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REGULAR ARTICLE

Effect of starter cultures on various classes of fatty acids in Sudanese fermented camel milk (*Camelus dromedarius*) *gariss*

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ABSTRACT

The objective of the present research was to study the variation of fatty acids classes in *gariss* (Sudanese fermented camel milk) prepared under controlled conditions (starter cultures and time of fermentation). Inoculations of raw camel milk with selected LAB strains (*E. duransR03, E.faecium NWL* and *L. plantarum BJ6* and their combination as well as the control - fermentation without starter cultures) was performed at varying periods of time (zero, 3, 6, 9 and 12h) at ambient temperature, then the role of these conditions on fatty acids classes were studied. Camel milk fermented under starter-culture controlled conditions contained unsaturated fatty acids, including the essential fatty acids. Considerable amounts of ω_3 and ω_6 fatty acids and the absence or presence of low amounts of short chain fatty acids were found compared to cow milk.

Keywords: Starter; Enterococcus; Fatty acids; LAB strains

INTRODUCTION

There are various traditional fermented camel milk products that are produced by camel herders in different parts of the world (Yagil, 1982; Abdelgadir et al., 1998; Lore et al., 2005; Hassan et al., 2008; Abdel Rahman et al., 2009; Konuspayeva and Faye, 2011). Fermented milk products such as *suusac* and *gariss* are produced from camel milk in Kenya, Somalia and Sudan (Abdelgadir et al., 1998; Lore et al., 2005).

Camel's milk is produced in certain areas of Sudan, under nomadic conditions. The camel's milk being abundant in remote localities, the camel herders have to prepare *gariss*, a fermented product, on which they sustain living for several months as the sole source of various nutrients (Dirar, 1993; Abdelgadir et al, 1998). *Gariss* is a special kind of fermented milk, prepared solely from camel milk under more or less shaking. Besides its use as food, camel milk has been used in many regions as a cure for certain diseases (Dirar, 1993; Abdelgadir et al., 1998; Suleiman et al., 2007). In the Horn of Africa, 10% of produced milk is derived from camels (Faye and Konuspayeva, 2012). However, most camel milk is produced in traditional farming or pastoral systems by hand milking that cannot provide consistent quantity and quality of raw milk for urban markets (Abeiderrahmane, 2005). The camel dairy industry, including machine milking, processing, and distribution, has been established in the last decade but it is still in an early stage of development (Nagy et al., 2013). Seifu et al. (2012) isolated and characterized lactic acid bacteria from Ethiopian traditional fermented camel milk, and they concluded that the isolated lactic acid bacteria species could be considered as potential candidates for development of starter cultures that can be used for the production of fermented camel milk products under controlled condition. *Enterococcus* species are known by their production of enterocins which exert different specific inhibition activity against pathogenic bacteria (Sabia et al., 2002).

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The study of microflora in traditional fermented dairy products as *gariss* and preparation of starters is of a good concern. To obtain the *gariss* with better quality and to produce this traditionally fermented product at the industrial level with high quality, control starter cultures must be used. For many authors, the presence of *enterococci* is evidence of possible fecal contamination and therefore a risk to consumers because although these strains are known for their low virulence, they pose serious health problems due to the emergence of many antibiotic-resistant strains (Akhmetsadykova et al., 2014). The objective of the present work was to know the changes in the fatty acids classes of *gariss* prepared under controlled conditions in order to assess the influence of the strains used.

MATERIALS AND METHODS

Fermented camel milk (*gariss*) was prepared under controlled conditions. Inoculations of camel milk was performed for varying periods of time (zero, 3h, 6h, 9h and 12h) at ambient temperature with selected LAB strains (*E. duransR03*, *E.faecium NWL* and *L. plantarum BJ6* and their combination as well as the control, fermentation without starter cultures). The preparation of the starter culture to be inoculated with the specific strain in non-sterilized camel milk prepared in last 24h (with the three strains i.e. *E. duransR03*, *E.faecium NWL* and *L. plantarum BJ6* and their combination). That means we used pure strain inoculated in camel milk (non sterilized one) left for 24 h, then it used for *gariss* preparation. A 3% starter culture was used to prepare *gariss*, and then the fermentation was carried out according to the traditional *gariss* preparation methods. Five *gariss* batches(Batch A= *E. duransR03,* Batch B=*E.faecium NW*, Batch C= *L. plantarum BJ6*, Batch D= the combination and Batch F= the control – fermentation without starter culture) were prepared, and for each 500 ml of camel milk 3% batch, 24 hours starter cultures were inoculated. Batch one was inoculated with strain *Enterococcus duransR03*, batch two with strain *E.faecium NWL*, batch three with *Lactobacillus plantarum BJ6*, batch four consisted of a mixture of the strains at equal proportions and batch five was a control batch which was left uninoculated. The preparation was left to ferment for 12 hours at ambient temperature. Samples were withdrawn in 0, 3, 6, 9 and 12hours to perform the fatty acids classes of the produced *gariss*.

Fatty acid analysis

From the extracted lipids, stored at 4°C, the method of Konuspayeva et al. (2008) was used to prepare and quantify fatty acid methyl esters which were taken for analysis by GC system (Massy, France) mass spectrometry. The fatty acids were identified by comparison of retention time with known standards and were expressed as percentage of total fatty acids, and then the fatty acids classes were calculated.

Definition of the fatty acid classes

The fatty acids (FA) were grouped into different classes according to their carbon chain length or their carbon saturation status:

Short chain fatty acids (SCFA): All FA with few Carbone atoms between C4 and C8.

Medium chain fatty acids (MCFA): All fatty acids with medium carbon atoms between C10 and C15

Long chain fatty acids (LCFA): All fatty acids with many carbon atoms between C16 and C22:6

Saturated fatty acids (USFA): All fatty acids with saturated carbon atoms.

Mono-unsaturated fatty-acids (MUSFA): All fatty acids with one unsaturated carbon atom.

Poly-unstaurated fatty acids (PUSFA): All fatty acids with more than two unsaturated carbon atoms.

Statistical analysis

Statistical Packages for Social Sciences (SPSS 16.00) was used to analyze data using ANOVA and Duncan Multiple Range Test (DMRT) for mean separation.

RESULTS AND DISCUSSION

All the classes of fatty acids in *gariss* prepared by starter cultures strains as well as the combination had variable trends during the study period.

Short chains fatty acids (SCFA)

The proportion of SCFA in *gariss* varied from 0.26 to 0.41% at t_0 (milk) to 0.50-0.71 % at t_{12h} according to the type of starter (Table 1). However, there was some difference between the used starters. In *gariss* prepared by *E. durans R03*, *E.faecium NWL, L. plantarum BJ6* and their combination, SFCA proportion significantly ($P \leq 0.05$) increased between t_0 and the end of fermentation (Table 1). The same trend was found in the control during the same period of fermentation. This indicated that fermentation with or without using starter cultures increased SCFA during fermentation process, contrary to that was reported by Abdelrahman (2007) for which SCFA were lowered by fermentation of camel milk using different starter cultures. Konuspayeva et al. (2008) reported that camel milk has low content of short- chain fatty acids but the proportion reported was slightly higher (1.16%).

Medium chains fatty acids (MCFA)

The proportion of MCFA in *gariss* varied from 14.99 to 15.36% at t_0 (milk) to 14.59-15.96 % at t_{12h} according to the type of starter (Table 1). However, there was some

Table 1: Effect of starter cultures and period of fermentation on *gariss* fatty acids chains

Sample	SCFA	MCFA	LCFC
0 time			
A	(0.35)^{hijk}±0.05	(15.36)^{i}±0.07	(84.29)^{m}±2.50
B	(0.41)^{fgh}±0.07	(14.99)^{i}±0.10	(84.60)^{i}±2.63
C	(0.41)^{fgh}±0.07	(14.99)^{i}±0.10	(84.60)^{i}±2.36
D	(0.29)^{jkl}±0.05	(15.11)^{k}±0.11	(84.60)^{i}±2.46
F	(0.26)^{kl}±0.05	(15.13)^{k}±0.40	(84.61)^{h}±2.45
3 h			
A	(0.62)^{abc}±0.17	(15.69)^{g}±0.36	(83.69)^{r}±2.51
B	(0.39)^{ghi}±00	(15.04)^{l}±0.13	(84.57)^{j}±2.63
C	(0.59)^{bcd}±0.05	(16.43)^{b}±0.21	(82.98)^{v}±2.45
D	(0.47)^{efg}±0.13	(16.21)^{c}±0.43	(83.32)^{u}±2.50
F	(0.31)^{ijkl}±0.08	(13.77)^{o}±0.50	(85.92)^{c}±2.59
6 h			
A	(0.57)^{cd}±0.11	(12.50)^{r}±0.69	(86.93)^{a}±2.53
B	(0.68)^{ab}±0.11	(13.12)^{P}±0.75	(86.2)^{b}±2.14
C	(0.45)^{efg}±0.12	(20.41)^{a}±0.77	(79.14)^{y}±2.11
D	(0.25)^{l}±0.06	(16.47)^{b}±0.12	(83.28)^{w}±1.85
F	(0.28)^{kl}±0.06	(15.37)^{i}±0.35	(84.35)^{l}±1.34
9 h			
A	(0.27)^{kl}±0.07	(14.6)^{m}±0.86	(85.13)^{e}±2.17
B	(0.38)^{ghij}±0.1	(13.94)^{n}±0.45	(85.68)^{d}±2.30
C	(0.33)^{gijkl}±0.08	(15.22)^{j}±0.21	(84.45)^{k}±2.31
D	(0.54)^{cde}±0.13	(15.89)^{e}±0.05	(83.57)^{s}±2.38
F	(0.53)^{cde}±0.09	(15.77)^{f}±0.57	(83.7)^{P}±2.42
12 h			
A	(0.71)^{a}±0.11	(14.64)^{m}±0.64	(84.65)^{g}±2.37
B	(0.52)^{de}±0.12	(15.2)^{j}±0.38	(84.28)^{n}±2.37
C	(0.67)^{ab}±0.12	(14.59)^{m}±0.17	(84.74)^{f}±2.55
D	(0.50)^{def}±0.15	(15.96)^{d}±0.66	(83.54)^{t}±2.38
F	(0.62)^{abc}±0.14	(15.6)^{h}±0.14	(83.78)^{o}±2.4

Values are means±(standard deviation) - Means not sharing a common superscript letter in a column are significantly different at. P ≥0.05 as assessed by Duncan's multiple-range test. A: *E. durans R03*, B: *E. faecium* NWL, C: *L. plantarum BJ6*, D: Combination and F: The control

Table 2: Effect of starter cultures and period of fermentation on *gariss* fatty acids saturation status

Sample	SFA	USFA	MUSFA	PUSFA
0 time				
A	(66.57)^{g}±2.02	(33.43)^{ij}±2.10	(29.43)^{ij}±3.05	(4.0)^{ghi}±00
B	(61.25)^{r}±2.17	(38.75)^{c}±2.55	(32.38)^{c}±000	(6.37)^{f}±1.50
C	(61.25)^{r}±2.17	(38.75)^{c}±2.55	(32.38)^{c}±000	(6.37)^{f}±1.74
D	(63.77)^{l}±2.60	(36.23)^{f}±2.12	(32.48)^{c}±1.15	(3.75)^{hi}±2.50
F	(64.24)^{k}±2.79	(35.76)^{g}±1.85	(31.63)^{de}±2.14	(4.13)^{ghi}±00
3 h				
A	(62.25)^{P}±2.17	(37.75)^{d}±2.03	(33.71)^{b}±3.40	(4.04)^{ghi}±1.04
B	(68.22)^{c}±2.54	(31.78)^{l}±1.99	(28.31)^{kl}±1.60	(3.47)^{i}±1./47
C	(67.24)^{e}±2.57	(32.76)^{k}±2.01	(28.9)^{jk}±3.80	(3.86)^{ghi}±0.86
D	(72.15)^{b}±2.25	(27.85)^{m}±2.03	(25.06)^{m}±4.00	(2.79)^{j}±1.79
F	(67.97)^{d}±2.74	(32.03)^{l}±2.05	(21.97)^{n}±4.60	(10.06)^{c}±1.06
6 h				
A	(52.71)^{u}±2.21	(47.29)^{a}±2.09	(28.07)^{l}±1.00	(19.22)^{a}±1.22
B	(55.67)^{t}±2.76	(44.33)^{b}±2.18	(29.15)^{j}±5.00	(15.18)^{b}±2.36
C	(85.65)^{a}±3.65	(14.35)^{n}±2.23	(12.69)^{o}±3.60	(1.66)^{k}±0.66
D	(66.99)^{f}±2.89	(33.01)^{jk}±2.22	(28.9)^{jk}±3.20	(4.11)^{ghi}±1.11
F	(64.93)^{j}±2.03	(35.07)^{h}±2.28	(30.7)^{fg}±2.20	(4.37)^{gh}±2.37
9 h				
A	(64.86)^{j}±2.15	(35.14)^{h}±1.90	(31.27)^{ef}±3.18	(3.87)^{ghi}±1.87
B	(61.09)^{s}±1.80	(38.91)^{c}±1.79	(34.45)^{a}±1.24	(4.46)^{g}±0.92
C	(63.17)^{n}±2.11	(36.83)^{e}±1.92	(33.21)^{b}±2.30	(3.62)^{i}±1.24
D	(66.04)^{h}±2.51	(33.96)^{i}±2.41	(29.91)^{hi}±2.28	(4.05)^{ghi}±1.05
F	(65.20)^{i}±1.56	(34.80)^{h}±2.08	(31.23)^{ef}±1.27	(3.57)^{i}±1.57
12 h				
A	(62.51)^{o}±2.75	(37.49)^{d}±2.26	(29.50)^{ij}±2.40	(7.99)^{d}±0.99
B	(63.53)^{m}±2.25	(36.47)^{ef}±3.04	(30.71)^{fg}±1.71	(5.76)^{f}±0.76
C	(61.10)^{s}±2.74	(38.90)^{c}±2.46	(31.91)^{cd}±2.91	(6.99)^{e}±0.99
D	(66.13)^{h}±2.21	(33.87)^{i}±2.14	(30.21)^{gh}±1.25	(3.66)^{i}±0.66
F	(64.94)^{j}±2.76	(35.06)^{h}±2.23	(32.33)^{c}±2.33	(2.73)^{j}±0.73

Values are means ± (standard deviation) - Means not sharing a common superscript letter in a column are significantly different at P ≥0.05 as assessed by Duncan's multiple-range test. A: *E.durans R03*, B: *E. faecium NWL*, C: *L. plantarum BJ6*, D: Combination and F: The control

difference between the used starters. MCFA of *gariss* prepared by *E. durans R03* and *L. plantarum BJ6* decreased significantly (P≤0.05) between t_0 and t_{12h}, while in *gariss* prepared by *E.faecium NWL* and their combination it increased significantly (P≤0.05), similar trend being found in the control during the same period of fermentation (Table 1). Abdelrahman (2007) reported that starter cultures fermentation of camel milk increased MCFA from 12.79% for raw camel milk to 17.92, 17.89, 18.70, 18.15 and 18.66% for camel milk fermented by *Lactobacillus acidophilus*, *Lactobacillus bulgaricus*, *Lactococcus lactis*, *Streptococcus thermophilus* and the Yoghurt culture (*Lactobacillus bulgaricus*: *Streptococcus thermophilus*), respectively.

Long chains fatty acids (LCFA)

For the LCFA the proportion in *gariss* varied from 84.29 to84.61% at t_0 (milk) to 83.54-84.74 % at t_{12h} according to the type of starter (Table 1). However, there was some difference between the used starters.

LCFA of *gariss* prepared by *E. durans R03* and *L. plantarum BJ6* significantly (P≤0.05) increased between t_0 and t_{12h} (Table 1), while LCFA in *gariss* prepared by *E.faecium NWL* and their combination it decreased significantly (P≤0.05) during the fermentation process, the same trend being found in the control. Abdelrahman (2007) reported that starter cultures fermentation of camel milk increased LCFA from 78.54% for raw camel milk to 92.11, 91.61, 91.35, 91.83 and 91.14% for camel milk fermented by *Lb. acidophilus, Lb. bulgaricus, L. lactis*, *S. thermophilus* and the Yoghurt culture (*Lb. bulgaricus: S. thermophilus*), respectively.

Saturated fatty acids (SFA)

For SFA, the proportion is passing from 61.25to 66.57% at t_0 (milk) to 61.10-66.13 % at t_{12h} according to the type of starter (Table 2). However, there was some difference between the used starters.

SFA of *gariss* prepared by *E. durans R03* and *L. plantarum BJ6* significantly (P≤0.05) decreased between t_0 and t_{12h}

Table 3: Role of starter cultures and period of fermentation on *gariss omega* fatty acids

Sample	Omega3	Omega6	US/SFA
0 time			
A	$(0.56)^{i}$±00	$(3.05)^{ab}$±0.05	$(0.50)^{hij}$±00
B	$(0.56)^{i}$±00	$(2.77)^{abc}$±00	$(0.63)^{cd}$±0.13
C	$(0.56)^{i}$±00	$(2.77)^{abc}$±00	$(0.63)^{cd}$±0.13
D	$(0.45)^{n}$±0.12	$(2.9)^{abc}$±0.13	$(0.57)^{defg}$±0.07
F	$(0.87)^{b}$±00	$(2.85)^{abc}$±0.12	$(0.56)^{efgh}$±000
3 h			
A	$(0.87)^{b}$±00	$(2.74)^{abc}$±0.13	$(0.60)^{cde}$±000
B	$(0.53)^{j}$±0.03	$(2.91)^{abc}$±0.90	$(0.47)^{ij}$±0.13
C	$(0.31)^{t}$±0.23	$(2.23)^{cd}$±0.46	$(0.49)^{ij}$±0.14
D	$(0.46)^{m}$±0.12	$(1.97)^{d}$±0.12	$(0.39)^{k}$±0.13
F	$(0.37)^{s}$±0.19	$(2.41)^{bcd}$±0.12	$(0.47)^{j}$±0.13
6 h			
A	$(0.40)^{p}$±0.16	$(2.48)^{abcd}$±0.13	$(0.90)^{a}$±000
B	$(0.27)^{u}$±0.12	$(2.56)^{abcd}$±00	$(0.80)^{b}$±000
C	$(0.05)^{w}$±00	$(1.29)^{e}$±1.20	$(0.17)^{l}$±0.05
D	$(0.65)^{e}$±0.12	$(3.08)^{ab}$±1.1	$(0.49)^{ij}$±0.12
F	$(0.99)^{a}$±0.12	$(2.98)^{ab}$±0.12	$(0.54)^{efghi}$±0.12
9 h			
A	$(0.64)^{f}$±0.08	$(2.96)^{ab}$±0.13	$(0.54)^{efghi}$±0.13
B	$(0.50)^{k}$±0.06	$(2.83)^{abc}$±0.83	$(0.64)^{c}$±000
C	$(0.59)^{g}$±0.13	$(2.95)^{ab}$±0.13	$(0.58)^{cdef}$±000
D	$(0.74)^{d}$±0.12	$(3.14)^{a}$±0.14	$(0.51)^{ghij}$±0.12
F	$(0.58)^{h}$±0.16	$(3.02)^{ab}$±0.12	$(0.53)^{fghij}$±0.13
12 h			
A	$(0.76)^{c}$±0.16	$(2.93)^{ab}$±0.13	$(0.60)^{cde}$±00
B	$(0.41)^{o}$±0.15	$(2.95)^{ab}$±0.12	$(0.57)^{defg}$±0.14
C	$(0.49)^{l}$±0.12	$(2.80)^{abc}$±0.80	$(0.64)^{c}$±0.14
D	$(0.38)^{r}$±0.17	$(3.10)^{ab}$±1.10	$(0.51)^{ghij}$±0.11
F	$(0.45)^{n}$±0.16	$(2.98)^{ab}$±0.14	$(0.54)^{efghi}$±0.12

Values are means±(standard deviation) - Means not sharing a common superscript letter in a column are significantly different at P ≥ 0.05 as assessed by Duncan's Multiple-Range Test. A: *E.durans R03*, B=*E. faecium NWL*, C: *L. plantarum BJ6*, D: Combination and F: The control

(Table 1), while in *gariss* prepared by *E.faecium NWL* and their combination significantly (P≤0.05) increased during the same sequence, similar trend being found in the control during the same period of fermentation. For Abdelrahman (2007) starter cultures for fermentation of camel milk increased SFA from 40.80% for raw camel milk to 73.92, 73.31, 74.90, 74.4 and 74.16% for camel milk fermented by *Lactobacillus acidophilus, Lactobacillus bulgaricus, Lactococcus lactis, Streptococcus thermophilus* and the Yoghurt culture (*Lactobacillus bulgaricus: Streptococcus thermophilus*), respectively.

Unsaturated fatty acids (USFA)

The proportion of USFA is passing from 61.25to 66.57% at t_0 (milk) to 61.10-66.13 % at t_{12h} according to the type of starter (Table 2). However, there was some difference between the used starters.

USFA of *gariss* prepared by *E. durans R03* significantly (P≤0.05) increased between zero time and the end of fermentation period; while the USFA of *gariss* prepared by *E. faecium NWL* and their combination significantly (P≤0.05) decreased(Table 1), the same trend being found in the control during the same period of fermentation. *Gariss* prepared by *L. plantarum BJ6* single culture was not affected by the period of fermentation process. Abdelrahman (2007) reported that the fermentation of camel milk decreased USFA from 38.74% for raw camel milk to 36.27, 36.69, 35.49, 35.92 and 35.85% for camel milk fermented by *Lb. acidophilus, Lb. bulgaricus, L. lactis, S. thermophilus* and the Yoghurt culture (*Lb. bulgaricus: S. thermophilus*), respectively.

Mono-unsaturated fatty acids (MUSFA)

The proportion of MUSFA varied from 61.25to 66.57% at t_0 (milk) to 61.10-66.13 % at t_{12h} according to the type of starter (Table 2). However, there was some difference between the used starters.

The proportion of MUSFA of *gariss* prepared by *E. durans R03* and *L. plantarum BJ6* were not changing between t_0 and t_{12h}, while in *gariss* prepared by *E.faecium NWL* and their combination it decreased significantly (P≤0.05) at the same time (Table 1). The MUSFA of the control significantly (P≤0.05) increased during the same period of fermentation. From his part, Abdelrahman (2007) reported that starter cultures fermentation of camel milk lowered MUSFA from 34.18% for raw camel milk to 30.97, 31.2, 30.30, 30.37 and 30.72% for camel milk fermented by *Lb. acidophilus*, *Lb. bulgaricus*, *L. lactis*, *S. thermophilus* and the Yoghurt culture (*Lb. bulgaricus*: *S. thermophilus*), respectively.

Poly unsaturated fatty acids (PUSFA)

The quantity in proportion of PUSFA is passing from 61.25to 66.57% at t_0 (milk) to 61.10-66.13 % at t_{12h} according to the type of starter (Table 2). However, there was some difference between the used starters.

PUSFA of *gariss* prepared by *E. durans R03* and *L. plantarum BJ6* significantly (P≤0.05) increased between t0 and t_{12h} while PUSFA in *gariss* prepared by *E.faecium NWL* significantly (P≤0.05) decreased, the same trend being found in the control (Table 1). The proportion of MUSFA of *gariss* prepared by the combination was not changing during all fermentation process. This result is reverse to that reported by Abdelrahman (2007) who reported that starter cultures fermentation of camel milk increased PUSFA from 4.56% for raw camel milk to 5.30, 5.49, 5.19, 5.55 and 5.13% for camel milk fermented by *Lb. acidophilus*, *Lb. bulgaricus*, *L. lactis*, *S. thermophilus* and the Yoghurt culture (*Lb. bulgaricus*: *S. thermophilus*), respectively.

Omega$_3$ and omega$_6$ fatty acids

The ω_3 and ω_6 fatty acids are in low proportion in milk and *gariss*. The range was 0.45-0.87 and 0.38-0.76% at t_0 and t_{12h}

respectively for ω_3, and 2.77-3.05 and 2.8-3.1% for ω_6 in the same time (Table 2).

The ω_3 and ω_6 fatty acids of *gariss* had opposite behavior during fermentation process (Table 3). While ω_3 in *gariss* prepared by *E. durans R03* significantly (P≤0.05) increased, ω_6 decreased. Elsewhere, in *gariss* prepared by *E.faecium NWL*, *L. plantarum BJ6* as well as their combination, ω_3 lowered significantly (P≤0.05) between t_0 and t_{12h} while it increased for ω6. No ω_3 or ω_6 fatty acids were found or determined in raw and fermented camel milk (Abdelrahman, 2007; Konuspayeva et al*.,* 2008; Faye et al*.,* 2008).

Unsaturated fatty acids to saturated fatty acids ratio USFA/SFA

The ratios of USFA/SFA of *gariss* prepared by *E. durans R03* significantly (P≤0.05) increased between t_0 and t_{12h}, while that of *gariss* prepared by *E.faecium NWL*, *L. plantarum BJ6* as well as their combination were not significantly (P≤0.05) affected, similar trend being found in the control. At reverse, Abdelrahman (2007) reported that the starter cultures fermentation of raw camel milk lowered ratio of unsaturated to saturated fatty acids from 0.95 for raw camel milk to 0.49, 0.50,0.47,0.48 and 0.48 for camel milk fermented by *Lb. acidophilus*, *Lb. bulgaricus*, *L. lactis*, *S. thermophilus* and the Yoghurt culture (*Lb. bulgaricus*: *S. thermophilus*), respectively. Finally, it appears that fermentation process with E. durans R03 increases, SCFA, LCFA, SFA,USFA, MUSFA, PUSFA, Omega3 and the ratio of US/SFA and decreases, MCFA, Omega6 in camel milk, while with *E. faecium* increases SCFA,SFA, MUSFA, PUSFA, Omega3 and the ratio of US/SFA and decreases MCFA, LCFA, USFA, Omega6 in camel milk, and that with *L. plantarum* BJ6 increases SCFA, LCFA, USFA, PUSFA, Omega6 and the ratio of US/SFA and decreases MCFA, SFA, MUSFA, Omega3 in camel milk, the combination of those strains increases SCFA, MCFA, SFA, Omega6, and decreases, LCFA, USFA, MUSFA, PUSFA Omega3 and the ratio of US/SFA in camel milk. The spontaneous fermentation (the control) increases SCFA, MCFA, SFA, MUSFA, Omega6 and decreases LCFA, USFA, PUSFA, Omega3 and the ratio of US/SFA in camel milk. The different trends on the effect of the different strains used as starter for the fermentation of camel milk.

Guler and Gursoy-Balci (2011) reported that the type of cultures storage periods had no effect on long-chain free fatty acids in yogurts from goat milk. During the storage, short-chain free fatty acids were different according to culture type used and increased during storage, while the levels of medium-chain free fatty acids, except for decanoic acid, were unchanged and the amount of long-chain free fatty acids decreased during storage.

As far as we know, our paper is the first attempt to use *E.faecium, E.durans* and *L. plantarum* as starter culture to produce fermented camel milk *(gariss)* in the laboratory conditions. LAB distribution showed a high diversity of species that are dominant and was frequently described in various dairy products. In fermented camel milk from Kazakhstan called *Shubat* different microorganisms were identified as *Enterococcus durans; Enterococcus faecalis; Enterococcus faecium* and others (Akhmetsadykova et al., 2014). By using well identified starter cultures of LAB strains associated with *gariss* preparation and by controlling the conditions of product preparation, a wholes me product of consistent quality will be desired for the consumers of the urban areas. That will lead to the commercialization of *gariss* product where fresh milk is procured by nomads in the remote areas. Consequently, it could be one of the most income generating activities that can give great push to those people of the remote areas.

CONCLUSION

The fatty acids classes of fermented camel milk have various trends affected by starter cultures fermentation. The uses of some species such as *E. duransR03*, *E.faecium NWL* and *L. plantarum BJ6* in production of laboratory scale fermented camel milk *gariss,* suggests their possible use as starter culture in the manufacture of commercially *gariss* products. However, more studies are needed to complete the isolation and characterization of new LAB strains that could be present in camel milk produced in Sudan and to compare the results with reports from other countries and regions. Also, the organoleptic analysis of the *gariss* produced under the above mentioned conditions are also recommended for further studies.

Authors' contributions

This work was carried out in collaboration between all authors. Ahmed designed the study and wrote the protocol, Faye interpreted the data. Mohemed and Yousif supervised the field study, gathered the initial data and performed preliminary data analysis. Also Ahmed and Faye managed the literature searches and produced the initial draft. Loiseau managed the Laboratory work for Ahmed during his stay in France. All authors read and approved the final manuscript.

REFERENCES

Abdel Rahman, I. E., H. A. Dirar and M. A. Osman. 2009. Microbiological and chemical changes and sensory evaluation of camel milk fermented by selected bacterial starter cultures. Afr. J. Food Sci. 3: 398-405.

Abdelgadir, W. S., T. K. Ahmed and H. A. Dirar. 1998. The traditional fermented milk products of the Sudan. Int. J. Food Microbiol. 44: 1-13.

Abdelrahman, I. E. 2007. Biochemical Changes in Camel Milk Fermented by Bacterial starter Culture, Ph.D. Thesis, Faculty of Agriculture, University of Khartoum, Khartoum North, Shambat, Sudan.

Abeiderrahmane, N. 2005. Modern dairy products from traditional camel herding, an experience in Mauritania. In: Faye, B. and P. Esenov, (Eds.), Desertification Combat and Food Safety: The Added Value of Camel Producers. NATO Science Series, IOS Press, Amsterdam, the Netherlands, Pp. 152-157.

Akhmetsadykova, S., A. Baubekova, G. Konuspayeva, N. Akhmetsadykov and G. Loiseau. 2014. Microflora identification of fresh and fermented camel milk from Kazakhstan. Emirates J. Food Agric. 26(4): 327-332.

Dirar, H. A. 1993. The Indigenous Fermented Foods of the Sudan. A Study in Africa Food and Nutrition, CAB International, England.

Faye, B. and G. Konuspayeva. 2012. The sustainability challenge of the dairy sector - The growing importance of the non-cattle milk production worldwide. Int. Dairy J. 24: 50-56.

Faye, B., G. Konuspayeva, M. Narmuratova and G. Loiseau. 2008. Comparative fatty acid gross composition of milk in Bactrian camel, and dromedary. J. Camelid Sci. 1: 48-53.

Guler, Z. and A. C. Gursoy-Balci. 2011. Evaluation of volatile compounds and free fatty acids in set types yogurts made of ewes', goats' milk and their mixture using two different commercial starter cultures during refrigerated storage. Food Chem. 127: 1065-1071.

Hassan, R. A., I. E. M. Elzubier and S. A. Babiker. 2008. Chemical and microbial measurements of fermented camel milk (Gariss) from transhumance and Nomadic herds in Sudan. Aust. J. Basic Appl. Sci. 2(4): 800-804.

Konuspayeva, G., E. Lemarie, B. Faye, G. Loiseau and D. Montet. 2008. Fatty acid and cholesterol composition of camel's (*Camelus bactrianus, Camelus dromedarius and hybrids*) milk in Kazakhstan. Dairy Sci. Technol. 88: 327-340.

Konuspayeva, G. and B. Faye. 2011. Identity, therapeutic virtues and health claims: the fermented products in Central Asia. In: OCHA exercise books. Coll, Vol. 15. Milk culture of the world, Paris, 5-6 Mai, 2010; Pp. 135-145.

Lore, T. A., S. K. Mbugua and J. Wangoh. 2005. Enumeration and identification of microflora in Suusac, a Kenyan traditional fermented camel milk product. Lebensm. Wiss. U. Technol. 38: 125-130.

Nagy, P., S. Thomas, O. Marko and J. Juhasz. 2013. Milk production, raw milk quality and fertility of dromedary camels (*Camelus dromedarius*) under intensive management. Acta Vet. Hung. 61: 71-84. http://dx.doi.org/10.1556/AVet.2012.051.

Sabia, C., G. Manicarda, P. Messai, S. De Niederhansern and M. Bondi. 2002. Enterocin 416 K1, an antilisterial bacteriocin produced by *Enterococcus casseliflavus* IM 416 K1 isolated from Italian sausages. Int. J. Food Microbiol. 75: 163-170.

Seifu, E., A. Abraham, M. Y. Kurtu and Z. Yilma. 2012. Isolation and characterization of lactic acid bacteria from *Ititu*: Ethiopian traditional fermented camel milk. J. Camelid Sci. 5: 82-98. Available from: http://www.isocard.org. [Last Assessed on 14/02/16].

Suleiman, A. E., R. Osawa and R. Tsenkova. 2007. Isolation and identification of *Lactobacill*i from Gariss, a Sudanese fermented camel milk product. Res. J. Microbiol. 2(2): 125-132.

Yagil, R. 1982. Camels and Camel Milk. FAO Animal Production and Health Paper, Rome, Italy. Available from: http://www.fao.org. [Last Assessed on 14/02/16]