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Original Article

Physicochemical characteristics and storage stability of clarified butter fat « smen » produced from pasteurized and non-pasteurized milk

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Abstract

Objectives of this work were studying physicochemical characteristics and oxidative stability of clarified butter fat "smen" produced from non-pasteurized and pasteurized cow's milk. A sensorial evaluation was applied to select more appreciate "smen" by consumers. An oxidative procedure was applied to test the stability of smen. Samples were kept in glass bottles and heated at 100°C. The resistance to oxidation of smen samples was studied by measuring Peroxide value (PV), Thiobarbituric acid (TBA), Free Fatty Acid (FFA), Specific absorptivity at 232 and 270 (K232 and K270) values and change in fatty acid composition, color, polyphenol contents and oxidation induction time in the Rancimat. When compared, smen produced from pasteurized milk has higher thermal stability than smen produced from non-pasteurized milk. All studies indicated that, smen produced from non-pasteurized cow's milk was more prone to oxidation than smen produced from pasteurized cow's milk. Regarding these specificities, the value of this product in food formulation may be justified.

Keywords: clarified butter "smen", physicochemical characteristics, sensorial evaluation, thermal stability.

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Introduction

In Tunisia most milk producers, process the milk produced in their farms into many products such as rayeb (sour milk), zebda beldi (raw butter), Leben (sour fermented milk) and smen (anhydrous butter fat).

Smen is widely used in Tunisia. It's perhaps the most common example of milk fat isolated by 'boiling-off' water (Andrewes, 2012). Production of smen in Tunisia takes place in villages at house hold level. Its preparation is based on the spontaneous fermentation of cow, sheep or goat milk then fermented overnight or more. The sour fermented milk is then churned in a sac made of tanned goat skin or other special container gourd until butter granules are formed (Bali et al., 2010). The butter was heated in a large pot or pan until all water has evaporated and the protein has settled to the bottom. The cooked and clarified butter is then spooned off to avoid disturbing the milk solids on the bottom of the pan. Recently, to standardize product quality and increase safety of smen, selected bacterial cultures were added to pasteurized milk to produce smen in Tunisia.

Smen is utilized for culinary cooking and frying of different foods. In addition, it is used in the preparation of a number of formulations for treating allergy, skin and respiratory diseases and is considered to induce many beneficial effects on human health (Jacobson, 1987; Mariod et al., 2010).

Because of low moisture content, smen has better shelf-life than other indigenous dairy products (Sserunjogi et al., 1998). However, it undergoes deterioration which spoils its appetizing flavor, making it unpalatable and toxic (Mariod et al., 2010).

Deterioration (lipolysis and oxidation) of milk fat due to several factors causes flavor impairment, lowers nutritional quality, and creates serious problems for storage stability (O¨ zkanlı and Kaya, 2007; Rafalowski et al., 2014). The main factors accelerating the rate of lipid oxidation are high temperature, light and trace elements (copper, iron, etc). Oxidation is inhibited by exclusion of oxygen, refrigeration and packaging in opaque or colored containers (O'connor and Tripathi, 1995). The onset of rancidity in clarified butter "smen" may be usually due to oxidation of unsaturated glycerides leading to development of peroxides and/or due to hydrolysis of glycerides resulting in increased levels of free fatty acids (Muir, 1996). It has been reported that, both storage time and type of treatment have highly significant effects on the peroxide value and free fatty acid content of clarified butter (Joshi and Thakar, 1994; Muir, 1996). Storage tests, like shelf-life tests or oven tests (at 60 or 100°C) could be used to study physico-chemical changes of edible fats and oils. Nissiotis and Tasioula-Margari (2002) indicated that heating at 100°C stimulates cooking conditions. The Rancimat method was the most frequently cited for determination of the resistance of fat and oil to oxidation (Halbault et al., 1997).

Literature related to effect of processing parameters on Tunisian smen quality and stability is still lacking. However, the stability of locally produced cow's smen, which is the most popular smen product in Tunisia, has not yet been investigated. Therefore objectives of this study were to carry out investigations of two commonly consumed smen products from non pasteurized cow's milk and from pasteurized cow's milk. Differences are indicative for their comparison in terms of their thermal stability, consequently for their shelf-life determinations. Therefore, effect of processing methods and storage conditions were evaluated.

Materials and Methods

Raw materials

Fresh raw cows' milk (Holstein breed) samples were obtained from a local farm in the South area of Tunisia (Sfax). Samples of cow's milk were collected, kept refrigerated and transport-

ed to our laboratory within 24 h. Each sample was pooled milk taken from 20 to 25 animals for bovine milk.

Smen preparation

For the preparation of smen produced from non-pasteurized milk, raw milk was left at room temperature (25 ± 2°C) until coagulation which takes up after ~ 18 h. During the gelation step, the product is called ''rayeb''. By churning, the ''rayeb'' is separated into an aqueous fraction (protein, lactose, mineral.) giving ''Leben'' and a fat-rich fraction called raw butter ''Zebda beldi'' (Bali et al., 2010). Traditionally, churning takes place in a skin bag called ''Checoua'' which is manufactured from a goat in one piece (Samet-Bali et al., 2012). The churning is achieved after hanging the ''Checoua'' which is filled with ''rayeb'' and vigorously shaking it back and forth till the coalescence of the fat globules. The end of churning is discerned by the sound of the butter lumps when shaking. The collected butter obtained was boiled in a metal pan at 100 - 120°C to evaporate the water (overheating was avoided as it burns the curd and impairs the flavor). The final product was judged by the light brown color for the smen residue and straw yellow for the smen product. The smen is then filtered and it solidifies when completely cool.

For the preparation of smen produced from pasteurized milk, milk was the pasteurized by heating at 82 °C for 30 min. Pasteurized milk was then cooled and 0.2% (w/v) of commercial starters were added, containing a mixed culture of mesophilic lactic bacteria: L. lactis subsp. lactis, L. lactis subsp. diacetylactis and L. lactis subsp. cremoris (Danisco, Rhodia Food, France) at 27°C during 12 h of fermentation (Samet-Bali et al., 2010). The fermented milk was then churned. After churning, the butter produced was boiled in a metal pan at 100-120°C to evaporate the water. The final product was judged by the light brown color for the smen residue and straw yellow for the smen product. The smen is then filtered.

After production (performed at least in triplicate), samples were kept in an airtight container to prevent oxidation until further analysis.

Analysis of smen

Peroxide value (PV) was determined by using the AOAC method (AOAC, 1999). About 5 g of smen was weighed into a 250 ml flask. Previously prepared acetic acid–chloroform solution (30 ml), saturated potassium iodide (0.5 ml), and distilled water (30 ml) were added with occasional shaking. The mixture was titrated with 0.1 N of Na2S2O3 by shaking approximately, 0.5 ml of 1% starch solution was added, and titration was continued with shaking vigorously to release all iodine from CHCl3 layer, until the blue color just disappeared. PV was calculated by using the following equation:

PV (meq.Peroxide / kg sample) = S×N×1000 / g sample

where S is the ml Na2S2O3 (blank corrected) and N is the normality Na2S2O3 solution.

Thiobarbituric acid (TBA) determination was carried out according to O¨ zkanlı and Kaya (2007).

Free Fatty Acid (FFA) content was determined in triplicate, by the titration method of AOAC (AOAC, 1999). About 7 g of smen was weighed into a 250 ml flask. Previously, neutralized hot ethyl alcohol (50 ml) and 1% phenolphthalein, as indicator, were added. The mixture was titrated with 0.1 N NaOH with vigorous shaking until permanent faint pink color appeared and persisted at least 1 min. The FFA content was calculated as percentage of oleic acid according to the following equation:

$$\% \text{ FFA (as oleic acid)} = \frac{V \times N \times 28.2}{m}$$

where m is the mass of the test portion (g), N the normality of NaOH, and V the volume of NaOH consumed (ml).

Specific absorptivity at 232 and 270 were determined using an UV spectrophotometer (Shimadzu Co., Kyoto, Japan) by measuring absorbance of 1% solution in cyclohexane at

232 and 270 nm with 1 cm of pass length.

CieLab coordinates (L*, a* and b*) were directly read with a spectrophotocolorimeter (Trintometre, Lovibond PFX 195 V 3.2, Amesbury, UK). In this coordinate system, the L* value is a measure of lightness, ranging from 0 (black) to 100 (white), the a* value ranges from –100 (greenness) to +100 (redness) and the b* value ranges from –100 (blueness) to +100 (yellowness).

Sensory evaluation of smen samples was carried out by 40 panelists. All of them, with experience of assessing smen, were non-smokers and their age ranged from 23 to 56 years old. The panelists were asked to evaluate the products for color, taste, smell, structure, appearance, texture and overall acceptability. The ratings were on 9-point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely). The mean sensory scores for various attributes of smen samples were calculated.

Thermal stability tests

Thermal stability of smen samples was tested at 100°C. Smen samples (70 g) were kept in equal portions in open flasks (30 ml capacity, 30 mm diameter and 70 mm height) in the dark in an oven (Binder, No. 970465, Tuttlinger, Germany). Accelerated storage test was evaluated by measuring periodically PV, TBA and FFA values, specific absorptivity at 232 and 270, total phenols contents and the change of fatty acid composition and color during heat treatment.

The total phenol contents of the smen samples were determined by the Folin–Ciocalteau spectrophotometric method at 765 nm, in terms of gallic acid (mg GA/kg oil) (Montedoro, 1992).

Fatty acid composition was performed using Gas Chromatography (GC). 50 μL of smen were converted to methyl esters using 500 μL hexane and 200 μL of 2 N KOH in methanol. The mixture was vortexed during 5 min, organic phase were recuperated. Fatty acid methyl esters (FAMES) were presented in the organic phase for GC analyses. Gas Chromatography analyses were performed on a Shimadzu, GC 17 A chromatograph, equipped with a flame hydrogen ionisation detector and a capillary column (FFAD, 50 m × 0.32 mm × 0.5 μm, PERICHROM Sarl, France). The oven temperature was programmed as follow: the initial temperature (100°C) was raised to 150°C at a rate of 30°C/min and held at this temperature for 5 min, then increasing at 10°C/min to 190°C and held at this temperature for 14 min, and then increasing at 5°C/min to 255°C and held at this temperature for 10 min. The injector and detector temperatures were 255°C and 270°C, respectively. Nitrogen was the carrier gas. The identification of the peaks was achieved by retention times and by comparing them with authentic standards analyzed under the same conditions. Peak areas of triplicate injections were measured with a HP computing integrator. Results were expressed as w/w (%) total fatty acid.

Oxidative stability was evaluated by Rancimat method. Stability was expressed as the oxidation induction time (h), measured with the Rancimat 679 apparatus (Metrohm AG, Herison, Switzerland) using a smen sample of 2.5 g, heated to 100°C and a purified air flow rate of 10 l/h. In the Rancimat method, the volatile degradation products were trapped in distilled water and determined conductometrically. The induction time was defined as the time necessary to reach the inflection point of the conductivity curve.

All analytical determinations were performed at least in triplicate.

Statistical analysis

Analysis of variance (ANOVA) was carried out by using the software SPSS statistics 19. Significant differences ($p<0.05$) among treatments were detected using Duncan's multiple range tests. Values expressed are means ± standard deviation of triplicate measurements.

Results and Discussion

Smen's quality indices

Table 1 presents the physico-chemical quality parameters of smen samples produced from pasteurized and non-pasteurized cow's milk. Processing methods were effective on the initial peroxide, TBA, FFA values and K232, K270 extinctions coefficients. Color values were also different due to formation of browning compounds during the heating process of milk and melting process (O¨ zkanlı and Kaya, 2007). Indeed, smen made from non-pasteurized milk showed a higher L* value and lower a* and b* values compared to smen made from pasteurized milk. This means that non-pasteurized smen was lighter-colored than pasteurized smen. Such a color seems to attract consumers.

Table 1: Quality indices of smen samples produced from cow's non-pasteurized and pasteurized milk

Analysis	Non-pasteurized milk smen	Pasteurized milk smen
Peroxide value (meq O2/kg fat)	1.20 ± 0.10[a]	1.50 ± 0.30[b]
FFA (% oleic acid)	1.97 ± 0.41[a]	0.28 ± 0.37[b]
TBA (mg MA/kg fat)	0.253 ± 0.037[a]	0.098 ± 0.002[b]
K232	0.11 ± 0.31[a]	0.18 ± 0.22[b]
K270	1.27 ± 0.17[a]	1.36 ± 0.43[b]
Color values		
L*	91.39 ± 0.50[a]	48.78 ± 0.32[b]
a*	-4.73 ± 0.22[a]	-2.29 ± 0.13[b]
b*	17.77 ± 0.27[a]	23.45 ± 0.28[b]

K232 and K270: specific coefficients at 232 nm and 270 nm respectively.
Means ± standard deviation (SD) of three separate determinations
[a,b] Values sharing lowercase letter within a column are not significantly different by Duncan's multiple-range test ($p<0.05$).

Sensorial evaluation

Results of sensorial evaluation of smen samples were presented in Table 2. It could be seen that no significant differences ($P<0.05$) were found regarding the structure, the appearance and the texture of the two kinds of smen. However, panelists prefer the taste and the smell of smen made from pasteurized milk and prefers the color of smen produced from non-pasteurized milk (as previously shown). Based on these results smen samples were selected for thermal stability tests.

Storage stability of smen samples

Figure 1a shows the change in PV values of smen made from non-pasteurized and pasteurized milk at 100°C. PV increased during heat treatment. It can be seen that the traditional method for determining PV serves as an indicator of smen quality. This method does not distinguish between various unsaturated fatty acids that undergo oxidation; it also does not supply information about the secondary oxidation products formed by hydroperoxide decomposition. However, it can generally be stated that the PV is an indicator of the primary level of oxidation.

TBA values also increased as the storage time and temperature increased (Table 3). PV and TBA values indicate that the rate of increase in PV and TBA values of non-pasteurized milk smen, were higher than that of pasteurized milk

Table 2: Sensorial evaluation of smen samples made from non-pasteurized and pasteurized milk

Parameters (%)	Smen produced from non-pasteurized cow's milk	Smen produced from pasteurized cow's milk
Color	8.60 ± 0.75[a]	6.51 ± 0.45[b]
Taste	3.17 ± 0.91[a]	7.82 ± 1.01[b]
Smell	4.85 ± 0.83[a]	7.97 ± 0.94[b]
Structure	7.20 ± 1.16[a]	7.60 ± 1.33[a]
Appearance	7.83 ± 0.54[a]	8.00 ± 1.61[a]
texture	7.17 ± 1.22[a]	7.31 ± 0.88[a]
overall acceptability	7.88 ± 0.76[a]	8.13 ± 1.07[a]

Means ± standard deviation (SD) of three separate determinations
[a,b] Values sharing lowercase letter within a column are not significantly different by Duncan's multiple-range test ($p<0.05$).

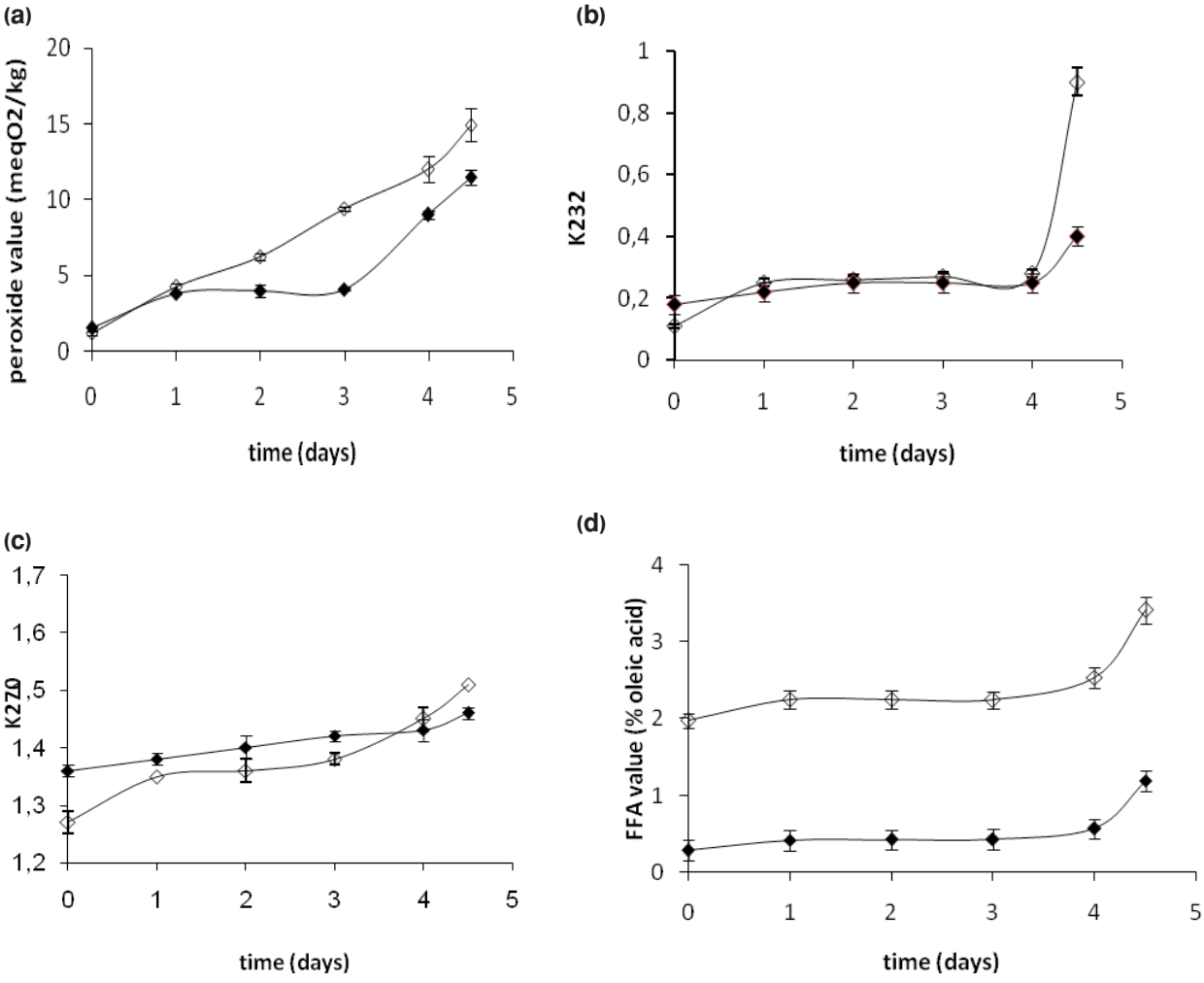

Figure 1. Change in peroxide (a), conjugated diene: K232 (b) and K270 (c) and FFA (d) values of smen made from non-pasteurized milk (◊) and pasteurized milk (♦) during thermal oxidation at 100°C.

Table 3: TBA values of smen samples during thermal oxidation at 100°C

Storage at 100°C		
Time (day)	TBA (mg MA/Kg fat) of Smen produced from	
	non-pasteurized milk	pasteurized milk
0	0.253 ± 0.037[a]	0.098 ±0.002[b]
1	0.440 ± 0.057[a]	0.158 ± 0.012[b]
2	0.878 ± 0.077[a]	0.234 ± 0.007[b]
3	0.786 ± 0.239[a]	0.252 ± 0.025[b]
4	1.004 ± 0.110[a]	0.428 ± 0.030[b]

Means ± standard deviation (SD) of three separate determinations
[a,b] Values sharing lowercase letter within a column are not significantly different by Duncan's multiple-range test ($p<0.05$).

smen during the storage at 100°C.

The results of the Rancimat test indicate that stability, expressed as the oxidation induction time (h), was about 22.40 h for smen produced from pasteurized milk and about 11.85 h for smen made from non-pasteurized milk. This difference may be explained by the fact that smen produced from non-pasteurized milk was more prone to oxidation.

The stability of pasteurized smen can be attributed to the pasteurization and heat treatment of milk. As a result of heat treatment, microorganisms and enzyme activities which could initiate lipid oxidation are eliminated. Heat treatment was not applied to smen produced from non-pasteurized milk. Therefore, this smen is more susceptible to enzymatic oxidation. PV and TBA values also support this result.

The formation of primary compounds of oxidation such as hydro peroxides coincided with the increase of absorptivity at 232 nm (Guillén and Ruiz, 2004). Figure 1b shows changes in K232 specific coefficients of smen samples versus heating at 100°C. Formation of primary compounds of oxidation occurred initially at a lower rate. This little increase suggested that smen were resistant to oxidation. After 4 days in an oven at 100°C, specific extinction at 232 nm became much higher for smen produced from non-pasteurized milk. This may be explained by the fact that smen produced from pasteurized milk was more resistant to oxidation (as previously shown). The primary products of oxidation are not stable under heating and then their degradation could lead to the formation of oxidation secondary product that absorb at about 270 nm (Vieira and Regitano d'Arce, 2001). Specific extinction at 270 nm did not considerably change during 4 days in an oven at 100°C (Figure 1c). This also confirmed the resistance of smen against the oxidative phenomenon. This resistance against oxidation of all smen samples may be explained by the presence of natural antioxidant such as phenolic compounds.

Phenolic compounds (PC) are very important constituents because they exhibit antioxidant activity by inactivating lipid free radicals, or by preventing the decomposition of hydroperoxides into free radicals (Maisuthisakul et al., 2007). Phenolic compounds are naturally present in milk fat (such as α-tocopherol, carotenoids, conjugated linoleic acid) and are the major compounds responsible for the stability of milk fat during storage and heating (Rafałowski et al., 2014). The total phenolic content in smen samples were determined from the regression equation of the calibration curve and expressed in gallic acid equivalents (Table 4). Initially, the content of total polyphenols ranged from 70.56

Table 4. Content in polyphenols of smen samples during heat treatment at 100°C.

	Time (day)	Smen produced from	
		non-pasteurized milk	pasteurized milk
Polyphenols content (mg of gallic acid/g of smen) at 100°C	0	70.56 ± 3.58[a]	9868.49 ± 56.38[b]
	1	74.90 ± 4.32[a]	5891.32 ± 63.21[b]
	2	820.75 ± 21.33[a]	3019.43 ± 51.87[b]
	3	1293.01 ± 48.21[a]	2833.65 ± 34.70[b]
	4	2670.37 ± 63.11[a]	2830.75 ± 31.21[b]
	overall acceptability	7.88 ± 0.76[a]	8.13 ± 1.07[a]

Means ± standard deviation (SD) of three separate determinations
[a,b] Values sharing lowercase letter within a column are not significantly different by Duncan's multiple-range test ($p<0.05$).

and 9868.49 (mg of gallic acid/g of smen) in smen produced from non-pasteurized milk and pasteurized milk, respectively. This difference in the phenolic contents between the two kinds of smen could be attributed to the pasteurization of milk. It was reported that pasteurizing the milk increased its content of PC (Stewart et al., 2000; Turkmen et al., 2005). This ascribed to the effect of pasteurization on the hydrogen bonds between the phenolic hydroxyl group and the receptor group of the proteins such as NH and CO (El-Din et al., 2010). During heating at 100°C, a significant decrease was observed in the level of polyphenols for smen produced from pasteurized milk, this may attributed to the transformation of PC which highly unstable compounds and undergo numerous enzymatic and chemical reactions during food storage as stated by El-Din et al. (2010). However, what was observed for smen made from non-pasteurized milk was different: an increase in polyphenolic contents was observed during the heat treatment at 100°C.

Figure 1d represents the FFA values of smen samples. FFA of smen remains relatively constant (stable) during 4 days at 100°C, than increased as the storage time increased. These results suggest that smen was resistant to oxidation. This can be explained by high temperature storage of samples, which inhibit the lipolytic activity.

Table 5 presents initial and final fatty acid profiles of smen made from non-pasteurized and pasteurized milk. In all eleven fatty acids were present, three of which were unsaturated. The most abundant fatty acids of all smen samples were oleic (C18:1), stearic (C18:0), palmitic (C16:0) and myristic (C14:0) which together composed about 80 % of the total fatty acids. Palmitic and oleic acids were the main fatty acids. These results are in agreement with previous studies (Al-Khalifah and Al-Kahtani, 1993; Sawaya et al., 1994; Mariod et al., 2010). The unsaturated (U)/saturated (S) fatty acid ratio was obtained by dividing the total unsaturated fatty acids by the total saturated fatty acids, regardless of chain length. The smen made from non-pasteurized milk had the highest U/S ratio (0.72) while the lowest U/S ratio (0.57) was observed for smen produced from pasteurized milk. The U/S ratio is of importance with regard to the lipid intake-health relationships. Smen produced for pasteurized milk presents low polyunsaturated fatty acid content (36.40%) compared to smen made from non-pasteurized milk (41.86%). This result suggested that smen produced from pasteurized milk was more resistant to oxidation against smen made from non-pasteurized milk (as previously shown).

Changes were observed in fatty acid composi-

Table 5: Fatty acid composition (%) of smen samples stored at 100°C

Fatty acid	Smen produced from non-pasteurized milk		Smen produced from pasteurized milk	
	before heating	after heating	before heating	after heating
$C_{6:0}$	0.92 ± 0.05[a]	0.79 ± 0.13[b]	1.49 ± 0.02c	0.91 ± 0.16[a]
$C_{8:0}$	0.74 ± 0.01[a]	0.71 ± 0.01[a]	1.03 ± 0.01[b]	0.79 ± 0.07[a]
$C_{10:0}$	2.31 ± 0.03[a]	2.28 ± 0.02[a]	2.52 ± 0.07[b]	2.15 ± 0.08[c]
$C_{12:0}$	3.35 ± 0.04[a]	3.33 ± 0.09[a]	2.83 ± 0.03[b]	2.67 ± 0.02[b]
$C_{14:0}$	11.09 ± 0.14[a]	12.05 ± 0.28[b]	11.26 ± 0.12[a]	11.29 ± 0.19[a]
$C_{15:0}$	2.25 ± 0.10[a]	2.48 ± 0.05[b]	0.94 ± 0.01[c]	0.98 ± 0.02[c]
$C_{16:0}$	31.35 ± 0.28[a]	34.87 ± 0.37[b]	33.96 ± 0.2[c]	34.39 ± 0.70[b]
$C_{16:1}$	5.15 ± 0.21[a]	4.29 ± 0.04[b]	3.92 ± 0.3[c]	3.51 ± 0.28[d]
$C_{18:0}$	6.07 ± 0.05[a]	7.05 ± 0.01[b]	9.02 ± 0.08[c]	10.41 ± 0.62[d]
$C_{18:1}$	32.23 ± 0.14[a]	29.33 ± 0.64[b]	28.95 ± 0.22[c]	29.09 ± 0.51[b]
$C_{18:2}$	4.48 ± 0.10[a]	2.78 ± 0.04[b]	3.53 ± 0.06[c]	3.75 ± 0.04[d]
Total	99.94	99.96	99.45	99.94
(SFA)	58.08	63.56	63.05	63.59
(UFA)	41.86	36.40	36.40	36.35
U/S	0.72	0.57	0.57	0.57

SFA: saturated fatty acids; UFA: unsaturated fatty acids
Means ± standard deviation (SD) of three separate determinations
[a,b,c,d] Values sharing lowercase letter within a column are not significantly different by Duncan's multiple-range test ($p<0.05$).

tion of smen during heat treatment. Indeed, a decrease in the relative percentages of oleic (C18:1) and linoleic (C18:2) acids and an increase in the percentage of palmitic (C16:0), myristic (C14:0) and stearic (C18:0) acids were detected in smen produced from non-pasteurized milk. In the other hand, there was only a slight increase of C16:0 and C18:1 in smen produced from pasteurized milk. This result consolidates the significant stability of pasteurized smen. This stability can be attributed to temperature effect which inhibits lipolytic activity (O¨zkanlı and Kaya, 2007).

CieLab coordinates (L*, a*, b*) of smen made from pasteurized and non-pasteurized milk during oxidation were given in Figure 2. The initial color (t = 0h) of smen samples was reported to be yellow, and this is due to its richness in yellow pigments (carotenoids). Figure 2 shows that heating at 100°C gives immediately a considerable increase in L* parameter at a rate of 50% from the initial value in pasteurized smen, whereas, L* parameter remain practically constant in non-pasteurized smen during heating. Furthermore, b* values increase at the beginning of the heating, and then decrease during heat treatment. However, what was observed for a* parameter was different: a decrease in values was observed at the beginning of heating, and then increased considerably at the end of the heat treatment. This color change was essentially marked by the loss of yellow color and then of yellow pigments, essentially ß-carotenes, beyond the oxidation induction

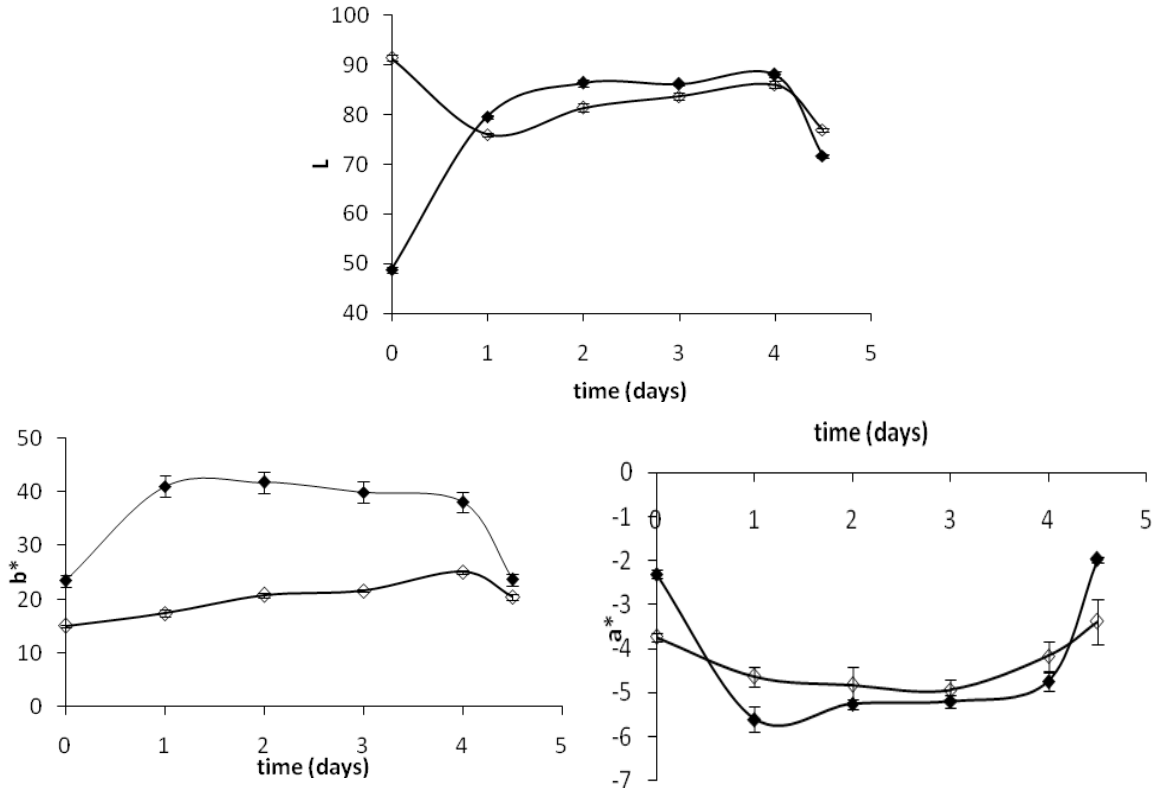

Figure 2: CieLab coordinates (L*, a*, b*) of smen made from non-pasteurized milk (◊) and pasteurized milk (♦) during thermal oxidation at 100°C

period. On the other hand, the color formation in smen samples, during heating processes, could be attributed to phospholipids degradation (Husain et al., 1986).

Conclusion

From all these results, it can be concluded that smen could be used safely for a certain long period if stored under suitable conditions. The stability of the product comes from the separation of the water phase (i.e., serum phase) of butter from the oil phase. Therefore, it has a longer shelf-life period than the butter. Another interesting point is the effect of pasteurization of milk on the thermal stability of smen. All studies indicated that, smen produced from non-pasteurized cow's milk was more prone to oxidation than smen produced from pasteurized cow's milk.

Regarding these specificities, the value of this product in food formulation may be justified.

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