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Comparative analysis of physical properties and fatty acid composition of set-yogurt manufactured from different milk types

Juni Sumarmono[1*], Triana Setyawardani[1], Mays Tianling[1], Nur Aini[2], Condro Wibowo[2], Tasnim H. Mohamed[3], Jintana Sangsopha[4], and Zainal A. Jelan[5]

[1] Faculty of Animal Science, Jenderal Soedirman University, Purwokerto, 53122, Indonesia
[2] Faculty of Agriculture, Jenderal Soedirman University, Purwokerto, 53122, Indonesia
[3] Faculty of Agriculture, Omdurman Islamic University, Khartoum, Sudan
[4] Faculty of Science and Technology Phetchaburi Rajabhat University, Ratchaburi, Thailand
[5] Faculty of Health and Medical Sciences, Taylor's University, Kuala Lumpur, Malaysia

Abstract

The increasing consumption of fermented milk products such as yogurt can be attributed to their health benefits as it contains milk-derived essential nutrients and probiotic lactic acid bacteria added as a starter culture. Yogurt is made from different types of fresh and reconstituted milk. The unique characteristics of goat milk provide an opportunity to produce yogurt that meets consumers' preferences. This study determined, evaluated and compared the physical properties, fatty acid composition and the nutrient/health index based on the fatty acids profiles of goat's and cow's milk set yogurt. The yogurt was made from different milk types, which were goat's milk, cow's milk, a combination of goat's and cow's milk, commercial pasteurized full-fat cow's milk, and low-fat cow's milk. Physical properties evaluated were spontaneous or free whey, syneresis, water-holding capacity, viscosity, and texture. The composition of fatty acids was determined, grouped, and used to assess the nutrient/health index. The physical differences between yogurt prepared from goat's milk and cow's milk were established. This study revealed 21 different fatty acids in set yogurt made from goat's and cow's milk, and the goat's milk yogurt contained 6 fatty acids in the highest proportion. The yogurt contained an average of 62.3% saturated fatty acids and 37.7% unsaturated fatty acids. This study demonstrated the effect of milk types on the variation of yogurt's physical properties and fatty acid composition. This information is valuable to establish the ways to enhance the product's quality.

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1. Introduction

In recent years, the consumption of fermented milk in Indonesia has been increasing. Yogurt is one type of fermented milk that receives particular interest and consumer demand. This trend aligns with the global trend, where the demand for probiotic fermented milk is increasing due to claims of health benefits (1). A recent systematic review conducted by Savaiano and Hutkins (2) supports the association of health and the consumption of fermented milk and health. The claims included enhanced lactose digestion and gastrointestinal health, decreased risk of colon cancer, weight control, and enhanced cardiovascular and bone health. The presence of probiotic bacteria originating from yogurt

* Correspondence : **Juni Sumarmono** juni.sumarmono@unsoed.ac.id

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culture and the nutritional content of fermented milk explains the health benefit of fermented milk (1,3–5).

Various types of yogurt are currently available, including set-type, drink/stirred-type, greek-style, and frozen yogurt types. Yogurt can be made from a wide range of types of fresh and pasteurized milk. However, the majority of yogurt sold commercially is made from reconstituted milk. The variation in milk characteristics and composition contributes to the quality and composition of yogurt. Compositional variations in fresh milk are primarily attributable to species differences, feeding and production management, and processing techniques. Therefore, there is an opportunity to increase consumer acceptance by manufacturing yogurt from various milk types (6).

Most fresh milk produced in Indonesia comes from modern and traditional dairy farms. Local goat milk production has grown significantly in recent years and has contributed significantly to total domestic milk production (7). The growing interest in non-bovine milk products, particularly goat milk, has increased due to the specific proteins in cow's milk that cause cow's milk allergy or CMA (6,8). Only a few communities practice buffalo milking in a much-localized area and only a small quantity of fresh milk is produced (9). Liquid milk reconstituted from imported powdered milk still dominates the market and is widely available. Pasteurized and packaged cow's milk is available in full-fat and low-fat types. Different types of milk influence the physical properties of yogurt and its acceptability to consumers (6).

Physical characteristics of set yogurt, such as the amount of spontaneous whey, the susceptibility of yogurt matrix to syneresis, viscosity, water holding capacity and texture, are important properties during processing and storage. The study of Guénard-Lampron et al. (10) revealed that yogurt's syneresis and flow resistance remained stable; however, viscosity, firmness, and flow time increased.

Milk fat significantly impacts the nutritional and sensory properties of yogurt. During fermentation by lactic acid bacteria, milk lipid undergoes various alterations depending on the types of bacteria present and the fermentation conditions. Milk from goats and cows differs in lipid composition (11,12). The fermentation process causes the fatty acid composition of milk to change. The fatty acid profile of goat milk is associated with its health benefits (13). To offer a more thorough understanding of the factors affecting fatty acid variability, it is important to gather additional details on the fatty acid composition of yogurt made from various types of milk. The physical properties of yogurt and its composition of fatty acids are two important quality attributes that determine the overall quality of yogurt. Providing scientific information on these two attributes is imperative to produce yogurt that meets consumers' demands. This study aimed to characterize the physical properties of yogurt and the fatty acid composition of set yogurt produced from goat's and cow's milk, their mixture, and commercial fresh milk. Estimation of the nutritional/health index of yogurt was also carried out based on the composition of fatty acids.

2. Materials and Methods

2.1. Milk Preparation

Five types of milk were used in this study. Fresh goat's milk (GM) of *Etawah* crossbred was procured from local farmers in the Banyumas region, Central Java Province. Fresh cow's milk (CW) was obtained from the university experimental farm. A 50:50 mixture of cow's and goats milk was obtained by mixing equal proportion of the milk at the beginning of the processing stage. Commercial full-fat (3.6% fat) and low-fat (1.0% fat) pasteurized cow's milk were obtained from a local supplier. These milks were prepared from fresh milk produced by a commercial dairy farm in the East Java Province.

2.2. *Yogurt Preparations*

Milk bases for yogurt production consisted of fresh GM, fresh CM, a combination of goat's and cow's milk (GM+CM), commercial pasteurized full-fat cow's milk (FFM), and low-fat cow's milk (LFM). All milk bases for yogurt production were standardized to contain 15% total solids by adding skim milk (0.9% fat content). We used a total of 2.5 kg milk base for each milk type.

The standardized milk bases were heated to 80°C for 5 min and then cooled to 42°C. Fermentation was initiated by directly adding freeze-dried yogurt starter (Lallemand Inc, Montreal, Canada) at a rate of 1 g/kg milk base. The yogurt starter contained 3 species of lactic acid bacteria: *L. delbrueckii subspecies bulgaricus, S. thermophilus,* and *L. acidophilus*. Each unit of set yogurt was produced in a 200mL capacity glass jar, and incubation was done at 42°C. Fermentation was terminated when the pH of the yogurt reached 4.5 in approximately 4 hours (14). All yogurt samples were refrigerated overnight at 5°C for further analysis.

2.3. *Measurement of Spontaneous Whey*

Spontaneous whey, or whey-off, is the release of free whey from yogurt gel that accumulates at the surface. The measurement method followed the procedure of Saleh et al. (15) with slight modifications. Prior to measurement, the yogurt sample in a glass jar was refrigerated overnight at 5 to 6°C. The jar was tilted at a 45-degree angle for 30 minutes to allow free whey to accumulate on one side of the jar. The free whey was drawn from the jar with a syringe, collected in a cup and weighed. Spontaneous whey was expressed as g/100gm yogurt sample.

2.4. *Measurement of Viscosity*

The yogurt viscosity measurements were carried out at ambient temperature using a Digital Rotary Viscometer NDJ-8S mounted with rotor No 2 and a rotational speed of 30 rpm. The readings were noted as centipoises (cP).

2.5. *Measurement of Whiteness Index (WI)*

A portable colorimeter (Konica CR410, Konica-Minolta Inc, Japan) was used to measure the color coordinates (L*a*b) of yogurt sample. Yogurt sample was placed in 25mL volume container. Measurements were carried out in duplicate for each sample. The WI of yogurt was calculated using the following formula (16):

$$WI = 100 - \sqrt{((100 - L*)^2) + a*^2 + b*^2} \quad (1)$$

2.6. *Measurement of Syneresis*

The susceptibility of yogurt to syneresis was determined by using a modified and improved drainage technique. A total of 50g yogurt sample was placed in a glass funnel lined with a Whatman filter paper No 1. The whey was allowed to drip for 60 minutes at room temperature. The syneresis was calculated using the following formula:

$$Syneresis\ (\%) = \frac{Whey\ (g)}{Yogurt\ sample\ (g)}\ x\ 100 \quad (2)$$

2.7. Measurement of Water Holding Capacity (WHC)

The water-holding capacity of yogurt gel was determined using the method of Jaman et al. (17) with slight modification. Yogurt sample of 10g was centrifuged at 4.500 x g for 15 minutes at 10°C. The supernatant or the whey was weighed and used for the calculation of WHC as follows:

$$WHC\ (\%) = \frac{Whey\ (g)}{Yogurt\ sample} \times\ 100 \quad (3)$$

2.8. Measurement of Gel Strength

The textural properties of set-yogurt gel were measured using a TA-XTPlus Food Texture Analyzer (Stable Micro Systems, Godalming, Surrey, UK). The machine was equipped with a cylindrical aluminum probe of 20mm, which penetrated the undisturbed samples of set yogurt. The measurement was done in duplicate at different locations of the yogurt sample. The pre-test speed was 1 mm/s, the test-speed 2 mm/s, and the post-test speed 5 mm/s. The gel strength (gr/cm^2) of yogurt gel was calculated using Exponent Lite v 6.1.16.0 software.

2.9. Determination of Fatty Acids Composition

Extraction of lipids from yogurt sample and the methylation procedures were carried out using procedures described by Serafeimidou et al. (18). Determination of the fatty acid methyl esters (FAME) were carried out using a gas chromatography according to AOAC Official Methods 969.33/963.22 as elaborated by Nurliyani et al. (19). Model GC-8A gas chromatograph (Shimadzu, Tokyo, Japan) with a flame-ionization detector was used to determine the fatty acids composition. The following GC condition was applied: capillary column with 10 & SP-1200: 1 mol/L H_3PO_4 in 80/100 mesh Chromosorb WAW (Supelco). Nitrogen served as the gas carrier at flow rate 75ml/min. The temperature settings for the oven, detector and injector were 125, 175 and 180°C, respectively. Fatty acids composition was expressed as mg per hundred grams of FAME.

2.10. Estimation of Nutrition and Health Index Based on Fatty Acids Composition

Estimation of the nutrition or health index of the fatty acids profile was conducted using previously published formulas (20,21). PUFA/SFA: Polyunsaturated Fatty Acids/Saturated Fatty Acids, Equation (4); MUFA/SFA: Monounsaturated Fatty Acid/Saturated Fatty Acids, Equation (5); IA: Index Atherogenicity, Equation (6); HFA: Hypercholesterolemic Index, Equation (7); HH: Hypocholesterolemia /Hypercholesterolemia ratio, Equation (8); HPI: Health Promoting Index, Equation (9).

PUFA/ SFA (4)
MUFA/ SFA (5)
[C12:0+ (4x C14:0) + C16:0]/ (MUFA + PUFA) (6)
∑C12:0 + C14:0 + C16:0 (7)
(cis−C18: 1+ ΣPUFA)/ (C12: 0+ C14: 0+ C16: 0) (8)
ΣUSFA/ [C12:0+ (4× C14:0) + C16:0] (9)

2.11. Experimental Design and Data Analysis

The experiment was conducted at the Laboratory of Animal Products Processing Technology, Faculty of Animal Science, Jenderal Soedirman University, Indonesia. The five treatments, each with five replicates, consisted of different types of milk: CM: fresh cow's milk, GM: fresh goat's milk, CM+GM: mixes of cow's and goat's milk, FFM: full-fat pasteurized cow's milk, LFM: low-fat pasteurized cow's milk.

One-way analysis of variance and graphic production were carried out using Graphpad Prism v9 (GraphPad Software, San Diego, California USA). The post-hoc honestly significant difference (HSD) test was used for multiple comparisons whenever needed.

3. Results and Discussions

3.1. Physical Properties

The physical properties include spontaneous whey release or spontaneous syneresis, syneresis, apparent viscosity, water holding capacity of yogurt gels, and texture (gel strength), and whiteness index (Table 1). The impact of milk types was significant on spontaneous whey, viscosity, syneresis, water-holding capacity and gel strength. The color or WI of yogurt was similar among milk types.

Table 1. Physical properties of set-type yoghurt produced from different types of milk (mean±SD)*

Components	Milk Type				
	GM	CM	CM+GM	FFM	LFM
Spontaneous whey (g/100g)	0.83 ± 8.7^{c}	6.59 ± 2.12^{a}	4.14 ± 2.98^{abc}	1.92 ±0.54^{bc}	5.43 ±1.42^{ab}
Viscosity (cP)	985.78 ± 271.09^{a}	223.16 ± 1.64.79^{b}	1068.2 ± 174.51^{a}	1135.58 ± 142.41^{a}	521.65 ± 107.83^{b}
Whiteness index	86.42 ± 4.03	80.09 ± 4.17	85 ± 1.95	85.23 ± 1.69	81.84 ± 3.49
Syneresis (%)	12.19 ± 5.86^{c}	32.62 ± 9.71^{a}	32.41 ± 9.16^{ab}	16.21 ± 5.47^{bc}	25.47 ± 5.92^{abc}
Water holding capacity (%)	54.23 ± 16.38^{b}	34.22 ± 4.35^{c}	46.25 ± 5.98^{bc}	83.14 ± 4.77^{a}	49.29 ± 5.76^{bc}
Gel Strength (g/cm^2)	12.48 ± 3^{ab}	11.11 ± 3.66^{ab}	13.22 ± 1.14^{a}	13.73 ± 1.34^{a}	7.89 ±0.35^{b}

*Values with different superscript letters within the same row differ significantly ($p < 0.05$). CM: Fresh cow's milk, GM: Fresh goat's milk, CM+GM: Mixes of cow's and goat's milk, FFM: Full-fat pasteurized cow's milk, LFM: Low-fat pasteurized cow's milk.

Fresh cow's milk produced yogurt with the highest amount of spontaneous whey. On the contrary, fresh goat's milk produced yogurt with the lowest amount of spontaneous whey. The viscosity of yogurt produced from fresh cow's and low-fat commercial cow's milk was significantly less viscous than those produced from goat's milk, combination of goat's and fresh cow's milk, and also full-fat commercial cow's milk. The whiteness index was not significantly different. The susceptibility to syneresis of yogurt made from goat's milk was comparable to that made from full-fat commercial cow's milk. In general, these two types of milk produced yogurt less susceptible to syneresis than yogurt made from other milk types. On the other hand, yogurt made from goat's and full-fat commercial cow's milk showed higher water holding capacity than yogurt made from other milk types.

This study shows that spontaneous or free whey from yogurt ranged from 0.8 % in goat milk yogurt to 6.6% in fresh cow's milk yogurt. During the fermentation process that turns milk into yogurt, the casein in the milk forms a gel-like matrix that entraps the whey within the yogurt. However, the whey can separate from the protein matrix and accumulate at the surface of the yogurt. The presence of free whey indicates the susceptibility of yogurt gel to syneresis. Low levels of free whey indicate yogurt is less susceptible to syneresis. Naturally, goat milk is more homogenous than cow's milk. Among other factors contributing to spontaneous whey formation is the high acid content. High levels of lactic acid in yogurt can cause the breakdown of the yogurt matrix, leading to the separation of whey on the surface.

Syneresis of yogurt refers to the release and separation of whey from the yogurt gel matrix (22). It is indicated that yogurt produced from fresh cow's milk has the highest syneresis, which aligns with the highest amount of spontaneous whey and the lowest capacity of the yogurt gel to retain water within its protein matrix. This characteristic is very important for maintaining the texture and consistency of the yogurt. Yogurt with high syneresis (low water holding capacity) is undesirable as it can lead to a thinner, watery texture, a sour taste and an overall decrease in quality. In addition to milk composition, several factors contribute to yogurt's WHC and syneresis in correlation with yogurt cultures. These include the type, proteolytic activity, production of exopolysaccharides and inoculation rate of the cultures (23). Adding hydrocolloids is recommended to reduce the susceptibility of yogurt to syneresis, particularly when fresh cow's milk is used (24). The addition of protein is also recommended as it creates a gel-like framework that traps water molecules during fermentation and gives it a high capacity to hold water molecules. Calcium ions assist protein cross-linking and boost their capacity to bind water while also serving to sustain this gel-like structure.

Our study demonstrates that different types of milk contribute to the viscosity of yogurt. Viscosity refers to the yogurt's thickness and consistency which contribute to its mouthfeel and overall texture. Fresh cow's milk yogurt and commercial low-fat cow's milk yogurt have significantly less viscosity than yogurt made from other milk types. Goat's milk, combination of goat's and cow's milk and full-fat cow's milk produce yogurt with similar viscosity. Low-fat milk was significantly less viscous than full-fat milk, which shows the importance of milk fat in determining the physical properties of yogurt.

The WI of yogurt was calculated based on the L*a*b values. The WI value of the set-yogurt made from goat's and cow's milk was comparable. Nevertheless, the presence of fat globules contributes to the color differences between goat's and cow's milk. Goat's milk has smaller fat globules than cow milk, which can give it a smoother texture and a lighter color (25).

This study showed that yogurt gel prepared from low-fat milk had the weakest gel strength. Fat plays a crucial role in yogurt texture, and it affects the gel structure by stabilizing the network of proteins and other components in the yogurt matrix. The texture is one of the most important physico-sensory characteristics of yogurt. Some textural impairments such as poor gel strength and syneresis, are likely to occur in different types of yogurt (23). These conditions will certainly influence consumer acceptance. One of the important factors affecting yogurt's texture is milk's composition. Goat's and sheep's milk have different compositions resulting in yogurts with different rheology (26). Adding milk of goat to cow's milk in varying proportions during yogurt production produced yogurt with distinct gel firmness and consistency (27).

3.2. Fatty Acids Composition

The present study revealed 21 different fatty acids in set yogurt made from goat's and cow's milk (Table 2). Significant differences were found in certain fatty acids contents. These were methyl octanoate (C8:0), methyl decanoate (C10:0), methyl laurate (C12:0), methyl palmitate (C16:0), methyl tricosanoate (C23:0), methyl cis-10-pentadecenoate (C15:1), methyl palmitoleate (C16:1); and methyl cis-11-eicosanoate (20:1).

The predominant fatty acids in GM yogurt include methyl octanoate (C8:0); methyl decanoate (C10:0); methyl laurate (C12:0); methyl tricosanoate (C23:0); methyl cis-10-pentadecenoate (C15:1); and methyl cis-11-eicosanoate (20:1). The predominant fatty acids in CM yogurt include methyl laurate (C12:0); methyl pentadecanoate (C15:0); methyl palmitate (C16:0); methyl heptadecanoate (C17:0); methyl palmitoleate (C16:1). One dominant fatty acids in GM+CM yogurt was methyl laurate (C12:0). Predominant fatty acids in FFM and LFM are similar: methyl palmitate (C16:0), methyl tricosanoate (C23:0), methyl palmitoleate (C16:1), and methyl cis-11-eicosanoate (20:1).

The most abundant fatty acid detected in all yogurts was methyl palmitate (C16:0), averaging 34.9%, while, methyl cis-11-, 14-17 eicosadienoate (C20:3 (cis-11, 14, 17)) was found in the lowest proportion averaging 0.13% of total fatty acids. Methyl cis-11-,14-17 eicosadienoate (C20:3 (cis-11, 14, 17)) was only detected in yogurt produced from commercial pasteurized cow's milk FFM and LFM.

Table 3 shows the composition based on grouped or classified fatty acids in the different set yogurts. The grouping includes Short Chain Fatty Acids (SCFA), Medium Chain Fatty Acids (MCFA), dan Long Chain Fatty Acids (LCFA), Saturated Fatty Acids (SFA), and Unsaturated Fatty Acids (USFA). USFA composed of Monounsaturated Fatty Acid (MUFA) and Polyunsaturated Fatty Acids (PUFA). This classification is based on the length of the carbon chain or saturation. Figure 1 shows the type of milk having a significant effect on MCFA and LCFA but not having a noticeable effect on SCFA. Goat milk (GM) produced yogurt with the highest MCFA, while the highest LCFA was obtained in yogurt made using cow's milk (CM, FFM, and LFM).

Table 2. Fatty acids composition of set-yogurt manufactured from different milk types*.

Components	Formula	Milk Type				
		GM	CM	CM+GM	FFM	LFM
Saturated Fatty Acids (SFA)						
Methyl butyrate	C4:0	0.81 ± 0.06	1.39 ± 0.06	1.11 ± 0.21	0.89 ± 0.22	0.7 ± 0.29
Methyl hexanoate	C5:0	1.7 ± 0.19	0.97 ± 0.01	1.3 ± 0.26	1.11 ± 0.26	0.92 ± 0.28
Methyl octanoate	C8:0	2.99 ± 0.35[a]	0.68 ± 0.01[c]	1.76 ± 0.13[c]	0.99 ± 0.23[bc]	0.87 ± 0.22[c]
Methyl decanoate	C10:0	11.49 ± 1.01[a]	1.53 ± 0.06[c]	6.33 ± 0.43[b]	2.66 ± 0.43[c]	2.49 ± 0.43[c]
Methyl undecanoate	C11:0	0.18 ± 0.02	0.19 ± 0.01	0.18 ± 0	0.21 ± 0.03	0.19 ± 0.04
Methyl laurate	C12:0	6.08 ± 0.45[a]	6.11 ± 0.18[a]	5.59 ± 0.26[a]	3.47 ± 0.47[b]	3.44 ± 0.52[b]
Methyl myristate	C14:0	10.78 ± 0.35	12.75 ± 0.17	11.08 ± 0.86	11.31 ± 0.86	11.31 ± 1.12
Methyl pentadecanoate	C15:0	0.59 ± 0[c]	1.94 ± 0.04[a]	1.12 ± 0.19[b]	1.30 ± 0.01[b]	1.2 ± 0.04[b]
Methyl palmitate	C16:0	28.71 ± 0.37[c]	34.8 ± 0.03[b]	30.9 ± 0.16[bc]	39.51 ± 1.3[a]	40.51 ± 2.8[a]
Methyl heptadecenoate	C17:0	0.47 ± 0[c]	0.6 ± 0.01[a]	0.55 ± 0.01[b]	0.39 ± 0[d]	0.39 ± 0.01[d]
Methyl henneicosanoate	C21:0	0.46 ± 0.11	0.55 ± 0.02	0.53 ± 0.01	0.39 ± 0.01	0.25 ± 0.18
Methyl tricosanoate	C23:0	0.23 ± 0.01[a]	0.13 ± 0[b]	0.18 ± 0[ab]	0.21 ± 0.03[a]	0.23 ± 0.01[a]
Unsaturated Fatty Acids (USFA)						
Methyl cis-10-pentadecenoate	C15:1	0.34 ± 0[a]	0.26 ± 0[c]	0.31 ± 0[b]	0.23 ± 0.01[d]	0.22 ± 0.01[d]
Methyl palmitoleate	C16:1	0.51 ± 0.04[c]	2.24 ± 0.04[a]	1.36 ± 0.22[b]	2.48 ± 0.01[a]	2.45 ± 0.08[a]
Methyl cis-10 heptadecenoate	C17:1	0.23 ± 0.01	0.37 ± 0	0.36 ± 0.01	0.24 ± 0.03	0.34 ± 0.14
Methyl cis-9-oleate	C18:1	1.8 ± 0	1.64 ± 0.06	12.9 ± 15.83	12.08 ± 15.24	11.99 ± 15.08

Methyl linolelaidate	C18:2n9t	19.91 ± 0.23	23.28 ± 0.27	11.15 ± 15.16	10.5 ± 14.06	10.12 ± 13.46
Methyl linoleate	C18:2	1.93 ± 2.57	1.46 ± 0.01	2.66 ± 0.06	1.76 ± 2.24	1.76 ± 2.26
Methyl trans-9-elaidate	C19:1n9c	10.61 ± 0.17	9.03 ± 0.21	10.49 ± 0.39	9.89 ± 0.47	10.29 ± 0.81
Methyl cis-11-eicosanoate	C20:1	0.22 ± 0.01[a]	0.11 ± 0[b]	0.16 ± 0[ab]	0.22 ± 0.03[a]	0.22 ± 0.01[a]
Methyl cis-11-,14-17 eicosadienoate	C20:3 (cis-11, 14, 17)	0	0	0	0.12 ± 0.01	0.15 ± 0.02

*Values are expressed as mean ± standard deviation for duplicate analysis. Different lowercase letters in the same row indicate significant differences ($p < 0.05$). [a]Description of milk = **CM**: Fresh cow's milk; **GM**: Fresh goat's milk; **CM+GM**: Mixes of fresh cow's and goat's milk; **FFM**: full-fat pasteurized cow's milk, **LFM**: low-fat pasteurized cow's milk.

Table 3. Composition of grouped fatty acids (mg/100 g FAME) and estimation of nutrition/health indexes (mean±SD) of set yogurt made from different milk types*.

Components	Milk Type				
	GM	CM	CM+GM	FFM	LFM
SCFA	2.51 ± 0.26	2.36 ± 0.08	2.4 ± 0.28	1.99 ± 0.47	1.63 ± 0.53
MCFA	14.65 ± 1.37[a]	2.39 ± 0.08[c]	8.28 ± 0.54[b]	3.85 ± 0.67[c]	3.55 ± 0.67[c]
LCFA	82.86 ± 1.63[c]	95.26 ± 0.16[a]	89.32 ± 0.83[b]	94.15 ± 1.15[a]	94.83 ± 1.2[a]
SFA	64.46 ± 2.92	61.62 ± 0.49	60.62 ± 1.34	62.49 ± 3.8	62.48 ± 4 .72
USFA	35.55 ± 2.92	38.39 ± 0.49	39.38 ± 1.34	37.51 ± 3.8	37.52 ± 4.72
MUFA	13.71 ± 0.13	13.65 ± 0.23	25.58 ± 16.44	25.13 ± 15.64	25.49 ± 15.93
PUFA	21.84 ± 2.79	24.74 ± 0.26	13.81 ± 15.1	12.39 ± 11.83	12.03 ± 11.21
PUFA/SFA	0.34 ± 0.06	0.41 ± 0.01	0.23 ± 0.25	0.20 ± 0.18	0.19 ± 0.16
MUFA/SFA	0.21 ± 0.01	0.23 ± 0.21	0.43 ± 0.28	0.42 ± 0.28	0.42 ± 0.28
IA	2.2 ± 0.24	2.39 ± 0.05	2.06 ± 0.11	2.38 ± 0.38	2.41 ± 0.49
HFA	45.57 ± 1.18[b]	53.66 ± 0.33[ab]	47.56 ± 0.69[ab]	54.36 ± 2.62[a]	55.26 ± 3.73[a]
HH	0.52 ± 0.01	0.49 ± 0.01	0.57 ± 0.02	0.45 ± 0.08	0.44 ± 0.11
HPI	0.46 ± 0.05	0.41 ± 0.01	0.49 ± 0.03	0.43 ± 0.06	0.43 ± 0.09

*Values are expressed as mean ± standard deviation for duplicate analysis. Means with Differentsuperscript letters within the same row indicate significant differences ($p < 0.05$). [a]Milk type = **CM**: Fresh cow's milk; **GM**: Fresh goat's milk; **CM+GM**: Mixes of fresh cow's and goat's milk; **FFM**: full-fat pasteurized cow's milk, **LFM**: low-fat pasteurized cow's milk. [b]Fatty acids = **SCFA** (Short Chain Fatty Acids)**:** carbon chain C4-C7; **MCFA** (Medium Chain Fatty Acids)**:** carbon chain C8-C11; **LCFA** (Long Chain Fatty Acids): carbon chain >C12; **SFA** (Saturated Fatty Acids): C4:0, C5:0, C8:0, C10:0, C12:0, C14:0, C15:0, C16:0, C17:0, C21:0, and C23:0. **USFA** (Unsaturated Fatty Acids): C15:1, C16:1, C17:1, C19:1n9c, C18:1, C18:2n9t, C18:2, C20:1, and C20:3 (cis-11, 14, 17). **MUFA** (Mono Unsaturated Fatty Acid): C15:1, C16:1, C17:1, C19:1n9c, C18:1, and C20:1. **PUFA (**Poly Unsaturated Fatty Acid): C18:2n9t, C18:2, and C20:3 (cis-11, 14, 17). **PUFA/SFA:** Polyunsaturated Fatty Acids/Saturated Fatty Acids, Equation (4); **MUFA/SFA:** Monounsaturated Fatty Acid/Saturated Fatty Acids, Equation (5); **IA:** Index of Atherogenicity, Equation (6); **HFA:** Hypercholesterolemic Index, Equation (7); **HH:** Hypocholesterolemic/Hypercholesterolemic ratio, Equation (8); **HPI:** Health Promoting Index, Equation (9).

The present study shows that short-chain fatty acids were the most abundant fatty acids in cow's and goat's milk yogurt. Meanwhile, the proportion of saturated fatty acids is significantly higher than that of unsaturated fatty acids (Figure 1). Among unsaturated fatty acids, the mono-unsaturated fatty acids of goat's milk and fresh cow's milk are in higher proportion than those in other milk types (Figure 2).

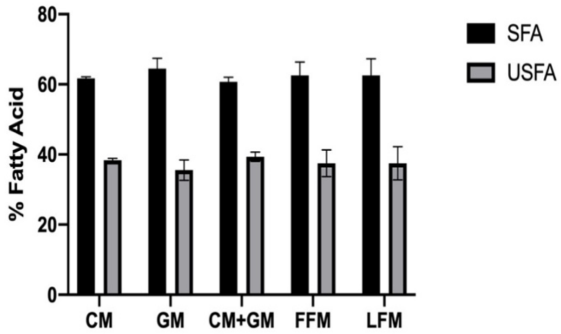

Figure 1. Comparison of SFA and USFA of set-type yogurt manufactured from different types of milk (% total fatty acids).

Milk types **CM**: Fresh cow's milk; **GM**: Fresh goat's milk; **CM+GM**: Mixes of fresh cow's and goat's milk; **FFM**: full-fat pasteurized cow's milk, **LFM**: low-fat pasteurized cow's milk. Fatty acids **SFA** (Saturated Fatty Acids): C4:0, C5:0, C8:0, C10:0, C12:0, C14:0, C15:0, C16:0, C17:0, C21:0, and C23:0. **USFA** (Unsaturated Fatty Acids): C15:1, C16:1, C17:1, C19:1n9c, C18:1, C18:2n9t, C18:2, C20:1, and C20:3 (cis-11, 14, 17).

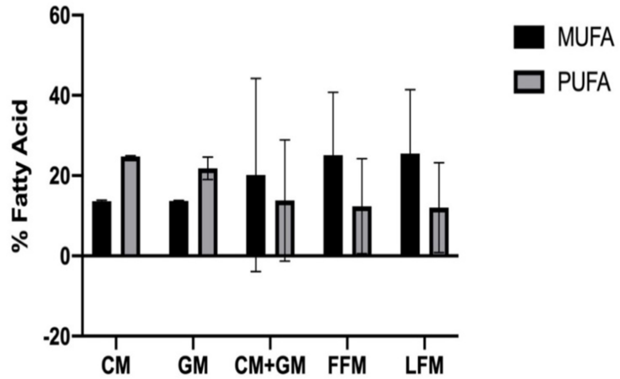

Figure 2. Comparison of MUFA and PUFA (%) of set-type yogurt made from cow's and goat's milk (% total fatty acids).

Milk types **CM**: Fresh cow's milk; **GM**: Fresh goat's milk; **CM+GM**: Mixes of fresh cow's and goat's milk; **FFM**: full-fat pasteurized cow's milk, **LFM**: low-fat pasteurized cow's milk. Fatty acids **MUFA** (Monounsaturated Fatty Acid): C15:1, C16:1, C17:1, C19:1n9c, C18:1, and C20:1. **PUFA (**Poly Unsaturated Fatty Acid): C18:2n9t, C18:2, and C20:3 (cis-11, 14, 17).

This study shows that the milk types significantly affected the composition of fatty acids in yogurt. When compared to other milk types, yogurt made from goat's milk (GM) has the highest proportion of fatty acids, with six; followed by yogurt made from fresh cow's milk (CM), which has five; pasteurized cow's milk (FFM and LFM), which has four; and yogurt made from a combination of cow's milk and fresh goat milk (CM + GM), which has one fatty acid.

Variation in fatty acid composition can be attributed to the raw material differences. The fatty acid composition of goat’s and cow’s milk differs (11). Goat’s milk contains a higher proportion of medium-chain and conjugated linoleic acids (CLA) and a lower amount of C18:0 and C18:1 compared to cow milk.

Milk lipids undergo several modifications during fermentation, including the hydrolysis of triglycerides, the creation of fatty acids with distinct flavors, such as diacetyl, and the generation of long and short-chain fatty acids. Yogurt culture's lactic acid bacteria can convert free fatty acids into short-chain fatty acids like butyric acid and caproic acid, enhancing the finished product's flavor and aroma. Fermentation can affect the composition of fatty acids, which can cause an increase or decrease in the composition of fatty acids (28). In addition to raw materials, the fatty acid profile of dairy products is also influenced by processing factors such as heat treatment, homogenization, fermentation, and storage (29). In general, the fermentation of milk by lactic acid bacteria can result in changes to the lipid content that contribute to the unique sensory properties and potential health benefits of fermented dairy products.

This study shows regardless of the types of milk, yogurt contains 2.2, 6.5, and 91.3% SCFA, MCFA, and LCFA, respectively. LCFA is the most abundant group of fatty acids. A previous study by Güler and Park (30) showed a similar order. The concentration of SCFA, MCFA, and LCFA was reported as within the range of 6.8-7.8%, 10.8-13.0%: dan 82.2-79.2%, respectively.

Some fatty acids may cause atherosclerosis. Methyl palmitate (C16:0) is known to have hypercholesterolemic properties and is responsible for insulin resistance, serving as a biomarker of inflammation, serum triglycerides, and obesity (31). Methyl butyrate (C4:0) and methyl hexanoate (C5:0) are SCFAs that contain the same content in all types of milk. Gu et al. (32) reported that methyl hexanoate (C5:0) is the most dominant SCFA fatty acid in yogurt, followed by methyl butyrate (C4:0). The SCFA increases by 1.25-2.01 folds during fermentation. The group of fatty acids that have been associated with potential benefits in preventing atherosclerosis are MUFA and PUFA.

Figure 2 shows SFA and USFA content of yogurt. On the average, yogurt contains SFA and USFA as much as 62.33% and 37.67%. SFA is associated with cardiovascular disease and coronary heart disease (33). The high SFA content in dairy products is undesirable (34).

USFA plays a crucial role in reducing atherosclerotic plaques and esterified fatty acid levels (35). Increasing the USFA concentration during the milk fermentation process can improve the final product's nutritional value. Therefore, numerous initiatives were undertaken to increase the ratio of USFA to SFA. The present study confirmed that SFA predominates in milk products. SFA is often considered "unhealthy" fats because it can increase LDL cholesterol levels and contribute to heart disease. Food product with high PUFA to SFA ratio is generally considered desirable because PUFAs in the diet can depress low-density lipoprotein cholesterol (LDL-C) and lower levels of serum cholesterol and suggests that the food is more healthy.

The study reveals no significant differences among treatments regarding MUFA and PUFA. Yogurt contains an average of 20.7% MUFA and 17.0% PUFA. Previous research demonstrated that the fermentation of milk into yogurt increased the levels of SFA, MUFA, and PUFA (32). PUFAs are considered to be "healthy" fats and are essential in the diet. PUFAs have numerous health benefits, such as reducing inflammation, enhancing cardiovascular health and promoting brain function.

Data on healthy indexes of fatty acids is presented in Table 3. The milk type significantly affects the hydroxy fatty acid index (HFA) parameter with the highest value found in yogurt made from pasteurized cow's milk (FFM and LFM). HFA measures the relative abundance of hydroxylated fatty acids in the yogurt sample. A higher HFA is associated with a lower risk of cardiovascular disease, possibly due to hydroxylated fatty acids' anti-inflammatory and antioxidant properties.

The ratio of fatty acids n-6 PUFA, n-3 PUFA, PUFA/SFA, and MUFA/SFA is an important parameter for determining the nutritional value of food (36). The MUFA/PUFA ratio of 0.34% is lower than that was reported by of Chalabi et al. (37). MUFA has the same effectiveness as PUFA in lowering serum cholesterol. The MUFA/PUFA ratio can be used as an indicator of protection from heart disease (38).

The ratio of PUFA to SFA in a food product can be used as a predictive factor for the impact of food consumption on cholesterol levels in the blood plasma. Yogurt in the present study has PUFA/SFA ratio of 0.27 and which is within the recommendations of the World Health Organization (less than 0.4).

This study indicates that the atherogenic index (AI) is comparable between goat's and cow's milk yogurt. The average AI value was 2.29 which is low based on the WHO recommendations. The AI is estimated based on SFA and USFA content (39). AI is a significant indicator of a food product's effect on cardiovascular health. A higher AI indicates that the food product is more likely to contribute to the development of atherosclerosis, whereas a lower AI indicates a reduced risk. Through the production of conjugated linoleic acids (CLA) and bioactive peptides by lactic acid bacteria, AI of milk can be decreased through fermentation. Consumption of low AI yogurt can reduce the likelihood of coroner's heart disease (20).

The hypocholesterolemic/hypercholesterolemic (HH) ratio indicates a relationship between hypocholesterolemia fatty acids and hypercholesterolemia fatty acids where a high HH ratio indicates a healthier lipid profile. This study shows that the HH ratio of goats milk yogurt is comparable to that of cow's milk yogurt. On the average, the HH ratio obtained was 0.49 which was comparable to 0.41 as reported by Paszczyk and Tońska (29).

The health-promoting index (HPI) of fatty acids measures the potential health benefits of a particular type of fatty acid, based on its composition and known physiological effects. As with AI and HH values, the HPI of goat’s and cow's yogurt is not significantly different. The average HPI is 0.44%, comparable to 0.48, as reported by Muelaswt et al. (40). However, Chen et al. (20) reported an HPI value of 2.95 for goat cheese.

4. Conclusions

In summary, this study demonstrates the effect of milk types on the variation of yogurt's physical properties and fatty acid composition. There are some major differences between cow’s and goat’s yogurt such as the amount of spontaneous whey, susceptibility to syneresis, viscosity and gel strength. The importance of milk fat to the physical properties of yogurt are confirmed. Yogurt made from low-fat milk possesed higher spontaneous whey, with lower viscosity, water-holding capacity, and gel strength than yogurt made from full-fat milk. There are 21 different fatty acids in set yogurt made from goat’s and cow's milk, and the goat’s milk yogurt contains 6 fatty acids in the highest proportion. The yogurt contains an average of 62.3% saturated fatty acids (SFA) and 37.7% unsaturated fatty acids (USFA). Based on the atherogenic index, hypocholesterolemic/hypercholesterolemic ratio, and health promoting index, goat's milk is comparable to cow's milk. This information is in enhancing the physical properties and organoleptic quality of yogurt manufactured from different milk types.

Author Contributions

J.S.: designing and coordinating the experiment, interpretation of results, overall manuscript preparation and submission; T.S., N.A., C.W.: laboratory works, data analysis, drafting manuscript; M.T., T.H.M.: handling the laboratory work and data collection-tabulation, J.S., Z.A.J.: result interpretation, manuscript proofreading.

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Conflicts of Interest

All authors declare no conflict of interest, financial or otherwise.

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