SAKARYA ÜNİVERSİTESİ
FEN BİLİMLERİ ENSTİTÜSÜ DERGİSİ

Sakarya University Journal of Science
SAUJS

ISSN 1301-4048 e-ISSN 2147-835X Period Bimonthly Founded 1997 Publisher Sakarya University
http://www.saujs.sakarya.edu.tr/

Title: The Fatty Acid Compositions and Textural Properties of Dry Clotted Creams Produced in Different Drying Systems

Authors: Esma ÇAPA, Bedia ŞİMŞEK

Recieved: 2022-06-07 00:00:00

Accepted: 2022-10-26 00:00:00

Article Type: Research Article

Volume: 26
Issue: 6
Month: December
Year: 2022
Pages: 1274-1287

How to cite
Esma ÇAPA, Bedia ŞİMŞEK; (2022), The Fatty Acid Compositions and Textural Properties of Dry Clotted Creams Produced in Different Drying Systems. Sakarya University Journal of Science, 26(6), 1274-1287, DOI: 10.16984/saufenbilder.1127548
Access link
https://dergipark.org.tr/en/pub/saufenbilder/issue/74051/1127548

Sakarya University Journal of Science 26(6), 1274-1287, 2022

The Fatty Acid Compositions and Textural Properties of Dry Clotted Creams Produced in Different Drying Systems

Esma ÇAPA[1], Bedia ŞİMŞEK*[1]

Abstract

In this study, the properties of dry clotted creams produced in different drying systems (vacuum and tray drying systems) and traditional methods have been determined. Physico-chemical, color, textural, microbiological, and sensory analysis as well as fatty acid composition analysis and appearance analysis of dry clotted creams were carried out during storage. During the storage, it was observed that pH and titration acidity values of samples increased. The hardness levels of the clotted cream produced with the tray dryer were found to be higher than the vacuum and traditional methods. The highest ratio of saturated fatty acids was observed in the samples produced with a vacuum dryer. As a result, it was faund that a product similar to traditional dry cream could be produced in industrial tray drying systems. When vacuum drying was applied, more successful results were obtained against oxidation than other drying techniques. However, it was determined that some of its features were also lost. It was also determined that in this system, the dry cream production time may be shortened by at least 50 % compared to the traditional production.

Keywords: Dry clotted cream, tray dryer, vacuum drying

1.INTRODUCTION

A drying process is applied to the food in order to extend the shelf life [1]. The most common drying methods for this product are air drying and shade drying. This process can result in negative effects such as taking a long time, low productivity, unhygienic conditions, and detrimental quality features such as loss of product flavor, color, texture and nutrients [2, 3]. For this reason, industrial drying systems have been developed for the dry food industry. The tray dryer system consists of a motor, fan and tray with an adjustable temperature and air-flow rate [4]. In vacuum drying systems, natural liquids and gases in the food system are removed through partial vacuum pressure, and low temperatures are produced in an oxygen-free environment [5]. It is seen that drying studies are mostly on fruits and vegetables. However, tray dryers can be used for drying dairy products such as Keş [6], Cokelek [7],

* Corresponding author: bediasimsek@sdu.edu.tr
[1] Süleyman Demirel University, Faculty of Engineering
E-mail: capaesma07@gmail.com
ORCID: https://orcid.org/0000-0002-7497-1542, https://orcid.org/0000-0002-9608-9710

İzmir Tulum Cheese [8], etc. It is seen that vacuum dryers are also involved in the production of Lor cheese [9] and dried cheese puffs [10]. When dairy products with high fat content are dried at high temperatures, the fat in the dairy product would leak. Therefore, it has been reported that dairy products with high fat content should be dried at low temperatures [11].

Milk fat is a food that does not last very long even in refrigerator conditions. The freezing process, on the other hand, brings a huge cost. Therefore, drying milk fat is seen as a good alternative to extend the shelf life [12]. Among the dried products with high milk fat content, the most widely known are cream powders and whole milk powders [13]. Among the dried products with high milk fat content, the most commonly known ones are cream powders and whole milk powders. Among the traditional products, dry clotted cream is one of the dried products containing high milk fat [14].

Clotted cream is a slightly acidic dairy product rich in milk fat. It is made from buffalo milk in Western and Central Anatolia, and from cow's milk in the Eastern regions [15, 16]. Dry clotted cream is a traditional product that has different properties from clotted cream. The texture of traditional dry clotted cream is hard and crunchy. It is also defined as a natural wafer in the Central Anatolia region [17]. Dry clotted cream is a homemade product produced by small-scale producers; the milk is frothed from height onto aluminum trays and then cooked slowly. It is kept in a cool environment for about 12 to14 hours and the fat layer is waiting for the fat layer to gather and harden on the surface. Afterwards, the clotted cream layer formed is cut with a knife and folded into half with the lower layers in the middle and then left to dry in a cool environment on a perforated container (sieve). It has been noted that 500 grams of dry clotted cream at a diameter of 60 to 70 cm is produced from approximately 6 liters of milk. The product obtained is used as a breakfast or a snack in the form of a wafer-like structure. In a study conducted on dry clotted cream, it was found that the fat content ranged from 55.5 % to 70 % and the protein content ranged from 14.3 % to 20.3 % [16].

Dry clotted cream production is a process that requires traditional conditions and takes a long time. For this reason, its industrial production is limited. In order to expand the production of this product in the industry, the ability to be produced with different dryers has been evaluated in this study. The study aims are to dry the clotted cream using various food drying systems (tray dryer, vacuum dryer) and to compare the product properties with the traditional drying method.

2.MATERIALS AND METHOD

In this study on dry clotted cream production, raw cow's milk was provided from the Isparta Unsut facility in Turkey and cow milk cream (60 %) was used for fat standardization.

Dry clotted creams were produced using a Mikrotest MSD2.50 D8 (Turkey) tray dryer (at 25 ℃ and an air velocity of 1.3 m/s), and a Korean- branded Wiseven Fuzzy Control System vacuum (under an 0.8 MPa vacuum at 25℃).

2.1.Dry Clotted Cream Production and Experimental Design

In order to standardize the thickness of the clotted cream, the raw milk fat was standardized at 60 % by adding cream. The first heat treatment was applied to raw milk at 95±2℃ for 20 minutes. Pasteurized milk, with a thickness of 12±3 mm, was transferred to the trays from a height of about one meter to foam it (to form a porous structure). The amount of height (approximately 1m) was determined by considering traditional production techniques. The milk in the trays has been left to cool to approximately 42±2 ℃. Then, a secondary heat

treatment was applied at 72±2 ℃. The clotted cream was then left to cool at +4℃ for about 12 hours to form a layer. The finally formed product layer was cut and placed on the perforated grids and separated from the milk at the bottom [18]. The resulting product was divided into three parts. The clotted creams were dried using a traditional drying method (natural drying with air at a room temperature of 25 °C) for the control group (A), with the tray drying system for group B, and the vacuum drying system for group C. The drying process was terminated when at least 75 % dry matter had been produced. The samples were dried at 25 °C for 46±2 hours, in the traditional drying method, 14±2 hours in tray drying system and 24 hours in the vacuum drying system. The products obtained were vacuum packed and stored at +4 ℃ for 20 days.

2.2. Physicochemical Analysis

The thickness of the dry clotted cream samples was measured using digital calipers to a tolerance of 0.001 mm (Mitutoyo, Tokyo, Japan) [19]. Dry matter ratios (%) of clotted cream and dry clotted cream samples were determined using the gravimetric method. The fat (%) and total nitrogen were analyzed by the Gerber method [20] and micro-Kjeldahl method, respectively. The protein ratio was determined by multiplying the total nitrogen by the coefficient of 6.38 [19]. The pH values were determined with the help of a digital pH meter (WTW pH 315-Weilhelm, Germany), and titratable acidity (LA %) was determined with titration [15]. For the determination of acidity values, 5 g of filtered pure milk fat was weighed. Then 50 ml of an alcohol-ether mixture (1:1) was added into the weighed milk fat to dissolve it. The acid value was then determined with the use of the formula by titrating with phenolphthalein indicator and 0.1 N NaOH [20].

2.2.1. Peroxide value

The peroxide values of clotted cream and dry clotted cream samples were found by weighing out 2 g fat extract, then, adding 25 ml of chloroform-acetic solution (2: 3) to dissolve the milk fat. Then, 0.5 ml of saturated potassium iodide was added. The samples were kept in the dark for 1 minute, before adding 75 ml of purified water. The value was then calculated with the help of the formula after titrating with 0.002 N sodium thiosulphate and 0.5 ml 1% starch solution indicator [19].

2.2.2. Thiobarbituric acid value

The 2-thiobarbituric acid (TBA) value was determined by a spectrophotometric method with a BOECO S20 (Hamburg, Germany) branded device. A 50 ml amount of 20 % cold trichloroacetic acid solution (TCA) was added to 5 g of each sample and homogenized. After adding 50 ml of cold distilled water, the extract was filtered through Whatman No: 1 filter paper. A 5 ml amount of the extract was poured into a tube and 5 ml of 2-TBA solution was added. An absorbance reading was then performed at wavelength of 532 nm [21].

2.2.3 Free fatty acids and the fatty acid composition

Fatty acid analysis of clotted cream and dry clotted cream samples were quantitatively determined on the 1st and 20th days of storage using Perkin Elmer Auto System XL branded gas chromatography (GC) device and the analysis of fatty acid methyl esters was performed according to the AOAC [22] 996.06 method. The flame ionization detector method used a mobile helium phase at 15 PSI, an injection volume of 1 µL, VARIAN CP sil 88 column (50 mx 0.25 mm) for FAME compounds and a film thickness of 0.2 microns. The sample injection rate (split) was 1/200. The injector and detector temperatures were 240°C. The column temperature was programmed to

be 80°C for 4 minutes, then maintained at 175°C for 25 minutes. The column was later maintained at 215°C for 2 minutes and operated at 240°C for 10 minutes. The total analysis time was approximately 40 minutes. The standard mix of FAMEs (Supelco® 37 Component FAME Mix, Cat. No. 47885 U) was obtained from Sigma-Aldrich (St. Louis, MO, ABD).

2.3. Textural Analysis

Dry clotted cream samples were kept at +4°C for at least 24 hours and measured by a TA XT 2i (Stable Micro Systems, UK) branded texture analyzer with the help of a ball-type probe P/ 0.75S number ¾ over 15 minutes [20]. The measurements were immersed in 3 different parts of the product at a speed of 1 mm/s to a depth of 10 mm and performed under a force of 1 N [15, 23].

2.4. Color Analysis

Color values (L*, a* and b*) of the samples were determined using a Chroma Meter CR 400. An AC Adapter 5V AC-A17 (Minolta Co. Ltd, Osaka, Japan) branded automatic color determination device was used to determine the L* value range from bright to dark (0 black, 100 white), the green/red a* value (-60 green, 60 red) and blue/yellow b* value (-60 blue, 60 yellow) [23].

2.5. Appearance Analysis

The surface photos of the dry clotted cream samples were obtained using a digital camera (Nikon D7100 DSLR, Japan), and then the images were analyzed with the help of a Windows 8.1 PC containing an Intel I5 CPU, using the OpenCV image processing library and the C ++ language. The program examined the contrast between the two phases in the image, the pores, and the surface. The color images were first converted to a grayscale where the pixel values were converted to units of length with the help of bars of known length. Porosity was expressed as the ratio of the area of pores in the cross section examined in the analysis of the total area [24].

2.6. Sensory Analysis

Sensory analysis of dry clotted cream samples were conducted according to a scoring method by 7 educated panelists (5 women and 2 men) aged 20-50 years on the 1st, 10th, and 20th days of storage. Two different methods, the Descriptive Analysis Method and the Hedonic Test, were used in the sensory analyses of the samples. Whereas the hedonic scale of 1 to 9 points was used in the sensory evaluation panel, the dry clotted cream samples were also evaluated in terms of color, appearance, texture, odor and general acceptability. Examples representing very good and very bad in terms of sensory characteristics were introduced to the panelists and necessary training was given on this subject. For the evaluation of the original samples, the panelists were asked to use these samples as references. The methods given by Lawless and Heymann, [25] were used in the application of sensory analysis.

2.7. Microbiological Analysis

Yeast-mold counts in cream and dried cream samples were counted on Potato Dextrose Agar (PDA) and E.coli, and coliform microorganisms were counted on Eosin Methylene Blue (EMB) agar media [26].

2.8. Statistical Analysis

The statistical evaluation of the study was performed by using the SPSS 17.0 program and by determining the significance of the differences between groups with the help of the Duncan multiple comparison test. The study was carried out with three replications. In this study, Principal Component Analysis method was applied to provide a visual representation of the similarity or distance model between a

set of objects and to reduce the size of the data. Analyzes were performed at 95% confidence intervals. Sensory analysis data (color, appearance, texture, odor) was evaluated in all samples (A, B, C, A10, B10, C10, A20, B20 and C20) using the principal component analysis (PCA) Xlstat trial version-2020.

3. RESULTS AND DISCUSSION

3.1. Clotted Cream Analysis Results

The dry matter (%), fat (%) and protein (%) percentages of the clotted cream used in the production of dry clotted cream were 65.89 Re±2.61 %, 64.66±0.47 % and 2.22±0.04 %, respectively. These results showed similarity to the research findings of Tosun [15]. The titration acidity of the clotted cream samples was 0.22±0.03 % and pH 6.23±0.04. The research results of Albay and Şimşek [27] showed similarity in terms of titration acidity and pH values. The peroxide, acid degree and TBA values of the samples were 0.44±0.04 meq O_2/ kg fat, 1.25±0.03 KOH/g fat and 04±0.008 malonaldehyde/kg fat respectively. In the study by Kocaturk et al. [28], the total free fatty acidity values are 0.40 to 0.51 meq O2/ 100 g oil, ranging from 0.40 to 0.51 meq O2/ 100 g oil, and Kahyaoglu [29] reported that the TBA value of butter varied between 0.01 and 0.03 mg malonaldehyde/kg fat at the beginning of storage. It was observed that the data of clotted cream in this study was close to the results of Tosun [15], Albay and Şimşek [24], Kocaturk et al. [28] and Kahyaoglu [29]. The L*, a*, and b* color values of samples were 88.87±1.26, -2.99±0.16 and 13.40±0.26, respectively. L* a* and b* color values in the study given by Albay and Şimşek [27] were similar to the values in this study.

3.2. Results of Dry Clotted Cream Analysis

3.2.1. Results of physicochemical analysis

In the thickness measurements of the dry clotted cream, B was reported to be the thickest sample (15.04±0.68 mm), while C was reported to be the thinnest (10.60±0.70 mm). Sample A was detected with a thickness of 12.23±0.13 mm. The statistical difference between the samples was found to be significant ($p<0.05$). Since the vacuum effect reduces fat globules and surface tension, it was thought that a thin structure might have been formed in the C sample.

The data, including the chemical properties of the dry clotted cream samples produced in different drying systems, have been presented in Table 1. In this study, the dry matter values of the dry clotted cream samples varied from 78.15±0.25 % to 79.59±0.88 % and similar to the dry matter values of 70.8 % to 91.3 % determined in the dry clotted cream study by Cakmakcı and Hayaloglu [16]. The fat content of the dry clotted cream samples was found to be adequate according to the Turkish Food Codex Custard and Cream Communique [30]. When the dry clotted cream samples were examined in terms of the amount of protein, it was observed that samples A and C were statistically close to each other, and sample B had a higher amount. Depending on the composition of the milk used in the raw material, the protein values found in this study were lower than those reported by Cakmakci and Hayaloglu [16] for dry clotted cream. At the beginning of storage, the dry clotted cream sample B had the lowest pH (6.03±0.04), while at the end of storage, a decrease was observed in all three samples and the highest pH was observed in the dry clotted cream sample C (5.34±0.05). It was observed that titratable acidity similarly increased in dry clotted cream samples due to a pH decrease. It was noted that the dry clotted cream B sample had the lowest titratable acidity while the dry clotted cream

samples had the highest titratable acidity. This change between the groups was attributed to the longer production process of the tray drying system compared to the vacuum drying system.

storage, the highest value at the end of storage was determined to be 1.41 ± 0.34 meq O2/ kg fat for the sample A. The peroxide value, which is one of the oxidation indicators related to fat

Table 1 Physicochemical properties of Dry Clotted Cream

Samples (**)	Dry Matter (%)	Fat (%)	Protein (%)	Titratable Acidity (%)	pH	Peroxide Value (meq O_2/kg fat)	Acid Value (mg KOH/g fat)	TBA Value (mg malonaldehyde /kg fat)
1st day (*)(M±SD)**								
A	78.31±0.49	69.33±1.69	2.42±0.08^{b}	0.37±0.04^{b}	5.91±0.05^{abc}	0.44±0.19^{bc}	1.34±0.09^{bc}	0.08±0.02^{bc}
B	79.57±0.76	70.33±1.24	2.58±0.09^{a}	0.35±0.03^{b}	6.03±0.04^{a}	0.42±0.31^{bc}	1.17±0.13^{c}	0.07±0.03^{bc}
C	78.15±0.25	71.33±0.94	2.38±0.05^{b}	0.37±0.05^{b}	5.98±0.02^{ab}	0.49±0.28^{bc}	1.14±0.07^{c}	0.09±0.05^{bc}
10th day (*)								
A	78.10±0.69	70.00±2.16	2.43±0.01^{b}	0.52±0.11^{ab}	5.79±0.01^{cd}	0.74±0.32^{abc}	1.83±0.06^{ab}	0.25±0.01^{a}
B	79.58±0.80	70.33±1.24	2.60±0.02^{a}	0.47±0.07^{ab}	5.93±0.04^{abc}	0.92±0.22^{ab}	1.21±0.02^{c}	0.11±0.04^{abc}
C	77.91±2.92	71.33±0.94	2.42±0.01^{b}	0.47±0.10^{ab}	5.79±0.17^{bcd}	0.59±0.37^{bc}	1.38±0.03^{bc}	0.14±0.02^{ab}
20th day (*)								
A	78.27±0.97	69.33±1.33	2.43±0.04^{b}	0.57±0.09^{ab}	5.69±0.05^{d}	1.41±0.34^{a}	2.16±0.15^{a}	0.28±0.02^{a}
B	79.59±0.88	70.33±1.24	2.63±0.05^{a}	0.50±0.12^{ab}	5.77±0.11^{cd}	1.31±0.39^{a}	1.66±0.26^{b}	0.16±0.01^{ab}
C	77.88±0.99	71.33±0.94	2.46±0.02^{b}	0.62±0.16^{a}	5.34±0.05^{e}	1.24±0.40^{a}	1.90±0.17^{ab}	0.15±0.05^{ab}

* a, b, c: Lower case letters indicate statistically significant differences ($p < 0.05$).
** A: Traditionally dried Clotted Cream; B: Tray dried Clotted Cream; C: Vacuum dried, M: Mean, SD:Standart deviation

Acid values of dry clotted cream samples produced by different drying techniques have increased in particular because of lipolysis during storage, and the highest acid value at the end of storage was determined in the dry clotted cream A sample (2.16±0.15 mg KOH / g fat). It has been reported that the acid value can reach 1.8 mg KOH / g and there is a distinctly inferior aroma [31, 32]. It was thought that the traditional drying method, which takes longer to dry samples than other methods causes faster lipolysis. Cakmakci and Hayaloglu [16] reported that the acid value of the dry clotted cream samples was 1.69 ± 0.61 mg/ KOH g fat. It has been seen that the acid value results of the dry clotted cream samples on the first day were similar to these data.

While the peroxide values of the dry clotted cream samples were similar at the beginning of

in dairy products was limited to 2 meq O2/kg fat by Downey [33]. Pearson [34] reported that the peroxide value in rancid butter was 6.3 meq O2/kg fat of fat. It was observed that the dry clotted cream samples were below this limit. The peroxide values of the samples at the end of the storage, seen in the samples using the vacuum drying system were lower than the other samples. Zhou et al [35] reported that in a study comparing different drying methods, the lowest peroxide value was obtained with vacuum drying. The TBA values of the dry clotted cream samples produced in different drying systems varied between 0.07±0.03 and 0.28±0.02 mg malonaldehyde/kg fat during the storage period, and the highest change occurred in the dry clotted cream samples produced by the conventional method. TBA results in other samples have been found to be close to each other.

3.2.2. Results of free fatty acids

The free fatty acid results of the dry clotted cream samples produced by traditional, tray and vacuum drying systems are presented in Table 2. It is observed that there are difference in the fatty acid profile depending on the parameters during production, drying times and changes during storage. In all dried cream samples, palmitic, oleic and myristic acid were the dominant fatty acids while c10-heptadecanoic acid, tridecanoic acid and c-10-pentadecanoic acids were detected at lower levels. In the study conducted by the examination of the saturated fatty acid amounts in dry clotted cream samples showed that the sum of short-chain fatty acids in the dry clotted cream C samples decreased during the storage period and increased in the other sample groups. It was statistically determined that this difference was influenced by caprylic acid. In addition, the amount of caprylic acid determined in the dry clotted cream C sample was higher since the removal of some fatty acids through drying systems (tray and vacuum drying systems) takes a shorter time compared to the traditional system. In the study conducted by Tosun [15], the fatty acids contents of clotted cream samples (short, medium and long chain) were determined as 5.23-5.87 %, 5.06 %-5.55 % and 52.44 %-53.92 %, respectively. It was noted that the total amount of unsaturated fatty acids decreased in the dry clotted cream B sample during storage but increased in other groups. Oleic acid, one of the monounsaturated fatty acids, and linoleic acid, one of the polyunsaturated fatty acids, were the cause of statistical difference between the groups. Free fatty acid composition and amount were mostly affected by raw material properties. It was also affected by both drying and storage [36]. Senel [37], it was reported that the decrease in the amount of total fatty acids was related to the catabolic reactions of microorganisms, that is, biochemical changes in the formation of aroma and flavor. It was also reported that volatile free fatty acids decreased with oxidation. During the removal of water in vacuum dryers, oxidation was prevented since there is no air in the environment. Prevention of oxidation was caused significant changes on fatty acids [38].

When evaluated in terms of fatty acids in both methods (vacuum and tray drying), the results obtained with the traditional method were found to be similar.

Table 2 Free Fatty Acid Profile of Dry Clotted Cream Samples (n: 3)

Methyl Ester	**Fatty Acid**	**1st day(*)(M ±SD)(%)**			**20th day(*)(M ±SD)(%)**		
		A(**)	B(**)	C(**)	A(**)	B(**)	C(**)
C4:0	Butyric	3.15±0.30	3.43±0.03	3.58±0.62	3.41±0.03	3.41±0.07	3.60±0.05
C6:0	Caproic	3.23±0.16	3.12±0.11	3.44±0.69	3.20±0.08	3.25±0.01	3.32±0.01
C8:0	Caprylic	2.02±0.19	2.20±0.02	2.35±0.22	2.12±0.04	2.19±0.08	2.31±0.05
C10:0	Capric	4.60±0.20	4.78±0.06	5.33±0.11	4.57±0.10	4.66±0.31	4.85±0.02
C11:0	Undecanoic	0.54±0.06	0.48±0.00	0.54±00	0.46±0.05	0.46±0.02	0.50±0.01
C12:0	Lauric	4.70±0.32	4.93±00	5.48±0.15	4.74±0.04	4.73±0.21	4.92±0.05
C13:0	Tridecanoic	0.14±0.02	0.12±00	0.12±0.01	0.12±00	0.13±0.01	0.12±00
C14:0	Myristic	12.82±0.86	13.41±0.02	15.03±1.19	13.22±0.12	12.85±0.56	13.32±0.02
C14:1	Myristoleic	1.48±0.41	1.13±0.01	1.57±0.43	1.83±0.01	1.08±0.05	1.12±0.01
	Saturated[1]	**64.95**	**67.93**	**73.67**	**67.54**	**66.13**	**67.81**
C15:0	Pentadecanoic	1.13±0.01	1.13±0.01	1.11±0.03	1.12±0.02	1.07±0.03	1.11±0.01
C15:1	c-10-pentadecanoic	0.42±0.05	0.34±0.02	0.34±0.02	0.37±0.01	0.35±0.005	0.37±0.01
C16:0	Palmitic	25.18±1.94	26.45±0.39	29.41±3.96	26.56±0.13	25.62±0.85	26.03±0.16
C16:1	Palmitoleic	1.20±0.07	1.26±0.02	1.22±0.02	1.22±0.03	1.26±0.01	1.25±0.01
C17:0	Heptadecanoic	0.57±0.02	0.54±0.05	0.55±0.04	0.58±0.01	0.55±0.00	0.57±0.00
C17:1	c-10 heptadecanoic	0.15±0.03	0.18±0.00	0.14±0.05	0.19±0.05	0.16±0.02	0.18±0.05
C18:0	Stearic	6.84±0.38	7.31±0.02	6.71±0.23	7.42±0.09	7.17±0.11	7.13±0.20
C18:1n9t	Elaidic	1.82±0.58	1.24±0.01	1.08±0.03	1.30±0.02	1.23±0.03	1.24±0.07

Table 2 Free Fatty Acid Profile of Dry Clotted Cream Samples (n: 3) (Continue)

Methyl Ester	Fatty Acid	1st day(*)(M ±SD)(%)			20th day(*)(M ±SD)(%)		
		A(**)	B(**)	C(**)	A(**)	B(**)	C(**)
C18:1n9c	Oleic	15.21±0.37	15.96±0.21	15.55±0.80	16.19±0.08	15.55±0.11	15.74±0.40
C18:2n6c	Linoleic	1.81±0.04	1.83±0.05	1.67±0.02	1.77±0.00	1.68±0.06	1.73±0.02
C18:3n39	Linolenic	0.47±0.10	0.58±0.00	0.54±0.04	0.60±0.01	0.60±0.02	0.58±0.00
	Monounsaturated[2]	**20.29**	**20.12**	**19.92**	**21.11**	**19.65**	**19.92**
	Polyunsaturated[3]	**2.28**	**2.42**	**2.22**	**2.37**	**2.42**	**2.31**
	Unsaturated[4]	**22.57**	**22.54**	**22.14**	**23.49**	**21.93**	**22.23**

* a, b, c: Lower case letters indicate that the difference is statistically significant ($p < 0.05$)
** A: Traditionally dried Clotted Cream; B: Tray dried Clotted Cream; C: Vacuum dried Clotted Cream; M: Mean, SD:Standart deviation
1: Saturated: Total of Saturated Fatty Acids; C4: 0 + C6: 0 + C8: 0 + C10: 0 + C11: 0 + C12: 0 + C13: 0 + C14: 0 + C15: 0 + C16: 0 + C17: 0 + C18: 0
2: Monounsaturated: Total of Monounsaturated Fatty Acids; C14: 1 + C15: 1 + C16: 1 + C17: 1 + C18: 1
3: Polyunsaturated: Total of Polyunsaturated Fatty Acids; C18: 2 + C18: 3
4: Unsaturated: Total of Unsaturated Fatty Acids; C10: 1 + C14: 1 + C16: 1 + C17: 1 + C18: 1 + C18

3.3. Results of Texture Analysis

The measurement values of the hardness, springiness, cohesiveness, gumminess, chewiness and resilience properties of the dry clotted cream samples examined in this study are presented in Table 3. Although there are very few studies investigating the textural properties of dry clotted cream, it was found in this study that the sample produced by drying in a tray dryer (B) reached the highest hardness value in the end of storage. The fact that the products dried in the vacuum system were not as hard as the products in the tray drying system may have been caused by the loss of bubbles on the dry clotted cream surface during the vacuum process and a decrease in the structural strength. While the highest value was found in sample A (0.96), springiness values were decreased in all samples during storage. The cohesiveness values of the dry clotted cream samples produced in different drying systems were determined to be between 0.17 and 0.45. The gumminess value in dry clotted cream samples were found to be between 98.25 N and 510.13 N. It was concluded that the dry clotted cream samples showed a change in parallel with the hardness values as it increased linearly. The chewiness values of the dry clotted cream samples were determined to be between 57.57 and 800.09, and group B showed the highest chewable property in the end of storage comparison to the other groups. While the C group (0.39 N) showed the highest level of resilience, it was observed that the dry clotted cream samples of the A and B groups were similar. These values were found to be close to those reported by Yıldırım et al. [39].

Table 3 Textural characteristics of Dry Clotted Cream Samples (n: 3)

Samples (**)	Hardness (N)	Springiness	Cohesiveness	Gumminess(N)	Chewiness	Resilience (N)
Day 1 (*) (M±SD)						
A	856.59±56.02^{b}	0.91±0.05^{ab}	0.25±0.08	211.25±55.17^{cdf}	198.76±62.60^{b}	0.09±0.01^{b}
B	973.02±95.24^{b}	0.54±0.06^{b}	0.38±0.01	327.79±32.02^{b}	182.42±39.28^{b}	0.14±0.01^{b}
C	421.34±120.13^{c}	0.57±0.13^{b}	0.34±0.05	134.41±16.51^{ef}	74.99±9.16^{b}	0.21±0.06^{ab}
Day 10 (*)						
A	845.74±55.32^{b}	0.83±0.08^{b}	0.28±0.01	245.20±32.28^{bcd}	208.20±46.39^{b}	0.11±0.02^{b}

Table 3 Textural characteristics of Dry Clotted Cream Samples (n: 3) (Continue)

Samples (**)	Hardness (N)	Springiness	Cohesiveness	Gumminess(N)	Chewiness	Resilience (N)
B	1121.91±195.01^{ab}	0.68±0.05^{b}	0.25±0.01	284.8±49.86^{bc}	480.07±320.02^{a}	0.10±0.01^{b}
C	421.84±131.51^{c}	0.68±0.09^{b}	0.29±0.01	103.97±5.72^{f}	72.19±14.62^{b}	0.17±0.06^{ab}
Day 20 (*)						
A	905.71±186.11^{b}	0.71±0.19^{b}	0.28±0.02	249.86±32.69^{bcd}	169.19±25.13^{b}	0.12±0.01^{b}
B	1342.50±237.69^{a}	0.65±0.05^{b}	0.31±0.01	422.15±87.98^{a}	284.55±80.32^{ab}	0.14±0.01^{b}
C	522.30±131.51^{c}	0.69±0.16^{b}	0.34±0.11	155.50±16.11^{def}	103.74±14.36^{b}	0.27±0.12^{a}

* a, b, c: Lower case letters indicate statistically significant differences (p <0.05).
** A: Traditionally dried Clotted Cream; B: Tray dried Clotted Cream; C: Vacuum dried Clotted Cream, M: Mean, SD:Standart deviation

3.4. Results of Color Analysis

L*, a* and b* color values of dry cream samples produced in three different drying systems are given in the Table 4. When dry clotted cream samples were evaluated in terms of the b* color value, statistically the group B sample was observed to decrease, and the group C dry clotted cream sample increased. Yıldırım et al. [39] determined the average b* values of the dry clotted cream sample to be 17.44. The results of the study were determined to be close to this value.

Table 4 Color properties of Dry Clotted Cream Samples

Samples (**)	L*	a*	b*
1st day	M±SD	M±SD	M±SD
A	85.25±1.33	-3.44±0.21^{abc}	16.71±0.77^{ab}
B	85.88±0.90	-4.11±0.19^{d}	18.39±1.33^{a}
C	84.33±1.60	-3.61±0.11^{ab}	15.18±1.14^{b}
10th day			
A	86.16±1.20	-3.19±0.22^{a}	17.09±1.10^{ab}
B	85.69±1.67	-3.92±0.35^{cd}	18.22±1.46^{ab}
C	86.56±1.38	-3.32±0.22^{ab}	16.00±1.15^{ab}
20th day			
A	85.46±1.77	-3.35±0.17^{abc}	16.14±1.70^{ab}
B	84.99±1.09	-3.89±0.14^{cd}	18.11±1.08^{ab}
C	84.94±2.06	-3.76±0.40^{bcd}	16.44±1.50^{ab}

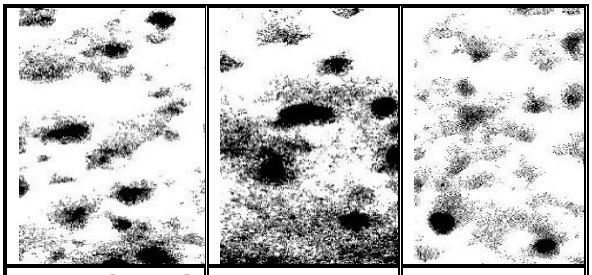
* a, b, c: Lower case letters indicate statistically significant differences (p <0.05).
** A: Traditionally dried Clotted Cream; B: Tray dried Clotted Cream; C: Vacuum dried; M:Mean; SD:Standard deviati

Although using the vacuum drying system took longer than the tray drying system, the b* value was found to be lower in these samples, so the vacuum effect caused the samples to be less yellow in color. However, no statistical difference was observed between the b* values of the samples on the 10th and 20th days of storage. Silva and Moriera [40] stated that the vacuum drying method reduced the color deterioration in the samples due to the absence of oxygen during the process.

3.5. Results of Appearance Analysis

In our study, surface imaging process was performed on dry clotted cream samples produced in different drying systems and is presented in Figure 1. The appearance analysis of the dry clotted cream samples was only measured on day 1 of storage. The textural analysis showed that porosity was formed when milk was poured to cause frothing. Detailed information about this feature has been obtained through the appearance analysis. It was determined that the group B dry clotted cream sample had the highest porosity rate of 25.36±1.15 %, while the lowest level of porosity was achieved with 12.57±1.55 % in the sample dried in the vacuum dryer. It was found that the porosity decreased due to the effect of the vacuuming. In the study conducted by Atamer et al. [17], the microtextural structure of dry clotted cream samples was examined and it was reported that the protein

layer surrounding the oil bubbles maintained the shape of the adsorption layer during the drying phase and that the fat globules that rose during the cooling phase formed a structure characterized by the penetration of the air bubbles.



A: Traditional Drying System	B: Tray Drying System	C: Vacuum Drying System

Figure 1 Images of Dry Clotted Cream Samples A; Traditional Drying System, B; Tray Drying System, C; Vacuum Drying System

3.6. Principal Component Analysis (PCA)

The sensory analysis results of dry clotted cream samples were analyzed by the principal component analysis (PCA) method. This test, which explained 57.34 % of the total variance, is presented in Figure 2. The first major component explained 38.70 % of the total variance, while the second component explained 18.63 %. The eigenvalue value of the first main component was determined to be 7.35, and for the second component was determined to be 3.54. According to the distance of the first basic component from zero and having the same sign, the order of porous appearance was 0.29, the yellowish color was 0.24, the cuttability was 0.31, the animal malodor was -0.26, the pleasant smell was 0.31, the foreign taste -0.29, the milk taste 0.25, the flavorless taste was -0.31, the sour taste - 0.23, an oxidized taste was -0.27, and a stale taste was -0.28. The order of the second main component was 0.35 for a smooth appearance, 0.41 for an elastic structure, and -0.33 for a crumby structure. In the first 10 days of storage, it was concluded that samples A and B had an elastic, smooth appearance, were porous yellowish, had a cuttable structure and a distinctive pleasant odor. While sample C had a milk odor at the beginning, at the end of the storage period (20th day) together with the other samples A and B, it turned into a stale, sour and oxidized product with a bad odor

.

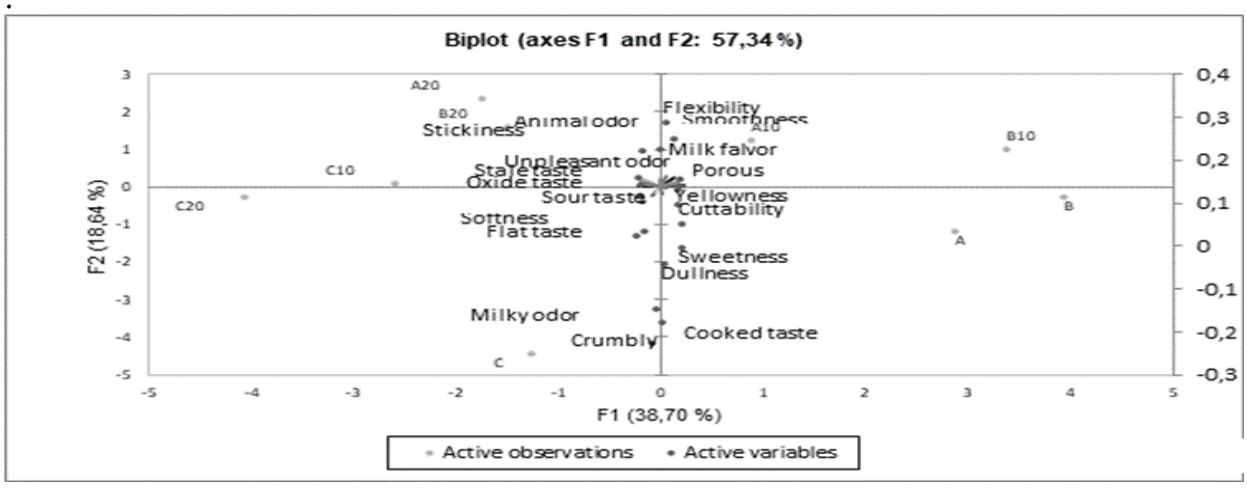


Figure 2 Principal Component Analysis Values of Dry Clotted Cream Samples
A: Traditionally dried Clotted Cream; B: Tray dried Clotted Cream; C: Vacuum dried Clotted Cream, A10,B10,C10: Samples on the 10th day of storage A20,B20,C20: Samples on the 20th day of storage

3.7. Results of Microbiological Analysis

Coliform growth and yeast and mold growth were not observed in the dried cream samples obtained by drying in different drying systems.

4. CONCLUSIONS

In this study, dry clotted creams producibility were evaluated using a traditional method and using a vacuum dryer and tray drying systems. It was observed that the dry clotted cream samples produced in tray drying systems had the lowest pH, titratable acidity, and free fatty acid values. Samples produced in tray drying systems were the most yellow in color, had the hardest and most porous structure. Dry clotted cream samples produced in vacuum drying systems were noted to be samples with the lowest values in terms of peroxide and TBA numbers, which determined the oil oxidation. It was observed that the amounts of saturated, short, and medium chain fatty acid in dry clotted creams produced by vacuum drying system were higher than the other samples. It was observed that the samples produced by traditional drying were the most desirable group in the sensory evaluation in terms of structure, texture, and odor qualities. Based on the results found in this study, it was concluded that the production duration could be shortened by using tray and vacuum drying systems. In addition, it was observed that the tray drying system yielded better results than the traditional drying system. It was seen that the vacuum drying system is not a suitable technique for the production of dry cream in the industrial sense. Although this technique had positive effects on the shelf life of cream, it did not show positive effects on physical and sensory properties. However, in this study, it has been seen that a production similar to conventional production in industrial terms can be carried out in a shorter time by using a tray dryer.

Funding
This study was financially supported by the Süleyman Demirel University Scientific Research Project Coordination Unit through project no FYL-2019-6928.

Conflict of nterest
The authors have declared no conflicts of interest for this article.

Author Contributions
The authors contributed equally to this work.

The Declaration of Ethics Committee Approval
This study does not require ethics committee permission or any special permission.

The Declaration of Research and Publication Ethics
The authors of the paper declare that they comply with the scientific, ethical and quotation rules of SAUJS in all processes of the paper and that they do not make any falsification on the data collected. In addition, they declare that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered, and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

REFERENCES

[1] İ. Doymaz, C. Aktaş "Patlıcan Dilimlerinin Kurutma ve Rehidrasyon Karakteristiklerinin Belirlenmesi" Journal of The Faculty Engineering and Architecture of Gazi Unıversıty, vol. 33 no. 3, pp. 833–841, 2018.

[2] T. Kovacı, E. Dikmen, Ş. A. Şencan "Kurutma Sistemleri , Enerji Tüketimleri ve Ürün Kalitesine Etkileri ve Örnek

Sistem Tasarımı" Teknik Bilimler Dergisi, vol.8, no.2, pp.25–39, 2018.

[3] A. D. Yazıcı, M. Daş "Güneş Enerjisi Destekli Kurutma Sistemi İle Elma Ürününün Kurutulması ve Kurutma Değerlerinin Yapay Sinir Ağı İle Modellenmesi" Intenational Journal of Multidisciplinary Studies and Innovative Technologies, vol. 2, no. 1, pp 8–13, 2018.

[4] E. Ozen, F. Kar "Farklı Teknikler Kullanılarak Domatesin Kurutulması" Fırat Üniversitesi Mühendislik Bilimleri Dergisi, vol. 30, no.1, pp. 47–57, 2018.

[5] M. Ayaz, E. Dikmen, A. Ş. Şahin "Isı Pompalı Vakumlu Kurutma Fırınında Tibbi Bitkilerin Kurutulması ve Kurutma Parametrelerinin Araştırılması" Süleyman Demirel Üniversitesi Teknik Bilimler Dergisi, vol. 6, no.1, pp. 1–11, 2016.

[6] A. Emirmustafaoğlu, H. Coşkun "Kızartmalık Keş Üretim Teknolojisinin Optimizasyonu" Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi, vol. 27, no.3, pp. 357–369, 2017.

[7] G. Ergene, S. Aslan "Chemical and sensory characteristics of dried Çökelek cheeses at different temperatures" Journal of Food Processing and Preservation, vol. 43, no. 6, pp. 1-8, 2019.

[8] G. Kizilalp, İ. Polat, M. Urgu, N. Koca "Evaluation of Izmir Tulum cheese pieces by drying with tray drier at different air flow rates and temperatures". En IDS 2018. 21st International Drying Symposium Proceedings. Editorial Universitat Politècnica de València. 1679-1685, 2018.

[9] E. A. Anli "Possibilities for using microwave-vacuum drying in Lor cheese production" International Dairy Journal, vol. 102, 104618, 2020.

[10] S. Chudy, A. Makowska, M. Piatec, M. Krzywdzińska-Bartkowiak "Application of microwave vacuum drying for snack production: Characteristics of pure cheese puffs" International Journal of Dairy Technology, vol. 72, no.1, pp.82-88, 2019.

[11] I. S. Hwang, K. B. Lee, Y. K. Shin, M. Y. Baik, B. Y. Kim, "Effect of drying and storage on the rheological characteristics of Mozzarella cheese" Food Science and Biotechnology, vol. 24, no. 6, pp. 2041–204, 2015.

[12] S. Danviriyakul, D. J. McClements, W. W. Nawar, P.Chinachoti, Physical stability of spray dried milk fat emulsion as affected by emulsifiers and processing conditions. Journal of Food Science, vol.67 No.6, pp. 2183-2189, 2002.

[13] P. Schuck, Milk Powder: Types and Manufacture. Encyclopedia of Dairy Sciences (2.Edition), Edited by Fuquay, J. W., Fox, P. F. , McSweeney, P. L. H. London, UK: Elsevier Academic Press 2011.

[14] A. B Himmetağaoğlu, Z. Erbay, M. Çam "Süt yağının toza dönüştürülmesi ve krema tozu" Akademik Gıda vol.17, No.1, pp.72-80, 2019.

[15] F. Tosun "Ekzopolisakkarit Üreten Laktik Kültürlerin Tereyağı, Yayık Tereyağı ve Kaymağın Kalite Özellikleri Üzerine Etkisi" Erciyes Üniversitesi Fen Bilimleri Enstitüsü, Doktora Tezi, pp. 194, Kayseri, 2016.

[16] S. Cakmakci, A. Hayaloğlu, "Evaluation of the Chemical , Microbiological and Volatile Aroma Characteristics of Ispir Kaymak , A Traditional Turkish Dairy Product" International Journal of Dairy Technology, vol.64, no.3, pp.444–450, 2011.

[17] M. Atamer "Tereyağı Teknolojisi" Sidaş Medya Ltd. Şti, pp. 169, Ankara, 2016.

[18] Ş. Pamuk "Geleneksel Afyon Kaymağı Üretimi" Atatürk Üniversitesi Veteriner Bilimleri Dergisi, vol.12, no.1, pp. 84–84, 2017.

[19] Anonymous "Ankara İl Kontrol Laboratuvar Müdürlüğü, Ham protein tayini Döküman Kodu: Yem" MT.004/P13, 2003.

[20] AOAC "In Official Methods of Analysis of AOAC International" (Vol. 17). Washington DC:Association of Official Analytical Chemists, 2000.

[21] A. Jha, A. Kumar, P. Jain, A. Kumar Gautam, P. Rasane, "Effect of Modified Atmosphere Packaging On The Shelf Life of Lal Peda" Journal of Food Science and Technology, vol. 52, no. 2, pp.1068-1074, 2015.

[22] AOAC, "AOAC Official Method 996.06", revised 2001. In: (eds) Official methods of analysis (18th edn.). AOAC International,Gaithersburg, MD, 2005

[23] P. Karatepe, B. Patır "Eugenol ve Thymol'ün Pastörize Tereyağının Kimyasal , Mikrobiyolojik ve Duyusal Kalitesi Üzerine Etkisi" Fırat Üniversitesi Sağlık Bilimleri Veteriner Dergisi, vol. 26, no.1, pp. 35–46, 2012.

[24] G. Dos Reis, B. Stroustrup, "A Principled, Complete, and Efficient Representation of C++". Mathematic Computer Science vol.5, pp.335–356, 2011.

[25] H. T. Lawless, H. Heymann "Sensory Evaluation of Food Principles and Practices", 2nd Edition, XXIII, ISBN 978-1-4419-6488-5, 2010.

[26] K. A. Halkman K A, Merck Gıda Mikrobiyolojisi Uygulamaları. Basak Matbaacılık Ltd. Şti, pp. 1-10, Ankara, 2005.

[27] Z. Albay, B. Şimşek "Tarçın ve Tarçın Uçucu Yağı ile Üretilen Kaymakların Bazı Özelliklerinin Belirlenmesi" In Ö. D. Gürcü (Ed.), Young Scholars Union Congress Proceeding and Abstarcts Book, pp. 191–203 Prauge, 2019.

[28] K. Kocaturk, Ö. Gökçe, F. Ergin, A. Küçükçetin, O. Gürsoy, "Geleneksel Yöntemlerle Üretilen ve Manda Kaymağı Olarak Pazarlanan Ürünlerin Bazı Özellikleri ile Konjuge Linoleik Asit İçerikleri" Akademik Gıda, vol.17, No.4, pp.476–484, 2019.

[29] D. T. Kahyaoğlu, "İnek, Koyun ve Keçi Sütlerinden Üretilen Tereyağlarında Depolama Süresince Uçucu Bileşikler, Oksidasyon Stabilitesi ve Diğer Bazı Kalite Kriterlerinin Belirlenmesi", Atatürk Üniversitesi Fen Bilimleri Enstitüsü, Doktora Tezi, pp.191, Erzurum, 2014

[30] Anonymous, "Türk Gıda Kodeksi Yönetmeliği, Krema ve Kaymak Tebliği", Resmi Gazete,27.09.2003, 2003.

[31] M. Atamer, E. Senel, A. A. Hayaloğlu, B. Özer, "Kuru Kaymağın Tekstürel Yapısı", Akademik Gıda, vol.14, no.2, pp.189–195, 2016.

[32] M. Atamer, E. Sezgin, "Tereyağlarında Lipolitik ve Oksidatif Bozulmaların Saptanmasında Yararlanılan Asit ve Peroksit Değerler ile Aroma Arasındaki İlişki" Gıda, vol. 6, pp.329-334, 1984.

[33] W. K. Downey, "Butter Quality", Published by An Foras Taluntais 19 Sadyamount Avenue Dublin4, Dairy Research and Review Series no. 7, pp.142, 1975.

[34] D. Pearson, "The assessment of rancidity of oils on a common cholorfm extract with special reference to TBA values" Journal of the Associatin of Public Analyts, vol.12, pp.73-76, 1974.

[35] X. Zhou, H. E. J. Gao, M. Wang, S. Wang, "Comparative Analyses of Three Dehydration Methods on Drying Characteristics and Oil Quality of In-shell Walnuts" Drying Technology, vol.36, no.1, pp.477-490, 2018.

[36] J. Yongsawatdigul, S. Gunasekaran "Microwave-vacuum drying of cranberries: Part II. Quality evaluation" Journal of Food Processing and Preservation, vol. 20 no.2, pp. 145- 156. 1996.

[37] E. Senel, "Some Carbonyl Compounds and Free Fatty Acid Composition of Afyon Kaymagi (clotted cream) and Their Effects on Aroma and Flavor" Grasas y Aceites, vol.62, no.4, pp. 418–427, 2011.

[38] R. Paez, N. Pensel, N. Sabbag, M. Taverna, A. Cuatrin, C. Zalazar, "Changes in free fatty acid composition during storage of whole milk powder" International Journal of Dairy Technology, vol. 59, No.4, pp. 236-241, 2006.

[39] K. Yıldırım, Z. Albay, E. Capa, B. Simşek, "Determination of the Chemical, Microbiological and Textural Properties of Kuru Kaymak (Dry Clotted Cream)" In Ö. D. Gürcü (Ed.), Young Scholars Union Congress Proceeding and Abstarcts Book . pp. 292. Prauge, 2019

[40] P. F. Silva, R. G. Moreira "Vacuum frying of high-quality fruit and vegetable-based snacks " LWT – Food Science and Technology vol.41, pp.1758-1767, 2008.