Original Research Article

Physicochemical and sensory characteristics of cows' milk butter processed in Khartoum State, Sudan

ABSTRACT

Aims: This investigation was conducted to evaluate the physicochemical and sensory characteristics, fatty acid and cholesterol contents of butter processed in Khartoum State, Sudan.

Methodology: Butter was manufactured traditionally by farmers in Khartoum north (T1) and Omdurman (T2), in addition to butter manufactured commercially in a dairy plant (T3) and butter manufactured by researchers in the laboratory (T4). Physicochemical and sensory characteristics in addition to cholesterol level and free fatty acids profile were evaluated at 1, 15, 30, 45 and 60- day intervals for samples stored at 5.0±1.0℃, and at 1, 7, 14, 21 and 28-day intervals for samples stored at 25±2.0℃.

Results: The results showed high moisture, acidity and specific gravity in T1 (28.98%, 0.860% and 0.940 respectively), while fat, pH value and iodine index were high in T4 (82.5%, 4.53 and 29.00 mg I/100g, respectively) and solids-non-fat and melting point were high in T3 (2.01% and 28.32℃ respectively). The saponification index was high in T2 and T3 (200.00 and 201.00 mg KOH/g respectively). The fatty acids C6:0 – C18:0, C16:1, C18:1 – C18:3, C20:0 were detected in varying concentrations. The cholesterol content was high in butter of T4 (166.7 mg/100 g). Butter of T1 was best in flavor (8.43) and overall acceptability (9.00), while butter of T3 was best in texture and colour (8.86).

Conclusion: There were variations in physicochemical and sensory characteristics in addition to cholesterol level and fatty acids content of butter manufactured by different methods

Keywords: Butter, cholesterol, fatty acid, physicochemical, sensory

1. INTRODUCTION

Butter is defined as the product made exclusively from milk or cream or both, with or without addition of colouring material and containing not less than 80% by weight of milk fat and more than 400 fatty acids, of which 66% are saturated, 30% monounsaturated and 4% polyunsaturated [1]. Stage of lactation, diet, dietary supplementation, season of the year and diseases have an impact on the fatty acid composition of milk fat. Fermentation is one of the oldest food processing techniques in the world which has been adopted across generations and most of these techniques producing an inferior final product of low yield and stability and requiring high labour input. The availability of small scale processing techniques is the important factor at the traditional farmer level for manufacture of high quality dairy products with good characteristics [2, 3].

Traditional butter which is locally called *"zebda beladi*" is one of the products resulting from spontaneous fermentation and rich in fat. Churning is the most important step for butter making, during which the oil-in-water emulsion is broken, leading to an aqueous phase separation and formation of water-in-oil emulsion [4]. Despite the application of preventive measures during its production and distribution, traditional butter has a limited shelf-life, and the deterioration (oxidation) may be usually due to oxidation of unsaturated glycerides resulting in increased level of free fatly acids. Most of the knowledge about the traditional fermentation has not been documented, thus, it is in danger of being lost since technologies are evolving and families are forgetting about the traditional food preservation practices [5]. The quality of stored butter is governed by such factors as cream ripening, the manufacturing process, good hygienic practice during processing and handling, the storage temperature and the type of animal feeding [6].

Lipid oxidation includes fatty acid oxidation which generates compounds that affect food quality and even nutrition and food safety. Oxidative rancidity or autoxidation cannot be stooped by lowering temperature of storage since it is a chemical reaction with low activation energy. Research concerning oxidative deterioration has been pursued for many years but it has been given a boost by recognition that such oxidation can cause damage to cell membranes and DNA which may be involved in aging process and cancer [7, 8]. Butter is prized for its rich flavor; many of compounds that play a role in characteristics of flavor of butter have been identified although there is currently no chemical mixture that has been able to replace the aroma of butter [9]. Diacetyl, lactones, short chain fatty acids, lipid-derived aldehydes and dimethyl sulfide are the components responsible for butter flavour. Sensory analysis has been employed as a method to evaluate the acceptable butter flavour. Previous studies have relied on grading and product shelf life to compare products or evaluate quality of butter and margarine and spread products [10].

In the traditional method, raw milk is left at room temperature (25±2ºC) until coagulation takes place after 18 hr. During the gelation step, the product is called "*laben rayeb*", which is separated by churning into an aqueous fraction "*rob*" and fat fraction "*furssah*". The containers used for fermentation and churning are the "*si'in*" and the *bukhssa*". The former is a leather bag from whole goat or sheep skin, while the latter is a large gourd with a lidded narrow mouth [11]. Due to the complexity steps to obtain butter products and for different processing methods used in manufacture of butter in Sudan, it is necessary to have accurate physicochemical evaluation and sensory characteristics that determine the quality and acceptability of the butter. This study was conducted to evaluate the physicochemical and sensory characteristics of butter produced traditionally and commercially in Khartoum State, Sudan.

2. MATERIALS AND METHODS

2.1 Butter manufacture

2.1.1 Butter traditionally manufactured by dairy farmers in Khartoum North and Omdurman (T1 and T2 respectively)

Raw milk was left at room temperature (25±2°C) overnight to coagulate and convert into "*laben rayeb*". Next morning *"laben rayeb*" was churned in a skin bag from goat called "*siin*" until the coalescence of fat globules was formed indicating the conversion of milk into butter "*furssa*h" and a by-product called *"rob*". Butter "*furssah*" was stored at 4°C till analysis.

2.1.2 Butter commercially manufactured in a dairy plant (T3)

Sweet cream obtained by cream separation of fresh milk (30% fat) was cooled at 4ºC till used. The cream was pasteurized at 82ºC for 30 min, cooled to 10ºC and held at this temperature for two hours (sometimes overnight) before working into butter. The cream temperature was adjusted to 11.6ºC and churning was started by filling the churn with ⅔ volume followed by addition of cold water, and churning was continued until granules were formed. Butter was washed with cold water for 5 min, repeating the washing twice, then the washed water was drained off and butter was wrapped, weighed, packed and stored at 4°C till analysis.

2.1.3 Butter manufactured by the investigators (T4)

Butter was manufactured in the dairy processing laboratory, Department of Dairy Production, Faculty of Animal Production, University of Khartoum. Raw milk was obtained from the University of Khartoum dairy farm. After fat determination, milk was warmed to 40ºC and the cream was separated by hand separator. The cream obtained was analyzed for fat content and kept overnight in the refrigerator (4ºC). Next morning the cream was churned at 12ºC by hand churner till whipped cream became coarser and semi-solid butter granules were formed that rapidly increased in size and separated sharply from the liquid buttermilk. Butter was washed with cold water several times and the excess water was removed. Butter was filled in sterile disposable polyethylene bags and stored at 4°C till analysis.

2.2 Sample preparation

To ensure uniform distribution of water, the samples were warmed in unopened airtight containers in a water bath at 35ºC, agitated to facilitate melting and the test sample was thoroughly mixed to a homogeneous form.

2.3 Sample analysis

Physicochemical (moisture, fat, solids-non-fat (SNF), pH, acidity, specific gravity, melting point, iodine index, saponification index, fatty acid composition, cholesterol content) and sensory characteristics (colour, flavour, texture, overall acceptability) were determined at the end of storage period of 60 days.

2.4 Physicochemical composition

The fat, moisture, SNF and acidity were determined according to AOAC [12]. Melting point, iodine index, saponification index and specific gravity were determined according to FSSAI [13]. Fatty acids were determined by gas chromatography (Shimadzu 8A equipped with flame ionization detector) according to the method described by Radwan [14]. Cholesterol content was determined by an enzymatic method for the determination of total serum cholesterol [15].

2.5 Sensory evaluation of butter

Butter samples were subjected to descriptive sensory analysis using the 9-point hedonic scale [16], where 9 = excellent, 8 = very good, 7 = good, 6 = slightly good, 5 = fair, 4 = poor, 3 = slightly poor, 2 = very poor, 1= extremely poor. Fourteen panelists were chosen to evaluate butter samples for colour, texture, flavour and overall acceptability.

2.6 Statistical analyses

The data were subjected to descriptive statistical analysis using Statistical Analysis Systems (SAS, ver. 9). One-way randomized complete design was used for physicochemical analysis, fatty acid profile, cholesterol content and sensory analysis. Means were separated by Duncan multiple range test at $P \leq 0.05$.

3. RESULTS AND DISCUSSION

3.1 Physicochemical properties of butter samples

There was a significant ($P<0.05$) effect of treatment on the physicochemical properties of butter (Table 1). The highest fat content (82.50%) was found in butter manufactured by researchers in the laboratory (T4), while the lowest fat content (69.75%) was found in traditional farms in Khartoum North (T1). The content of fat in butter obtained from traditional farms in Khartoum north, Sudan is higher than those reported by Samet-Bali et al. [17] who found that fat content of traditional Tunisian butter was 65.70±2.16%. The moisture content ranged between 28.98% in T1 and 16.77% in T4. The moisture is higher in the traditional butter than the limits established for industrial butter. These findings are in agreement with previous studies [18, 19], and lower than those reported by Kacem and Karam [20]. SNF content of butter was as high as 2.01±0.01% in T3 and as low as 0.90% in T4. The results of T1, T2 and T4 are lower than those reported by Makawi [22] who indicated that, the average solids-non-fat content was 2.04%, while the results of T3 are similar to Makawi [21]. Butter in T3 and T4 was less acidic (0.280%) than the other treatments (0.860% and 0.595% for T1 and T2 respectively). The results in this study are in agreement with the findings of Kacem and Karam [20] who reported the titratable acidity (TA) of butter to be 0.36-0.90%. Meshref [22] reported a TA value of 0.04% - 0.55% in cooking butter in Beni-Suef governorate, Egypt. In this study, the specific gravity of butter ranged between 0.900 in T2 and 0.940 in T1. The highest melting point was in butter from T3 (28.32℃), while the lowest value (27.44℃) was in T1. These values are in line with those reported by Asresie et al. [19] who reported values of 11.0±0.100 – 42.9±1.00℃ for butter made from camel milk alone and blending it with goat milk. Significantly ($P<0.05$) higher iodine index was found in T4 (29.00), while the lower index was in T2 (26.25 mg I /100 g). The results of this study are lower than those obtained by Idoui et al. [18] who reported a value of 35.35 - 48.33 mg I/100 g in traditional Algerian butter from cow milk, and Idoui et al. [23] who reported a value of 37.17 – 85.95 mg I /100 g in Algerian traditional butter from goat milk. However, the results in this study are higher than those reported by Rady and Bader [24] who reported that the iodine index of cow's butter samples was 24.87-25.12 mg I /100 g, and that the value was not altered neither by gamma irradiation nor cold storage. The saponification index of butter was significantly ($P<0.01$) higher (200.00 mg KOH/g) in T2 and lower (192.90 mg KOH/g) in T1. The results are in accordance with those reported by Idoui et al. [18, 23] for traditional Algerian butter from cows and goats respectively.

3.2 Free fatty acid profile

Butter samples from all treatments were subjected to gas chromatography and lipids resolved were determined to their constituent's fatty acids. The results showed that 12 fatty acids were identified; $C_{6:0}$, $C_{8:0}$, $C_{10:0}$, $C_{6:14}$, $C_{14:0}$, $C_{16:0}$, $C_{16:1}$, $C_{18:0}$, $C_{18:1}$, $C_{18:2}$, $C_{18:3}$ and $C_{20:0}$ (Table 2). Total saturated fatty acids (SFA%) are 55.81, 57.68, 56.28 and 56.03, while total mono and poly unsaturated fatty acids (MUFA+PUFA%) are 44.19, 42.31, 43.72 and 43.97 for T1, T2, T3 and T4 respectively. Important differences were found in fatty acids composition among butter samples, which contained a high percentage of saturated fatty acids (SFA), with the palmitic acid being the major (21.12-24.23%) followed by stearic acid (11.93-14.66%) and myristic acid (9.61-10.06%). These results are in line with those reported by Rady and Bader [24] who reported that, palmitic acid was the major SFA (22.81%) in butter followed by stearic acid (10.21%). Idoui et al. [18] reported that traditional cows' butter contained a high percentage of SFA and palmitic acid was the major SFA (24.33-36.95%) followed by myristic acid (18.49-27.35%) and stearic acid (7.68-14.05%). The predominance of palmitic acid in butter milk fat was also reported in previous studies [18, 23]. In a study conducted by Ito et al. [25], it was found that heated butter contained 27.06% palmitic. Oleic acid was the predominant mono-unsaturated fatty acid (34.16-35.41%). Total saturated fatty acids in this study were higher than those reported by Rady and Bader [24], while total unsaturated FA was lower. Butyric acid ($C_{4:0}$) is the most prevalent short-chain fatty acid and often identified with butter due to its characteristics impact on flavour. In this study, butyric acid was not identified, probably due to its volatility. Some of the fatty acids such as caproic, caprylic, capric, lauric, palmitoleic, linoleic, linolenic and arachidic were present in samples from all treatments.

3.3 Cholesterol content

Cholesterol content was significantly affected by the source of butter samples, being higher (166.7 mg/100g) in T4 and lower (136.7 mg/100g) in T2 (Table 3). Cholesterol is indispensable for life, it serves to build and maintain the membranes that surround the cells, and it is necessary for the synthesis of some hormones especially sexual ones. It also contributes in producing biliary acid that plays a role in digestion of fat, in addition to contributing in biosynthesis of vitamin D [26]. Milk and milk products play an important part in healthy diet as they contribute to intake of essential nutrients and protein of a high nutritional quality. However, due to high content of cholesterol raising saturated fatty acids (SFA) in milk fat, decrease in the intake of fat-rich dairy products is recommended, although there is no doubt that mixture of long-chain saturated fatty acids in milk increases plasma cholesterol [27]. Rady and Badr [24] reported that cholesterol is the only sterol compound showing a slight decrease upon the application of accident doses γ-rays which may be attributed to partial slight oxidation.

3.4 Sensory evaluation

Flavour of butter samples in T1 significantly scored the highest (8.43), while samples in T4 scored the lowest (7.43). However, the samples in T3 had the best texture (8.86) followed by samples in T1, T2 and T4 respectively. The colour of samples in T3 was the best (8.86) and the colour of samples in T2 as the worst (6.28). Overall, butter samples in T1 were highly acceptable (9.0), while samples in T2 were the least acceptable (8.43) (Table 4). In this study, the greatest difference was observed for colour, ranging from 6.28 to 8.86. The butter samples after storage were highly accepted by descriptive analysis and this is in agreement with Krause et al. [28] who reported that, for optimum quality, butter quainter should be refrigerated for at least 6 months; but when frozen at -20 ^{0}C, stick can be stored up to 2 years, and for bulk butter in refrigerated containers, flavor quality is maintained for at least 9 months. Fernandes et al. [29] reported that the color of butter is not only determined by the level of carotene in the milk fat, but also by the size distribution of water droplets, and the finer the droplets, the greater the scattering of the light, and therefore the lighter the colour of the butter. Several studies revealed that, although texture changes with milk fatty acid composition, the effect on flavour is not significant [24, 31]. Rady and Bader [24] reported that, mean scores of colour and appearance of cow's butter samples was found as well as flavor (including aroma, taste and texture). Post-treatment and upon refrigeration storage, it is obvious that gamma irradiation had no adverse effect on the sensory quality attributes of butter [24].

4. CONCLUSION

From the results obtained, it could be concluded that, the general perquisites for high quality butter are influenced by the different methods of manufacturing cow's milk butter in Sudan. The desirable flavour and overall acceptability in terms of sensory properties and high content of unsaturated fatty acids is the major feature of butter manufacture by the traditional methods. This could highlight the role of this section to provide a good quality butter for consumers in Sudan.

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Table 1. Physicochemical characteristics of cow's milk butter manufactured in Khartoum state, Sudan

Physicochemical characteristics	**Treatment[1]**				**CV**	**SE**	***p***
	T1	**T2**	**T3**	**T4**			
Fat (%)	69.75^{c}	70.72^{c}	79.80^{b}	82.50^{a}	0.17	0.0454	0.0409
Moisture (%)	28.98^{a}	28.20^{a}	18.19^{b}	16.77^{c}	1.37	0.0225	0.0112
Solids-non-fat (%)	1.27^{b}	1.07^{c}	2.01^{a}	0.90^{d}	8.94	0.0683	0.0234
Acidity (% lactic acid)	0.860^{a}	0.595^{b}	0.280^{c}	0.280^{c}	2.15	0.0002	0.0221
Specific gravity	0.940^{a}	0.900^{c}	0.910^{b}	0.903^{c}	1.04	0.0002	0.0195
pH value	4.36^{b}	4.30^{c}	4.33^{c}	4.53^{a}	0.22	0.0002	0.0432
Melting point (°C)	27.44^{c}	28.08^{b}	28.32^{a}	27.50^{c}	0.15	0.0258	0.0334
Iodine index (mg I/100g)	27.12^{b}	26.25^{c}	27.00^{b}	29.00^{a}	2.94	0.4715	0.0020
Saponification index (mgKOH/g)	192.90^{c}	200.00^{a}	198.00^{b}	201.00^{a}	0.41	0.4715	0.0290

Means in each row bearing similar superscripts are not significantly different (P>0.05)
** = P<0.01
* =P<0.05
CV = Coefficient of variation (%)
SE =Standard error of means
SL = Significance level
[1] Treatments 1, 2, 3 and 4 refer to butter manufactured in Khartoum North, Omdurman, the dairy plant and the laboratory respectively

Table 2. Fatty acid profile (%) of cow's milk butter manufactured in Khartoum state, Sudan

Fatty acid	Symbol	Treatment[1]				CV	SE	*p*
		T1	T2	T3	T4			
Caproic	C6:0	1.355^{b}	1.627^{a}	1.305^{b}	1.500^{ab}	8.16	0.0683	0.0212
Caprylic	C8:0	1.882^{d}	1.996^{c}	1.677^{e}	2.250^{a}	1.96	0.0182	0.0442
Capric	C10:0	4.378^{bc}	4.368^{bc}	3.914^{cd}	3.666^{d}	5.68	0.1494	0.0409
Lauric	C12:0	3.116^{b}	3.308^{b}	2.982^{b}	3.000^{b}	12.55	0.2588	0.0329
Myristic	C14:0	9.61^{a}	9.59^{a}	10 .06^{a}	9.50^{a}	3.27	0.1713	0.0449
Palmitic	C16:0	21.74^{bc}	22.05^{b}	24.23^{a}	21.12^{cd}	2.36	0.2834	0.0119
Palmitoleic	C16:1	3.564^{b}	3.229^{c}	2.795^{d}	3.749^{b}	4.44	0.0948	0.0129
Stearic	C18:0	13.53^{b}	14.60^{b}	11.93^{c}	14.66^{b}	5.24	0.4367	0.0385
Oleic	C18:1	34.49^{ab}	34.38^{ab}	35.41^{a}	34.16^{ab}	2.11	0.4054	0.0299
Linoleic	C18:2	5.755^{b}	4.299^{d}	5.143^{bc}	5.557^{b}	6.08	0.2244	0.0400
Linolenic	C18:3	0.3727^{c}	0.4040^{c}	0.3730^{c}	0.5000^{b}	5.56	0.0182	0.0291
Arachidic	C20:0	0.1893^{d}	0.1643^{f}	0.1860^{e}	0.3330^{b}	4.25	0.0001	0.0333
Total saturated	-	55.81^{b}	57.68^{a}	56.28^{b}	56.03^{b}	0.93	0.3028	0.0400
Total unsaturated	-	44.19^{b}	42.31^{c}	43.72^{b}	43.97^{b}	1.21	0.3055	0.0126

Means in each column (capital letter) and row (small letter) bearing similar superscripts are not significantly different (P>0.05).

* = P<0.05
CV = Coefficient of variation (%)
SL = Level of significance
SE =Standard error of means

[1] Treatments 1, 2, 3 and 4 refer to butter manufactured in Khartoum North, Omdurman, the dairy plant and the laboratory respectively

Table 3. Cholesterol content of cow's milk butter manufactured in Khartoum state, Sudan

Treatment[1]	Cholesterol content (mg/100g)
T1	146.7[c]
T2	136.7[e]
T3	142.0[d]
T4	166.7[b]
CV (%)	6.97
LS	0.0081
SE	0.3978

Means in column bearing similar superscripts are not significantly different (P>0.05).
** = P<0.01
CV = Coefficient of variation
LS = Level of significance
SE = Standard error of means
[1] Treatments 1, 2, 3 and 4 refer to butter manufactured in Khartoum North, Omdurman, the dairy plant and the laboratory respectively

Table 4. Sensory evaluation of cow's milk butter manufactured in Khartoum state, Sudan

Treatment[1]	Sensory attributes			
	Flavour	**Texture**	**Colour**	**Overall acceptability**
T1	8.43[a]	8.43[b]	6.57[d]	9.00[a]
T2	7.85[b]	8.14[c]	6.28[e]	8.43[c]
T3	8.14[ab]	8.86[a]	8.86[a]	8.71[b]
T4	7.43[c]	6.71[d]	8.57[b]	8.71[b]
CV (%)	5.49	4.87	5.08	5.34
LS	0.0236	0.0443	0.0376	0.0165
SE	0.0831	0.0532	0.0429	0.0576

Means in each column bearing similar superscripts are not significantly different (P>0.05).
* = P<0.05
CV = Coefficient of variation
LS = Level of significance
SE = Standard error of means
[1] Treatments 1, 2, 3 and 4 refer to butter manufactured in Khartoum North, Omdurman, the dairy plant and the laboratory respectively