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Effects of fermentation with *Lactobacillus rhamnosus* GG on product quality and fatty acids of goat milk yogurt

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ABSTRACT

The effect of fermentation with *Lactobacillus rhamnosus* GG on the product quality of goat milk yogurt using traditional yogurt starter was studied through single-factor experiments and orthogonal experiments. The optimum fermentation condition was evaluated by the titratable acidity of goat milk yogurt, water-retaining capability, sensory score, and texture properties; the fatty acids of the fermented goat milk were determined by a gas chromatograph. Results indicate that high product quality of goat milk yogurt can be obtained and the content of short-chain and medium-chain fatty acids can be decreased significantly when amount of sugar added was 7%, inoculation amount was 3%, the ratio of 3 lactic acid bacteria—*Lactobacillus delbrueckii* ssp. *bulgaricus*, *Streptococcus thermophilus*, and *L. rhamnosus* GG—was 1:1:3, and fermentation temperature was 42°C.
Key words: *Lactobacillus rhamnosus* GG, goat milk yogurt, product quality, fatty acid

INTRODUCTION

Goat milk is a healthy and nutritious food (Haenlein, 2004) and is recognized as the most similar in nutritive value to human milk. In addition, goat milk has been attributed certain therapeutic values in human nutrition (Park, 1994; Spuergin et al., 1997; Alférez et al., 2001; Barrionuevo et al., 2002; Zhao et al., 2014). However, the smell of goat milk has been described specifically as "goaty" and has resulted in consumers discarding goat milk products in the past (Haenlein, 2001). The specific smell of goat milk is related primarily to the composition of the fatty acids (Chilliard et al., 2003). The content of caproic ($C_{6:0}$), caprylic ($C_{8:0}$), and capric ($C_{10:0}$) acids in goat milk are slightly higher than that of cow milk (Barber et al., 1997; Chilliard et al., 2000), and these acids compose 13.3% of the total fatty acids in goat milk (Soryal et al., 2003). During fermentation, goat milk will lose its "goaty" smell and the nutritive value of goat milk can increase (Slacacac et al., 2010). This mechanism of "goaty" smell removal through fermentation has not been clearly studied in-depth.

As the public's interest in potential beneficial health effects of probiotics has increased, many products have been proposed as carrier foods for probiotics to improve the health and nutrition of people (Gilliland, 2003; Senaka Ranadheera et al., 2013). Goat milk yogurt is a fermented milk products (Merin, 2000) with the potential to carry probiotic bacteria (Hekmat and Reid, 2006; Settachaimongkon et al., 2014). To exert any beneficial health effect, the concentration of probiotics in a product must be over 10^6 cfu/mL (Donkor et al., 2007). Most commercial probiotics incorporated in dairy products are strains belonging to the genera *Lactobacillus* and *Bifidobacterium* (Lourens-Hattingh and Viljoen, 2001). But the research on fermentation with probiotic strain such as *Lactobacillus rhamnosus* GG of goat milk yogurt is rare. The ability of *L. rhamnosus* GG to survive and colonize in the gastrointestinal tract has been shown for both adults and children (Goldin et al., 1992; Millar et al., 1993; Saxelin et al., 1993). It can adjust intestinal flora, prevent and cure diarrhea, eliminate toxins, and enhance immunity against dental caries (Linares et al., 2011).

In our study, goat milk yogurt was fermented with a mixture of *L. rhamnosus* GG and traditional yogurt starter cultures, *Lactobacillus delbrueckii* ssp. *bulgaricus* and *Streptococcus thermophilus*, through single-factor experiments and orthogonal experiments. The aim of this study was to investigate the effect on the product quality and fatty acids of goat milk yogurt through the fermentation, which can provide better process parameters and process flow for a new goat milk product.

MATERIALS AND METHODS

Materials

Fresh goat milk was obtained from the Xinong Saanen dairy goat seed farm in Yangling (Shaanxi Prov-

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ince, China). Yogurt starter cultures, *S. thermophilus* and *L. delbrueckii* ssp. *bulgaricus*, were provided by our laboratory. *Lactobacillus rhamnosus* GG was bought from the China Industrial Culture Collection Center (Beijing, China).

Fatty acid methyl esters standard material, used as a reagent, was produced by Supelco (Bellefonte, PA). Methanol, *n*-hexane, boron trifluoride-methanol solution (14%), 0.55 *M* potassium hydroxide methanol solution, pyrogallic acid methanol solution (10%), chloroform, and saturated sodium chloride solution were also used as reagents.

Preparation of the Starter

Strains were activated first via sterilization of the skim milk at 105°C, of which the solids concentration is 11% (wt/wt). The lyophilized powder of *S. thermophilus*, *L. delbrueckii* ssp. *bulgaricus*, and *L. rhamnosus* GG was activated in the skim milk and then stored at 4°C.

Mother culture was prepared with sterilized skim milk that had 5% inoculation amount of the activated strains. The mother cultures of *S. thermophilus* and *L. delbrueckii* ssp. *bulgaricus* were incubated at 42°C and the mother culture of *L. rhamnosus* GG was incubated at 37°C. They were then stored at 4°C until the curd was firm.

Fermentation of Goat Milk Yogurt

The raw goat milk was purified using a filter cloth. After adding sugar, goat milk was heated to 95°C for 5 min using pasteurization and cooled to 45°C. Then the goat milk was inoculated with *S. thermophilus*, *L. delbrueckii* ssp. *bulgaricus*, and *L. rhamnosus* GG in different ratios, which were determined by the preliminary experiments; finally, goat milk was fermented at 4°C.

Determination of Titratable Acidity

According to China National Standard GB 5413.34–2010, the titratable acidity of goat milk yogurt was determined with 0.1 *M* NaOH standard solution titration method (Lin et al., 2004), where 10 g of goat milk yogurt sample was added to 2 mL of phenolphthalein solution (1% wt/vol in ethanol) and the mixture was titrated with standardized 0.1 *M* NaOH until the color changed to pink. The volume consumed by titration of NaOH standard solution was recorded and then the titratable acidity (degrees Thorner; °T) of goat milk yogurt was calculated according to equation [1]:

$$°\mathrm{T} = c \times v \times 100/(m \times 0.1), \quad [1]$$

where c is the molarity of NaOH standard solution; v is the volume consumed by titration of NaOH standard solution; and m is the mass of the goat milk yogurt sample.

Determination of Water-Retaining Capability

Water-retaining capability was determined by the methodology proposed by Hassan et al. (1996). Samples of the goat milk yogurt (15–20 g) were centrifuged at 13,500 × *g* for 30 min at 10°C. The centrifuge tube was kept inverted for 10 min after decanting the clear supernatant, and then the sediment was weighed. The water-retaining capability was calculated according to the equation [2]:

$$\text{Water-retaining capability (\%)} = [\text{weight of sediment (g)}/\text{weight of sample (g)}] \times 100\%. \quad [2]$$

Analysis of the Quality and Structure of Goat Milk Yogurt

The quality and structure of goat milk yogurt were analyzed by the Texture Analyzer (TA. XT2i/50, Stable Micro Systems Ltd., Godalming, UK). Samples of the goat milk yogurt were placed on the platform of the machine and then penetrated by a 35-mm-diameter A/BE probe (Stable Micro Systems Ltd.). Samples were tested by a trigger force of 5 × *g* at an acquisition rate of 200 points per second. The test parameters were set as follows: pretest speed = 1.0 mm/s; test speed = 1.0 mm/s; post-test speed = 1.0 mm/s. The penetration distance was 30.0 mm. Three replications were analyzed using separate repeat samples. The results were expressed as firmness, cohesiveness, and index of viscosity.

Sensory Evaluation

The sensory qualities of the goat milk yogurt were evaluated by 5 trained panelists (3 male, 2 female; 20 to 30 yr old) using the quantitative response scales method (ISO 4121; ISO, 2003). The panelists were trained on flavor profiles, the sniffing technique, the use of scales, and the intensity-rating procedure in accordance with international standards (ISO 8586; ISO, 2012). The sensory training was carried out before sensory evaluation (Yang et al., 2015).

Samples of the goat milk yogurt, contained in screw-cap glass bottles, were randomly marked with 3-digit numbers and presented in random order. Before tasting each sample, the panelists were required to rinse their mouth thoroughly with deionized water. Samples were

scored in terms of whiteness (the score ranged from 0 to 20), aroma (the score ranged from 0 to 20), taste (the score ranged from 0 to 30), and shape (the score ranged from 0 to 30) according to the provided standards. Three replicates were measured using separate repeat samples.

Extraction of Goat Milk Yogurt Fatty Acid

For extraction of fat, 2.4 mL of fermented goat milk yogurt was put into a 30-mL polypropylene centrifugal tube. Next, 1.6 mL of distilled water, 10 mL of methanol, and 5 mL of chloroform were added, blended, and shaken. Five milliliters of distilled water and chloroform were then added, oscillated (2 min), and centrifuged (1,700 × *g*, 10 min at 10°C). The chloroform solution in the bottom layer of the centrifugal tube was transferred into a conical flask and was evaporated until dry in a 65°C water bath.

Methyl esterification of fatty acid was done by adding 0.25 mL of pyrogallic acid methanol solution into fat concentrate, as mentioned above, and then evaporated until dry in a 65°C water bath. Subsequently, 2.5 mL of potassium hydroxide methanol solution was added into the concentrate and it was reflowed for 5 to 10 min in an 80 ± 1°C water bath. The fluid was then reflowed for 15 min in an 80 ± 1°C water bath again after adding 1.5 mL of boron trifluoride-methanol solution; then, the fluid was transferred into the centrifugal tube with 3 mL of saturated sodium chloride solution. Next, 2.5 mL of N-hexane was added into the centrifugal tube and then centrifuged at 2,200 × *g* for 10 min at 10°C after oscillation. The supernatant was measured after microfiltration by a gas chromatograph (Shimadzu GC-2014C, Kyoto, Japan) with a DB-17 column (30 m, 0.25 mm i.d., Agilent, Santa Clara, CA). Temperatures of the inlet and flame-ionization detector were 260 and 280°C, respectively. The oven temperature was kept at 100°C for 5 min and then raised to 240°C at a rate of 4°C/min, with a final isotherm of 15 min. The pressures of the flame-ionization detector air, hydrogen gas, and carrier gas (high-purity nitrogen, ≥99.999%) were 50, 75, and 100 kPa, respectively. The amount of sample was 1 μL. The injection port was operated in split mode (30:1). The data were analyzed using Tukey multiple comparison method with DPS software (version 6.55, Zhejiang University, China).

RESULTS AND DISCUSSION

Effects of Single Factors on the Product Quality of Goat Milk Yogurt

Amount of Sugar Added. Table 1 shows the effects of the amount of sugar added on the product quality of goat milk yogurt. The amounts of sugar added were 5, 6, 7, 8, 9, and 10%. The inoculation amount was 4%. The ratio of 3 lactic acid bacteria—*L. delbrueckii* ssp. *bulgaricus*, *S. thermophilus*, and *Lactobacillus rhamnosus* GG—was 1:1:2 because in our preliminary experiments this ratio had demonstrated good product quality in yogurt. The fermentation temperature was 42°C and ripening time was 16 h. The product quality of goat milk yogurt was evaluated by the titratable acidity, water-retaining capability, sensory score, and texture properties.

Adding sugar into the goat milk yogurt not only augments DM content but also promotes yogurt solidification, which then makes yogurt taste sour and sweet. As shown in Table 1, the sensory quality and texture quality were good when amounts of sugar added were 6, 7, 8, or 9%. If the amount of sugar added was too high the yogurt would taste sour, and if the amount of sugar added was too low the yogurt would taste too sweet. The values of titratable acidity and sensory score were the best and water-retaining capability, firmness, cohesiveness, and index of viscosity were good when the amount of sugar added was 7%. Therefore, 6, 7, 8, and 9% were chosen as the amounts of added sugar in the orthogonal experiment.

Inoculation Amount. Effects of inoculation amount on the product quality of goat milk yogurt were shown in Table 2. The amounts of inoculation were 2, 3, 4, 5, 6, and 7%. The amount of sugar added was 8%. The ratio of the 3 lactic acid bacteria—*L. delbrueckii* ssp. *bulgaricus*, *S. thermophilus*, and *L. rhamnosus* GG—was 1:1:2. The fermentation temperature was 42°C

Table 1. Effects of the amount of sugar added on the product quality of goat milk yogurt

Sugar added (%)	Titratable acidity (°T)	Water-retaining capability (%)	Firmness (g)	Cohesiveness (g)	Index of viscosity (g·s)	Sensory score
5	90	24.91	37.195	16.784	32.723	76
6	95	26.29	37.262	17.156	37.570	81
7	101	28.35	38.024	17.257	33.993	85
8	89	27.13	42.182	20.163	36.934	92
9	85	26.03	39.797	17.294	46.758	88
10	80	24.91	38.676	17.066	36.067	79

Table 2. Effects of inoculation amount on the product quality of goat milk yogurt

Inoculation amount (%)	Titratable acidity (°T)	Water-retaining capability (%)	Firmness (g)	Cohesiveness (g)	Index of viscosity (g·s)	Sensory score
2	80	26.33	50.845	23.505	48.029	71
3	97	30.04	53.995	24.656	61.786	94
4	95	28.60	52.229	24.465	58.968	89
5	93	27.30	44.809	19.534	37.086	84
6	92	26.50	41.018	17.656	39.250	79
7	88	25.62	39.413	16.341	23.084	75

and ripening time was 16 h. The product quality of goat milk yogurt was then evaluated by the titratable acidity, water-retaining capability, sensory score, and texture properties.

As shown in Table 2, the value of titratable acidity was the lowest. Sensory score and texture quality were very low when the inoculation amount was 2%. When the inoculation amount was 3%, the value of titratable acidity was the best. Sensory score and texture quality were also good. Therefore, the inoculation amounts of 2, 3, 4, and 5% were chosen in the orthogonal experiment.

Ratio of Strains. Effects of the ratio of strains on the product quality of goat milk yogurt were shown in Table 3. The ratios of the 3 lactic acid bacteria—*L. delbrueckii* ssp. *bulgaricus*, *S. thermophilus*, and *L. rhamnosus* GG—were 2:2:1, 1:1:1, 1:1:2, 1:1:3, 1:1:4, and 1:1:5. The amount of sugar added was 8%, the inoculation amount was 4%. The fermentation temperature was 42°C and ripening time was 16 h. The product quality of goat milk yogurt was then evaluated by the titratable acidity, water-retaining capability, sensory score, and texture properties.

As shown in Table 3, the values of titratable acidity, water-retaining capability, sensory quality, and texture quality were good when the ratio of the 3 lactic acid bacteria was 1:1:4. The values of titratable acidity, water-retaining capability, and index of viscosity clearly decreased when the proportion of *L. rhamnosus* GG was increased. Protein gel would be dehydrated when the value of titratable acidity was too high. As a result, it lowered the water-retaining capability and made whey dissolve out of yogurt; thus, the index of viscosity was lessoned. The quality of goat milk yogurt would be improved when *L. rhamnosus* GG was added within proper proportion. Therefore, the ratios of the 3 lactic acid bacteria of 1:1:1, 1:1:2, 1:1:3, and 1:1:4 were chosen in the orthogonal experiment.

Fermentation Temperature. Effects of fermentation temperature on the product quality of goat milk yogurt are shown in Table 4. The fermentation temperatures were 36, 38, 40, 42, 44, and 46°C. The amount of sugar added was 8%. The inoculation amount was 4%. The ratio of the 3 lactic acid bacteria was 1:1:2 and ripening time was 16 h. The product quality of goat milk yogurt was then be evaluated by the titratable acidity, water-retaining capability, sensory score, and texture properties.

As shown in Table 4, the sensory quality was the best when the fermentation temperature was 38°C. Lactic acid bacteria grew slowly when the fermentation temperature was 36°C, which lengthened the curd time; thus, the titratable acidity, sensory quality, and texture quality were not very good. When the fermentation temperature was 46°C, such a high temperature restrained lactic acid bacteria growth. As a result, the water-retaining capability, sensory quality, and texture quality were not very good. Therefore the fermentation temperatures of 36, 38, 40, and 42°C were chosen in the orthogonal experiment.

Optimization of Goat Milk Yogurt Fermentation

To determine the optimum fermentation process, amount of sugar added, inoculation amount, ratio of strains, and fermentation temperature were selected with titratable acidity, water-retaining capability, and sensory score as index by L_{16} (4^4) orthogonal experiment. Results of the orthogonal experiment and ANOVA are shown in Tables 5 and 6.

A synthetic weighting method was used to determine the optimum fermentation process. It is hard to curdle yogurt if only *L. rhamnosus* GG is used as a starter. When *L. delbrueckii* ssp. *bulgaricus*, *S. thermophilus*, and *L. rhamnosus* GG were used as a starter in the fermentation process, curd time would be shortened, water-retaining capability and sensory quality would be improved, but titratable acidity would not have been affected. Therefore, water-retaining capability weighted value was 40%, sensory score weighted value was 40%, and the titratable acidity weighted value was 20%.

The range (R) value from Table 5 showed that factor B (inoculation amount) had a great influence on the product quality of goat milk yogurt compared with factors C (ratio of strains), A (amount of sugar added), and D (fermentation temperature), and the optimum

Table 3. Effects of the ratio of strains (*Lactobacillus delbrueckii* ssp. *bulgaricus* to *Streptococcus thermophilus* to *Lactobacillus rhamnosus* GG) on the product quality of goat milk yogurt

Ratio	Titratable acidity (°T)	Water-retaining capability (%)	Firmness (g)	Cohesiveness (g)	Index of viscosity (g·s)	Sensory score
2:2:1	80	26.63	41.532	18.477	34.218	78
1:1:1	85	26.99	43.946	18.994	37.444	81
1:1:2	88	26.78	44.790	19.470	38.373	86
1:1:3	90	27.21	46.500	19.800	40.265	89
1:1:4	92	28.03	49.304	21.225	42.398	90
1:1:5	86	27.85	40.887	17.738	33.294	84

Table 4. Effects of fermentation temperature on the product quality of goat milk yogurt

Fermentation temperature (°C)	Titratable acidity (°T)	Water-retaining capability (%)	Firmness (g)	Cohesiveness (g)	Index of viscosity (g·s)	Sensory score
36	74	21.72	32.934	17.806	26.111	77
38	86	25.80	41.127	21.101	35.686	94
40	91	22.70	39.758	20.584	48.603	89
42	92	23.40	38.019	20.055	44.925	85
44	94	22.46	36.324	18.781	41.483	83
46	90	21.74	35.169	18.826	40.559	82

Table 5. Results and analysis of orthogonal experiments

Test number[1]	Factor[2]				Titratable acidity (°T)	Water-retaining capability (%)	Sensory score	Overall
	A	B	C	D				
1	1 (6%)	1 (2%)	1 (1:1:1)	1 (36°C)	82	24.66	69	80.20
2	1	2 (3%)	2 (1:1:2)	2 (38°C)	98	35.36	93	96.87
3	1	3 (4%)	3 (1:1:3)	3 (40°C)	85	29.56	70	80.95
4	1	4 (5%)	4 (1:1:4)	4 (42°C)	90	34.08	94	96.14
5	2 (7%)	1	2	3	94	28.05	85	86.25
6	2	2	1	4	86	31.24	92	92.10
7	2	3	4	1	102	33.88	84	90.41
8	2	4	3	2	96	28.36	88	89.06
9	3 (8%)	1	3	4	91	28.53	75	80.97
10	3	2	4	3	101	34.02	90	95.15
11	3	3	1	2	96	31.80	81	88.16
12	3	4	2	1	107	29.80	80	92.22
13	4 (9%)	1	4	2	103	27.69	73	80.71
14	4	2	3	1	89	30.65	80	86.45
15	4	3	2	4	104	39.62	67	88.62
16	4	4	1	3	79	30.23	70	81.96
K_1	88.5400	82.0325	85.6050	87.3200				
K_2	89.4550	92.6425	90.9900	88.7000				
K_3	89.1250	87.0350	84.3575	86.0775				
K_4	84.4350	89.8450	90.6025	89.4575				
R	5.0200	10.6100	6.6325	3.3800				

[1]K_1, K_2, K_3, and K_4 = the sum of experimental results of levels, 1, 2, 3, and 4, respectively; R (range) = $K_{max} - K_{min}$.
[2]A = amount of sugar added; B = inoculation amount; C = ratio of strains; D = fermentation temperature.

Table 6. Variance analysis of orthogonal experiments

Sources of variation[1]	Sum of squares	df	Mean square	*F*-value	*P*-value
A	65.3359	3	21.7786	4.0385	0.1408
B	245.7984	3	81.9328	15.1931	0.0256
C	138.6697	3	46.2232	8.5713	0.0555
D	26.8928	3	8.9643	1.6623	0.3433
Error[2]	16.1783	3	5.3928		

[1]A = amount of sugar added; B = inoculation amount; C = ratio of strains; D = fermentation temperature.
[2]Random error.

Table 7. Effects of fermentation with *Lactobacillus rhamnosus* GG on short-chain fatty acids of goat milk yogurt

Item[1]	C4	C6	C8	C10	Σ(C4∼C10)
E	0.71 ± 0.004[a]	1.44 ± 0.03[a]	1.94 ± 0.03[a]	7.27 ± 0.02[a]	11.36 ± 0.03[a]
F	0.75 ± 0.002[b]	1.51 ± 0.009[a]	2.04 ± 0.04[b]	7.44 ± 0.06[a]	11.74 ± 0.08[b]
G	0.00 ± 0.00[b]	1.84 ± 0.004[c]	0.00 ± 0.00[b]	4.77 ± 0.04[c]	0.52 ± 0.02[b]

[a–c]Means within the same column without a common superscript are significantly different ($P < 0.05$).

[1]E = raw goat milk; F = goat milk fermentation with *Lactobacillus rhamnosus* GG; G = goat milk fermentation with the optimum fermentation condition.

combination was $A_2B_2C_2D_4$. The product quality of goat milk yogurt was the best when the amount of sugar added was 7%, the inoculation amount was 3%, the ratio of the 3 lactic acid bacteria was 1:1:3, and fermentation temperature was 42°C. As shown in Table 6, factor B had a significant ($P < 0.05$) effect on the result, whereas factor A, C, and D had no significant effect on it. This is probably due to the small difference levels between each factor or a large error of measurement.

Analysis of Goat Milk Yogurt Fatty Acids

The fatty acids of raw goat milk (marked as E), goat milk fermentation with *L. rhamnosus* GG (marked as F), and goat milk fermentation with the optimum fermentation conditions (marked as G) were determined by a gas chromatograph.

As shown in Tables 7, 8, and 9, the content of short-chain and medium-chain fatty acids increased significantly ($P < 0.05$) and the content of long-chain fatty acids decreased in goat milk fermentation with *L. rhamnosus* GG compared with raw goat milk. This is likely due to short-chain and medium-chain fatty acids being in the sn-3 position of the triglyceride molecule and these fatty acids were hydrolyzed first by lipoprotein lipase in fermented goat milk, which increased the percentage of short-chain and medium-chain fatty acids and decreased that of long-chain fatty acids, which improved absorptivity and health function of goat milk. The content of short-chain and medium-chain fatty acids deceased significantly ($P < 0.05$) and the content of long-chain fatty acids increased in goat milk fermentation with the optimum fermentation conditions compared with raw goat milk. This is probably due to inhibited activity of the lipoprotein lipase when *L. delbrueckii* ssp. *bulgaricus* and *S. thermophilus* with *L. rhamnosus* GG were mixed as a starter culture. The content of short-chain and medium-chain fatty acids decreased so as to weaken the "goaty" smell of goat milk.

CONCLUSIONS

The optimum fermentation conditions were optimized through single-factor experiments and orthogonal experiments. The results show that high product quality of goat milk yogurt can be obtained when the amount of sugar added was 7%, inoculation amount was 3%, the ratio of the 3 lactic acid bacteria—*L. delbrueckii* ssp. *bulgaricus*, *S. thermophilus*, and *L. rhamnosus* GG—was 1:1:3, and the fermentation temperature was 42°C. Through the demonstration test, the value of titratable acidity is 101°T, the water-retaining capability is 39.89%, the sensory score is 95, and the viable count reaches 10^8 to 10^9 cfu/mL when the optimum fermentation conditions were used. The content of short-chain and medium-chain fatty acids decreased significantly ($P < 0.05$) and the smell of goat milk was weakened in goat milk fermentation with the optimum fermentation conditions compared with raw goat milk and goat milk fermentation with *L. rhamnosus* GG through the analysis of goat milk yogurt fatty acids by a gas chromatograph. The resulting goat milk yogurt features

Table 8. Effects of fermentation with *Lactobacillus rhamnosus* GG on medium-chain fatty acids of goat milk yogurt

Item[1]	C11	C12	C13	C14	C15	Σ(C11∼C15)
E	0.06 ± 0.005[a]	2.93 ± 0.01[a]	0.08 ± 0.003[a]	8.00 ± 0.01[a]	1.05 ± 0.05[a]	12.12 ± 0.05[a]
F	0.00 ± 0.00[b]	3.06 ± 0.06[a]	0.00 ± 0.00[b]	8.05 ± 0.004[a]	1.08 ± 0.009[a]	12.34 ± 0.0002[b]
G	0.00 ± 0.00[b]	1.44 ± 0.02[b]	0.00 ± 0.00[b]	3.57 ± 0.02[b]	0.48 ± 0.003[b]	5.49 ± 0.007[c]

[a–c]Means within the same column without a common superscript are significantly different ($P < 0.05$).

[1]E = raw goat milk; F = goat milk fermentation with *Lactobacillus rhamnosus* GG; G = goat milk fermentation with the optimum fermentation condition.

Table 9. Effects of fermentation with *Lactobacillus rhamnosus* GG on long-chain fatty acids of goat milk yogurt

Item[1]	C16	C17	C18:0	C18:1	C18:2	C18:3	Σ(C16~C18)
E	24.52 ± 0.17[a]	1.47 ± 0.04[a]	0.33 ± 0.04[a]	10.54 ± 0.006[a]	18.47 ± 0.2[a]	0.11 ± 0.009[a]	55.32 ± 0.3[a]
F	24.35 ± 0.01[a]	1.39 ± 0.02[a]	0.23 ± 0.007[b]	9.174 ± 0.04[b]	18.04 ± 0.05[a]	0.00 ± 0.00[b]	53.18 ± 0.06[b]
G	25.63 ± 0.01[b]	1.49 ± 0.01[ab]	0.24 ± 0.008[b]	29.53 ± 0.003[c]	3.85 ± 0.05[b]	0.00 ± 0.00[b]	60.73 ± 0.06[c]

[a–c]Means within the same column without a common superscript are significantly different ($P < 0.05$).

[1]E = raw goat milk; F = goat milk fermentation with *Lactobacillus rhamnosus* GG; G = goat milk fermentation with the optimum fermentation condition.

weak curds, fine and smooth texture, rich flavor, and pure yogurt taste.

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