taste, color, and texture parameters, and the obtained data are presented in *Table 10*. The sensory properties generally exhibit a balanced distribution. The odor and color parameters received higher scores, highlighting the product's characteristic quality. Bay laurel fixed oil received particularly high scores for odor (8.1 ± 0.7; α = 0.92) and color (7.8 ± 0.6; α = 0.89), while taste and texture were rated at relatively lower but acceptable levels. Panelist reliability was determined using Cronbach's alpha (α), and the obtained α values (0.85–0.92) indicated a high level of internal consistency among the panelists.

The dark green color of the seed's fixed oil indicates high levels of chlorophyll and carotenoid pigments, which are related to environmental factors (light, soil minerals, humidity). Pigment density affects the oil's color and antioxidant capacity. The low solid particles in the seed increase extraction efficiency. The aromatic odor is attributed to the volatile compounds and esters in the fixed oil, increasing the product's value in the food and cosmetics sectors. The bitter taste, however, originates from the fatty acids, phenolic compounds, and alkaloids and does not negatively affect quality in cosmetics and soap production.

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***Table 10.** Organoleptic properties of bay leaf fixed oil*

Parameter	Mean score (±SD)	Panelist consistency (α)	Description
Color	7.8 ± 0.6	0.89	Dark Green
Odor	8.1 ± 0.7	0.92	Slightly pungent
Taste	7.5 ± 0.8	0.87	Aromatic
Texture	7.3 ± 0.5	0.90	Bitter

Analytical properties of bay laurel fruit seed fixed oil

Determination of analytical properties such as density, acid number, saponification number, and unsaponifiable matter content in vegetable oils is essential for determining the oil's quality, industrial potential for the soap, cosmetics, and food sectors, and its potential applications. The fixed oil obtained from laurel (Laurus nobilis L.) fruit has a triglyceride structure and contains both saturated and unsaturated fatty acids. The results of analytical analyses performed on samples obtained from different regions in the Western Black Sea Region are presented in *Table 11*.

***Table 11.** Analytical properties of fixed oil from laurel (Laurus nobilis L.) fruit seeds obtained from different regions in the Western Black Sea Region*

Analyses	Sinop	Kastamonu	Bartın	Zonguldak
Density (d20)	0.8464	0.8325	0.8675	0.8140
Acid Number	14.30	12.46	13.20	11.57
Saponification Number	183.6	173.2	179.4	169.7
Unsaponifiable Matter (%)	1.32	1.46	1.40	1.58

Density values ranged from 0.8140 to 0.8675, with the highest density found in the Bartın samples. The acid number was highest in Sinop (14.30) and lowest in Zonguldak (11.57). Saponification numbers ranged from 169.7 to 183.6, with the highest value in the Sinop samples. The unsaponifiable matter content was found to be low (1.32 to 1.58), indicating the high purity of the oil. The findings reveal that bay laurel seed fixed oil has suitable quality characteristics for industrial use, although it shows regional differences.

In another study on the analytical properties of bay laurel fixed oil, saponification value (~140 mg KOH/g), acid value (~26.5 mg KOH/g), FFA (~13.25%), peroxide value (~10.28 meq O_2/kg) were reported for the fixed oil obtained from bay laurel plant seeds; it was stated that the fixed oil was suitable for cosmetic/cleaning products and for the production of activated carbon from seed waste (Yagmur et al., 2024).

Fatty acid composition in laurel (Laurus nobilis L.) seeds in the Western Black Sea region depending on elevation

Determination of fatty acid composition is critical for the nutritional, pharmaceutical, and industrial value of bay laurel seed fixed oil. The results are presented in *Table 12*. The predominant fatty acids in bay laurel seed fixed oil from the Western Black Sea region were determined to be oleic (44.1–45.9%) and lauric (12.3–15.0%). Lauric acid was found to be highest in Bartın samples (14.96%) and lowest in Zonguldak (12.31%). Oleic acid content was above 44% in all regions, with the highest level in Zonguldak

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samples (45.9%). Linoleic acid ranged from 21.9–23.3%, and linolenic acid ranged from 0.7–0.9%. The general trend shows that lauric acid content decreases with increasing altitude, while oleic and linoleic acid content increases.

Determining the ratios of saturated and unsaturated fatty acids in vegetable oils is important for determining the nutritional value, oxidative stability, and industrial use potential of the oil. It has been determined that the ratios of saturated and unsaturated fatty acids in fixed laurel seed oils obtained from different altitudes in the Western Black Sea region vary. Unsaturated fatty acid concentrations were found to range from 67.4–70.6% in Sinop samples, 68.1–71.1% in Kastamonu, 66.6–70.0% in Bartın, and 68.3–72.8% in Zonguldak. According to average values, the highest unsaturated fatty acid concentration was found in Zonguldak (70.6%), and the lowest in Bartın (67.9%).

Table 12. *Major fatty acid composition (%) of laurel (Laurus nobilis L.) seed oil obtained from different elevations in the Western Black Sea Region of Turkey*

Region	Altitude	Lauric	Miristic	Palmitic	Stearic	Oleic	Linoleic	Linolenic
Sinop	0	14.27	0.92	15.78	1.60	43.10	22.91	0.76
	150	13.86	0.98	14.46	1.51	44.32	23.31	0.81
	400	12.58	1.10	14.34	1.42	45.00	23.76	0.90
	Mean	13.57	1.00	14.86	1.51	44.16	23.32	0.82
Kastamonu	0	13.82	1.23	15.56	1.33	44.30	22.63	0.57
	150	12.96	1.26	14.43	1.35	45.70	22.87	0.74
	400	11.72	1.30	14.40	1.44	45.60	24.10	0.80
	Mean	12.83	1.26	14.79	1.37	45.20	23.20	0.70
Bartın	0	15.40	1.37	15.25	1.43	43.30	21.46	1.06
	150	15.10	1.13	14.86	1.62	44.06	21.42	0.99
	400	14.40	1.16	13.13	1.34	45.01	23.03	0.79
	Mean	14.96	1.22	14.41	1.46	44.12	21.97	0.94
Zonguldak	0	13.42	1.02	15.75	1.51	44.97	21.90	0.71
	150	12.41	1.16	14.33	1.42	46.13	22.87	0.89
	400	11.10	1.27	13.11	1.69	46.61	24.38	0.97
	Mean	12.31	1.15	14.39	1.54	45.90	23.05	0.85

An examination of the general trend reveals that as altitude increases, saturated fatty acid levels decrease, while unsaturated fatty acid levels increase. This suggests that altitude has a significant impact on the fatty acid composition of bay laurel seed fixed oil. A decrease in saturated fatty acids and an increase in unsaturated fatty acids were observed with increasing altitude. Analysis of bay laurel fruit seed fixed fatty acid composition revealed that its composition consists of an average of 28–33% saturated and 67–72% unsaturated fatty acids. This suggests that the oil is rich in unsaturated fatty acids with high biological value. These findings demonstrate that bay laurel seed oil is a valuable oil source, both nutritionally and functionally, thanks to its high unsaturated fatty acid content.

In another study, the sequential use of supercritical CO_2 hydrodistillation of *L. nobilis* seed metabolites resulted in a fixed oil composition of ≈48% saturated, ≈29% unsaturated (oleic) and ≈23% unsaturated (linoleic) acids as the main active ingredients of the seed fixed oil (Awada et al., 2023).

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The region demonstrates that bay laurel fixed oil has versatile potential for use in the industrial, pharmaceutical, and food sectors. Determining the fatty acid profiles of vegetable oils is essential for determining the oil's nutritional value, functional properties, and industrial potential. The ratio of saturated to unsaturated fatty acids, in particular, allows for evaluation in the food, cosmetic, and pharmaceutical sectors. *Figure 4* shows the fatty acid composition of bay laurel (*Laurus nobilis* L.) fruit seed fixed oil. Oleic acid is the predominant component, ranging from 20–60%. Lauric acid and linoleic acid were also found in significant amounts, while other fatty acids were present at low levels. These findings demonstrate that bay laurel seed fixed oil is nutritionally and functionally valuable, particularly due to its high oleic acid content, and also has significant potential for various industrial uses. The graph shows that oleic, lauric, myristic and linoleic acids are the main components in the fatty acid distribution of bay laurel (*Laurus nobilis* L.) seed fixed oil and their ratios are shown in *Table 13*.

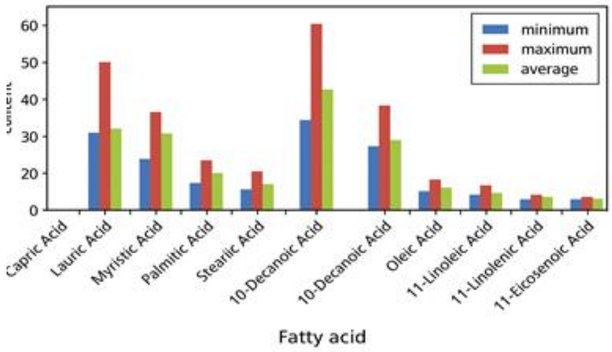

Figure 4. *Fatty acid components of laurel (Laurus nobilis L.) fruit seed fixed oil (min.–max.–mean values)*

Table 13. *Fatty acid main active ingredient composition of bay laurel (Laurus nobilis L.) seed fixed oil (%)*

Region	Oleic acid (%)	Lauric acid (%)	Miristic acid (%)	Linoleic acid (%)
Kastamonu	40.2	23.5	12.8	9.4
Bartın	38.0	24.0	12.5	9.6
Zonguldak	37.5	24.5	12.6	9.5
Sinop	38.0	24.5	13.0	9.6

According to the results in the table, oleic acid content varied between 37.5% (Zonguldak) and 40.2% (Kastamonu), with the highest value being found in Kastamonu samples. Lauric acid was found to be in the range of 23.5–24.5% and was found to be higher in Bartın and Sinop samples.

These results indicate that oleic acid is the predominant unsaturated fatty acid and lauric acid the predominant saturated fatty acid in Western Black Sea bay laurel seed oil. Although regional differences are limited, a comparative comparison of the fatty acid compositions of bay laurel seeds from the Western Black Sea regions is presented in *Figure 5*. Comparing the fatty acid compositions based on regional differences is important for revealing the effects of ecological conditions on chemical content and for assessing the oil's industrial

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utilization potential. This comparison provides fundamental data for determining the quality parameters of bay laurel seed oil and its applicability in different sectors. Oleic acid (37.5–40.2%) is observed to be the predominant component in all regions, and together with lauric acid (23.5–24.5%), it constitutes the majority of the total fatty acid composition. Myristic acid (12.5–13.0%) and linoleic acid (9.4–9.6%) are found in low amounts among the provinces and are particularly important for soap production.

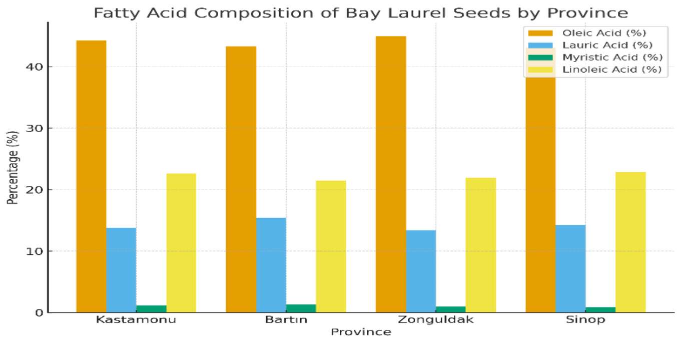

Figure 5. *Comparative distribution (%) of fatty acid compositions of bay laurel (Laurus nobilis L.) seeds obtained from Western Black Sea regions*

Essential oil content and components of bay leaf peel and seeds

Essential oil content in bay laurel (Laurus nobilis L.) fruit varied between the peel and seed. The amount of essential oil determined in the seed was found to be higher than in the peel (0.26%) with 0.38%. This result reveals that the biochemical composition of the fruit is not homogeneous and that the essential oil is concentrated especially in the seed. In addition, among the main essential oil components detected in bay laurel (*Laurus nobilis* L.) fruit seeds, 1,8-cineole (33.53%) was found in the highest amount. This was followed by α-pinene (12.55%), β-elemene (9.85%), sabinene (8.89%), α-terpinenyl acetate (7.68%), trans-β-ocimene (10.28%) and camphene (5.45%).

Analysis showed that oxygenated monoterpenes and monoterpene hydrocarbons were the dominant components in the bayberry seed essential oil. 1,8-cineole (33.53%) was detected at the highest concentration, which is consistent with the characteristic profile of bay laurel essential oils and supports its potential for industrial use.

Discussion

The morphological, biochemical, and physiological properties of bay laurel (*Laurus nobilis* L.) seeds naturally growing in the Western Black Sea Region were determined. It was concluded that morphological variations are due to intraspecific genetic diversity and environmental conditions, while the high oil content and qualified fatty acid profiles strengthen the seeds' potential for industrial use. The large, high-moisture seeds obtained in the Bartın and Zonguldak regions reflect microclimatic advantages. The relationship between fruit morphology and color characteristics and pigment (chlorophyll, carotenoid, anthocyanin) content reveals both the sensory qualities and antioxidant capacity of the fixed oil as determinants.

Chemical analyses showed that oleic and lauric acids were the dominant components in bay laurel seed oil, with limited regional variation. Elevation analyses revealed that

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fixed oil yields were higher in lower-elevation coastal ecosystems, with sea-level samples from Bartın and Sinop being particularly prominent. The findings suggest that microclimatic differences play a role in determining the chemical composition of bay laurel (Laurus nobilis L.) fruit fixed oil, and that low-elevation areas should be prioritized in sustainable production planning.

The fatty acid profile showed that saturated fatty acids predominate at lower altitudes and unsaturated fatty acids at higher altitudes. Increases in oleic and linoleic acid levels enhance the nutritional and pharmaceutical value of the oil, with oleic and lauric acid being the primary components. Hexane extractions contained 29–32% saturated and 68–71% unsaturated fatty acids. The high saponification value supports its suitability for the soap and detergent industries, while the richness of unsaturated fatty acids supports its potential for food, cosmetics, and pharmaceutical use.

Organoleptic analyses showed that bay laurel seed fixed oil is characterized by high aromatic intensity, a spicy odor, and a dark green color. Panel evaluations revealed an aroma score of 8.1 ± 0.7, confirming high reliability with Cronbach's Alpha ($\alpha > 0.85$). The findings suggest that the oil has attractive potential as a raw material in the food and cosmetics sectors, while its characteristic taste and texture provide advantages in soaps and aromatherapy products.

Western Black Sea bay laurel seeds stand out for their high processability, richness of bioactive compounds, and sensory quality profile. These characteristics provide an important basis for standardization of the fixed oil, product development processes, and various industrial applications.

The aromatic qualities of bay laurel seed fixed oil are particularly strong, but improvements in taste and texture may be needed. Indeed, the literature reports that the organoleptic properties of fixed oils can vary depending on the extraction method, raw material quality, and storage conditions (Özcan and Chalchat, 2005; Korkmaz and Duman, 2019).

Analytical findings varied among provinces. The highest acid number was found in Sinop (14.30), while the lowest was found in Zonguldak (11.57). These results reflect free fatty acid content and oxidative stability. Sinop samples are noted for their saponification capacity, while Zonguldak samples, with their low acid number and high unsaponifiable matter content, are prominent for cosmetic and antioxidant uses.

Western Black Sea laurel (*Laurus nobilis* L.) seed fixed oils are characterized by a high saponification number. This property demonstrates the oil's value in the soap and detergent industries and explains the chemical basis for its preference in traditional laurel soaps. Saponification number was found to be highest in Sinop (183.6) and lowest in Zonguldak (169.7); higher values provided better foam quality and ease of dissolution. Unsaponifiable matter ratio remained between 1.32 and 1.58%, below average. Seed morphology revealed larger and heavier seeds in the Bartın and Zonguldak samples, and this was associated with microclimatic conditions and soil properties.

Bay laurel seed essential oil exhibits a cineole-dominant profile, with a high 1,8-cineole content and a rich structure of other monoterpenes. This composition makes the oil valuable for both industrial flavoring and food additives and pharmacological applications. The Western Black Sea Region holds a significant position in Turkey for the production of fixed oil from bay laurel seeds, due to the recent shift towards natural products. For the region, bay laurel is not just a plant; it is a natural resource, an economic development tool, and a sustainable forest management tool. Therefore, its protection, planned utilization, and integration into the value chain are of paramount importance.

Physicochemical properties of fixed oils from bay laurel berries from the Western Black Sea Region were compared with data obtained from Hatay and Mersin-Silifke regions in the south of Türkiye (Beis and Dunford, 1994).

Organoleptic analyses showed that bay laurel seed fixed oil is characterized by high aromatic intensity, a spicy odor, and a dark green color. Panel evaluations revealed an aroma score of 8.1 ± 0.7, confirming high reliability with Cronbach's Alpha (α > 0.85). The findings suggest that the oil has attractive potential as a raw material in the food and cosmetics sectors, while its characteristic taste and texture provide advantages in soaps and aromatherapy products.

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Bay laurel fixed oils obtained from the Western Black Sea regions showed lower oil yields (14.3–16.8%) compared to literature values from Hatay and Silifke. However, density values (0.814–0.898) exhibited regional variation, with Zonguldak samples being particularly notable for their lowest density (0.814). The acid number was higher in Hatay (17.4%) and Silifke (21.9%) samples, ranging from 11.6 to 14.3 in the Western Black Sea provinces. Saponification numbers ranged from 169.7 to 183.6, similar to those in Silifke (177.6 to 179.4). The amount of unsaponifiable matter (1.32 to 1.58%) was found to be similar in all regions. The moisture content was slightly higher in the Western Black Sea region, at 70–74%, than in Silifke (60–70), and the ash content ranged from 1.9 to 2.3%.

The saponification numbers of the fixed oils from the Western Black Sea laurel berries ranged from 169.7 to 183.6, and were lower than those in the Hatay (187.1) and Silifke (177.6–179.4) regions. Density values ranged from 0.909–0.913 in the Mediterranean region, while they were measured as 0.8140–0.8975 in the Western Black Sea region; this difference was attributed to variations in the chemical composition of the oil. Unsaponifiable matter content varied between 1.0–1.6% across all regions, and the Western Black Sea findings were consistent with results reported in the literature.

The analytical properties of bay laurel (*Laurus nobilis* L.) fruit fixed oil were compared with data obtained from previous studies (Hatay and Silifke), (Beis and Dunford, 2006), and from the Western Black Sea regions (Sinop, Kastamonu, Bartın, Zonguldak). The findings indicate significant differences among the regions. *Figure 6* visualizes the results by region, and "Comparative Oil Yield and Acid Number" is provided to support the table.

The highest acid number values were reported in Hatay (17.4%) and Silifke (21.9%) samples, while lower values were determined in the Western Black Sea region, ranging from 11.57 to 14.30. Kastamonu (12.46) and Zonguldak (11.57) samples, in particular, have advantages in terms of oxidative stability. The highest fixed oil yield was recorded in Silifke at 34% (Beis and Dunford, 2006), while lower values were found in the Western Black Sea region, ranging from 14.32% (Zonguldak) to 16.82% (Sinop). These findings indicate that fixed oil yield in the Western Black Sea region is limited compared to the Mediterranean region, and that ecological conditions play a determining role in yield.

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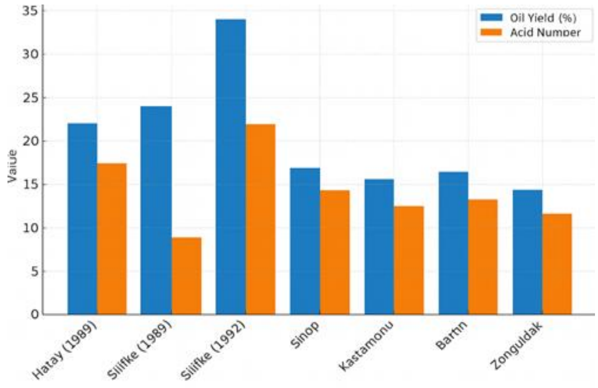

***Figure 6.** Comparative fixed fatty acid count and fixed oil yield of bay laurel fruit by region (%)*

When the fatty acid composition of bay laurel oil was examined in the Western Black Sea region, oleic acid stood out as the most dominant component (44.1–45.9%), exceeding values found in the Mediterranean region (15.1–40.6%). Lauric acid was relatively low in the Western Black Sea region (12.3–14.9%), while significantly higher values were reported in samples from Tarsus (52.4%) and Hatay (17.9%). Myristic acid was around 1% in the Western Black Sea region, which is similar to data from the Mediterranean reported in the literature. Palmitic acid ranged from 12–19% in all regions, while the Western Black Sea region showed a balanced distribution of around 14%. Linoleic acid was determined to range from 21.9–23.3% in the Western Black Sea region, showing values similar to those in the Mediterranean region. Linolenic acid was below 1% in all regions.

In the composition of fixed oils extracted with hexane from Western Black Sea laurel (Laurus nobilis L.) fruits, oleic (44.1–45.9%), lauric (12.3–14.9%), linoleic (21.9–23.3%), and palmitic (14.3–14.9%) were identified as the primary fatty acids. Oils from this region have the highest oleic acid values reported in Turkey.

In general, Western Black Sea samples are notable for their oleic acid richness, while lauric acid levels are well below those from the Mediterranean region. This suggests that Western Black Sea oils offer higher nutritional value and oxidative stability potential, but lower lauric acid yields for soap production than those from the Mediterranean region.

The fatty acid profile is notable for its oleic and lauric acid richness; The skin barrier strengthening properties of oleic acid (Gunstone, 2002) and the antimicrobial properties of lauric acid make bay laurel oil a valuable product for the food, cosmetics, and soap industries.

In general, Western Black Sea Bay laurel seeds, with their high oil content, functional fatty acid profile, saponification capacity, and organoleptic properties, are considered a strategic biological resource for both industrial applications and genetic resource conservation strategies. Comparatively, Mediterranean regions (Hatay, Tarsus, Dörtyol) were found to be higher in lauric and other saturated fatty acids, while Western Black Sea regions were found to be richer in unsaturated fatty acids, particularly oleic acid. This demonstrates the superiority of Western Black Sea oils in terms of nutritional quality, oxidative stability, and pharmaceutical potential. Overall, despite regional differences, the fatty acid profile of Western Black Sea Bay laurel oils supports functional quality for pharmaceutical, food, and cosmetic applications. *Figure 7* shows the comparative saturated and unsaturated fatty acid ratios of bay laurel oils obtained from different

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regions of Turkey, revealing that saturated fractions predominate in Mediterranean oils, while unsaturated fractions predominate in Western Black Sea oils.

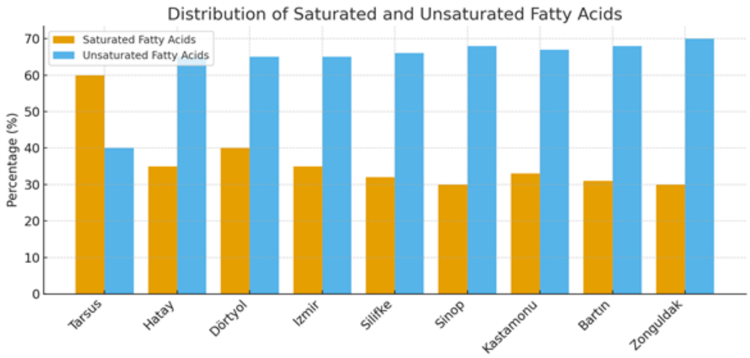

Figure 7. *Saturated and unsaturated fatty acid ratios of bay laurel oils obtained from different regions of Türkiye*

The results showed that regional differences significantly affect the chemical composition of bay laurel (*Laurus nobilis* L.) fruit fixed oil. Saturated fatty acids were higher in Mediterranean regions, while samples from the Western Black Sea region were more prominent in unsaturated fatty acids. This suggests that Western Black Sea oils have higher functional potential for food and pharmaceutical applications.

Given the increasing demand for pure plant-based products, the development of standard production criteria for bay laurel oil and soap will both ensure quality assurance and increase the economic value of bay laurel soap production in the Western Black Sea region by preventing unfair competition.

When bay laurel fruit samples from the Western Black Sea region were compared with those from Hatay, it was observed that the Hatay samples had significantly higher fruit size and 1000-seed weight (1432 g; length 17.2 mm; width 13.1 mm). In contrast, the Western Black Sea samples exhibited smaller sizes, with 1000-seed weights ranging from 1045–1250 g and 13.9–15.8 mm in length.

The seed ratio was higher in the Western Black Sea region, at 67.6–70.2%, than in Hatay (63.7%), while the peel ratio was relatively lower. This suggests that the region may be particularly advantageous for obtaining fixed oil. Fruit moisture content was higher in the Western Black Sea region, at 70–74%, than in Hatay (65%), while ash content was lower in Hatay (1.5%).

Overall, the results suggest that the Hatay samples stand out with their large and heavy fruit structure, while the Western Black Sea samples, with their higher seed ratio and moisture content, offer distinct industrial potential. These differences suggest that the water content and mineral composition of the fruit vary depending on ecological conditions. A comparative graph showing 1000-seed weight, moisture content, and ash content is presented in *Figure 8*.

Bay laurel berries from the Western Black Sea region have a lower 1000-seed weight (1045–1250 g) compared to Hatay samples. Hatay samples (1432 g) stand out with their large and heavy fruits. In contrast, the seed ratio was found to be higher in Western Black Sea fruits, providing an advantage for the region in terms of fixed oil production. The moisture content was measured at 70–74% in the Western Black Sea region, higher than

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in Hatay (65%). This could be considered a factor that could affect the fruit's storage and processability. Ash content was found to be between 1.7–2.0% in the Western Black Sea region and lower in Hatay (1.5%). In general, Hatay samples have larger and heavier fruit structure, while Western Black Sea samples have higher seed ratio and moisture content, demonstrating different industrial use potential.

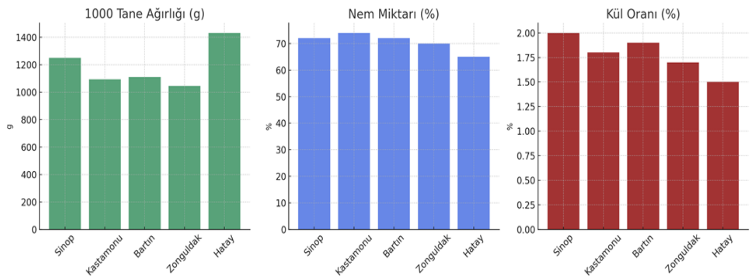

Figure 8. *Regional distribution of 1000-grain weight, moisture and ash content values of bay laurel (Laurus nobilis L.) fruit*

In conclusion, Western Black Sea Bay laurel seeds are an important biological resource, both ecologically and economically. The findings highlight the need for management of this species in a way that can contribute to regional development and the natural product industry.

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