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Effects of Moisture Conditioning and Hull Removal Levels in Sunflower Seeds on Oil Yield and Fatty Acid Composition during Oil Extraction

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ABSTRACT

Sunflower (*Helianthus annuus* L.) is an important oilseed crop valued for its nutritional and industrial applications. This study investigated the effect of seed hull proportion on moisture content, oil yield, and fatty acid composition. The moisture content of the sunflower seeds used in the study was determined as 8.20%, 6.18%, and 3.83%, respectively. The highest moisture content was found in the sunflower seed hull (8.20%), followed in decreasing order by the hulled and unhulled seeds. The oil content of shelled and unshelled sunflower seeds at different ratios was determined to be between 17.90% (shelled seeds) and 32.20% (unshelled seeds). The palmitic and stearic acid contents of sunflower seed oils with hulls and those from which the hulls were partially removed were determined to range from 6.11% (1/1; 5 g unshelled seed/5 g shelled seed) and 6.76% (dehulled sunflower seed oil) to 3.56% (dehulled sunflower oil) and 3.67% (shelled sunflower seeds), respectively. In addition, oleic and linoleic acid amounts of the sunflower seed oils were characterized to be between 29.11% (shelled sunflower seed) and 29.99% (3/1; shelled/unshelled) to 58.68% (3/1; shelled/unshelled) and 59.89% (1/1; unshelled /shelled), respectively.

Behenic acid was present at slightly higher levels compared with arachidic and linolenic acids in all samples.

Overall, variation in hull proportion affected both oil yield and fatty acid composition, indicating that sunflower seed processing can be used to modulate oil quantity and quality. These findings provide relevant information for optimizing sunflower seed utilization in food and industrial applications.

Keywords: shelled and unshelled sunflower seeds, oil, fatty acids.

INTRODUCTION

Sunflower seeds come from plants belonging to the *Helianthus* genus, particularly *Helianthus annuus L.*, and are among the four most commonly cultivated and consumed oilseed crops worldwide (Adeleke and Babalola, 2020; Xiang et al., 2024). It ranks as the fourth most produced vegetable oil globally, and its composition can be significantly enhanced for both nutritional and industrial uses through genetic selection and seed breeding (Mouloungui et al., 2006; Merah et al., 2012). Edible vegetable oils supply lipids in the human diet, serving as an important source of energy, essential fatty acids, and fat-soluble vitamins (Dorni et al., 2018, Yang et al., 2018). In recent years, oleic acid has attracted growing global interest due to its positive health effects, especially its link to a lower risk of coronary heart disease (Sales-Campos et al., 2013). Oilseeds are primarily utilized as a source of vegetable oils that possess distinct physicochemical characteristics (Sarwar, 2013). Conventional extraction methods typically include mechanical pressing - either hot or cold - or the use of chemical solvents (Savoire et al., 2013). Sunflower is widely cultivated across Europe and many other regions, mainly for oil production. It is preferred due to its high oil content of around 40-50%, strong adaptability to diverse climates, and suitability for mechanized farming. Additionally, it is easy to grow and market. Beyond oil, it is also used in food, feed, and ornamental applications (Kaya, 2016). In recent years, significant advances have been achieved in research on sunflower seeds, with a primary emphasis on sunflower seed oil (Ahmar et al., 2020; Fu et al., 2020). Sunflower oil's

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unsaturated fatty acid profile consists mainly of oleic acid (14-43%) and linoleic acid (44-75%), along with small amounts of other fatty acids (0.7%) (Baydar and Turgut, 1999). A high proportion of linoleic acid is generally considered an indicator of high-quality vegetable oil (Wagner et al., 2001). These five major fatty acids - oleic, linoleic, linolenic, stearic, and palmitic acids - play key roles in determining the quality of vegetable oils. Among them, oleic, linoleic, and linolenic acids are unsaturated and are preferred in high-quality edible oils for consumers. In contrast, saturated fatty acids such as stearic and palmitic acids are generally desired in lower amounts in vegetable oils (Rauf et al., 2017; Aşkın et al., 2022). In sunflower oil, a higher level of linoleic acid is considered more suitable for cooking purposes, whereas oils with higher oleic acid content are better for frying because they provide greater thermal stability at high frying temperatures (Aşkın et al., 2022). Many researchers have investigated different sunflower lines and hybrids to identify high-oleic types and distinguish them from low-oleic genotypes using molecular marker techniques (Nagarathna et al., 2011; Kaya, 2016; Dimitrijevic et al., 2017). Sunflower seeds are among the most widely produced oilseed crops worldwide, together with rapeseed, soybean, and cottonseed (Mirpoor et al., 2021). Their nutritional composition varies depending on several factors such as genotype, soil characteristics, farming practices, climate conditions, and processing methods (Gültekin Subaşı et al., 2021). Similar findings have been reported in Romanian studies, where drought and climatic variability significantly influenced sunflower performance and contributed to genotype-dependent variation in yield and stress tolerance (Anton et al., 2023, Cojocaru et al., 2023). Sunflower seed oil has been reported to possess a range of biological effects, including wound-healing, gastroprotective, anti-inflammatory, antimicrobial, antioxidant, antidiabetic, and antihypertensive properties. It has also been associated with antitumor activity and with lowering total cholesterol as well as low-density lipoprotein (LDL) cholesterol levels (Guo et al., 2017). The aim of this study was to determine the effects of different levels of moisture adjustment and hull removal in sunflower seeds on oil yield obtained through oil extraction, as well as to evaluate the resulting changes in the fatty acid composition of the extracted oils.

MATERIAL AND METHODS

Material

Sunflower seeds have been processed in varying amounts with and without shells. Sample 1 (code **1**) contains 10 g of shelled seeds, sample 2 (code **2**) contains 10 g of unshelled seeds, sample 3 (code **3**) contains 2.5 g of unshelled seeds and 7.5 g of shelled seeds, sample 4 (code **4**) contains 5 g of unshelled seeds and 5 g of shelled seeds, and sample 5 (code **5**) contains 7.5 g of unshelled seeds and 2.5 g of shelled seeds. The shelled portion represents the entire seed (shell + kernel). The unshelled portion represents only the kernel of the seed. The moisture and oil content of the prepared samples were determined.

Moisture content

The water content of sunflower seed samples was determined by keeping them in an oven at 105±3°C. The % water content of the samples was calculated (AOAC, 1990).

Fat content

Sunflower samples were dried in an oven at 70°C until they reached a constant weight. The samples were extracted using petroleum ether in a Soxhlet apparatus and the solvent was removed using a vacuum evaporator. % oil content of sunflower samples was calculated (AOCS, 1989).

Fatty acid composition

The esterification of sunflower sees oil samples was carried out according to the ISO (1978) method using n hexane and KOH with methanol. Fatty acid methyl esters were analyzed by gas chromatography (Shimadzu GC 2010, Japan). A flame ionization detector (FID) and capillary column (Teknokroma TR CN100, P/N TR 882162 fused silica column, 60 m x 0.25 mm x 0.20 μm) were used. Detector and injection block temperatures were 260°C and Nitrogen gas was used as mobile phase with a flow rate of 1.51 ml/min.

Statistical analyzes

Minitab 16 statistical program was used to interpret the data obtained as a result of the research of sunflower seed. The data were subjected to analysis of variance. The mean values and standard deviations of the obtained results are given.

RESULTS AND DISCUSSION

The moisture and oil contents of sunflower seeds with different hull ratios

The moisture and oil contents of sunflower seeds with different hull ratios for oil extraction are shown in Table 1.

Table 1. Moisture content and oil content of sunflower seed with different hull ratios for oil extraction

	Moisture content (%)	Samples	Oil concent (%)
Shell	8.20±0.01[A]*	10 g shelled seeds	17.90±1.56[b]**
Shelled	6.18±0.15[B]	10 g unshelled seeds	32.20±0.99[a]
Unshelled	3.83±0.01[C]	2.5 g unshelled seeds-7.5 g shelled seeds	24.40±0.14[ab]
		5 g unshelled seeds-5 g shelled seeds	24.35±4.74[ab]
		7.5 g unshelled seeds-2.5 g shelled seeds	28.10±1.27[a]

*Values are mean ± standard deviation and those with different letters in each column are significantly different ($p \leq 0.01$), ** $p < 0.05$.

The moisture content of the sunflower seeds used in the study was determined as 8.20%, 6.18%, and 3.83%, respectively. The highest moisture content varied significantly among samples, ranging from 8.20% in seed hulls to 3.83% in unshelled seeds, with intermediate values observed in shelled seeds. The high moisture content in the seed hull is likely due to the higher cellulosic structure. A common cause of high moisture in sunflower seed hulls during processing is inadequate drying before or during storage, leaving water trapped in their fibrous structure. They can also absorb moisture from humid air or condensation caused by temperature changes due to their hygroscopic nature. Poor ventilation, improper storage, or delays between harvest and processing can worsen the problem, reducing processing efficiency and product quality. The oil content of shelled and unshelled sunflower seeds at different ratios was determined to be between 17.90% (shelled seeds) and 32.20% (unshelled seeds). The oil content of 2.5 and 5 g of unshelled sunflower seeds was found to be similar. The reason why 2.5 g of dehulled plus 7.5 g of hulled sunflower seeds show a similar oil content to a mixture of 5 g dehulled plus 5 g hulled seeds is mainly related to how the total mass is distributed between kernel and shell. The hull contains very little oil, while the kernel is the main source of lipids. Therefore, when a higher proportion of the sample consists of hulled seeds, the actual oil-yielding material is lower. In the first mixture, much of the 7.5 g hulled seeds is non-oily shell, reducing total oil contribution. In the second mixture, the proportion of kernel is higher overall. As a result, both mixtures end up having a similar effective oil content. The oil content of 7.5 g of unshelled sunflower seeds was determined to be 28.10%. Comparable findings were reported in previous studies showing that sunflower oil yield is strongly influenced by genotype, kernel proportion, and processing conditions (Aguirre et al., 2014; Lužaic et al., 2025).

The fatty acid compositions of oils extracted from ground sunflower seeds

The fatty acid compositions of oils extracted from ground sunflower seeds containing varying proportions of sunflower hulls are shown in Table 2.

Table 2. Fatty acid composition (%) of sunflower seed oil

Fatty acids (%)	In-shell sunflower seeds	Dehulled sunflower seeds	In-shell / dehulled sunflower seed ratio		
			3/1 (2.5 g unshelled seeds-7.5 g shelled seeds)	1/1 (5 g unshelled seeds-5 g shelled seeds)	1/3 (7.5 g unshelled seeds-2.5 g shelled seeds)
Palmitic	6.26 ± 0.07^{*}	6.76 ± 0.15	6.50 ± 0.39	6.11 ± 0.23	6.44 ± 0.47
Stearic	3.67 ± 0.01	3.56 ± 0.02	3.65 ± 0.05	3.57 ± 0.02	3.60 ± 0.04
Oleic	29.11 ± 0.02^{C**}	29.38 ± 0.10^{BC}	29.99 ± 0.15^{A}	29.30 ± 0.05^{BC}	29.73 ± 0.16^{AB}
Linoleic	59.80 ± 0.08^{A}	59.17 ± 0.04^{B}	58.68 ± 0.16^{B}	59.89 ± 0.07^{A}	59.09 ± 0.24^{B}
Arachidic	0.27 ± 0.00	0.26 ± 0.00	0.27 ± 0.01	0.26 ± 0.01	0.26 ± 0.01
Linolenic	0.13 ± 0.01	0.13 ± 0.01	0.15 ± 0.00	0.14 ± 0.01	0.13 ± 0.02
Behenic	0.76 ± 0.02	0.75 ± 0.02	0.76 ± 0.03	0.73 ± 0.07	0.74 ± 0.01

Different superscript letters in the same row are not significant (*p>0.05). Different superscript letters in the same row indicate significant differences (**p<0.01) were compared with Duncan test.

Changes in hull proportions resulted in partial differences in the fatty acid compositions of sunflower oil. Changes in hull ratio affect the fatty acid composition of sunflower oil because they influence both the amount of oil-rich kernel available and the efficiency of oil extraction. A higher hull proportion reduces the kernel content, leading to lower oil yield and less efficient extraction. In addition, hull components such as fiber and phenolic compounds can interfere with solvent penetration and pressing, causing uneven extraction of lipid fractions. As a result, the proportions of saturated and unsaturated fatty acids in the final oil may vary depending on the hull ratio. The differences in the fatty acid composition of oils extracted from sunflower seeds with varying degrees of hull removal can be attributed primarily to the structural and biochemical heterogeneity between the seed kernel and the hull. The kernel, which is the main storage tissue, is rich in lipids - particularly unsaturated fatty acids such as linoleic and oleic acids - while the hull contains significantly lower oil content and a different composition, including more structural components like cellulose and phenolic compounds. As the proportion of hull material in the extraction process increases or decreases, it effectively dilutes or concentrates the lipid-rich fraction derived from the kernel. Additionally, the presence of hulls may influence extraction efficiency and promote minor oxidative or enzymatic changes, further contributing to variations in the measured fatty acid profile. Consequently, oils obtained from seeds with higher levels of dehulling tend to exhibit a fatty acid composition more representative of the kernel, whereas those with more residual hull content show slight deviations due to these compositional and processing effects (FAO, 1992; Shahidi, 2005). The palmitic and stearic acid contents of sunflower seed oils with hulls and those from which the hulls were partially removed were determined to range from 6.11% (1/1; 5 g unshelled seed/5 g shelled seed) and 6.76% (dehulled sunflower seed oil) to 3.56% (dehulled sunflower oil) and 3.67% (shelled sunflower seeds), respectively. In addition, oleic and linoleic acid amounts of the sunflower seed oils were characterized to be between 29.11% (shelled sunflower seed) and 29.99% (3/1; shelled/unshelled) to 58.68% (3/1; shelled/unshelled) and 59.89% (1/1; unshelled/shelled), respectively. The behenic acid content of sunflower seed samples was found to be slightly higher than the arachidic and linolenic acid content. Behenic acid amounts of sunflower seeds oils were identified to be between 0.73% (1/1; unshelled/shelled) ve 0.76% (dehulled sunflower seed and shelled/unshelled (3/1). In general, commercially available sunflower varieties contain lower levels of oleic acid (20-25%) (Premnath et al., 2016). Brevedan et al. (2000) found that two different sunflower oils contained 6.2-6.4% palmitic acid, 3.1-3.5% stearic acid, 21.8-23.4% oleic acid, and 66.9-68.3% linoleic acid. Similarly, Li et al. (2024) reported that sunflower seed oil mainly consists of oleic acid (18.72-79.30%) and linoleic acid (10.11-51.72%). For pumpkin seed oil, both hulled and unhulled samples were found to contain 8.58% and 9.5% palmitic acid, 2.86% and 3.74% stearic acid, 46.27% and 46.88% oleic acid, and 42.29% and 39.88% oleic acid, respectively (Charaya et al., 2023). Sunflower oil primarily contains oleic acid (19.81%) and linoleic acid (64.35%), both of which cannot be synthesized by the human body and therefore must be obtained through the diet. In addition, sunflower seeds contain approximately 65.42% lipids (Petraru et al., 2021). Khalil (2000) found significant variation in stearic acid levels among sunflower genotypes and stated that exposure to low temperatures during plant growth stages leads to an increase in stearic acid content. Ahmad and Hassan (2000) also reported that low temperatures and a reduced accumulation of degree-days promote the build-up of stearic acid. Similarly, Popa et al. (2017) observed that linoleic acid content at late sowing ranged from 59.02% to 64.11% and noted that it tends to increase as sowing is delayed. Öztürk et al. (2017) and Çalışkan et al. (2002) reported that earlier sowing dates resulted in higher oil content compared to later sowings. It has also been shown in other relevant studies that oil content can vary considerably depending on cultivars and growing conditions such as soil type, agricultural practices, and climatic factors (Özer et al., 2003; Coşge and Ulukan, 2005; Gültekin Subaşı et al., 2021). The observed differences in oil content in the present study were mainly attributed to variations among cultivars and their different maturity groups. Cvejić et al. (2015) reported significant genotype-related differences in oil content and oil yield across different locations, depending on environmental and climatic conditions. Similarly, Alem et al. (2016) found that oil content in sunflower genotypes grown in different locations ranged between 28.18% and 33.50%. Our findings regarding fatty acids showed partial differences compared to previous studies. The chemical composition of sunflower seeds may vary due to several factors, including growing conditions, temperature, fertilization, irrigation practices, and cultivar characteristics.

Lipid index values of oils extracted from sunflower seeds

Lipid index values of oils extracted from sunflower seeds with varying hull ratios are presented in Table 3. Differences in hull ratios in the oily material resulted in differences in the lipid index values of the oils. Nutritive value index (NVI) and Cox values of the sunflower oils were characterized to be between 4.87 (dehulled sunflower seeds) and 5.38 (5 g hulled seeds/5 g shelled seeds) to 6.38 (2.5 g unshelled seeds/ 7.5 g shelled seeds) and 6.49 (5 g unshelled seeds/5 g shelled seeds), respectively.

Table 3. Lipid index values of fatty acid compositions of oils extracted from sunflower seeds with different proportions of hull removal

Lipid indices	Shelled (Hulled) sunflower seed	Dehulled sunflower seed	3/1 (2.5 unshelled seeds/ 7.5 g shelled seeds)	1/1 (5 g unshelled seeds/ 5 g shelled seeds)	1/3 (7.5 g unshelled seeds/ 2.5g shelled seeds)
Nutritive Value Index (NVI)	5.24	4.87	5.18	5.38	5.18
Oxidizability Value (Cox)	6.48	6.42	6.38	6.49	6.41
Oleic Desaturation Rate (ODR)	0.673	0.669	0.662	0.672	0.666
Linoleic Desaturation Rate (ODR)	0.001	0.001	0.002	0.002	0.001

Also, ODR and LDR values of the sunflower oil samples extracted from sunflower seeds were demonstrated to be between 0.662 (2.5 unshelled seeds/ 7.5 g shelled seeds) and 0.673 (shelled sunflower seeds) to 0.001 (shelled and unshgelled sunflower seeds and 7.5 g unshelled seed/ 2.5 g shelled seeds) and 0.002 (2.5 g unshelled seeds/ 7.5 g shelled seeds and 5 g unshelled seeds/ 5 g shelled seeds), respectively. As a results, the variation in lipid indices among oils extracted from sunflower seeds with different hull ratios reflects subtle but meaningful changes in fatty acid composition and oxidative behavior.

The Nutritive Value Index (NVI) shows a slight increase in mixed samples, with the highest value observed in the 1/1 ratio, suggesting a more favorable balance of fatty acids compared to both fully hulled and dehulled seeds. This improvement may be attributed to the combined effect of kernel lipids and minor bioactive compounds contributed by the hull. The Oxidizability Value (Cox) remains relatively stable across samples, although the slightly higher value in the 1/1 mixture indicates a marginal increase in susceptibility to oxidation, likely due to a higher proportion of polyunsaturated fatty acids or pro-oxidant components. Similarly, the Oleic Desaturation Rate (ODR) varies within a narrow range, with the highest value again in the 1/1 sample, implying a modest shift toward increased desaturation activity. The Linoleic Desaturation Rate (LDR) values are very low overall, but the slight increase in mixed ratios (3/1 and 1/1) may indicate minor enzymatic or compositional influences from the hull fraction. Overall, the 1/1 mixture appears to balance nutritional quality and oxidative characteristics, while fully dehulled seeds tend to show slightly lower nutritional indices but more stable oxidation-related parameters, likely due to reduced contamination from hull-derived pro-oxidants such as metal ions.

CONCLUSIONS

This study demonstrated that the proportion of seed hulls significantly influences the moisture content, oil yield, and fatty acid composition of sunflower seeds. The results showed that increasing the hull proportion reduced the overall oil content, whereas partial or complete dehulling improved oil yield. Variations in hull proportion also produced measurable changes in the fatty acid profile, particularly in the levels of palmitic, stearic, oleic, and linoleic acids, while behenic acid consistently remained at slightly higher concentrations than arachidic and linolenic acids. These findings highlight that controlled dehulling is not only an effective strategy for enhancing oil recovery but also a practical approach for tailoring the nutritional and functional quality of sunflower oil. Consequently, optimizing hull proportion during processing offers valuable opportunities to improve the efficiency of sunflower utilization and to produce oils with characteristics better suited for specific food and industrial applications.

Future studies should investigate the effects of different dehulling techniques and processing conditions on oil quality, bioactive compounds, oxidative stability, and storage performance to further optimize sunflower seed processing.

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