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Characteristics and fatty acid composition of milk fat from Saudi Aradi goat

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SUMMARY: Goat milk is the second most prevalent edible milk in Saudi Arabia and is one of the most prominently produced milks in the world. Few studies have focused on the physicochemical properties of goat milk fat (GMF). Samples of Saudi Aradi goat milk were obtained during the spring dairy season to determine the physicochemical characteristics and fatty acid composition of the GMF. The physicochemical properties of Saudi Aradi GMF were as follows: iodine value, 23.2 g of $I_2 \cdot 100\ g^{-1}$ of fat; saponification value, 213.2 mg $KOH \cdot g^{-1}$ of fat; refractive index (25 °C), 1.4583; unsaponifiable matter, 0.54%; acidity, 0.52%; and peroxide value, 2.07 meq $O_2 \cdot kg^{-1}$ of fat. α-Tocopherol was the major tocol (70.9%), followed by β-tocopherol (22.02%). GMF had significant contents of polyunsaturated fatty acid (FA) (6.16%), conjugated linolenic acid (0.36%), saturated FA (67.04%) and branched FA (1.98%). The thermal profiles of the Saudi Aradi GMF samples were examined using a thermal gravimetric analysis (TGA) and differential scanning calorimetry (DSC). Saudi Aradi GMF showed some absorbance in the UV-C range. This study demonstrated that the milk fat from the Saudi goat has physically and chemically favorable properties, as well as good nutritional properties, as a source of essential fatty acids and fat-soluble vitamin E.

KEYWORDS: *Fatty acids; Goat milk fat; Physicochemical properties; Thermal analysis*

RESUMEN: ***Características y composición en ácidos grasos de la grasa láctea de cabras de Arabia Saudí***. La leche de cabra es la segunda leche comestible predominante en Arabia Saudí y es una de las leches de mayor producción en el mundo. Pocos estudios se han centrado en las propiedades físico-químicas de la grasa de leche de cabra (GLC). Muestras de leche de cabra Arabia Saudí fueron obtenidas durante la temporada de mayor producción lechera, durante la primavera, y se determinaron sus características físico-químicas y la composición de ácidos grasos de la GLC. Las propiedades fisicoquímicas determinadas de la GLC de Arabia Aradi fueron las siguientes: índice de yodo, 23,2 g de $I_2 \cdot 100\ g^{-1}$ de grasa; índice de saponificación: 213,2 mg de $KOH \cdot g^{-1}$ de grasa; índice de refracción a 25 °C: 1.4583; insaponificable: 0,54%; acidez: 0,52%; y el índice de peróxidos, 2,07 meq $O_2 \cdot kg^{-1}$ de grasa. α-tocoferol fue el principal tocol (70,9%), seguido de β- tocoferol (22,02%). La GLC tiene un contenido significativo de ácidos grasos poliinsaturados (FA) (6,16%), ácido linoleico conjugado (0,36%), ácidos grasos saturados (67,04%) y ácidos grasos ramificados (1,98%). Los perfiles térmicos de las muestras de GLC de Arabia Aradi fueron examinados utilizando análisis térmico gravimétrico (ATG) y calorimetría diferencial de barrido (CDB). La GLC de Arabia Aradi mostró cierta absorbancia en el rango UV-C. Este estudio demostró que la grasa de la leche de la cabra de Arabia tiene propiedades física y químicamente favorables, así como buenas propiedades nutricionales, como fuente de ácidos grasos esenciales y vitamina E liposoluble.

PALABRAS CLAVE: *Ácidos grasos; Análisis térmico; Grasa de leche de cabra; Propiedades fisicoquímicas*

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1. INTRODUCTION

Goats were among the first farm animals to be domesticated. They are among the most important providers of essential foods in the form of meat and dairy products worldwide. Goats have been raised in various areas of the world and are well known for their high ability to adapt to tropical and subtropical regions, especially in the arid regions. In Saudi Arabia, where the climate is suitable for goats, the number of these animals is approximately 2.2 million (Aziz and Al-Hur, 2013). Najdi, Harri and Aradi goat breeds are among the most widely spread goat breeds in Saudi Arabia (Sabir *et al*., 2013) and Aradi goats are the most desirable goats and are widely existing in the western region and the southern part of the Kingdom.

Goat milk is considered a useful alternative for infants and adults who are sensitive or allergic to cow milk (Park, 1994; Fabre, 1997; Sabbah *et al*., 1997). Goat milk is also recognized for its high therapeutic and nutritional value because of its relatively elevated levels of caproic, caprylic, capric and medium-chain fatty acids, which have been used for the treatment of a variety of malabsorption syndromes (Park, 1994; Alférez *et al*., 2001), and because of its smaller fat globule size, which makes goat milk more easily digestible than cow milk (Jandal, 1996).

Saudi goat milk is drunk directly after boiling, or made into yogurt, or made into ghee, or cheese. In modern industry, goat milk is converted to several economic products with high nutritional value, including pasteurized milk, yoghurt, cheese, cream, butter and milk powder.

Fat is one of the most important components in the technological and nutritional quality of goat milk. Goat milk fat is more digestible (Alferez *et al*., 2001; Haenlein, 2001) and may be considered an excellent source of energy for use in various metabolic processes (Boza and Sanz Sampelayo, 1997; Ceballos *et al*., 2009), even for combating metabolic diseases (Ceballos *et al*., 2009).

Shingfield *et al*. (2008) reported that lipid and fatty acid compounds are deemed to be positive or negative factors with respect to the health of human consumers. This consideration supports the interest in studying the characteristics and fatty acid composition of goat milk fat.

The present study aimed at evaluating the physicochemical characteristics of Saudi Aradi goat milk fat, which is widely used in the Kingdom of Saudi Arabia. A detailed analysis of its important parameters, such as iodine value, saponification value, peroxide value, kinematic viscosity, specific gravity, and acid value, wa conducted. Furthermore, a study of the thermal stability and the UV/visible spectrum of the goat milk fat was conducted. These results may allow a better understanding of this milk fat and thus the possible uses of it.

2. MATERIALS AND METHODS

2.1. Milk collection and sample preparation

Raw goat milk was obtained in April from a local farm in Qurayyat, Al Jawf province, northern Saudi Arabia. The collected goat milk used in the present study is a mixture of the milks produced by 10 Saudi Aradi goats during their lactating season (after their first kidding). The milk yields for the Aaradi goats during lactation were 1000±100 g·day^{-1}. The goats were kept under identical conditions of feeding and management. They were ear-tagged and housed in a semi-shaded, open-front barn and fed on a commercial concentrate and alfalfa hay. The amounts of concentrate and alfalfa hay were calculated according to the nutritional requirements for goats depending on the animals' ages and production status (NRC, 1985). Water, straw, salt and minerals supplemented in the blocks were freely available to all goats. To perform an analysis of the fatty acid composition of the Aradi goat milk, three milk samples were collected during two weeks, at three different times from the end of March until mid-April. Each sample contained three liters of goat milk. The milk samples were centrifuged at 1000 rpm for a duration of four minutes, and afterwards, the floating globules were collected. This portion consisted of fat matter appropriately extracted from raw goat milk. The resulting fat was melted at 70 °C and filtered through a Whatman filter paper no. 2 (W&R Balston Ltd., England). The yellow extracted fat was stored at −20 °C during the experimental period.

2.2. Analytical methods

The analyses were conducted in triplicate. The values of different parameters were expressed as the means±standard deviation (x±S.D.).

2.2.1. Physicochemical properties

The International Organization for Standardization (ISO) standards were used to determine the peroxide value (ISO, 2001), acidity (the percentage of free fatty acids was calculated as the oleic acid) (ISO, 1996), saponification value (ISO, 2002) and amount of unsaponified matter (ISO, 2000) of the GMF. The refractive index of the GMF was determined using an Abbe refractometer (Bellingham and Stanley, Ltd., Kent, England). The kinematic viscosity was determined using an Ubbelohde-type size 2 viscometer (Koehler, Bohemia, New York, USA). The melting point of the GMF was measured using a Stuart SMP 11 melting point apparatus (Bibby Scientific, Staffordshire, UK). UV spectra of the 0.01%, 1%, and 10% (v/v) fats in hexane were measured at 200–290, 290–400, and 400–800 nm, respectively, using a UVmini-1240 spectrophotometer (Shimadzu, Kyoto, Japan). The theoretical iodine value was calculated using the average molecular weight and the absolute number of double bonds obtained from the ^{1}H NMR spectrum (Nehdi *et al*., 2013). The ^{1}H NMR analyses were performed using a JEOL ESC 400 MHz spectrometer equipped with 5-mm BBO probes at 7.05 T. Deuterated chloroform ($CDCl_3$) and trimethylsilane (TMS) were used as the solvent and internal standard, respectively. Chlorophyll and carotenoid contents were determined spectrophotometrically using a method described by Allalout *et al*. (2009).

2.2.2. Infrared analysis

The infrared spectra were recorded on a Bruker Tensor 27 FT-IR spectrometer interfaced to a personal computer operating under Opus 6.5 Software (Bruker, Rheinstetten, Germany). The spectrum was obtained through the horizontal attenuated total reflectance (ATR) technique using a removable ZnSe crystal. The samples were dissolved in CCl_4, and the spectrum was obtained over 64 scans with a spectrum resolution of 4 cm^{-1}. Three spectra in the region of 4000–400 cm^{-1} were collected, and the averaged spectrum was plotted as a percent transmittance curve versus wavenumbers.

The assignments of bands to a specific functional group vibration mode were performed by comparison with previous studies of seed oils.

2.2.3. Fatty acid composition

The analysis of the total fatty acid composition of GMF was performed using standard techniques and reagents. The GMF samples were saponified and methylated, as reported by Nehdi *et al*. (2013). Fatty acid methyl esters were obtained by adding 1 mL hexane and 200 μL of 2 M sodium methoxide to 40 mg oil. The mixture was heated in a water bath at 50 °C for a few seconds, and then 200 μL of 2 M HCl were added. A 1-μL aliquot of the top layer was used for analysis. The identification and quantification of fatty acids were performed using a gas chromatography-mass spectrometry (GCMS-QP2010, Shimadzu, Kyoto, Japan) Ultra instrument and an Rtx-1 column (30 m×0.25 mm i.d., 0.25 μm film thickness) with helium as the carrier gas at a flow rate of 1.41 mL·min^{-1}. The oven temperature was increased from 150 to 180 °C at a rate of 15 °C·min^{-1}, followed by an increase to 210 °C at 1 °C·min^{-1}. The temperatures of the injector and detector were 220 °C and 275 °C, respectively. For GC/MS detection, an electron ionization system with an ionization energy of 70 eV was used. The ion source temperature was 230 °C, and the interface temperature was 280 °C. The components were identified by comparing their relative retention times and mass spectra with those of standards (main components) using the Wiley 8 library data of the main system.

The relative percentages of the individual fatty acids were calculated based on the ratios of the peak areas of the fatty acid species to the total peak area of all the fatty acids in the fat sample.

2.2.4. Tocol composition

The tocols in the GMF were analyzed via high-performance liquid chromatography (HPLC) according to the ISO, 2006 standard. The HPLC system was equipped with a Shimadzu LC-20AT pump (Shimadzu, Kyoto, Japan), a Shimadzu-RF 20A fluorescence detector (at excitation and emission wavelengths of 295 and 330 nm, respectively), and a Rheodine 7725(i) manual injector (Rohnert Park, USA). The tocols were separated on a normal-phase column (Hypersil silica, 15 cm×3 mm I.D., 3-μm particle size; Thermo scientific) with a mobile-phase flow rate of 0.5 mL·min^{-1} at ambient temperature. The mobile phase was a mixture of n-hexane:isopropanol (99.5:0.5) (v/v). The data were integrated and analyzed using Shimadzu's LC solution software. A 0.5 g GMF sample was diluted with 25 ml of hexane, and 20 μL of the diluted sample were injected into the column. A mixture of standard alpha, beta, gamma, and delta tocopherol and tocotrienol isomers (Sigma Chemical Co., St. Louis, Mo., U.S.A.) was dissolved in hexane at 2 μg·mL^{-1}, and aliquots were used to identify and quantify the peaks. The tocopherol quantity in the extracts was calculated in mg tocopherols per 100 g fat sample.

2.2.5. Thermal analysis

The thermal properties were evaluated using a thermal balance (TGA-50, Shimadzu, Kyoto, Japan) under an air atmosphere (100 mL·min^{-1}) using alumina crucibles in non-isothermal conditions. The thermogravimetric (TG) and first derivative thermogravimetric (DTG) curves were obtained using a sample mass of 5.0±0.5 mg, heating rate of 10 °C·min^{-1}, and temperature range of 25–600 °C. The Shimadzu TA-60 WS (2.20) software was used to analyze the data from the three independent measurements and to obtain the TG/DTG curves.

2.2.6. Differential scanning calorimetry

DSC curves were measured with a Shimadzu DSC-60 differential scanning calorimeter (Shimadzu, Kyoto, Japan) that had been previously calibrated with indium. Samples weighing between 10 and 12 mg were packed in aluminum DSC pans before being placed in the DSC cell. The samples were subjected to the following temperature program: 100 °C isotherm for 1 min, cooled to −100 °C at a rate of 20 °C·min^{-1}, and held for 1 min. The same sample was then heated from −100 °C to 100 °C at the same rate. The samples were cooled and heated under a constant flow of nitrogen (99.9999% purity).

3. RESULTS AND DISCUSSION

3.1. The physicochemical properties of GMF

The results of the physico-chemical analysis of the Saudi Aradi GMF are presented in Table 1. The fat content of the studied goat milk was approximately 4.2% (w/w). The studied GMF presents a yellow color. The color of GMF is mainly related to the presence of chlorophylls and carotenoids, which also provide oxidation protection in the dark. As shown in Table 1, chlorophylls and carotenoids comprised 2.88 and 1.31 mg·kg^{-1} of the GMF, respectively.

TABLE 1. Physicochemical properties, chlorophylls, carotenoids and Tocopherol compositions of Saudi Aradi goat milk fat

Physicochemical parameters	Unit	Goat milk fat
Color		yellow
State at ambient temperature		Solid
Melting point	°C	35–36
Milk fat content	% (w/w)	4.2±0.2
Refractive index (40 °C)		1.4583±0.06
Kinematic viscosity (40 °C)	mm^2·s^{-1}	25.8±0.52
Unsaponifiable matter	(%, w/w)	0.54±0.02
Saponification value	mg KOH·g^{-1} fat	213.2±2.6
Peroxide value	meq O_2·kg^{-1} fat	2.07±0.1
Free fatty acid	as oleic %	0.52±0.02
Acid value	mg KOH·g^{-1}	1.04±0.04
Iodine number	g·100 g^{-1} fat	23.2
Molecular weight	g·mol^{-1}	789.36
Chlorophylls	mg·kg^{-1}	2.88±0.09
Carotenoids	mg·kg^{-1}	1.31±0.06
Tocopherols	mg·100 g^{-1}	%
α- Tocopherol	2.80±0.3	70.9±0.9
γ- Tocopherol	0.87±0.2	22.02±0.27
δ- Tocopherol	0.14±0.01	3.58±0.08
δ- Tocotrienol	0.14±0.01	3.48±0.08

The iodine value (23.2 g of I_2·100 g^{-1} fat) of the GMF was low due to its high content of saturated fatty acids (67.04%); it was low compared to buffalo milk fat (34–37) (Abd El-Aziz *et al*., 2012) but slightly higher than a previous value of goat milk (19–20) (Park *et al*., 2007). The saponification value of GMF was 213.2. This value is directly related to the mean molecular mass. The high saponification value is due to the presence of short- and medium-chain fatty acids (Table 2). The peroxide value of GMF was 2.07 meq O_2·kg^{-1}. Generally, fats with peroxide values of less than 10 meq O_2·kg^{-1} are considered safe for human consumption. The content of free fatty acids as a percentage of oleic acid was 0.52%. The kinematic viscosity of the GMF was 25.8 mm^2·s^{-1} and was lower compared to the kinematic viscosity of butter fat (42 mm^2·s^{-1}; 43 °C). The refractive index of GMF was 1.4583, which is approximately the same value found by Park *et al.* (2007) for goat milk.

Regarding vitamin E, four tocopherol isomers were identified and quantified. The mean levels of alpha-, delta-, and gamma-tocopherols and delta-tocotrienol for the samples were 2.8, 0.87, 0.14 and 0.14 mg·100 g^{-1} of GMF, respectively (Table 1). These values were higher than those found by Raynal-Ljutovac *et al.* (2008).

3.2. Fatty acid composition

The fatty acid composition of Saudi Aradi goat milk fat (GMF) is shown in Table 2. The results showed that GMF contained a lower percentage of saturated fatty acid (SFA) (67.15%). Alonso *et al.* (1999) reported that GMF contained 72.23% of SFA (Table 2). In human dietary trials, the consumption of novel milk products with reduced SFA proportions significantly lowered the total plasma cholesterol, and most of this decrease was noted in the low density lipoprotein cholesterol fraction (Cattaneo *et al.*, 2006). Saudi Aradi GMF contained a high amount of monounsaturated fatty acid (MUFA) (26.78%) and some polyunsaturated fatty acid (PUFA) (6.16%). MUFA and PUFA are useful in the prevention of cardiovascular diseases and some inflammatory disorders (Blasi *et al.*, 2008). Saudi GMF appears to be more favorable for human health than other milk fats. Caproic acid (C6:0) was the most abundant (1.29%) in the GMF samples compared with other short-chain fatty aicds (SCFAs). Capric acid (C10:0) was the main (5.97%) medium-chain fatty acid (MCFA) (Table 2). As in all GMF, palmitic acid (C16:0) was the most abundant SFA (31.7%), followed by myristic acid (C14:0; 9.04%) and stearic acid (C18:0; 8.81%). A lower proportion of myristic acid in milk fat appears to be favorable for human health because of its negative role in atherosclerosis (Pfeuffer and Schrezenemeir, 2000). Among the MUFAs, oleic acid (C18:1*c*9) showed a significantly higher content

TABLE 2. The fatty acid profile of goat milk fat (% of total fatty acids) from Saudi and Spain

	GMF (Saudi)	GMF (Spain)[a]
C4:0	1.2±0.06	2.18
C6:0	1.29±0.06	2.39
C8:0	1.56±0.07	2.73
C9:0	0.07±0.01	Nd
C10:1	1.66±0.08	0.24
C10:0	5.97±0.3	9.97
C11:0	0.12±0.01	Nd
C12:1	0.66±0.03	0.19
C12:0	2.77±0.14	4.99
C13:0	0.12±0.01	0.15
C14:1*c*9	0.14±0.01	0.18
C14:0	9.04±0.45	9.81
anteiso-C15:0	0.12±0.01	0.21
iso-C15:0	0.37±0.02	0.13
C15:0	1.04±0.05	0.71
iso-C16:0	0.29±0.01	0.24
C16:1*t*7	0.28±0.01	1.59
C16:1*c*9	0.82±0.04	
C16:1*t*11	0.2±0.01	
C16:0	31.7±0.8	28.2
anteiso-C17:0	0.33±0.02	0.42
iso-C17:0	0.87±0.04	0.34
C17:0	0.63±0.03	0.72
C18:2*c*9,*c*12	3.73±0.2	3.19
C18:3*c*9,*c*12,*c*15	1.87±0.09	0.42
C18:1*c*9	18.53±0.46	19.3
C18:1*t*8	1.38±0.07	
C18:1*t*9	1.5±0.07	
C18:1*t*10	0.22±0.01	
C18:1*t*11	0.21±0.01	
C18:1*t*12	0.15±0.01	
C18:0	8.81±0.4	8.88
C18:2*c*9,11*t*	0.33±0.02	0.7
C18:2*t*9,11*t*	0.03±0.02	
C20:4*c*5,*c*8,*c*11,*c*14	0.19±0.01	Nd
C20:1*c*11	1±0.04	Nd
C20:0	0.63±0.03	0.15
C22:1*c*13	0.24±0.01	Nd
C22:0	0.07±0.01	Nd

[a]Park *et al.* (2007); Nd: not detected; SCFA: short chain fatty acids (C4-C6); MCFA: medium chain fatty acids (C8-C13); SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; UFA: unsaturated fatty acids (PUFA+MUFA).

in GMF. CLA was also detected in GMF (0.33%) and acts as a potent inhibitor of milk fat synthesis (De Veth *et al*., 2004). Branched-chain fatty acids were also quantified in Saudi GMF. Among them, the most important in quantitative terms were the iso- and anteiso-C15:0 (0.37% and 0.12%), iso- and anteiso-C17:0 (0.87% and 0.33%), and iso-C16:0 (0.29%) (Table 1), which confirm the findings of Alonso *et al*. (1999). Branched-chain fatty acids lend characteristic flavors to many dairy foods (Park *et al*., 2007). The *trans* fatty acids (TFA) content in GMF comprised 3.97% of the total fatty acids. The main TFA found was elaidic acid (C18:1*t*9).

3.3. Infrared spectroscopy

A representative spectrum of Saudi Aradi GMF is shown in Figure 1. The fat spectrum showed characteristic absorption bands for common triglycerides and fatty acids. The assignments of prominent peaks are given in Table 3. The FTIR spectrum of the GMF exhibited a characteristic band at 966 cm^{-1}, corresponding to the C-H out-of-plane deformation that is highly characteristic of unconjugated double bonds with a *trans* configuration. The distinctive band at 3470 cm^{-1} represents the overtone of the C=O ester stretch (Henna Lu and Tan, 2009).

3.4. Crystallization and melting behavior

Figure 2 shows the DSC cooling and heating curves for Saudi Aradi GMF. The melting DSC curve exhibited two melting peaks at 15.4 °C and 38.7 °C, with enthalpies of 57.8 $J\cdot g^{-1}$ and 12.2 $J\cdot g^{-1}$, respectively. The large shoulder endothermic peak is attributed to the melting of triacylglycerol with a combination of unsaturated fatty acids, and SCFA and MCFA, while the small shoulder endothermic peak is attributed to the melting of triacylglycerols with a combination of long-chain SFAs, mainly C16:0 and C18:0, and MUFAs with a *trans*-configuration (Ten Grotenhuis *et al*., 1999). The melting enthalpy of GMF is slightly lower than that of anhydrous milk fat (72.9 $J\cdot g^{-1}$) due to its low SFA content (Sabariah *et al*., 1998). The cooling DSC curve (Figure 2) exhibited a crystallization peak at 1.9 °C with an enthalpy of −68.8 $J\cdot g^{-1}$. Cisneros *et al*. (2006) noted that the mixture of high- and low-melting milk fat fractions crystallized originally in the α polymorph but, due to the presence of a liquid phase, the transformation into the β' polymorph occurred rapidly. High-melting milk fat fractions (10–25 °C) are used in laminated pastries to promote layering and, in the chocolate industry, to inhibit fat blooming. Low-melting milk fat fractions (35–50 °C) can be used for creaming applications in the biscuit and cheese industries (Gibon, 2006; Van Aken *et al*., 1999).

3.5. Thermal analysis

The thermogravimetric data (TGA) and first derivative data (DTG) of the GMF under a dry heating air atmosphere are presented in Figure 3.

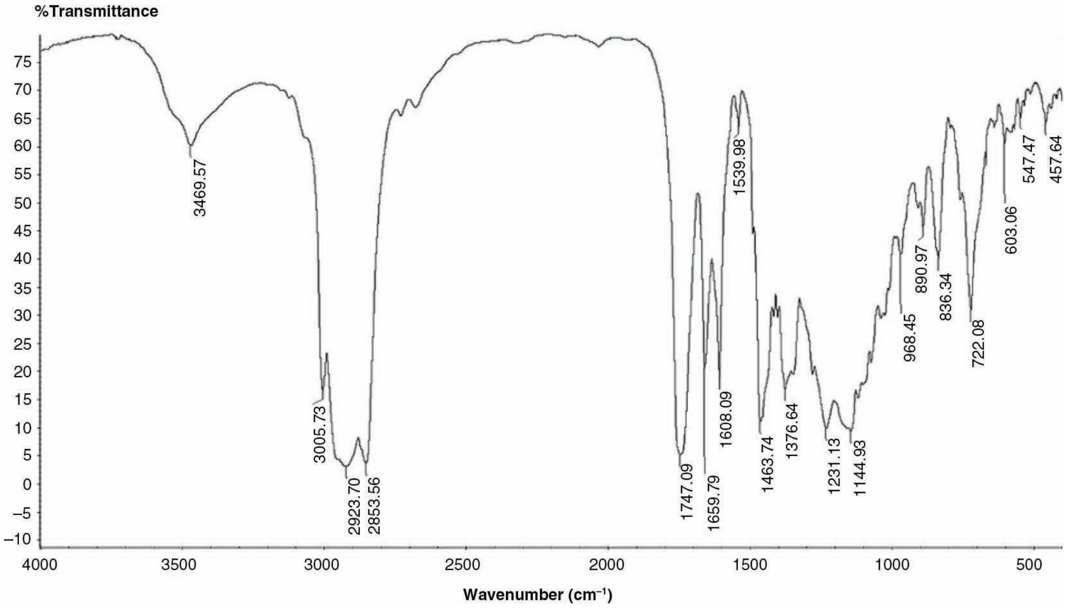

FIGURE 1. FT-IR spectrum of goat milk fat sample.

The thermogram indicated that the GMF was thermally stable up to 276.3 °C, with a mass loss of 5%. A 90% mass loss occurred at 485.8 °C. The profiles of the TGA/DTG curves (Figure 3) showed three stages of decomposition for GMF, with a maximum at 316.5 °C, 440 °C and at 541.3 °C.

Szabo *et al.* (2012) reported that the temperature range corresponding to the first stage could be attributed to the thermal decomposition of the unsaturated fatty acids, mainly C18:1, C18:2 and C18:3 and the SCFA (C4-C6). This stage is considered the most important and represents the initial phase of triacylglycerol degradation. In this phase, the oxidation of PUFAs occurs. The second and third phases represent the decomposition of the *trans* isomer fatty acids and SFAs, respectively.

TABLE 3. Fequencies, Functional Groups, Vibration Mode, and Intensity of GMF in FTIR spectra

Wavenumber (cm^{-1})	Functional group	Mode of vibration	Intensity
3470	-C=O (ester)	Overtone	W
3009	=C-H (*cis*-)	Stretching	M
2952	-C-H (CH_3)	Stretching (asymmetric)	S
2923	-C-H (CH_2)	Stretching (asymmetric)	S
2853	-C-H (CH_2)	Stretching (symmetric)	S
1747	-C=O (ester)	Stretching	S
1654	-C=C- (*cis*)	Stretching	W
1464	-C-H (CH_2, CH_3)	Bending (scissoring)	S
1417	=C-H (*cis*)	Bending (rocking)	W
1377	-C-H (CH_3)	Bending (symmetric)	M
1239	-C-O, -CH_2-	Stretching, bending	W
1165	-C-O, -CH_2-	Stretching, bending	S
1113	-C-O	Stretching	W
967	-HC=CH- (*trans*)	Bending out of plane	W
722	-$(CH_2)n$-,	Bending (rocking)	M
	-HC=CH- (*cis*)	Bending out of plane	

W: weak band; M: moderate band; S: strong band.

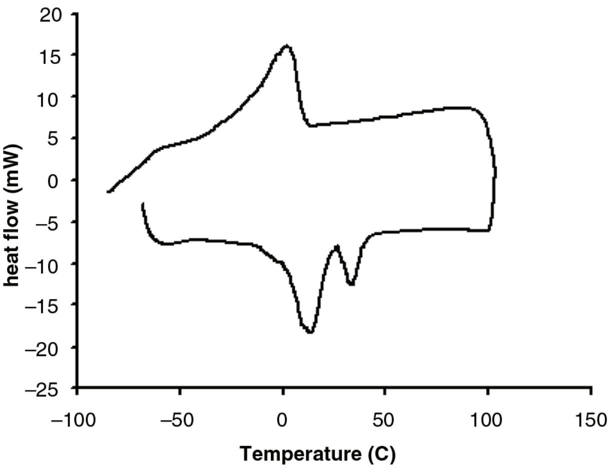

FIGURE 2. Heat flow of goat milk sample during heating and cooling process.

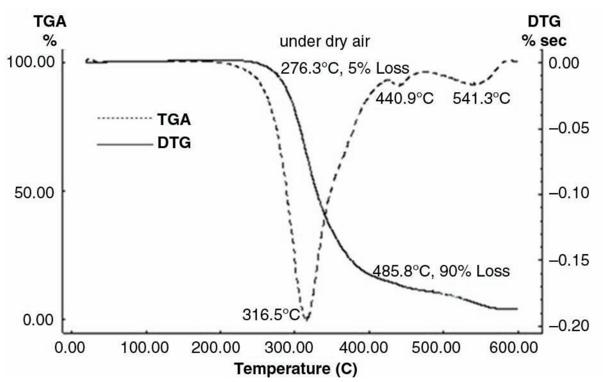

FIGURE 3. TGA/DTG curves of goat milk fat under dry air.

3.6. UV/Visible spectrophotometry of the GMF

Saudi Aradi GMF exhibits characteristic medium-intensity (1–1.5) absorbance peaks in the UV-C (100–290 nm) range between 200 and 230 nm (Figure 4). Thus, the GMF may be used in the formulation of sunscreens that provide protection against UV-C radiation (Fatnassi *et al.*, 2009). GMF exhibited low-intensity absorbance (0.4–0.65) in the 400–440 nm range (412 and 432 nm), indicative of the corresponding carotenoid pigments, which explains the yellow color of the Saudi Aradi GMF. This yellow color, which includes carotenoids, is beneficial because it simulates the appearance of butter without the use of primary colorants, such as carotenes and annattos, which are commonly used in the oil and fat industries (Elleuch *et al.*, 2007). The GMFs exhibited a slight absorbance in the visible region at 600–750 nm, which is related to a low chlorophyll content. These data confirm the results presented in Table 1.

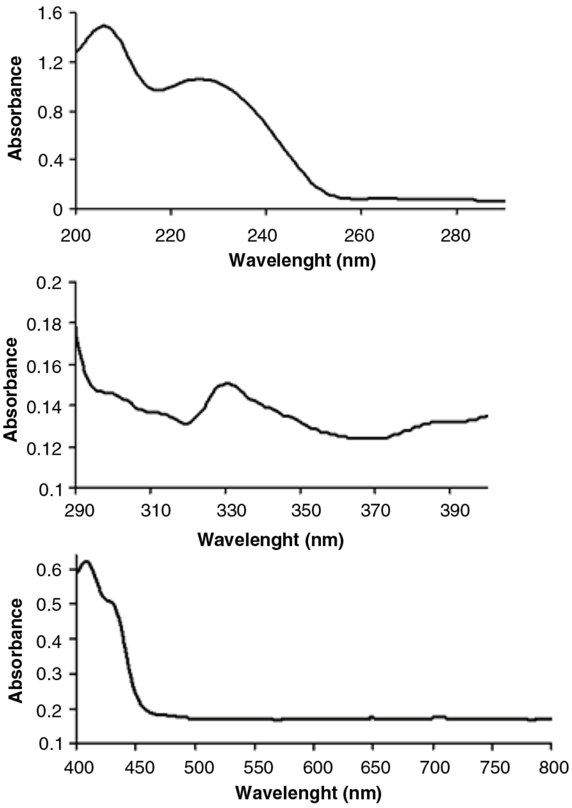

FIGURE 4. Ultra violet/visible spectra of goat milk fat (Figure derived from scans (λ=200–290 nm) of fat diluted 1:1000; from scans (λ=290–400 nm) of fat diluted 1:100 and from scans (λ=400–800 nm) of fat diluted 1:10, all in hexane.

4. CONCLUSIONS

According to the results obtained in the current study, Saudi Aradi GMF possesses favorable properties, both physically and chemically, and may have promising nutritional properties as a source of essential fatty acids and fat-soluble vitamins. These results may also be important for the production of milk fat products, such as butter and cheese, and potentially for the use of such cow milk fat substitutes.

This study achieved the primary step of evaluating the physicochemical properties of Saudi Arabia GMF and should be followed by further studies using a larger number of goats from different geographical regions in the Kingdom to determine the seasonal and feeding factors that affect the GMF composition. Goat milk fat also shows great potential for future use in skin care and cosmetics products.

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