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Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorpjn@gmail.com

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Effect of Heating Treatments, Processing Methods and Refrigerated Storage of Milk and Some Dairy Products on Lipids Oxidation

Meshref, A. Al-Rowaily
Department of Medically Laboratory Science,
Collage of Applied Medical Science, Al-Jouf University, Saudi Arabia

Abstract: The effect of heating treatments (pasteurization and boiling), micro waving, processing steps and storage of milk and some locally produced dairy products (Brined white cheese (Nabulsi), Yogurt and Labaneh on chemical changes of milk lipids were evaluated. The Peroxide value (POV) p-anisidine value (p-AV), thiobarbituric acid (TBA), free fatty acid and totox were determined. The heating treatments of milk do significantly increase the levels of the oxidation parameters such as POV compared to those of fresh raw milk. The highest POV value (mEq O_2/kg fat) was for milk pasteurized at 95±1.0°C for 15 min (0.435), followed by milk heated at 63±1.0°C for 30 min (0.381), whereas, the lowest value was for milk pasteurized at 85±1.0°C for 16 sec (0.234).

Key words: Fat oxidation, peroxide value, ultra-high temperature, thiobarbituric acid, ρ-anisidine value, microwave heating

Introduction

Dairy products are an important group in human nutrition. They are consumed as such or used in preparation of many food items such as pastries, pies, cakes,...etc to provide specific functional properties (e.g., texture, crust color, flavor,...etc.). Milk lipids are considered to be one of the outstanding milk constituents with respect to presence of lipid classes, variety and number of identified fatty acids which was found to be more than 400 (Jensen *et al.*, 1990 and 1991). Milk lipids may undergo chemical and physical changes during processing and storage such as autoxidation and formation of trans fatty acids (Semma, 2002). Fat autoxidation leads to the production of low molecular weight substances (aldehydes, ketones and lactones) with offensive odor that could decrease the quality and nutritional value such as vitamins content (Frankel, 1984; Frankel *et al.*, 1987). Furthermore, some of the autoxidation products are associated with ageing, membrane damage, heart diseases and cancer (Keys, 1980; Addis and Warner, 1991).

Milk and milk products usually undergo different changes during their preparation (boiling and micro waving) or processing, which may include moderate or severe heat treatments that can lead to undesirable changes in lipids or proteins. Cooking and reheating of foods by microwave ovens are widely used in food preparation in millions of kitchens throughout the world. Food heating by microwave results from the conversion of microwave energy into heat by friction of water molecules vibration due to rapid fluctuation in the electromagnetic field (Potter and Hotchkiss, 1996; Decareau, 1992).

The trend of using the microwave oven in food processing could be attributed to the speed of heating and energy saving. Although microwave oven is widely used as a means of food preparation, insufficient information is available on the consequences of microwave heating on the composition and nutritional quality of the food. Some studies revealed that microwave heating affect fat oxidation and fatty acid isomer formations (Albi *et al.*, 1997 a and b).

Therefore, the objectives of this study were to evaluating the effect of the conventional heating methods, processing of milk into white brined cheese (Nabulsi), yogurt and labaneh and microwave heating of milk and milk products on lipid oxidation.

Materials and Methods

Raw Cow's milk used in the study was obtained from the bulk tank of three dairy plants: Danish Jordan Dairy Company (DJD), Jordan University Dairy Plant (JUDP) and Al-Sanabel Dairy CO. (SDC). The milk was produced by Cow's Breeder Society, Jordan University farm and from Haj Mustafa Farm, respectively. The rations that were given to the cows are approximately composed of 200-kg Soya, 300-kg bran, 150-kg corn, 300-kg barely, 25-kg salt and 25-kg $CaCO_3$. Daily consumption of each cow is 12 kg concentrate, 8-kg green alfalfa and 1-kg straw. White-brined cheese (Nabulsi) was produced from Ewe's milk provided by SDC, yogurt and labaneh were from DJD and JUDP. The UHT (at 140±1.0°) and Pasteurized (at 85.0±1.0°C) milk were from DJD CO.

Heat treatments of milk and milk products: The raw cow's milk obtained from the three selected sources was subjected to different heat treatments as shown in Table 1.

Table 1: Cow's milk and milk products produced by different heat treatments

Milk		Heating Treatment			
Producer	Source	Type	Temperature (°C)	Time	Product
CBS[1]	DJD[2]	Tube pasteurization	85	16sec	Pasteurized milk
			95	5 min	Yogurt
			82	16 sec	labaneh
			140	4 sec	UHT[3]
		Lab scale pasteurization	63±1.0	30 min	Pasteurized milk
		Lab scale boiling	97.5±1.0	5 min	Boiled milk
		Microwave boiling	96.8±1.0	5 min	Microwave boiled milk
MDF[4]	SDC[5]	Plate pasteurization	95	15 min	Yogurt
			95	15 min	labaneh
		Lab scale pasteurization	63±1.0	30 min	Pasteurized milk
		Lab scale boiling	97.5±1.0	5 min	Boiled milk
		Microwave boiling	96.8±1.0	5 min	Microwave boiled milk
JUDF[6]	JUDP[7]	Batch pasteurization	85-90	2 min	Yogurt
			85-90	2 min	Labaneh
		Lab scale pasteurization	63±1.0	30 min	Pasteurized milk
		Lab scale boiling	97.5±1.0	5 min	Boiled milk
		Microwave boiling	96.8±1.0	5 min	Microwave boiled milk

[1]Cow's Breeder Society; [2]Danish Jordan Dairy Co.; [3]Ultra-high temperature; [4]Mahmoud Dairy Farm. [5]Sanabil Dairy Co.; [6]Jordan University Dairy farm; [7]Jordan University Dairy Plant

Labaneh production: Labaneh used in the present study were produced according to the following methods:

Traditional method (cloth sacks): The set yogurt after cooling was stirred and then poured in a cloth sacks overnight to drain off the whey for 12 to 24 hrs. The drained yogurt labaneh was salted with 1% (NaCl), blended, filled into suitable plastic containers and refrigerated at 4°C. The produced labaneh was of 23-25 percent total soluble solids and a pH of 5 to 5.5.

Separator method (centrifugal separator): Cream was separated, milk was pasteurized at 83 to 85°C for 16 sec, salt (1% NaCL) was added, the pasteurized skim milk was inoculated with ca 0.002% (w/v) powder freeze dried mixed starter culture (Danisco, Denmark) and kept for 15-17 hr at 42-44°C. When the pH of the yogurt reached 4.5 to 4.6, the product was stirred and the whey separated via separator at 40°C. The concentrated skim yogurt and the cream (40% butter) were mixed to have a total solid not less than 23% and 10% fat. The produced labaneh was filled into suitable plastic containers and stored at 4°C.

Cheese production and heat treatments: White brined cheese (Nabulsi) was produced according to the traditional method described by Humeid and Tukan (1986) and Humeid *et al.* (1990) from Ewe's milk. Two desalted, grated cheese samples of approximately 200 g each were heated in a microwave oven (Galanz, 800 Watts, WD800B, Korea) at 80% power. The first one was heated at 96.3±1.0°C until browning (Ca. 10 min), while the second was filled in a polyethylene bag, placed in a Pyrex saucepan, filled with water (distilled water) and boiled while floating in the microwave oven at 96.3±1.0°C for 5 min. Another two cheese samples (ca 100g) were desalted grated and placed in polyethylene bags in Pyrex saucepan, covered with distilled water and boiled on a gas cooker for 5 min at 95.5±1.0°C.

UHT reconstituted milk: UHT milk sample produced from powder milk (reconstituted) produced by Kuwaiti Danish Dairy CO., Kuwait (KDD) were purchased from the local market for comparison (production date 09/09/02 and expired on 09/03/03).

Production of set yogurt: Set yogurt was produced from milk pasteurized at 95±1.0°C for 5 minutes (tube pasteurization), 95±1.0°C for 15 (plate pasteurization) or 85-90°C for 2 min (batch pasteurization). The milk was cooled to 45±1.0°C and inoculated with 2-3% freeze-dried mixed starter culture (Danisco, Denmark), then filled into plastic containers of different sizes, incubated at 42±1.0°C up to 2 to 2.5 hr. When the desired acidity of 0.7% or a pH of 4.5-4.6 was reached, the yogurt was cooled at 4±1.0°C.

Storage of milk and milk products: The milk and milk products used in the present study; (pasteurized milk, UHT milk, yogurt and labaneh) were stored at 5.0±1.0°C and analyzed after a storage period of 3, 5, 7, 15 days for pasteurized milk, UHT milk, yogurt and labaneh,

Table 2: Effect of heat treatment and storage[1] time of milk on lipid oxidation[2]

Treatment	POV[3]	pAV[4]	%FFA (OA)[5]	TBA[6]	TOTOX[7]
Raw cows milk	0.115^{i}±0.011	0.244^{g}±0.026	0.107^{c}±0.003	0.014^{e}±0.005	0.473^{h}±0.046
Pasteurized milk (63.0±1.0°C, 30 min)	0.381^{ef}±0.039	0.601^{c}±0.100	0.109^{c}±0.004	0.022^{cbd}±0.009	1.395^{de}±0.176
Pasteurized milk (85.0±1.0°C, 16 sec)	0.234^{h}±0.095	0.327^{fg}±0.090	0.108^{c}±0.006	0.017^{de}±0.0011	0.795^{g}±0.1277
Pasteurized milk after 3 days storage. (85±1.0°C, 16 sec)	0.508^{c}±0.082	0.827^{b}±0.149	0.165^{b}±0.030	0.017^{de}±0.003	1.843^{b}±0.122
Pasteurized milk (85-90±1.0°C, 2 min)	0.337^{gf}±0.020	0.503^{cde}±0.009	0.110^{c}±0.011	0.017^{de}±0.008	1.178^{ef}±0.047
Pasteurized milk (95.0±1.0°C, 5 min)	0.337^{fg}±0.011	0.508^{cde}±0.021	0.110^{c}±0.011	0.016^{de}±0.003	1.178^{ef}±0.047
Pasteurized milk (95.0±1.0°C, 15 min)	0.435^{de}±0.011	0.565^{cd}±0.021	0.118^{c}±0.002	0.020^{cde}±0.004	1.455^{de}±0.039
Boiled cow's milk (96.3±1.0°C, 5min)	0.296^{gh}±0.027	0.337^{fg}±0.037	0.118^{c}±0.010	0.018^{de}±0.002	0.929^{fg}±0.021
Microwave boiled milk (95.8±1.0°C, 5min)	0.297^{gh}±0.057	0.397^{efg}±0.131	0.107^{c}±0.002	0.032^{a}±0.008	0.991^{fg}±0.243
UHT milk [8] (140°C, 4 sec)	0.33^{gfi}±0.029	0.446^{def}±0.092	0.1099^{c}±0.024	0.015^{de}±0.003	1.108^{f}±0.139
UHT milk (140.0±1.0°C, 4 sec and stored for 5 days)	0.453^{cde}±0.033	0.58^{cd}±0.040	0.181^{b}±0.016	0.019^{cde}±0.004	1.488^{cd}±0.092
UHT milk (140.0±1.0°C, 4 sec and stored for 15 days	0.836^{a}±0.029	1.010^{a}±0.183	0.211^{b}±0.036	0.027^{b}±0.002	2.631^{a}±0.239
UHT milk (reconstituted)[9]	0.455^{cd}±0.047	0.800^{b}±0.014	0.165^{b}±0.016	0.027^{b}±0.001	1.710^{bc}±0.107
UHT milk (reconstituted) after 5 days storage.	0.583^{b}±0.016	0.830^{b}±0.120	0.217^{a}±0.015	0.025^{cb}±0.004	1.997^{b}±0.135

[1]Commercial refrigeration at 5.0±1.0°C for 3, 5 and /or 15 days. [2]Values represent means±SD (n = 4). Means values in the same column with different superscript letters are significantly different ($p \leq 0.05$) according to (ANOVA) Duncan's multiple range test. [3]Peroxide value (mEq of O_2/ kg of Fat). [4] p-Anisidine value. [5]Free fatty acid as (oleic acid). [6]Thiobarbituric acid value. [7] 2 × POV + PAV. [8]Ultra high temperature pasteurization of fresh cow's milk provided by Danish Jordan Dairy Company (DJD). [9]Milk prepared from cow's milk powder after reconstitution of KDD brand name (Kuwaiti Danish Dairy Company), purchased from local market

respectively, as indicated on the package lable (commercial shelf life). On the other hand, the produced white brined cheese (Nabulsi) was evaluated after one month of storage in tins at room temperature at 18±1.0°C (Table 2).

Milk fat extraction and analysis: Lipids were extracted from the milk and milk products samples with chloroform and methanol as described by Bligh and Dyer (1959) with some modifications regarding sample weight, solvent volume and centrifugation speed and time. Approximately 70 g of cheese, yogurt or labaneh and 100 mL of fluid milk products were homogenized with 100 mL methanol and 100 mL chloroform using a Hamilton Beach Scovel homogenizer (NSF, USA) for 2 min at a medium speed. Then to the mixture, 100 mL of chloroform were added and the mixture was rehomogenized for an additional 2 min. The homogenate was centrifuged at 4000 rpm for 20 min using Haeraeus centrifuge (Haeraeus Christ, GmbH, Osterode/Harz, OJ3, Germany). The upper layer (methanol and water layer) was removed through aspiration. The middle and the lower layer (chloroform layer and precipitated protein layer) were filtered through a filter paper to separate precipitate particles. The chloroform-lipid extracts were again filtered through anhydrous sodium sulfate (Na_2SO_4) and the Na_2SO_4 was rinsed 3 times with 30 mL chloroform 10 mL each. The lipid extracts were dried under nitrogen using rot evaporator (LABOROTA, 4001 WB, Heidolph, Germany) with 150 rpm at 50°C and stored for analysis in 5 mL vials (brown glass) under nitrogen at-18°C.

Chemical analyses: Peroxide value (POV), free fatty acid (FFA), Thiobarbituric acid (TBA), ρ-anisidine value (pAV) and totox were determined for the extracted lipid as described by Kirk and Sawyer (1991).

Statistical analysis: Data were analyzed using the analysis of variance (ANOVA) procedure of SAS Institute Inc., Cary, NC, USA 1998. Duncan's multiple range tests were produced to determine significance between different treatments.

Results and Discussion

Influence of heating milk on chemical changes of lipids: Lipid oxidation is known to be increased by many factors such as heat, light, radiation, moisture, low pH and storage (Savage *et al*., 2002). Oxidation can also be induced by reactive oxygen species and free radicals

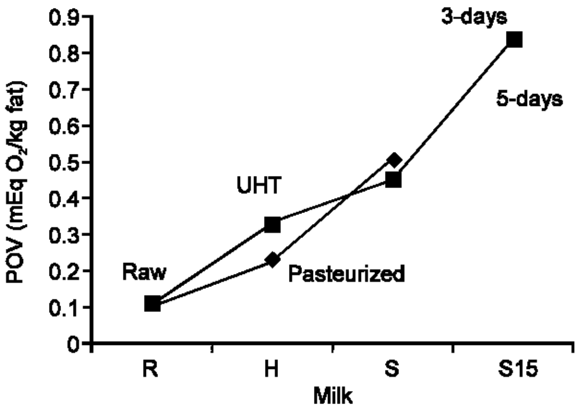

Fig. 1: Effect of heating temperature and storage time of raw, pasteurized and UHT milk on peroxide value (R; raw, H; milk pasteurized at 86±1.0°C for 16 sec; UHT, milk heated at 140±1.0°C for 4 sec, S: pasteurized milk stored for 3 and UHT for 5 days and S15; UHT milk stored for 15 days)

that alter biomolecules and damage cell components yielding peroxides, alcohols, aldehydes and ketones (Ferrari, 2000) The influence of heating treatments and commercial storage of milk on the oxidation of milk fat fraction was evaluated using the oxidation indicators: peroxide (POV), p-anisidine (p-AV), Free Fatty Acid (FFA), thiobarbituric acid (TBA) and totox values.

The results are presented in Table 2. The data obtained show that POV of the extracted fat from raw milk was significantly ($p < 0.05$) different from those of pasteurized, microwave and UHT heat treated milk samples. The percent increase in the peroxide values for milk pasteurized at 85±1.0°C for 16 sec, microwave heated at 95.8±1.0°C for 5 min, Ultra-High Temperature (UHT) heated at 140±1.0°C for 4 sec and milk pasteurized at 63±1.0°C for 30 min were Ca. 103, 158, 186 and 231%, respectively, of that of the raw milk sample. For example, the peroxide values for raw and a microwave heated milk were 0.115 and 0.296 mEq O_2/kg fat, respectively. However, no significant differences were found between the POV of milk heated in a microwave oven and those of milk pasteurized at different temperature/time combinations (85-90±1.0°C for 2 min, 95±1.0°C for 5 min or boiling at 96.3±1.0°C for 5 min). Furthermore, the heat treatments had no significant effect on the level of the free fatty acids (%FFA).

On the contrary, TBA values for the microwave heated milk was significantly ($p<0.05$) different from all other heating treatments. The TBA value of microwave heated milk samples was 0.032. The noticeable increase in the TBA of the microwave heated milk oven which was not reflected in POV and p-AV values could be due to the fact that POV is used to measure primary oxidation products (hydroperoxide or peroxide), p-AV is specific for 2-alkenal or 2,4-dienals, whereas, TBA is used to measure the formation of dienal. Thus, at those levels of oxidation which were occurred in milk TBA could be more representative for oxidation status than POV.

Storage of pasteurized and UHT heated milk after opening (at 5±1.0°C for 3 and 5 days, respectively) has a significant effect ($p<0.05$) on the oxidation of milk fat as compared to the same samples freshly packaged. For example, the POV values for pasteurized milk at 85±1.0°C for 16 sec were 0.234 and 0.508 mEq O_2/kg fat before and after storage, respectively. The effect of storage of milk samples (raw, pasteurized and UHT) after opening on POV is illustrated in Fig. 1.

The increase in the peroxide value of stored samples compared to that of freshly produced product could be seen as continuation of the oxidation process started upon heating, since these products are stored without protective gas (N_2), which means that oxygen is available in the headspace and dissolved in the milk. The effect of storage on lipid oxidation was found to be consistent with the results obtained by Chan *et al.* (1993), Nourooz-Zadeh and Appelqvist (1988); and Fedele and Bergamo (2001) who found that the stability of milk powder could be improved by packaging the milk in oxygen impermeable systems and/or using protective gas.

Influence of processing and refrigerated storage of yogurt and labaneh on lipid oxidation: The effect of processing and storage of yogurt and labaneh on oxidation of milk fat were evaluated and the results obtained are presented in Table 3.

The results obtained for chemical oxidation parameters (POV, $_{P-}$AV and TOTOX value) showed that lipid oxidation was significantly ($p<0.05$) enhanced by milk pasteurization (the first step in yogurt processing) compared with those values of raw milk. For example, the values of the POV for raw milk and milk heated at *85-90*±1.0ºC for 2 min (batch pasteurization) were 0.115 and 0.337 mEq O_2/kg fat, respectively.

On the other hand, no significant differences ($p>0.05$) were found between yogurt and pasteurized milk in all oxidation parameters (POV, p-AV, FFA and TBA), whereas, a significant difference was found between milk pasteurized at 85±1.0°C for 16 sec and yogurt (produced from the same milk) for only the totox value. From these results, it can be concluded that the conversion of pasteurized milk to yogurt and whey separation from yogurt to produce labaneh do not affect the oxidation status of milk lipids.

Furthermore, no significant difference ($p>0.05$) in the oxidation parameters was observed between labaneh produced by conventional method (straining in cloth bags) and labaneh produced mechanically by separator, in spite of the differences in the time and processing conditions of labaneh in different dairy companies. The averaged POV values for labaneh strained in cloth and labaneh strained by separator were 0.377 and 0.400 mEq O_2/kg fat, respectively.

Table 3: Effect of processing and refrigerated storage[1] of labaneh and yogurt on common oxidation parameters of milk lipids[2]

Treatment	POV[3]	PAV[4]	%FFA (OA)[5]	TBA[6]	TOTOX[7]
Raw milk[8]	$0.115^{f}\pm0.011$	$0.244^{f}\pm0.023$	$0.108^{f}\pm0.002$	$0.014^{d}\pm0.004$	$0.474^{f}\pm0.041$
Pasteurized milk[9] (85-90±1.0ºC, 2 min)	$0.337^{e}\pm0.020$	$0.503^{de}\pm0.009$	$0.110^{f}\pm0.011$	$0.016^{cd}\pm0.003$	$1.178^{d}\pm0.047$
Pasteurized milk[10] (85.0±1.0°C, 16 sec)	$0.234^{e}\pm0.095$	$0.327^{ef}\pm0.090$	$0.108^{f}\pm0.006$	$0.017^{cd}\pm0.0011$	$0.795^{e}\pm0.1277$
Yogurt	$0.342^{e}\pm0.009$	$0.455^{e}\pm0.011$	$0.125^{ef}\pm0.016$	$0.022^{cb}\pm0.002$	$1.139^{d}\pm0.172$
Labaneh produced by conventional method[11].	$0.377^{de}\pm0.027$	$0.473^{e}\pm0.046$	$0.162^{cd}\pm0.026$	$0.021^{bcd}\pm0.002$	$1.310^{cd}\pm0.101$
Labaneh produced by modern techniques[12].	$0.400^{cd}\pm.033$	$0.509^{de}\pm0.035$	$0.144^{de}\pm0.012$	$0.0165^{cd}\pm0.003$	$1.227^{d}\pm0.086$
Yogurt after 7 days storage	$0.417^{cd}\pm.022$	$0.628^{c}\pm0.080$	$0.132^{ef}\pm0.004$	$0.025^{b}\pm0.002$	$1.462^{c}\pm0.114$
Yogurt after 15 days storage	$0.819^{a}\pm0.028$	$1.080^{a}\pm0.130$	$0.368^{a}\pm0.033$	$0.086^{a}\pm0.011$	$2.717^{a}\pm0.178$
Labaneh produced by conventional method after 15 days storage	$0.698^{b}\pm0.075$	$0.767^{b}\pm0.040$	$0.258^{b}\pm0.025$	$0.021^{bcd}\pm0.007$	$2.162^{b}\pm0.120$
Labaneh produced by modern technique after 15 days storage	$0.687^{b}\pm0.042$	$0.768^{b}\pm0.110$	$0.170^{c}\pm0.013$	$0.020^{bcd}\pm0.005$	$2.142^{b}\pm0.082$

[1]Storage at 5.0±1.0ºC for 7 and 15 days (yogurt and labaneh, respectively). [2]Values represent means±SD (n = 4). Means with different letters within a column are significantly different ($p\leq0.05$) according to (ANOVA) Duncan's multiple range test. [3]Peroxide value (mEq of O_2/ kg of Fat). [4]p-Anisidine value. [5]Free fatty acid as (oleic acid). [6]Thiobarbituric acid value. [7]2× POV + PAV. [8,9,10]milk used in production of yogurt and labaneh. [11]Straining in cloth and produced from milk pasteurized at 85-90±1.0ºC for 2 min. [12]Straining by separators and produced from milk pasteurized at 85.0±1.0°C for 16 sec

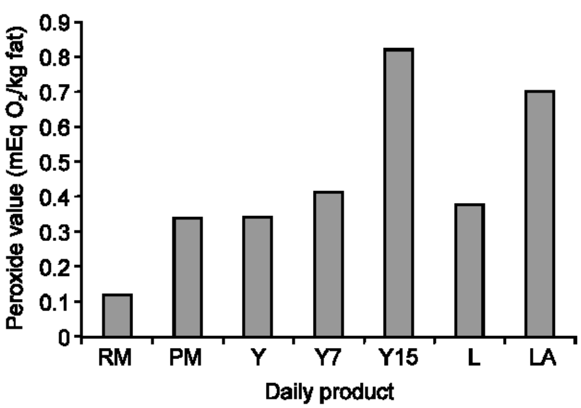

Fig. 2: Effect of processing and refrigerated storage of yogurt and labaneh on peroxide value (RM; raw milk, PM; pasteurized milk, Y; yogurt, Y7; yogurt stored for 7 days, Y15; yogurt stored for 15 days, L; labaneh cloth strained and LA; labaneh stored for 15 days)

On the other hand, refrigerated storage of yogurt for seven days and labaneh for 15 days caused a significant ($p<0.05$) increase in POV (as shown in Fig. 2) and in p-AV and Totox values as well. For example, the p-AV for yogurt and labaneh (cloth strained) were 0.455, 0.628 and 0.473, 0.767 before and after storage, respectively. It is worth to notice that the POV of labaneh strained in cloth had lower POV compared to that of labaneh strained by separator.

Furthermore, the oxidations parameters (POV,p-AV) in Table 3 show an increase of values for labaneh since separation and straining of the whey includes handling, which is necessarily, introduce air in the mass of labaneh. However, though significant differences were found after storage of labaneh for 15 days, the values of POV remained low when compared with max. limits set for butter (5 mEq O_2/kg fat) in Jordanian Standards (MIT, 1980) and high when compared to Indian standards [BIS, 2002) for the heat treated samples (< 0.8 mEq O_2/kg fat).

Influence of processing, heating methods and storage of white brined boiled cheese (Nabulsi) on lipid oxidation: Table 4 shows the effects of heating, processing and one-month storage of white brined boiled cheese (Nabulsi) on lipid oxidation. The results indicate that processing steps had no significant ($p>0.05$) effect on the values of measured lipid oxidation parameters. For example, the POV values for raw sheep milk, fresh curd and boiled cheese curd were 0.131, 0.134 and 0.137 mEq of O_2/kg fat, respectively. On the contrary, reheating of cheese (while dipped in water as some times practiced before consumption) was found to have a significant ($p<0.050$) effect on POV, p-AV, %FFA and TOTOX values. For instance, the POV values for boiled Nabulsi cheese and a microwave reheated cheese for 5 min were 0.137 and 0.449 mEq O_2/kg fat, respectively. This means that a microwave reheating of cheese increased the POV ca. 2.27 fold compared to that of boiled cheese. On the other hand, the reheating methods (boiling, micro waving) did not cause any significant differences on lipid oxidation among each other.

Table 4: Effect of heat treatment, processing conditions and storage[1] on chemical lipid changes of white brined cheese (Nabulsi)[2]

Treatment	POV[3]	PAV[4]	%FFA (OA)[5]	TBA[6]	TOTOX[7]
Raw sheep milk	0.131^{c}±0.005	0.250^{e}±0.009	0.107^{f}±0.005	0.013^{b}±0.003	0.512^{c}±0.011
Fresh curd	0.134^{c}±0.006	0.268^{e}±0.012	0.126^{f}±0.002	0.011^{b}±0.001	0.536^{c}±0.024
White brined boiled cheese[8]	0.137^{c}±0.003	0.265^{e}±0.026	0.167^{ef}±0.032	0.024^{b}±0.002	0.535^{c}±0.031
Boiled white brined cheese[9] reheated on gas cooker (96.3±1.0°C, 5min)	0.532^{b}±0.043	0.504^{cd}±0.104	0.257^{d}±0.019	0.021^{b}±0.009	1.568^{b}±0.182
White brined boiled cheese after one-month storage.	0.463^{b}±0.131	0.623^{c}±0.112	0.142^{ef}±0.023	0.016^{b}±0.002	1.549^{b}±0.09
White brined boiled cheese[10] reheated within a liquid in microwave oven. (94.3±1.0°C, 5min)	0.509^{b}±0.039	0.534^{cd}±0.062	0.301^{bcd}±0.224	0.021^{b}±0.005	1.551^{b}±0.118
White brined boiled cheese[11] reheated in microwave oven (94.3±1.0°C, 5min)	0.449^{b}±0.058	0.419^{d}±0.052	0.283^{cd}±0.032	0.026^{b}±0.003	1.317^{b}±0.169
White brined boiled cheese reheated in microwave oven after one-month (94.3±1.0°C, 5min)	0.546^{b}±0.021	0.508^{cd}±0.010	0.318^{bc}±0.011	0.017^{b}±0.008	1.600^{b}±0.052
White brined boiled cheese reheated within a liquid in microwave oven after one-month storage.	0.481^{b}±0.085	0.450^{d}±0.167	0.358^{b}±0.005	0.019^{b}±0.005	1.391^{b}±0.054
White brined boiled cheese reheated on gas cooker after one-month storage (94.3±1.0°C for 5min)	0.511^{b}±0.035	0.609^{c}±0.047	0.195^{e}±0.055	0.041^{b}±0.0033	1.631^{b}±0.122
White brined boiled cheese reheated in microwave oven[12] at 94.3±1.0°C, 10min.	1.704^{a}±0.216	1.960^{b}±0.113	0.542^{a}±0.092	0.105^{a}±0.009	5.369^{a}±0.168
White brined boiled cheese reheated in microwave oven 94.3±1.0°C for 10min after one-month storage.	1.780^{a}±0.141	2.162^{a}±0.216	0.597^{a}±0.076	0.079^{a}±0.010	5.370^{a}±0.234

White brined boiled cheese pieces stored in tins at room temperature of 18±1.0°C for one month.[2]Values represent means±SD (n = 4). Means with different letters within a column are significantly different ($p \leq 0.05$) according to (ANOVA)Duncan's multiple range test. [3]peroxide value (mEq of O_2/ kg Fat). [4]p-Anisidine value. [5]Free fatty acid (oleic acid). [6]2-thiobarbituric acid values. [7]2× POV + PAV. [8]White brined cheese pieces boiled in brine (17% NaCl) at 94.3±1.0°C measured at the centre of the cheese pieces for 5min. [9]Desalted grated white brined boiled cheese reheated in a liquid medium (distilled water). [10]Desalted grated white brined boiled cheese reheated in a liquid medium (distilled water) in microwave oven at 80% power. [11]Desalted grated white-brined boiled cheese reheated directly in microwave oven at 80% power. [12]White brined desalted grated cheese heated directly till browning of the cheese particles

However, reheating of the cheese without any liquid in a microwave oven for a longer time (10 min) resulted in a significant increase in the oxidation levels of the milk fat as shown in Fig. 3. For example, the p-AV values for a microwave reheated cheese for 5 and 10 min were 0.508 and 1.960, respectively. The effect of microwave heating time on lipid oxidation was found to be in agreement with the results obtained by Albi *et al.* (1997a,b), Yoshida and Kajimoto (1994) and Yoshida *et al.* (1991) who studied the effect of microwave heating on chemical and physical characteristics of vegetable oils.

The enhanced oxidation as a result of reheating may be attributed to the initiation of the oxidation process or by degradation (exhausting) of the protective components in the milk that have an antioxidant activity such as carotenoids. Moreover, reheating cause decomposition of fat globule membrane that release copper ions, which are known as active prooxidant. It has been often observed that butter oil is expelled out of Nabulsi cheese during heating specially by micro waving. It is obvious that this liberated oil is more susceptible to oxidation than that protected by globule membranes.

Storage of white brined cheese in cans covered with brine solution (17% NaCl) for one month at room temperature (18±1.0°C) after processing did not cause significant changes ($p>0.05$) in POV, p-AV and TOTOX values but do significantly affect the FFA% compared to freshly boiled cheese. However, reheating of the cheese after storage did not cause any significant changes in the oxidation parameters, with the exception of microwave reheating (for 10 min) which significantly ($p<0.05$) increase the oxidation levels. For example, the POV values for stored cheese and cheese reboiled on gas cooker after one month storage were 0.463 and

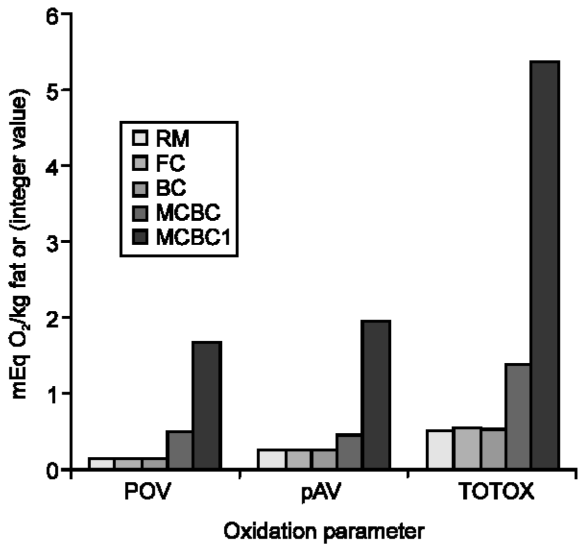

Fig. 3: Effect of heating time of white brined boiled (Nabulsi) cheese on POV (peroxide value), p-AV (paranisidine value) and totoxs value (RM; raw sheep milk, FC; fresh curd, BC; boiled curd, MCBC; microwave boiled cheese at 94.3±1.0°C for 5 min, MCBC1; microwave boiled cheese 94.3±1.0°C for 10 min)

0.511 mEq O_2/kg, respectively. Whereas, the POV value of the extracted lipids from microwaved Nabulsi cheese for 10 min was 1.704 against 1.780 mEq O_2/kg before and after storage respectively. Nevertheless, the increase in oxidation indicators (POV, p-AV) due to storage could be attributed to degradation of some cheese constituents that may release certain amino acids, which act as prooxidants (Nawar *et al.*, 1991). The degradation of Nabulsi cheese during storage is expected since growth of halophilic bacteria constitutes a real problem of its keeping ability (Herzallah, 1994).The relatively high increase in p-AV of stored and microwaved cheese for 10 min demonstrates the effect of severe micro waving in producing primary and secondary oxidation products. Strong browning of the cheese illustrates this severity. It is reminded that such changes often occur during baking and frying.

Conclusions: Various chemical changes were induced in lipids by heating dairy products may lead to organoleptic and heath problems. Milk and milk products are generally subjected to heat treatments, during processing and preparation that varies with the type of the product. The severity of the heat treatments (temperature, time and the energy level) of milk and milk products affects the extent of transformation and changes in the oxidation parameters of milk lipids. Thus, boiling or micro waving Nabulsi cheese for 5 minutes caused an increase in the POV of about three times, whereas, micro waving for 10 min increase POV 12 times compared to that of fresh curd. The latter increase may demonstrate the effect of water evaporation (dryness) due to excessive heating on the susceptibility of lipid oxidation. The oxidation level in UHT milk produced from milk powder (reconstituted milk) was significantly higher than those of UHT produced from fresh milk. This draws our attention towards unsuitability of the use of milk powder in the production of UHT milk (multi-heating effect).

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