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Comparison of Chemical Properties and Fatty Acid Composition of Artisanal and Commercial Butters

Oğuz Gürsoy[1] ✉, Kübra Kocatürk[2,3], Ayşe Deniz[2,4], Hande Özge Güler Dal[1], Yusuf Yilmaz[1]

[1]Department of Food Engineering, Faculty of Engineering and Architecture, Burdur Mehmet Akif Ersoy University, Istiklal Campus, 15200 Burdur, Türkiye
[2]Division of Food Engineering, Graduate School of Natural and Applied Sciences, Burdur Mehmet Akif Ersoy University, Istiklal Campus, 15200 Burdur, Türkiye
[3]Gebze Organize Sanayi Bölgesi, İhsan Dede Cad. 700. Sk. No: 704, 41400 Gebze, Kocaeli, Türkiye
[4]Burdur İl Tarım ve Orman ve Orman Müdürlüğü, Bahçelievler, Hare Sk. No: 3, 15100 Burdur, Türkiye

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✉ *Corresponding author (Yazışmalardan Sorumlu Yazar): ogursoy@mehmetakif.edu.tr (O. Gürsoy)*
+90 248 213 27 23 +90 248 213 27 04

ABSTRACT

This study compares the chemical properties, fatty acid composition, and conjugated linoleic acid (CLA) levels of artisanal (homemade) (n=10) and commercial butter samples (n=10) produced from cow's milk. Artisanal butters were collected from local producers who maintain their own livestock across various villages within the Burdur province in Türkiye, while commercial samples were acquired from various national and local markets. On average, the dry matter content was significantly higher in commercial butters (84.15%) than artisanal samples (82.60%) ($p<0.05$). However, the difference in the mean fat contents of commercial (84.08%) and artisanal (82.98%) butter samples was insignificant ($p>0.05$). Furthermore, the mean titratable acidity values of commercial and artisanal butters were found as 0.30% and 0.51% (percent lactic acid), respectively ($p<0.05$). Interestingly, artisanal butters exhibited a significantly higher mean CLA content (6.89 mg/g fat) compared to their commercial counterparts (4.11 mg/g fat) ($p<0.05$). However, there were no statistically significant differences in the relative ratios of polyunsaturated fatty acids between commercial and artisanal butters, with respective values of 3.32% and 4.01% ($p>0.05$). In conclusion, this study showed significant differences in the dry matter content, titratable acidity, and CLA content between artisanal and commercial butter samples, indicating potential nutritional and quality variations between the two types of butter, particularly emphasizing the higher CLA content observed in artisanal butter despite comparable fatty acid composition.

Keywords: Butter, Artisanal, Commercial, Fatty acid, Conjugated linoleic acid

Ticari ve Ev Yapımı Tereyağlarının Kimyasal Özellikleri ve Yağ Asidi Kompozisyonlarının Karşılaştırılması

ÖZ

Bu çalışmada, inek sütünden elde edilen ev yapımı (n=10) ve ticari tereyağı örneklerinin (n=10) kimyasal özellikleri, yağ asidi kompozisyonu ve konjuge linoleik asit (KLA) seviyeleri karşılaştırılmıştır. Ev yapımı tereyağı örnekleri, Burdur ilindeki çeşitli köylerde kendi hayvanlarını besleyen yerel üreticilerden, ticari tereyağı örnekleri ise çeşitli ulusal ve yerel marketlerden temin edilmiştir. Ortalama kuru madde içeriğinin ticari tereyağlarında (%84.15) ev yapımı örneklerden (%82.60) önemli ölçüde daha yüksek ($p<0.05$) olduğu, ticari (%84.08) ve ev yapımı (%82.98) tereyağı örneklerinin ortalama yağ içerikleri arasındaki farkın ise önemsiz olduğu bulunmuştur ($p>0.05$). Bu çalışma, kuru madde içeriği, titre edilebilir asitlik ve KLA içeriği bakımından ev yapımı ve ticari tereyağı örnekleri arasında önemli farklılıklar olduğunu ortaya koymuştur. Özellikle benzer yağ asidi bileşimlerine rağmen, ev yapımı tereyağının daha yüksek KLA içeriğine sahip olması, bu tereyağı türleri arasındaki potansiyel beslenme ve kalite farklılıklarını öne çıkarmaktadır.

Anahtar Kelimeler: Tereyağı, Ev yapımı, Ticari, Yağ asidi, Konjuge linoleik asit

INTRODUCTION

Milk and dairy products play an essential role in human nutrition and well-being. Butter, a widely traded dairy product, exhibits varying consumption patterns across countries, with a global per capita consumption on the rise. In Asia, butter holds the distinction of being the most consumed processed dairy product, constituting nearly half of all processed dairy consumption in terms of milk solids. While Europe and North America currently dominate butter consumption, consumption rates in Asia are witnessing the strongest growth. Statistical data from 2023 indicates that approximately 2.1 million metric tons of butter were produced within the European Union alone [1]. Butter, the most widely consumed animal fat in Türkiye, is rich in short-chain fatty acids and omega-9, making it a significant component of human nutrition due to its nutritional value and sensory attributes. In addition to commercial production, butter is also produced domestically and sold in public markets across Türkiye [2-4]. According to the Turkish Food Codex [5], butter is defined as a product containing a minimum of 80% and a maximum of 90% milk fat, with a maximum of 2% non-fat milk solids and 16% water by weight. Butter production typically involves two methods: churning and emulsification. Traditionally, butter is produced by separating milk fat into cream, followed by churning, crystallization, and finally, kneading of pasteurized cream with added cultures [6].

The fat content and fatty acid composition of dairy products are major quality indicators that significantly impact human health, food quality, and product pricing. Fatty acid profiles in milk are influenced by various factors such as genetics, diet, lactation stage, and seasonal variations, and processing parameters for milk, including heat treatments, addition of starter cultures, maturation conditions (temperature and duration), and storage temperatures, also influence the fatty acid composition of dairy products [3, 7-9]. Monounsaturated oleic acid is recognized for its health benefits as it helps in reducing plasma cholesterol, LDL cholesterol, and triacylglycerols [10]. Studies suggest that the texture and spreadability of butter are positively associated with the proportion of unsaturated fatty acids in its composition [11].

Long-chain polyunsaturated fatty acids (PUFAs) offer numerous potential health benefits. Despite milk fat containing 5% saturated fat, it contributes positively to health due to its constituents such as conjugated linoleic acid (CLA), sphingomyelin, butyric acid, and myristic acid, which have been linked to mitigating chronic diseases [12]. CLA, a mixture of conjugated, positional, and geometric isomers of linoleic acid with 18 carbon atoms and two double bonds (C18:2, cis-9, trans-12), is particularly noteworthy for its unique array of positive effects [15]. Research studies have increasingly explored the beneficial impact of this biologically active compound on human health. CLA is known to significantly reduce the risk of cardiovascular diseases by lowering total plasma cholesterol, triglycerides, and low-density lipoproteins (LDL) [13]. Additionally, it exhibits antioxidant properties and contributes to combating obesity by reducing fat tissue while increasing protein, mineral, and water accumulation in the body [14-18]. The beneficial effects of CLA vary depending on the isomer type, dosage, and metabolic context in which it is administered [19]. Generally, CLA in milk originates from rumen bacteria, and its presence in fermented milk products depends on the activities of the lactic starters employed. The ripening conditions of the products and the starters used can be pivotal in CLA formation [17]. Milk and dairy products represent one of the richest dietary sources of CLA, accounting for approximately 70% of total CLA intake [19]. The average CLA content in milk ranges widely from 2 to 30 mg/g fat [20]. To harness the health benefits associated with CLA, it is recommended that a healthy individual weighing 70 kg consume 1.3-3.0 g of CLA per day [21].

To the best of our knowledge, there is currently no study comparing the CLA contents of artisanal and commercial butters. This study aimed to compare several chemical properties (including CLA content, fat content, dry matter content, fat in dry matter content, titratable acidity, acid degree values, and fatty acid profiles) of commercial butter samples with those of artisanal ones obtained from the city of Burdur, Türkiye. Additionally, the results of the present study were compared with the regulatory standards.

MATERIALS and METHODS

Materials

Various brands of commercial butter (designated as C1-C10) were purchased from national or local markets, while artisanal butter samples (designated as A1-A10) were obtained from local producers in different villages within the Burdur province of Türkiye. All butter samples, whether commercial or artisanal, were derived from cow's milk. The commercial butter brands selected for this study were representative of the prominent brands available in the Turkish market. Subsequently, the butter samples were stored under refrigerated conditions at 4±1°C until they were analyzed.

Methods

Chemical Analyses

The dry matter contents of butter samples were determined by using a rapid moisture analyzer (Kern DBS 60-3, Kern & Sohn GmbH, Balingen, Germany). The fat contents of butter samples were determined by the

Gerber method, which is a widely used reference method for the determination of fat content in milk and milk products, and the fat content was expressed as g/100 g butter [22]. The titratable acidity of butter samples was determined according to Metin and Öztürk [23] by using Eq. 1.

$$\text{Percent acidity (\% lactic acid)} = \frac{V \times F \times 0.009}{m} \times 100 \qquad (1)$$

where V is the amount of NaOH solution (mL) consumed in titration, m is the weight of the sample used in titration (g), F is factor of NaOH solution and 0.009 is the milliequivalent grams of lactic acid.

Lipid Extraction and Acid Degree Values

To extract lipids and determine the total free fatty acid values (acid degree value, ADV), the methods outlined by Renner [24] were used. Initially, butter samples were thoroughly crushed in a beaker along with an ample amount of kieselguhr (Fluka Chemie GmbH, Buchs, Switzerland). Diethyl ether (Fluka Chemie GmbH, Buchs, Switzerland) was subsequently added to the mixtures and thoroughly mixed. The mixture underwent filtration through coarse filter paper to separate butter particles and kieselgur from the solvent. This process was repeated multiple times to ensure complete extraction of lipids into the solvent, and the solvent-lipid mixture was collected in a volumetric flask. The diethyl ether was then removed from the solvent-lipid mixture at 45°C using a rotary evaporator (Heidolph, Schwabach, Germany). The lipid extract was then dried completely under nitrogen flushing and stored at -20°C until further analysis.

To determine the ADV, a procedure involving the addition of 40 mL of an ether-alcohol mixture (1:1) to the weighed lipid extract in an Erlenmeyer flask was employed. The mixture was then titrated with potassium hydroxide (KOH) solution (0.1 N) using phenolphthalein (1%) as an indicator. The total free fatty acid values were calculated using Eq. 2, and the results were expressed as grams of oleic acid per 100 grams of milk fat.

$$\text{Percent oleic acid} \left(\frac{g}{100\ g}\right) = \frac{282 \times n \times F}{E \times 100} \qquad (2)$$

where n is the volume of KOH solution consumed (mL), 282 is the molecular weight of oleic acid (g/moL), F and E are the factors of 0.1 N KOH solution and the weight of butter samples (g), respectively.

Preparation of Fatty Acid Methyl Esters and their Chromatographic Analyses

To prepare fatty acid methyl esters (FAMEs) from the lipid extracts prior to gas chromatographic analyses, the method proposed by Yılmazer and Seçilmiş [24] was followed. Initially, 1 mL of 1.5 M methanolic HCl was added to a lipid extract (200 µL) and maintained at 80°C for two hours. Subsequently, the mixture was cooled to room temperature, and 0.5 mL of water was added. The FAMEs were then extracted using 1 mL of hexane.

The fatty acid and CLA compositions of the butter samples were analyzed using an Agilent 7890A gas chromatography (GC) unit, coupled with a Agilent 5975C quadrupole mass spectrometer detector (MS). Electron ionization at 70 eV energy was used in the GC-MS analyses, with fragment ions analyzed in scanning mode within the mass range of 30-500 m/z. FAMEs were separated using a fused silica capillary column (DB WAX, 50 m × 0.20 mm, 0.20 µm film thickness; Chrompack, Midelburg, Netherlands). Injector and detector temperatures were set to 240°C, with an injection volume of 1 µL. Helium served as the carrier gas at a flow rate of 1 mL/min, with a split ratio of 1/20 in the analyses. Fatty acids and CLAs were identified using a standard mixture of FAMEs (Supelco® 37 Component FAME Mix, Catalog No: 47885 U, Sigma-Aldrich, St. Louis, MO, USA) and a CLA standard (Sigma Chemical Company, P Code: 1002398739, Sigma-Aldrich St. Louis, MO, USA).

Statistical Analysis

The experimental data were analyzed using the SAS package program (The SAS System for Windows 9.0, Chicago, USA) employing the analysis of variance (ANOVA) and Duncan's multiple comparison test as a post-ANOVA analysis. The relative fatty acid ratios (%) in the artisanal and commercial butter samples in Table 4 were compared using a t-test. Results were presented as mean ± standard deviation, with a significance level of $\alpha=0.05$ considered.

RESULTS and DISCUSSION

Chemical Properties of Butter Samples

The fat and water contents, acidity and ADV values of butter samples are presented in Table 1. The moisture content of commercial and artisanal butter samples ranged from 13.25 to 25.00%. The mean dry matter content of commercial butters (84.15%) was found significantly higher than that of the artisanal ones (82.60%) ($p<0.05$). Three commercial butters (C1, C9 and C10) and five artisanal butters (A3, A7, A8, A9 and A10) exceeded the maximum water limit (16%) regulated by the Turkish Food Codex. Fat content of butter samples ranged from 75.00 to 86.75%, with one artisanal butter (A8) falling below the specified codex limit (>80% fat). However, the difference in the fat contents of commercial (84.08%) and artisanal (82.98%) butters was found insignificant ($p>0.05$). Additionally, Tahmas Kahyaoğlu and Çakmakçı [26] determined the dry matter and fat contents ranging from 82.77 to 83.00% and 81.50 to 81.90%, respectively, in butters produced from different animal milks during a 90-day storage period. Tavella et al. [27] reported a fat content of 85% in butter samples sold in Argentina.

Acidity value serves as a crucial parameter reflecting the oxidative stability of butter, with higher values indicating a faster oxidation process [28]. Titratable acidity values of the butter samples in this study ranged from 0.21% to 1.35% lactic acid. Furthermore, the mean titratable acidity values were found significantly higher in artisanal butters (0.51% lactic acid) compared to commercial butters (0.30% lactic acid) ($p<0.05$). This suggests that artisanal butters are more susceptible to oxidation reactions than their commercial counterparts. Similarly, Tahmas Kahyaoğlu and Çakmakçı [26] reported titratable acidity values ranging from 0.13% to 0.51% lactic acid in butters produced from different animal milks. Akgül et al. [29] found that the titratable acid values of butter samples produced in Trabzon, Türkiye, ranged between 0.32-3.37%.

The ADV of lipids serves as a measure of their free fatty acid content, reflecting the degree of rancidity and lipolysis. ADVs of the butter samples ranged from 0.57% to 5.75% oleic acid. Commercial butters exhibited significantly lower ADV values (0.50%) compared to artisanal butters (0.94%), indicating that commercial butter is less susceptible to rancidity. Berhe et al. [30] determined the acid degree value of butter made from camel milk to be 6.7 mg KOH g^{-1}. Similar to the results of our study, Demirkol [31] found that the acidity values of butters sold in Çanakkale, Türkiye, varied between 0.55-1.22 mg KOH g^{-1}.

Ozkan et al. [31] reported fat, water, and titratable acidity values of butters containing *Satureja cilicica* essential oil as 84.16%, 14.30%, and 0.03%, respectively. In a study on commercially available butter samples, Keskin Çavdar [33] found that moisture and fat contents were 20.67% and 74.53%, respectively. Okur and Seydim [34] assessed the quality characteristics of commercial milk and dairy products sold in Isparta (Türkiye), noting that dry matter and fat contents of butters ranged from 82.09% to 86.86%, and from 83.50% to 86.75%, respectively. Seçkin et al. [33] determined the fat content of commercial butter samples (n=8) between 82.00% and 83.00%. The reults of the present study were in a good agreement with the literature data. Similar total solid contents (84.2-95.7%) and fat contents (81.4–92 g/100 g of total solids) were also reported in butters by Méndez-Cid et al. [34].

Table 1. Results of chemical analyses in commercial and artisanal butter samples

Sample	Fat (%)	Water (%)	Fat (%, dry matter basis)	Titratable Acidity (lactic acid%)	Acid Degree Value (% oleic acid)
C1*	83.00±1.41^{EDF**}	17.00±1.41^{CDE}	490.280±49.10^{FED}	0.33±0.01^{EDF}	0.57±0.04^{I}
C2	84.25±0.35^{EBDFC}	15.75±0.35^{GCFDE}	535.08±14.26^{FBEDC}	0.25±0.01^{IH}	0.62±0.03^{HI}
C3	85.00±0.71^{BDAC}	15.00±0.71^{GHFE}	567.41±31.47^{BDC}	0.28±0.03^{GHF}	0.82±0.10^{HIGF}
C4	84.75±0.35^{EBDAC}	15.25±0.35^{GHFDE}	555.92±15.21^{BEDC}	0.27±0.01^{GH}	0.89±0.11^{HIGEF}
C5	84.00±1.41^{EBDFC}	16.00±1.41^{GCFDE}	527.46±55.46^{FBEDC}	0.28±0.00^{GHF}	0.90±0.05^{HIGEF}
C6	86.75±1.77^{A}	13.25±1.77^{H}	661.50±101.59^{A}	0.33±0.01^{ED}	1.34±0.11^{DE}
C7	84.50±0.71^{EBDC}	15.50±0.71^{GFDE}	545.84±29.47^{FBEDC}	0.34±0.01^{D}	1.27±0.04^{DEF}
C8	86.00±0.00^{BA}	14.00±0.00^{GH}	614.29±0.00^{BA}	0.21±0.01^{I}	0.79±0.08^{HIGF}
C9	80.00±1.41^{G}	20.00±1.41^{B}	401.26±35.45^{G}	0.27±0.01^{GH}	0.89±0.02^{HIGEF}
C10	82.50±2.12^{EF}	17.50±2.12^{CD}	475.66±69.78^{FEG}	0.42±0.00^{C}	1.83±0.08^{C}
A1	84.00±0.00^{EBDFC}	16.00±0.00^{GCFDE}	525.00±0.00^{FBEDC}	0.43±0.03^{C}	1.13±0.01^{HDGEF}
A2	84.25±0.35^{EBDFC}	15.75±0.35^{GCFDE}	535.08±14.26^{FBEDC}	0.22±0.01^{I}	1.16±0.10^{DGEF}
A3	83.25±0.35^{EDFC}	16.75±0.35^{CFDE}	497.15±12.60^{FED}	0.30±0.02^{EGF}	1.41±0.05^{DC}
A4	85.50±0.71^{BAC}	14.50±0.71^{GHF}	590.48±33.67^{BAC}	0.29±0.00^{EGF}	0.89±0.49^{HIGEF}
A5	85.75±0.35^{BA}	14.25±0.35^{GH}	601.98±17.42^{BAC}	0.44±0.01^{C}	0.61±0.01^{I}
A6	84.25±1.06^{EBDFC}	15.75±1.06^{GCFDE}	536.37±42.86^{FBEDC}	0.45±0.03^{C}	1.30±0.07^{DEF}
A7	82.00±0.71^{GF}	18.00±0.71^{CB}	455.99±21.84^{FG}	0.30±0.01^{EGDF}	0.75±0.02^{HIG}
A8	75.00±0.00^{H}	25.00±0.00^{A}	300.00±0.00^{H}	1.08±0.04^{B}	4.47±0.74^{B}
A9	83.75±0.35^{EBDFC}	16.25±0.35^{GCFDE}	515.53±13.39^{FEDC}	1.35±0.01^{A}	5.75±0.20^{A}
A10	82.00±0.00^{GF}	18.00±0.00^{CB}	455.56±0.00^{FG}	0.30±0.04^{EGF}	1.17±0.06^{DGEF}
			Mean Values		
Commercial	84.08±2.05^{A}	15.85±1.15^{A}	537.47±79.08^{A}	0.30±0.06^{A}	0.50±0.19^{A}
Artisanal	82.98±3.01^{A}	17.40±3.23^{B}	501.31±84.64^{A}	0.51±0.37^{B}	0.94±0.86^{B}

*C and A letters in the column represent commercial and artisanal butter samples, respectively. **A-J: Different letters in the same column represent significant differences between the means (p<0.05).

Fatty Acid Composition of Butter Samples

The fatty acid compositions of both commercial and artisanal butter samples are detailed in Tables 2 and 3, respectively, with an overview of the average fatty acid composition presented in Table 4. Across all butter samples, palmitic, oleic, and myristic acids emerged as the dominant fatty acids, collectively constituting over 58% of the average total fatty acids in both types of butter. These results confirm prior studies, which highlighted that artisanal butter contains approximately 40% short-chain fatty acids (C4–C14), predominantly palmitic and oleic acids [4]. In a study on the effect of cream cooling temperature and acidification methods on some technological properties of butters, Ceylan and Ozcan [37] identified palmitic, stearic, and myristic acids as the primary saturated fatty acids, with oleic acid being the dominant unsaturated fatty acid. Similarly, Okur and Seydim [33] studied the fatty acid compositions of various butter samples and reported the concentrations of myristic, palmitic, stearic, and oleic acids as 11.47, 32.06, 15.07, and 26.89 mg/g fat, respectively. In a study on the effect of salt addition, storage temperature, and duration on fresh butter, palmitic acid was identified as the predominant fatty acid (33.0%), followed by oleic acid (24.8%), myristic acid (11.5%), and stearic acid (9.8%) [37].

In a study by Tavella et al. [27], palmitic acid (16:0) was found to be the predominant fatty acid in butter, comprising 30.88% of the total fatty acid content, followed by oleic acid at 29.51%, stearic acid at 14.59%, and myristic acid at 11.12%. Another study on butter samples from Pakistan [38] reported saturated fatty acid contents ranging from 63.7% to 68.5% and *cis* polyunsaturated fatty acids ranging from 1.20% to 2.94%. Additionally, Serim [39] determined that butter contains 31% oleic acid, 23% palmitoleic acid, 3% linoleic acid, and 2% linolenic acid, with the highest saturated fatty acid contents attributed to palmitic (28%), myristic (11%), and stearic acids (10%).

Table 2. Changes in the fatty acid compositions of commercial butter samples (relative ratio, %)

Compound	Butter Sample									
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
C4:0	4.00±0.03	3.46±0.05	4.23±0.06	4.86±0.04	3.61±0.03	4.18±0.03	4.41±0.06	2.98±0.02	2.98±0.02	4.80±0.03
C6:0	5.08±0.04	4.16±0.06	6.14±0.09	5.46±0.04	5.46±0.04	4.48±0.03	5.13±0.07	5.00±0.04	3.91±0.03	5.74±0.04
C8:0	3.06±0.02	2.40±0.03	3.87±0.06	3.53±0.03	3.25±0.02	2.64±0.02	3.66±0.05	3.79±0.03	2.94±0.02	4.29±0.03
C10:0	4.49±0.03	5.13±0.07	6.85±0.10	4.65±0.03	6.65±0.05	6.10±0.04	4.68±0.07	6.06±0.04	4.82±0.04	6.50±0.05
C11:0	0.89±0.01	0.65±0.01	0.55±0.01	0.59±0.00	0.52±0.00	1.03±0.01	0.49±0.01	1.73±0.01	0.83±0.01	0.79±0.01
C12:0	5.04±0.04	4.79±0.07	5.96±0.09	4.77±0.03	5.41±0.04	5.04±0.04	4.92±0.07	5.53±0.04	5.47±0.04	5.54±0.04
C14:0	14.99±0.11	13.91±0.20	15.01±0.61	15.33±0.11	13.52±0.10	13.17±0.10	13.58±0.20	13.41±0.10	14.53±0.11	14.86±0.11
C14:1n-5	4.22±0.03	3.20±0.05	4.17±0.06	3.22±0.02	4.13±0.03	3.88±0.03	3.29±0.05	3.10±0.02	3.04±0.02	2.59±0.02
C15:0	1.06±0.01	0.86±0.01	0.85±0.01	0.88±0.01	0.59±0.00	1.03±0.01	0.59±0.01	0.44±0.00	0.29±0.00	0.19±0.00
C16:0	28.04±0.20	30.53±0.44	22.83±0.37	26.88±0.20	27.58±0.20	24.88±0.18	25.21±0.37	24.93±0.18	26.16±0.19	24.11±0.09
C16:1n-7	0.41±0.00	0.42±0.01	0.49±0.01	1.03±0.01	1.17±0.01	0.72±0.00	0.82±0.01	1.97±0.01	1.40±0.01	0.56±0.00
C17:0	0.24±0.00	0.46±0.01	0.33±0.00	0.41±0.00	0.46±0.00	3.48±0.03	1.17±0.02	0.70±0.00	0.28±0.00	0.38±0.00
C18:0	5.45±0.04	7.47±0.11	5.31±0.08	4.66±0.03	4.32±0.03	4.00±0.03	5.04±0.07	5.45±0.04	5.11±0.04	4.09±0.03
C18:1	17.11±0.12	15.12±0.22	15.96±0.23	17.42±0.13	15.98±0.12	17.52±0.13	20.36±0.30	16.76±0.12	18.81±0.14	17.96±0.57
C18:2n-6	1.11±0.01	1.97±0.03	1.86±0.03	1.18±0.01	1.63±0.01	2.89±0.02	1.51±0.02	1.41±0.01	2.02±0.01	2.14±0.02
C18:3n-6	0.99±0.01	1.01±0.01	1.01±0.01	0.61±0.00	0.65±0.00	0.77±0.01	0.80±0.01	0.67±0.00	1.23±0.01	0.62±0.00
C18:3n-3	0.41±0.00	0.65±0.01	0.79±0.01	1.03±0.01	0.72±0.01	0.57±0.00	0.46±0.01	0.67±0.00	1.38±0.01	0.49±0.00
C20:1	0.02±0.00	0.02±0.00	0.05±0.00	0.05±0.00	0.10±0.00	0.06±0.00	0.09±0.00	0.05±0.00	0.05±0.00	0.09±0.00
Others	3.39±0.69	3.81±1.39	3.74±0.12	3.44±0.71	4.23±0.71	3.57±0.70	3.80±1.40	5.36±0.68	4.75±0.70	4.28±0.27
SFA*	72.34±0.52	73.81±1.07	71.92±1.47	72.03±0.53	71.38±0.53	70.03±0.51	68.87±1.00	70.02±0.50	67.32±0.49	71.29±0.43
MUFA	21.75±0.16	18.76±0.27	20.67±0.30	21.71±0.16	21.39±0.16	22.18±0.16	24.55±0.36	21.88±0.16	23.30±0.17	21.19±0.60
PUFA	2.51±0.02	3.62±0.05	3.67±0.05	2.81±0.02	3.00±0.02	4.22±0.03	2.78±0.04	2.74±0.02	4.62±0.03	3.24±0.02

*SFA: Saturated fatty acids; MUFA: Monounsaturated fatty acids; PUFA: Poly-unsaturated fatty acids. Values represent means ± SD.

Table 3. Changes in the fatty acid compositions of artisanal butter samples (relative ratio, %)

Compound	Butter Sample									
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
C4:0	3.94±0.06	3.45±0.13	4.33±0.06	1.68±0.01	5.96±0.04	4.27±0.03	3.19±0.05	3.77±0.03	4.72±0.03	1.81±0.01
C6:0	5.00±0.07	4.13±0.15	5.39±0.08	2.80±0.02	4.83±0.04	5.27±0.04	4.20±0.06	3.07±0.02	3.89±0.03	2.41±0.02
C8:0	3.01±0.04	2.39±0.09	3.17±0.05	1.19±0.01	2.67±0.02	3.52±0.03	3.89±0.06	3.07±0.02	2.46±0.02	2.37±0.02
C10:0	4.42±0.07	5.11±0.19	5.05±0.07	2.27±0.02	3.95±0.03	5.20±0.04	6.60±0.10	5.85±0.04	4.48±0.03	3.60±0.03
C11:0	0.87±0.01	0.65±0.02	0.63±0.01	0.23±0.00	0.60±0.00	0.54±0.00	0.77±0.01	0.73±0.00	0.59±0.00	0.20±0.00
C12:0	4.97±0.07	4.76±0.17	5.67±0.08	3.89±0.03	4.16±0.03	4.94±0.04	2.89±0.04	6.05±0.04	4.53±0.03	7.08±0.05
C14:0	14.76±0.22	13.84±0.50	15.48±0.23	8.78±0.06	8.29±0.06	14.34±0.10	16.55±0.24	12.42±0.09	15.34±0.11	10.91±0.08
C14:1n-5	4.15±0.06	3.18±0.12	3.02±0.04	1.95±0.01	1.88±0.01	1.57±0.01	1.95±0.03	1.12±0.01	0.98±0.01	0.96±0.01
C15:0	1.05±0.02	0.85±0.03	1.10±0.02	0.34±0.00	0.66±0.00	0.42±0.00	0.99±0.01	0.73±0.00	0.46±0.00	0.81±0.01
C16:0	27.61±0.40	29.07±0.73	28.37±0.51	39.66±0.29	22.39±0.17	23.62±0.17	27.20±0.40	23.40±0.17	23.77±0.17	34.65±0.45
C16:1n-7	0.41±0.01	0.42±0.01	1.44±0.02	1.28±0.01	1.58±0.01	2.57±0.02	1.08±0.02	1.03±0.01	0.68±0.00	0.40±0.00
C17:0	0.24±0.00	0.46±0.02	0.59±0.01	0.28±0.00	0.20±0.00	0.45±0.00	0.33±0.00	0.14±0.00	0.63±0.00	0.20±0.00
C18:0	5.37±0.08	7.44±0.27	3.63±0.05	3.20±0.02	6.87±0.05	4.10±0.03	3.52±0.05	3.47±0.02	3.34±0.02	3.80±0.03
C18:1	16.85±0.25	15.04±0.55	15.85±0.42	23.21±0.17	25.71±0.19	21.32±0.15	17.54±0.26	26.51±0.19	26.16±0.19	24.04±0.17
C18:2n-6	1.09±0.02	1.96±0.07	1.56±0.02	3.24±0.02	2.41±0.02	1.98±0.01	1.92±0.03	2.29±0.02	2.36±0.02	2.31±0.02
C18:3n-6	0.98±0.01	1.01±0.04	0.46±0.01	1.25±0.01	1.18±0.01	0.89±0.01	1.04±0.02	1.52±0.01	1.18±0.01	0.73±0.00
C18:3n-3	0.41±0.01	0.65±0.02	0.62±0.01	0.98±0.01	1.14±0.01	1.05±0.01	0.97±0.01	1.05±0.01	1.11±0.01	0.76±0.01
C20:1	0.02±.00	0.02±0.00	0.02±0.00	0.13±0.00	0.09±0.00	0.16±0.00	0.06±0.00	0.18±0.00	0.09±0.00	0.02±0.00
Others	4.88±1.39	5.59±1.65	3.61±0.17	3.66±0.71	5.45±0.70	3.81±0.70	5.30±1.38	3.60±0.69	3.24±0.71	2.96±0.00
SFA*	71.22±1.04	72.14±2.30	73.42±1.16	64.31±0.47	60.57±0.45	66.67±0.48	70.13±1.02	62.70±0.45	64.19±0.47	67.83±0.69
MUFA	21.42±0.31	18.67±0.68	20.33±0.49	26.56±0.19	29.26±0.22	25.61±0.19	20.63±0.30	28.84±0.21	27.91±0.20	25.42±0.18
PUFA	2.47±0.04	3.61±0.13	2.63±0.04	5.47±0.04	4.73±0.03	3.91±0.03	3.94±0.06	4.86±0.03	4.66±0.03	3.79±0.03

*SFA: Saturated fatty acids; MUFA: Monounsaturated fatty acids; PUFA: Poly-unsaturated fatty acids. Values represent means ± SD.

Table 4. Comparison of the fatty acid relative ratios (%) in artisanal and commercial butter samples

Fatty Acid	Commercial Butter	Artisanal Butter
C4:0	3.95±0.68[A*]	3.71±1.29[A]
C6:0	5.06±0.70[A]	4.10±1.06[B]
C8:0	3.34±0.59[A]	2.77±0.75[A]
C10:0	5.59±0.93[A]	4.65±1.21[A]
C11:0	0.81±0.37[A]	0.58±0.22[A]
C12:0	5.25±0.39[A]	4.89±1.18[A]
C14:0	14.23±0.80[A]	13.07±2.88[A]
C14:1n-5	3.48±0.57[A]	2.08±1.06[B]
C15:0	0.68±0.30[A]	0.74±0.27[A]
C16:0	26.12±2.22[A]	27.97±5.50[A]
C16:1n-7	0.90±0.50[A]	1.09±0.68[A]
C17:0	0.79±0.98[A]	0.35±0.17[A]
C18:0	5.09±1.00[A]	4.47±1.54[A]
C18:1	17.30±1.52[A]	21.22±4.52[B]
C18:2n-6	1.77±0.53[A]	2.11±0.57[A]
C18:3n-6	0.84±0.21[A]	1.02±0.29[A]
C18:3n-3	0.72±0.29[A]	0.87±0.25[A]
C20:1	0.06±0.03[A]	0.08±0.06[A]
Others	4.04±0.63[A]	4.21±0.99[A]
SFA	70.90±1.88[A]	67.32±4.35[B]
MUFA	21.74±1.53[A]	24.47±3.88[B]
PUFA	3.32±0.70[A]	4.01±0.96[A]

*[A-B]: Different letters given for C (commercial) and A (artisanal) in each fatty acid represent the significant differences of the mean values ($p<0.05$).

According to Table 4, minor differences were observed in the fatty acid compositions between commercial and artisanal butters. The total SFA content was 70.90% for commercial butters and 67.32% for artisanal butters. However, the percentage of oleic acid (C18:1) was significantly higher in artisanal butters compared to commercial butters ($p<0.01$). Conversely, caproic acid and myristoleic acid contents were significantly higher in commercial butters than in artisanal butters. The difference in mean SFA values between commercial (70.90%) and artisanal (67.32%) butters was statistically significant ($p<0.05$). There was a significant difference in the monounsaturated fatty acid (MUFA) contents between commercial and artisanal butter samples, with artisanal butters being more advantageous from a nutritional standpoint. However, no statistically significant difference was found in the PUFA contents between commercial (3.32%) and artisanal (4.01%) butter samples ($p>0.05$). Similarly, Keskin Çavdar [33] reported average SFA, MUFA, and PUFA contents of commercial butters as 68.30%, 27.90%, and 2.98%, respectively. In a study by Draman [38], MUFA contents of butter samples (n=5) ranged from 58.22% to 66.76%, while MUFA and PUFA contents varied between 28.48%-37.12% and 4.25%-4.57%, respectively. Anwar et al. [38] found SFA contents of commercial butter samples from ten different brands between 63.7% and 68.8%. The PUFA C18:2 and C18:3 contents were reported to be between 0.50 and 2.00%, and 0.20 and 1.40%, respectively, which aligns with our results. Seçkin et al. [35] determined the fatty acid composition of various Turkish dairy products, including butter (n=10), where the most abundant saturated fatty acids were palmitic, stearic, and myristic acids. The average SFA, MUFA, and PUFA contents of butter were reported as 71.25, 27.70, and 0.38% of fatty acids, respectively. In the present study, variations found in fatty acid composition of the butter samples, could be attributed to a variety of factors. The absence of a standardized production method for artisanal butters, variations in production process conditions, diverse feeding methods of dairy animals, and discrepancies in storage and packaging conditions of the final products might be potential reasons for these differences [41]. In summary, while minor differences were noted in the fatty acid compositions of commercial and artisanal butters, significant distinctions emerged in their saturated and monounsaturated fatty acid profiles. Artisanal butters exhibited higher proportions of oleic acid and lower levels of caproic and myristoleic acids compared to their commercial counterparts. These findings emphasize the potential nutritional advantages of artisanal butter, particularly in terms of monounsaturated fatty acid content. However, no significant variance was observed in polyunsaturated fatty acid levels between the two types of butter. These results corroborate previous studies and provide valuable insights into the compositional variations of butter samples in the market.

CLA Contents of Butter Samples

Figure 1 illustrates the CLA contents of both commercial and artisanal butter samples. The average total CLA content was notably higher in artisanal samples (6.89 mg/g fat) compared to commercial ones (4.11 mg/g fat), with a significant difference observed ($p<0.05$).

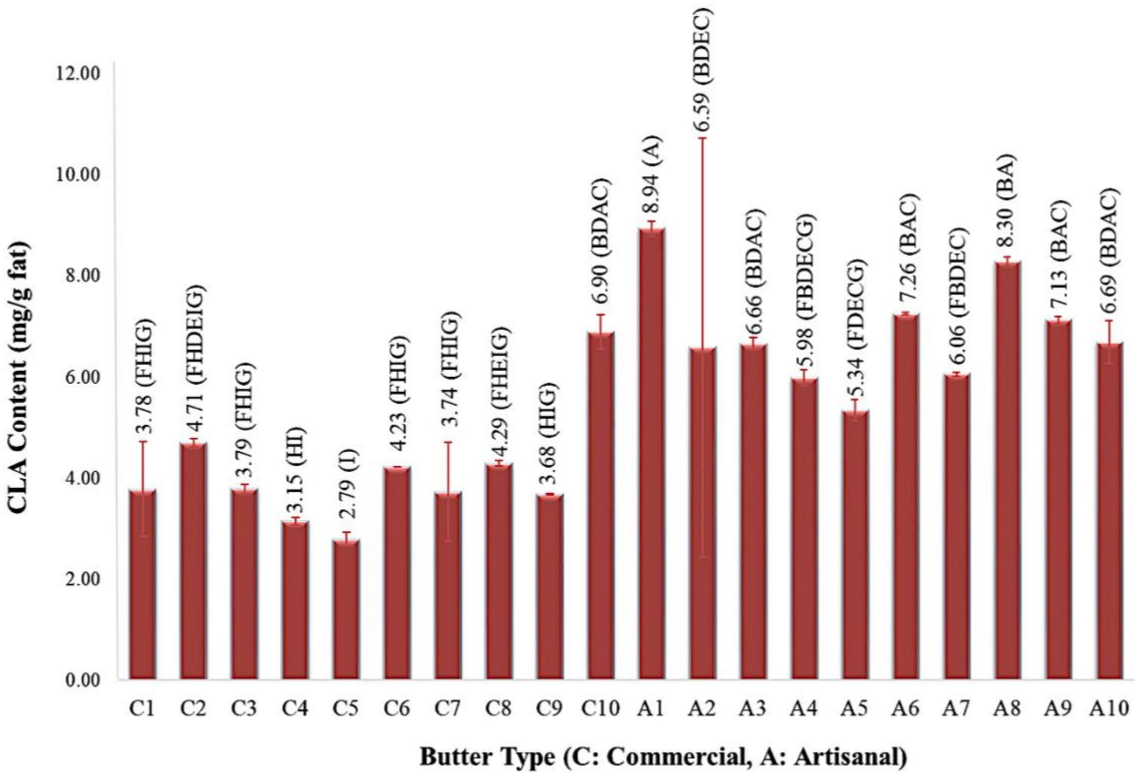

Figure 1. Conjugated linoleic acid (CLA) content (mg/g fat) contents of commercial and artisanal butter samples (**A-I: Different letters in the same column represent the significant differences of the mean values ($p<0.05$)).

In line with our results, Shantha et al. [42] studied the effect of storage and processing on CLA content in salted and unsalted butters, revealing CLA contents ranging from 6.39 to 8.11 mg/g fat. Similarly, Draman [40] reported CLA levels in butter samples averaging between 0.72% and 0.86% of fatty acids. In a study by Okur and Seydim [34], the total CLA content of butter was reported as 0.94 mg/g fat. Seçkin et al. [35] observed CLA contents ranging from 2.85 to 4.67 mg/g fat in butters. Méndez-Cid et al. [36] found CLA content in butters to be between 0.65% and 0.83% of total methyl esters, noting that increasing storage temperature generally led to higher CLA content and that elevated temperatures along with salt addition increased oxidative and lipolytic changes in butters. Furthermore, Ledoux et al. [3] analyzed the fatty acid composition, particularly CLA isomers, of butters collected from France throughout different seasons. They reported an average CLA level in butters ranging from 0.45 to 0.80 g CLA/100 g butter, emphasizing regional variations in CLA content. Collectively, these studies underscore the variability in CLA content across different butter samples and highlight the multifaceted influences of storage conditions, processing methods, and regional factors on CLA levels.

In milk and milk products, a myriad of factors may contribute to variations in CLA content, including the inherent properties of raw materials influenced by animal feed composition and seasonal fluctuations, as well as process-related variables such as oxidative reactions, processing methods, and storage conditions [17]. Oxidative reactions play a significant role in CLA concentration, as they accelerate the formation of free radicals of linoleic acid, subsequently facilitating the transformation of double bonds into conjugated structures, thereby increasing CLA levels. However, oxidative reactions can also lead to structural deteriorations of conjugated double bonds, thereby altering CLA content [42]. The discrepancies observed between commercial and artisanal butters in CLA content could be attributed to these various factors, primarily influenced by differences in the diets of the cows producing the milk.

CONCLUSION

The study aimed to compare artisanal and commercial butters and assess their compliance with regulatory standards. Results indicated that some butter samples from various artisanal sources and industrial markets did not meet the criteria outlined in the Turkish Food Codex, primarily due to their high moisture or low fat contents. Moreover, titratable acidity and ADVs were notably higher in artisanal butters compared to commercial ones, suggesting increased susceptibility to oxidative processes. Analysis of fatty acid compositions revealed variations among the butter samples, with artisanal butter demonstrating a CLA content higher than commercial counterparts. Additionally, moisture content in artisanal butters was significantly elevated compared to commercial varieties. These differences may also stem from non-standardized processing techniques, variable salting practices, disparate animal diets, regional climatic influences, and other pertinent factors.

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CONFLICT of INTEREST

The authors declare no conflict of interest.

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