Çukurova Tarım Gıda Bil. Der. Çukurova J. Agric. Food Sci.
39(1):97-107
doi: 10.36846/CJAFS.2024.136

Research Article

# Utilizing Salt and Calcium Carbonate as Coadjuvants in Malaxation Process of Virgin Olive Oil Extraction

**Fatma KÖYLÜOĞLU[1], Sedef AYDIN[1*], Gülcan ÖZKAN[1]**

**ABSTRACT**
Technological coadjuvants were utilized at the beginning of the malaxation phase of the olive oil extraction process. The present work aimed to evaluate the effect of different amounts of $CaCO_3$: NaCl combination at a rate of 1%, added to olive paste. The effects of coadjuvants' effect on the extraction yield and some quality parameters of oil obtained from Gemlik olives were investigated. According to the results, in terms of increasing yield, it was determined that the utilization of salt was more effective than calcium carbonate. Across all trials, the coadjuvants effectively mitigated increase in free acidity and peroxide levels. The amount of pigment increased with the addition of calcium carbonate and decreased with the addition of salt. Also, the addition of salt increased the amount of total phenolics and the contents of linoleic and palmitoleic acids. These findings highlight the superior efficacy of salt over calcium carbonate as a coadjuvant, increasing oil extraction yield while improving quality. Since salt is naturally occurring, inexpensive, easily accessible, and inert, it can provide the olive oil industry with a promising alternative coadjuvant.
**Keywords**: Calcium carbonate, salt, malaxation, olive oil, yield

# Sızma Zeytinyağı Ekstraksiyonunun Yoğurma Prosesinde Yardımcı Katkı Maddesi Olarak Tuz ve Kalsiyum Karbonatın Kullanımı

**ÖZ**
Zeytinyağı ekstraksiyon prosesinde malaksasyon aşamasının başlangıcında teknolojik yardımcı maddelerden yararlanılmaktadır. Bu çalışmada, Gemlik zeytinlerinden elde edilen yağın ekstraksiyon verimi ve kalitesi üzerine malaksasyon aşamasında zeytin ezmesine eklenen %1 oranında farklı miktarlardaki $CaCO_3$: NaCl kombinasyonunun etkisi araştırılmıştır. Sonuçlara göre yağ verimi açısından tuz kullanımının kalsiyum karbonata göre daha etkili bir artışa sebep olduğu tespit edilmiştir. Tüm denemelerde $CaCO_3$ ve NaCl, yardımcı maddenin kullanılmadığı kontrol grubuna göre serbest asitlik ve peroksit seviyelerindeki artışları etkili bir şekilde hafifletmiştir. Renk maddelerinin miktarı kalsiyum karbonat ilavesiyle artmış, tuz ilavesiyle azalmıştır. Aynı zamanda tuz ilavesi toplam fenolik miktarı ile linoleik ve palmitoleik asit içeriklerini arttırmıştır. Araştırma sonuçları, tuzun bir yardımcı madde olarak kalsiyum karbonattan daha etkin olduğunu vurgulayarak, kaliteyi artırırken yağ ekstraksiyon verimini de artırmıştır. Doğal, uygun maliyetli, kolaylıkla bulunabilen ve inert özellikleri göz önüne alındığında tuz, zeytinyağı endüstrisi için umut verici bir alternatif yardımcı katkı maddesi özelliği sunmaktadır.
**Anahtar Kelimeler:** Kalsiyum karbonat, tuz, malaksasyon, zeytinyağı, verim

ORCID ID (Yazar sırasına göre)
0000-0003-3491-4057, 0000-0003-0457-7731, 0000-0002-3333-7537

Yayın Kuruluna Geliş Tarihi: 16.04.2024
Kabul Tarihi: 02.05.2024
[1] Suleyman Demirel University, Engineering Faculty, Food Engineering Department, Isparta, Turkey
[*]E-posta: sedefaydin03@gmail.com

# Utilizing Salt and Calcium Carbonate as Coadjuvants in Malaxation Process of Virgin Olive Oil Extraction

## Introduction

Botanically, the cultivated olive tree belongs to the subspecies *Olea europeae sativa* of the Oleaceae family (Hashmi *et al.*, 2015). Turkey holds a significant position in olive oil production, yielding 225.000 tons in the 2019/20 season, which is noteworthy compared to other producing countries (IOOC, 2021). Olive cultivation is widespread across various regions in Turkey, including Marmara, Aegean, Mediterranean, and Southeastern Anatolia. Notably, the Gemlik variety predominates in the Marmara region, constituting over 80% of the total table olives produced (Ozturk *et al.*, 2021). Gemlik olives, known for their high oil content, are largely used for oil extraction, making them the most popular and growing olive variety in Turkey.

Beyond its sensory attributes, the Gemlik variety is favored by consumers for its health benefits attributed to its fatty acid composition and antioxidant content (Lazzez *et al.*, 2008). The advancement of extraction technologies is imperative for olive oil producers to achieve high-quality oil. Commercially, the best olive oil is obtained through physical processes such as washing, pressing, centrifuging, and filtering (TGK, 2017). The primary objective of olive oil production is to maximize oil extraction while preserving important bioactive components such as phenols, tocopherols, sterols, and desired flavor compounds.

Malaxation, a critical phase in olive paste processing, is indispensable for obtaining extra virgin olive oil (EVOO). Numerous studies have investigated the effects of kneading temperature and time on olive oil quality (Çevik et al., 2015; Aydın et al., 2020; Dalgic et al., 2016; Delil et al., 2022). During the malaxation process of the extraction, not all the oil can be released from the olives. However, part of the oil becomes an emulsion with plant water or remains in the olive paste's colloidal structure. Depending on several conditions, some olive pastes are considered difficult to extract the oil from their emulsified structure (Cruz et al., 2007). To address this, co-adjuvants such as salt, talc, and calcium carbonate are commonly added during malaxation to facilitate oil extraction by breaking emulsions (Köylüoğlu and Özkan, 2012).

Studies investigating the influence of coadjuvants in olive oil extraction have recently increased in Spain, Italy, and other Mediterranean countries. Recent studies in Mediterranean countries have studied the efficacy of co-adjuvants such as warm water, enzymes, salt, micronized talc, and calcium carbonate in increasing oil extraction efficiency and improving oil quality (Elsorady, 2020; Squeo et al., 2016; Tamborrino et al., 2017; Clodoveo *et al.*, 2013). Calcium carbonate is a co-adjuvant known for its affordability and inert qualities, and acts as an absorbent medium that promotes the coalescence and separation of oil. (Dentel, 1991; Tamborrino et al., 2017). Additionally, it is approved as a coadjuvant by European Union regulations (CE Directive 30/2001). One of the first mineral resources and a potent demulsifier, salt, or sodium chloride, is also acknowledged as a co-adjuvant. Its efficacy during the kneading process comes from the physical phenomena of separating the hydrophilic phase from the oil due to its density and higher ionic characteristics (Cruz et al., 2007). Given these considerations, it would be beneficial to investigate the impact of salt and calcium carbonate on both the oil extraction efficiency and the quality parameters of the Gemlik variety (Dentel, 1991; Tamborrino et al., 2017).

This study aims to evaluate the potential of calcium carbonate, salt, and their combination as co-adjuvants in olive oil extraction, particularly focusing on the Gemlik variety. Although there exists literature regarding the fruit and oil quality of Gemlik olives (Dıraman and Dibeklioğlu, 2009; Demirag and Konuskan, 2021), investigations into the benefits of co-adjuvant utilization for Gemlik olive oil extraction have been lacking in the scientific literature. Specifically, there is an important gap in the current literature concerning the advantageous application of co-adjuvants in the process of extracting olive oil from Gemlik olives.

# Utilizing Salt and Calcium Carbonate as Coadjuvants in Malaxation Process of Virgin Olive Oil Extraction

## Material And Methods

### Material

The research's material, the Gemlik olive variety, cultivated in the Manavgat district of Gundogdu town, Antalya province. Olives were harvested from all aspects of the olive trees, ensuring representation of the sample area at optimal ripeness (5.71). Following physical analysis, olive oil extraction was promptly conducted. The resulting olive oils were stored in opaque glass bottles at -20°C until subjected to physical-chemical analysis.

### Determination of Moisture and Oil Content

Olive samples were weighted (2 g) and dried until a constant weight in an oven (Nüve, FN500, Turkey) at 105°C, the moisture was expressed as percent (%). Approximately 2 g of dried paste samples were weighed and extracted with 150 ml of hexane in a Soxhlet for about 4 hours, and the results were expressed as g oil/100 g dry sample (Guinda et al., 2003). The analyses were carried out in triplicate.

### Olive Oil Extraction

An Abencor system with a two-phase vertical centrifuge system (Haus Centrifugal Technologies, Aydin, Turkey) consisting of laboratory-scale mini crusher (100 kg/h), kneader (malaxator, 250 rpm), and mini vertical centrifuge decanter (maximum: 5800 rpm) was used for olive oil extraction. 1 kg of olive paste was crushed in a mini crusher and turned into olive paste. Following, it was kneaded at 35°C for 45 minutes by adding coadjuvants in the determined proportions (Table 1). The paste obtained from kneading was kept in a two-phase mini vertical centrifugal decanter operating at 5080 rpm for 5 minutes, and olive mill wastewater and olive oil were separated from the olive pomace. After dehumidifying the olive oils with sodium carbonate, they were stored in dark glass bottles at -20 °C until analysis. The total amount of crude oil was calculated as g oil/100 g dry sample.

**Table 1. Trials used in olive oil extraction with and without coadjuvants.**

| Trials | CaCO3(%) | : | NaCl(%) |
|---|---|---|---|
| Control | 0 | : | 0 |
| Trial-1 | 100 | : | 0 |
| Trial-2 | 75 | : | 25 |
| Trial-3 | 50 | : | 50 |
| Trial-4 | 25 | : | 75 |
| Trial-5 | 0 | : | 100 |

**Oil extraction yield (OEY, %)** was calculated with the help of the formula given below (1):

***OEY (%)*** = (Crude Oil (g oil/100 g dry sample)/ Total oil amount) *100

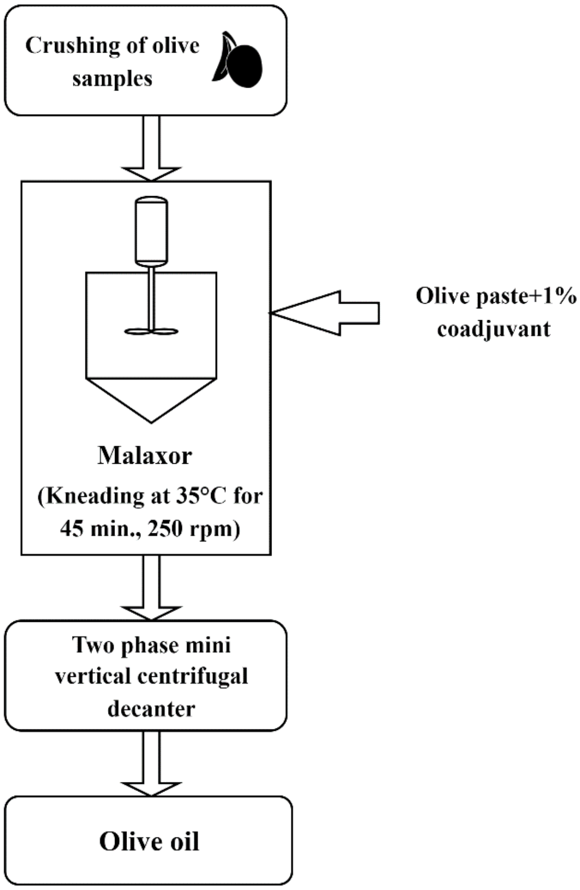


**Figure 1.** Flow Diagram of Oil Extraction

## Determination of Physicochemical Properties

### Determination of Free Acidity (FFA), Peroxide value (PV), Absorbance values ($K_{232}$, $K_{270}$), and Refractive Index (RI)

Free acidity, given as percent oleic acid, was determined according to AOCS Official Method Ca 5a-40, peroxide value (meq O2/kg oil) with AOCS Official Method Cd 8-53 (AOCS, 2003) and specific absorbance values ($K_{232}$, $K_{270}$) in UV light were determined by the Codex Alimentarius (2001). All the parameters were determined in triplicate for each sample. The refractive index of virgin olive oil samples was measured with a 60/70 Abbe Refractometer (Belligham+Stanley Ltd., England).

### Determination of the Total Chlorophyll (TCL) and Carotenoid Content (TCC)

The amount of chlorophyll and carotenoid of the oils was determined using the method defined by Isabel Minguez-Mosquera et al. (1991). Total carotenoid (3) and total chlorophyll (4) amounts were calculated using the following formula:

*The amount of carotenoid (mg carotenoid/kg oil)* $= (A_{470} \times 10^6)/ (2000 \times 100 \times L)$ (3)

*The amount of chlorophyll (mg chlorophyll /kg oil)* $= (A_{670} \times 10^6)/ (613 \times 100 \times L)$ (4)

$A_\lambda$ is the absorbance, and L is the spectrophotometer cell thickness (1 cm). All the parameters were determined in triplicate for each sample.

### Determination of Total Phenolic Content (TPC)

Phenolics in olive oil extracted with methanol: water (80:20, v/v) mixture and total phenolic content was determined using the Folin-Ciocalteu spectrophotometric method (T70+UV/VIS spectrophotometer, PG Instruments, England) (Singleton and Rossi, 1965). Results were calculated as mg gallic acid equivalent (GAE)/kg oil using the calibration curve.

### Determination of Fatty Acid Composition (FAC)

The fatty acid composition of the Gemlik oil was determined by gas chromatography (Shimadzu GC-17A GC-Gas Chromatograph equipped with silica capillary column (Cp WAX 52 CB 50 m*0.32 mm, 1.2 µm)) as fatty acid methyl esters (FAMEs). The methyl esters and fatty acid composition of olive oils were determined by the modifying method Ce 1-62 (AOCS, 2003). The oil samples (50 µl) were converted into FAMEs. Accordingly, derivatization was carried out by adding 500 µl 0.5% Na-Methylate (0.5 g Na-Methylate + 80 ml methanol + 20 ml iso-octane) to 50 µl oil and keeping it overnight at room temperature. Before the injection, 1 ml of hexane was added, and 5 µl of the clarified supernatant was injected. The flow rate of helium, used as carrier gas at a flow rate of 15 cm $s^{-1}$; split ratio was 1/10 ml $min^{-1}$. The temperature of both injector and flame ionization detector was 250°C. Column temperature was set up according to the following temperature program: 60 ºC, hold for 4 min; 4 ºC $min^{-1}$ up to 175 °C; hold for 27 min; 4 ºC $min^{-1}$ up to 215 ºC; hold for 5 min; 4 ºC $min^{-1}$ up to 240 ºC. In the determination of fatty acids, a mixture of methyl esters of 37 fatty acids from butyric acid to nervonic acid (SUPELCO (LB-81678)) was used as a standard. The fatty acid composition of the samples was calculated in area (%).

### Tocopherols (TCP) Analysis

Tocopherol component analysis of olive oils was carried out by modifying the AOCS Official Method (Ce 8-89) (AOCS, 2003). 250 µl of olive oil was dissolved in the mobile phase Heptane/THF (95:5, v/v) solvent, and the volume was completed to 1 ml. Following, 100 µl of sample was injected into the high-performance liquid chromatography (HPLC-Agilent 1100 (Waldbronn, Germany), equipped with a fluorescence detector and Luna silica column (Phenomenex, 250*4.6 mm, 5 µm). The flow rate was 1.2 mL/min, and the fluorescence detector was set at 295 nm for excitation and 330 nm for emission. The peak integration and the quantitative calculations were performed with the calibration curve. In the analysis, α-(alpha), β-(beta), γ-(gamma), and δ-(delta) tocopherols (Cabliochem, Germany) were used as standards.

**Statistical analysis**

The SPSS (Chicago, IL, USA) statistical program was used to analyze the data obtained. The significance of the difference between the combinations (at a 1% confidence level) was evaluated by the analysis of variance, while the difference between the groups was determined by the Duncan one-way comparison test.

**Results**

**Physical and Physicochemical Characteristics of Gemlik Olive Oil**

The degree of ripening, moisture content (%), and oil content (%) of the Gemlik olive variety were determined to be 5.71, 45.07, and 61.10%, respectively, based on their physical characteristics. Compared to the literature, the oil content of the Gemlik variety in this study was higher than 61.10% (Köylüoğlu and Özkan, 2012; Tanilgan et al., 2007; Demirag and Konuskan, 2021).

Physicochemical evaluation of olive oil provides information on its authenticity and safety. Therefore, in this study we assessed the oil yield, free acidity, and values of peroxide, $K_{232}$, $K_{270}$, ΔK of olive oil (Table 2).

**Table 2. OEY (%), FFA (% oleic acid), PV (meq O2/kg oil), $K_{232}$- $K_{270}$ and ΔK values of Gemlik olive oil (n=3)**

| Trials | OEY | FFA | PV | $K_{232}$ | $K_{270}$ | ΔK |
|---|---|---|---|---|---|---|
| Control | $59.37\pm0.65^{c}$ | $0.68\pm0.01^{a}$ | $7.59\pm0.12^{a}$ | $1.45\pm0.04^{abc}$ | $0.08\pm0.01^{a}$ | $0.00\pm0.00^{a}$ |
| Trial-1 | $56.47\pm0.45^{d}$ | $0.58\pm0.01^{c}$ | $7.31\pm0.03^{ab}$ | $1.50\pm0.02^{ab}$ | $0.08\pm0.01^{a}$ | $0.00\pm0.00^{a}$ |
| Trial-2 | $61.92\pm0.69^{b}$ | $0.63\pm0.01^{b}$ | $7.46\pm0.13^{a}$ | $1.43\pm0.02^{bc}$ | $0.06\pm0.01^{abc}$ | $0.00\pm0.00^{a}$ |
| Trial-3 | $64.22\pm0.37^{a}$ | $0.65\pm0.01^{ab}$ | $7.28\pm0.06^{ab}$ | $1.40\pm0.03^{c}$ | $0.06\pm0.00^{bc}$ | $0.00\pm0.00^{a}$ |
| Trial-4 | $64.69\pm0.06^{a}$ | $0.66\pm0.02^{ab}$ | $6.71\pm0.24^{c}$ | $1.42\pm0.03^{c}$ | $0.05\pm0.01^{c}$ | $0.00\pm0.00^{a}$ |
| Trial-5 | $65.16\pm0.47^{a}$ | $0.66\pm0.01^{ab}$ | $6.85\pm0.03^{bc}$ | $1.51\pm0.03^{a}$ | $0.06\pm0.01^{abc}$ | $0.00\pm0.00^{a}$ |

*The mean values marked with the same letter in the same column are not statistically different from each other ($p\leq0.001$); **Please see Table 1 for trials.

When Table 2 is examined, statistically the highest OEY (%) was found in the trial-5 (65.16), and the lowest OEY was found in the trial-1 (56.4). The addition of calcium carbonate reduced the yield of oil, whereas salt increased it. Tamborrino et al. (2017) found that using of calcium carbonate lowered OEY, which is consistent with our findings. However, Espínola *et al.* (2009) showed that high calcium carbonate dosages led to higher extraction efficacy. The use of salt during malaxation resulted in higher levels of OEY than calcium carbonate. This could be because the salt has stronger emulsion breaking impact than calcium carbonate does. In this study, adding of a higher amount of salt and calcium carbonate to the olive paste during the malaxation process had no significant effect on OEY. When calcium carbonate is added in a lower amount, the hygroscopic characteristic of the carbonate helps in extracting oil by causing the olive paste emulsion to breakdown. As a consequence, the oil droplets coalesce into larger drops. In other words, the decrease in OEY with the addition of more calcium carbonate could be related to the coadjuvant's ability to retain oil (Squeo et al., 2016).

By the current study, all the samples comply with the EU limits (Reg. EU 2568/91) for FFAs, PV, $K_{232}$, and $K_{270}$ for extra virgin olive oil. The results of free acidity, peroxide value, $K_{232}$, and $K_{270}$ varied between 0.58-0.68 (oleic acid%), 6.71-7.59 (meq $O_2$/kg oil), 1.40-1.51, and 0.05-0.08, respectively (Table 2). The results indicated that the increase in free acidity and peroxide was suppressed in all trials that used the coadjuvants. Similar to the current study, different researchers reported that the FA and PV decreased with an increase in calcium carbonate concentration (Tamborrino et al., 2017). In the current study, it was determined that the use of calcium carbonate caused a slight decrease in acidity and peroxide values compared to the use of salt. Moya et al. (2010) and Khaleghi et al. (2023) obtained similar results to ours in their study. In contrast with our results, some studies found that adding calcium carbonate increased the levels of acidity and peroxide (Elsorady, 2020; Espínola et al., 2009; Espínola et al., 2015).

The ΔK value is a measure that changes with the refining process and is known as a value used to determine whether olive oils are virgin or refined (Kiralan *et al.*, 2008). There was no statistically significant difference between the trials in the ΔK values. In line with current results, Moya et al. (2010) and Tamborrino et al. (2017) indicated that calcium carbonate did not statistically affect $K_{232}$ and $K_{270}$ values. According to Pérez et al. (2008), $K_{232}$ and $K_{270}$ values increased as the amount of salt used increased. $K_{232}$ and $K_{270}$ values of oils by using salt, calcium carbonate, and their combinations were lower than those of the control group. The study indicated that while the differences between yield, peroxide, free acidity, $K_{232}$ and $K_{270}$ values were significant at $p \leq 0.001$; the difference between ΔK values was not found to be statistically significant.

**RI, TCL, TCC, Pa, TPC and TCP of Gemlik Olive Oils**

Chlorophyll, carotenoids, and pheophytin a are pigments responsible for the color of olive oil. In addition, pheophytin a is reduction product of chlorophyll and is a pigment that gives a mat green color to olive oil. The RI values of all samples were found to be 1.47 (Table 3). In agreement with the current study, Tanilgan et al. (2007) also reported the refractive index of Gemlik olive oil as 1.47. The values of TCL, TCC, and pheophytin-a for the control, trial-1, trial-2, trial-3, trial-4, and trial-5 are displayed in Table 3 and found as 0.29-0.39, 0.01-0.10, and 0.24-0.45 (mg/kg), respectively. Higher amounts of pheophytin-a, carotenoids, and chlorophylls were detected in trials utilizing calcium carbonate compared with trials using salt. According to Cruz et al. (2007) and Elsorady (2020), adding salt increased the amount of total carotenoid and chlorophyll in olive oil. This is consistent with the findings of Moya et al. (2010), who demonstrated that the amounts of carotenoids and chlorophylls in olive oil were not significantly affected by calcium carbonate.

Phenolic compounds play a very important role in increasing the oxidation stability of virgin olive oil due to their natural antioxidant properties. In trials, TPC ranged from 70.82 to 133.92 mg GAE/kg oil. The trial with the highest salt concentration (Trial 5) exhibited the highest total phenolic content with 133.92 mg GAE/kg oil.

**Table 3. RI, TCL (mg/kg), TCC (mg/kg), pheophytin a (mg/kg) and TPC (mg GAE/kg oil) values of olive oil.**

| Trials | RI | TCL | TCC | pheophytin a | TPC |
|---|---|---|---|---|---|
| Control | 1.47±0.00[a] | 0.33±0.11[a] | 0.31±0.03a | 0.07±0.01[ab] | 103.93±1.79[c] |
| Trial-1 | 1.47±0.00[a] | 0.41±0.19[a] | 0.33±0.07[a] | 0.01±0.01[c] | 71.99±0.58[e] |
| Trial-2 | 1.47±0.00[a] | 0.45±0.14[a] | 0.39±0.06[a] | 0.01±0.01[c] | 70.82±2.11[e] |
| Trial-3 | 1.47±0.00[a] | 0.36±0.07[a] | 0.36±0.03[a] | 0.02±0.01[bc] | 94.38±1.35[d] |
| Trial-4 | 1.47±0.00[a] | 0.30±0.05[a] | 0.32±0.02[a] | 0.04±0.02[bc] | 112.30±2.68[b] |
| Trial-5 | 1.47±0.00[a] | 0.24±0.08[a] | 0.29±0.04[a] | 0.10±0.02[a] | 133.92±3.25[a] |

*The mean values marked with the same letter in the same column are not statistically different from each other (p≤0.001); **Please see Table 1 for trials.

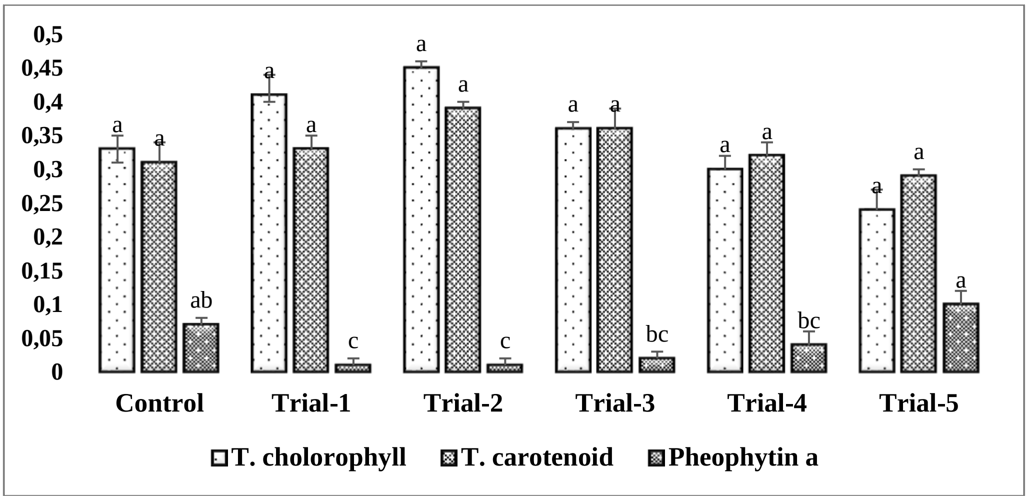


**Figure 2.** Average values for olive oil TCL (mg/kg), TCC (mg/kg), and pheophytin a (mg/kg). Duncan one-way comparison test results (n=3). The mean values marked with the same letter in the same column are not statistically different from each other (p≤0.001). Please see Table 1 for trials.

Trial 2 had the lowest phenolic concentration (70.82 mg GAE/g oil), and it also had the highest calcium carbonate ratio. Trials' phenolic concentrations differed considerably (p≤0.001). The TPC increased with higher salt concentrations and decreased with the usage of calcium carbonate. This might be explained by the fact that calcium carbonate retains phenolic compounds in oil by binding water. Additionally, it may be related to the increased amount of salt that affects the transition of phenolics into the oil (Pérez *et al.*, 2008). In accordance with our findings, Pérez et al. (2008) and Elsorady (2020) showed that the addition of salt during the malaxation process raised the total phenolic content in olive oil. While Khaleghi (2023) demonstrated a rise with the addition of a coadjuvant, Moya et al. (2010) determined no significant effect of calcium carbonate on TPC. The means of the TPC and α-TCL values of olive oils produced using calcium carbonate, salt, and their combinations are shown in Figure 3.

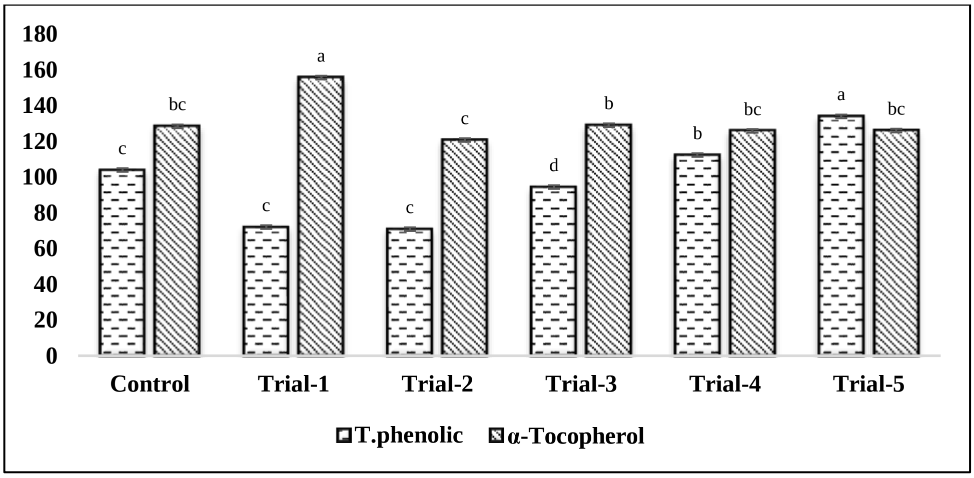


**Figure 3.** Average values for olive oil total phenolic content (mg GAE/kg oil) and α-tocopherol (mg/kg oil) Duncan one-way comparison test results (n=3). The mean values marked with the same letter in the same column are not statistically different from each other ($p \leq 0.001$). Please see Table 1 for trials.

## FAC of Gemlik Olive Oils

The averages of the fatty acid components of the olive oils produced by using calcium carbonate, salt, and their combinations are given in Figure 4 and Figure 5. In the current trials, oleic (C18:1), palmitic (C16:1), and linoleic acids (C18:2) were determined as the major compounds, and stearic, palmitoleic and linolenic acids were found as minor compounds (Figures 4 and 5). The amount of (%) oleic acid, palmitic acid, linoleic acid, stearic acid, and palmitoleic acid ranged from 60.24 to 67.93; 14.11 to 22.63; 11.85 to 13.10; 2.97 to 3.86; and 1.52 to 1.96, respectively. In addition, it should be mentioned that all fatty acids except linolenic were within the range of IOOC (2021). In the current study, the amount of linolenic acid ranged from 0.00 to 1.34. The amount of oleic acid exhibited higher concentrations in the control group compared to the coadjuvant-applied oil. (Figure 4). The findings revealed that the addition of calcium carbonate had no effect on the level of palmitic acid (C16:1), but that it increased when using additional salt. Concerning the amount of linoleic acid, there was no statistically significant difference between the trials and the control group. Khaleghi et al. (2023) also found that the addition of calcium carbonate did not affect the amount of linoleic acid, which is in line with our findings.

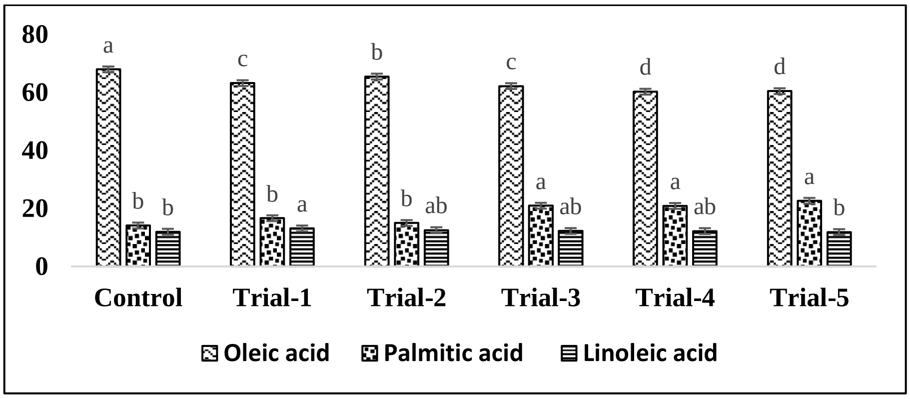


**Figure 4.** Average values for the major fatty acid components; Oleic acid(C18:1), Palmitic acid(C16:0), Linoleic acid (C18:2) (%). Please see Table 1 for trials.

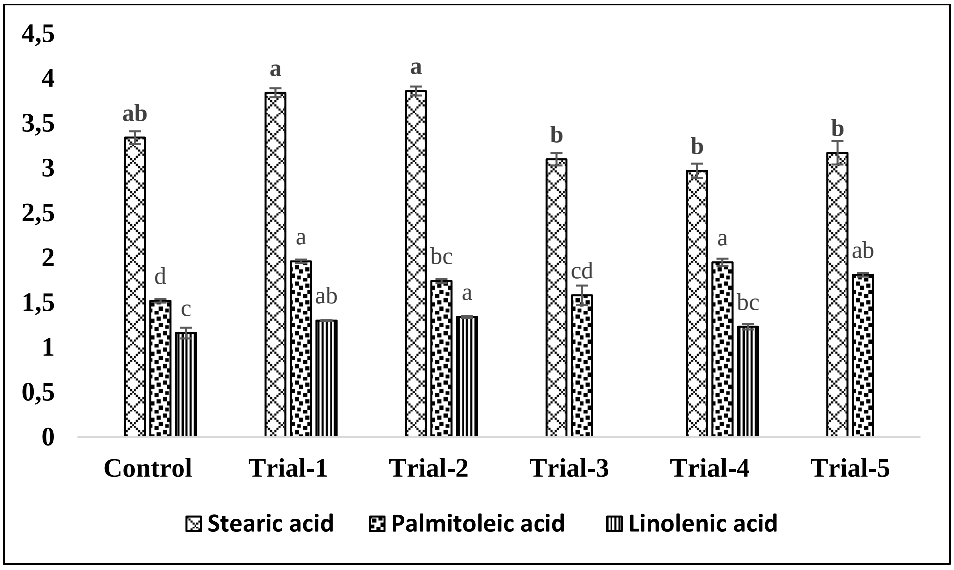


**Figure 5.** Average values for olive oil minor fatty acid components (%):Stearic acid (C16:0), Palmitoleic acid and Linolenic acid. Please see Table 1 for trials.

The addition of coadjuvants had no noticeable impact on the minor fatty acid amounts (Figure 5). Furthermore, according to other research, adding calcium carbonate has a minimal effect on fatty acid levels (Cruz et al., 2007; Moya et al., 2010; Elsorady, 2020; Khaleghi, E. et al., 2023). The percentages of palmitic acid, palmitoleic acid, stearic acid, oleic acid, linoleic acid, and linolenic acid displayed statistically significant differences at the $p \leq 0.001$ level for trials and the $p \leq 0.01$ level for oleic acid levels.

## Conclusion

The utilization of salt as a coadjuvant for the production of olive oil highlighted a positive effect on yield. On the other hand, a decrease in yield was observed with an additional amount of calcium carbonate. Regarding the physicochemical effects of applied coadjuvants, the addition of salt in the process increased the acidity value and pheophytin a content whereas calcium carbonate applied oil had lower peroxide and K values. The refractive indexes of olive oil obtained in different trials were similar. Trials 2 and 3 have a higher pigment transition to oil from paste than the control and other trials. The highest amount of TPC was determined in the control and trials 4 and 5, while the lowest TPC was found in trials 2, 3, and 4. Also, in the current study, calcium carbonate and salt applications slightly affect the fatty acid composition of olive oil.

As a result, both coadjuvants had a more positive effect on oil yield and some olive oil quality parameters compared to the control group. However, the application of salt during the malaxation process was found to be more advantageous than calcium carbonate. Therefore, salt can be recommended as a coadjuvant to produce olive oil. According to FAO/WHO, salt is inexpensive and widely available, with no daily consumption restriction. Consequently, it could potentially be recommended as a natural coadjuvant by the olive oil industry.

## References

AOCS, 2003. Official Methods and Recommended Practices of the American Oil Chemists' Society Methods Cd 3d-63, Cd 8b-90, and Ch5-91, 5th edn. AOCS Press, Champaign.

Aydın S., Özkan G. and Yorulmaz A. (2020). Çeşit, Olgunluk ve Yoğurma Şartlarının Zeytinyağının Sterol Profili Üzerine Etkisi. *Akademik Gıda,* **18,** 87-95. https://doi.org/10.24323/akademik-gida.730207

Clodoveo, M.L., Durante V. and La Notte D. (2013). Working towards the development of innovative ultrasound equipment for the extraction of virgin olive oil. *Ultrasonics sonochemistry,* **20,** 1261-1270. https://doi.org/10.1016/j.ultsonch.2013.02.001

Codex Alimentarius, (2001). Codex Standard for olive oil, virgin. and refined, and for refined olive-pomace oil. Codex Standard. 33- 1981 (Rev. 1- 1989).

Cruz, S.,Yousfi, K., Pérez A.G.,Mariscal C. and Garcia J.M. (2007). Salt improves physical extraction of olive oil. *European Food Research and Technology,* **225,** 359-365. https://doi.org/10.1007/s00217-006-0423-9

Çevik, Ş., Özkan, G. and Kiralan, M. (2015). Çeşit, Olgunluk ve Yoğurma Şartlarının Zeytinyağı Verimi, Bazı Kalite Parametreleri ve Aroma Profili Üzerine Etkisi. *Akademik Gıda,* **13,** 335-347.

Dalgic, L., Ozkan G. and Karacabey, E., (2016). Altın Çilek Çeşnili Zeytinyağı Üretiminde İşlem Koşullarının Kalite Parametreleri Üzerine Etkilerinin İncelenmesi ve Optimizasyonu. *SDU Journal of the Faculty of Agriculture/SDÜ Ziraat Fakültesi Dergisi,* **11,** 21-34.

Delil, S.O.S., Özkan, G. and Karacabey, E. (2022). Phenolic Transition from Olive Fruits at Different Ripening Stages to Olive Oil: Process Optimization and Determination by Spectrophotometric and Chromatographic Methods. *Food Analytical Methods***,** 1-14. https://doi.org/10.1007/s12161-022-02364-6

Demirag, O. and Konuskan, D.B. (2021). Quality properties, fatty acid and sterol compositions of East Mediterranean region olive oils. *Journal of Oleo Science,* **70,** 51-58. https://doi.org/10.5650/jos.ess20179

Dentel, S.K. (1991). Coagulant control in water treatment. *Critical Reviews in Environmental Science and Technology,* **21,** 41-135. https://doi.org/10.1080/10643389109388409

Dıraman, H. and Dibeklioğlu, H. (2009). Characterization of Turkish virgin olive oils produced from early harvest olives. *Journal of the American Oil Chemists' Society,* **86,** 663-674. https://doi.org/10.1007/s11746-009-1392-5

Elsorady, M.E. (2020). Effect Of Using Some Extraction Coadjuvants On Extraction Yield And Quality Of Olive Oil Extracted From Some Egyptian Olive Cultivars. *Annals. Food Science and Technology,* **21**.

Guinda, A., Dobarganes, M.C., Ruiz-Mendez, M.V. and Mancha, M. (2003). Chemical and physical properties of a sunflower oil with high levels of oleic and palmitic acids. *European journal of lipid science and technology,* **105,** 130-137. https://doi.org/10.1002/ejlt.200390028

Hashmi, M.A., Khan, A., Hanif, M., Farooq, U. and Perveen, S. (2015). Traditional uses, phytochemistry, and pharmacology of Olea europaea (olive). *Evidence-Based Complementary and Alternative Medicine,* **2015**. https://doi.org/10.1155/2015/541591

IOOC (2021). *International Olive Oil Council. Available from: https://www.internationaloliveoil.org/worlds-olive-oil-production-has-tripled*.

*accessed January 2021* [Online]. [Accessed].

Isabel Minguez-Mosquera, M., Rejano-Navarro L., Gandul-Rojas, B., SanchezGomez, A.H. and Garrido-Fernandez, J. (1991). Color-pigment correlation in virgin olive oil. *Journal of the American Oil Chemists' Society,* **68,** 332-336. https://doi.org/10.1007/BF02657688

Khaleghi, E., Moghadam, H.N., Mortazavi, S.M.H. (2023). The effects of processing aids and techniques on olive oil extractability and oil quality indices. *Grasas y Aceites 74*(1), e494-e494.

Kıralan, M., Bayrak, A., Çalıkoglu, E. (2008). Effect of nigella seed extract on oxidative stability of refined sunflower oil. *Asian Journal of Chemistry,* 20, 3313-3318.

Köylüoğlu, F. and Özkan, G. (2012). Yardımcı katkı maddeleri kullanımının zeytinyağı verim ve kalite parametreleri üzerine etkisi. *Electronic Journal of Food Technologies,* **7,** 32-45.

Lavee, S. and Wodner, M. (2004). The effect of yield, harvest time and fruit size on the oil content in fruits of irrigated olive trees (Olea europaea), cvs. Barnea and Manzanillo. *Scientia Horticulturae,* **99,** 267-277. https://doi.org/10.1016/S0304-4238(03)00100-6

Moya, M., Raínola, F., Fernández, D.G., de Torres, A., Marcos, J.,Vilar, J., Josue, J., Sánchez, T. and Castro, E. (2010). Industrial trials on coadjuvants for olive oil extraction. *Journal of food engineering,* **97,** 57-63. https://doi.org/10.1016/j.jfoodeng.2009.09.015

Ozturk, M., Altay, V., Gönenç, T.M.,Unal, B.T., Efe, R., Akçiçek, E. and Bukhari, A. (2021). An overview of olive cultivation in Turkey: Botanical features, eco-physiology and phytochemical aspects. *Agronomy,* **11,** 295. https://doi.org/10.3390/agronomy11020295

Pérez, A.G., Romero, C., Yousfi, K. and García, J.M. (2008). Modulation of olive oil quality using NaCl as extraction coadjuvant. *Journal of the American Oil Chemists' Society,* **85,** 685-691. https://doi.org/10.1007/s11746-008-1252-8

Singleton, V.L., Rossi, J.R. (1965). Colorimetry of Total Phenolics with Phosphomolibdic-Phosphothungstic Acid. *American Journal of Enology and Viticulture,* 16, 144- 158.

Squeo, G., Silletti, R., Summo, C., Paradiso V., Pasqualone, A. and Caponio, F., (2016). Influence of calcium carbonate on extraction yield and quality of extra virgin oil from olive (Olea europaea L. cv. Coratina). *Food Chemistry,* **209,** 65-71. https://doi.org/10.1016/j.foodchem.2016.04.028

Tamborrino, A., Squeo, G., Leone, A., Paradiso, V.M., Romaniello, R., Summo, C., Pasqualone, A., Catalano, P., Bianchi, B. and Caponio, F. (2017). Industrial trials on coadjuvants in olive oil extraction process: effect on rheological properties, energy consumption, oil yield and olive oil characteristics. *Journal of Food Engineering,* **205,** 34-46. https://doi.org/10.1016/j.jfoodeng.2017.02.019

Tanilgan, K., Özcan, M.M. and Ünver, A. (2007). Physical and chemical characteristics of five Turkish olive (Olea europea L.) varieties and their oils. *Grasas y aceites,* **58,** 142-147. https://doi.org/10.3989/gya.2007.v58.i2.78

TGK (2017). Türk Gıda Kodeksi, Zeytinyağı ve Prina Yağı Tebliği (TebliğNNo:2017/26). Gıda, Tarım ve Hayvancılık Bakanlığı, Resmi Gazete.