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Seasonal Variation and Dietary Effects in the Fatty Acid Composition of Bulk Tank Milk in Taiwan

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ABSTRACT

Background: Information about seasonal variation in the fatty acid (FA) composition of bulk tak milk and its relationship with dietary factors in Taiwan remains to be completed. This study aimed to determine the average FA composition of milk in different seasons and collect dietary information to investigate the relationship between dietary characteristics and lactation performance, including FA concentration in bulk tank milk.

Methods: Bulk tank milk samples were collected monthly from 90 dairy farms across Taiwan for two years to capture seasonal variations. Additionally, 36 bulk tank milk samples from three farms were collected monthly from August 2022 to July 2023.

Result: Milk production (kg/day), fat (%), crude protein (%), true protein (%), lactose (%) and solids-not-fat (%) were significantly higher in the cold season than in the hot and warm seasons (P<0.05) over the studied period. In contrast, somatic cell counts were significantly lower in the cold season than in the hot and warm seasons (P<0.05). Total saturated FA and C14:0 concentrations were significantly higher in the cold season than in the hot and warm seasons (P<0.05). In contrast, the C18:1 concentration was significantly higher in the hot and warm seasons than in the cold season (P<0.05). However, the C18:0 concentration did not differ significantly by season. Fat and FA concentrations varied significantly among three selected dairy farms (P<0.05). Milk fat only differed significantly between the three farms in the hot season, with Farm B having the lowest milk fat concentration (P<0.05). FA concentrations showed significant seasonal effects at all three farms. These results provide an overview of milk FA variation and identify the critical factors influencing variation in bulk tank milk fat and individual farm FA concentrations: dietary ether extract content and forage choice.

Key words: Bulk tank milk, Dietary effect, Fatty acid, Season.

INTRODUCTION

Milk comprises 87.5% water, 3.9% fat, 3.4% protein and 5.2% lactose. Milk fat is an essential nutrient for growth and development. Milk fat contains triglycerides and the most abundant fatty acids (FAs) in milk are myristic (C14:0), palmitic (C16:0), stearic (C18:0) and oleic (C18:1) acids. Typically, FAs are classified as saturated, unsaturated, monounsaturated and polyunsaturated.

The frequency of high-temperature days has been increasing recently due to global climate change, which can affect dairy cows' nutritional status and milk quality. Notably, heat stress adaptation is an important issue affecting the dairy industry in tropical and subtropical regions and cows with high milk yield and fat production are more sensitive to heat stress (Coppock, 1985). Moreover, heat stress negatively affects dairy cow health and milk production (West, 2003). High ambient temperatures and humidity can induce a cascade of metabolic reactions in the animal body to maintain thermal balance. At ambient temperatures above 25-26°C, lactating cows exhibit increased body temperature and decreased performance (Berman *et al.,* 1985). Similarly, dairy cow dry matter intake and milk production significantly decrease at temperature humidity indexes (THIs) above 77 (Johnson *et al.,* 1963). Specifically, the milk production of dairy cows decreases by 0.2 kg per unit increase in THI when the THI is above 72 (Ravagnolo *et al.,* 2000). Heat stress can also decrease the short- and medium-chain FA content and increase the long-chain FA content of milk (Hammami *et al.,* 2015).

Recent studies on raw milk fat have focused on the proportions of specific FAs of rumen origin or body fat reserves because the FA profile of dairy cattle is closely related to feeding and management practices. Information on changes in the FA profile and composition can improve our understanding of rumen health and nutritional status in dairy cattle. Currently, gas chromatography (GC) can be used to analyze more than 400 unique FAs in milk. Dairy herd improvement (DHI) milk testing laboratories worldwide primarily use Fourier-transform mid-infrared spectroscopy

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(FT-MIR) for raw milk component analysis (Kaylegian *et al.,* 2006) because it is less time-intensive than GC for milk FA analysis. Moreover, raw milk FA and DHI laboratories' routine milk quality analyses using FT-MIR can provide instant and accurate insights into cattle feeding management and nutritional status for decision-making.

FT-MIR-based FA profiles can be divided into three groups: de novo, mixed and preformed. Using the compositional changes in the three FA types when assessing feed, management and economic performance is crucial for effective livestock management in Asian countries, especially in Taiwan, which is located in a subtropical region greatly affected by high temperatures. Therefore, this study aimed to evaluate the FA profiles of raw milk samples from bulk tanks at local dairy farms using FT-MIR and investigate the effects of seasonal and dietary factors on milk composition in Taiwan.

MATERIALS AND METHODS

Experimental design and sample collection

This study collected 2,073 bulk tank milk samples from 90 dairy farms monthly from 2020 to 2021. After collection, all milk samples were immediately placed on ice and sent to the milk-testing laboratory at the Northern Region Branch of the Livestock Research Institute, Ministry of Agriculture (MOA), Taiwan, Republic of China. The environmental data for each season are shown in Table 1, with the average seasonal THI ranging from 65.65 to 80.88.

Additionally, 36 bulk tank milk samples were collected monthly from three farms in Miaoli (120°94′17.00″E and 24°48′92.70″N; Farm A; N= 12), Changhua (120°31′59.99″ E and 24°03′60.00" N; Farm B; N= 12) and Tainan (120° 10′60.00″E and 22°58′59.99″N; Farm C; N= 12) from August 2022 to July 2023. The animals were fed with total mixed ration (TMR) with different diet compositions among the farms (Farm A: 15.49% crude protein [CP], 3.91% ether extract [EE], 36.67% neutral detergent fiber [NDF], 37.94% non-fiber carbohydrate [NFC] and 21.08% starch; Farm B: 15.90% CP, 4.45% EE, 37.26% NDF, 35.73% NFC and 20.07% starch; Farm C: 15.83% CP, 6.09% EE, 35.14% NDF, 37.15% NFC and 22.01% starch; Table 2). The average milk production for cows at Farms A, B and C were 28.5±3.1, 30.1±2.5 and 28.2±2.2 kg, respectively. The average days in milk, cows age and first artificial insemination conception rate of Farms A, B and C were 170, 198 and 185 days; 41.58, 43.06 and 41.06 months; 33.6%, 34% and 24.4%, respectively.

Milk composition analysis

Milk fat, CP, true protein, lactose, solid-not-fat, total saturated FA (TSFA), total unsaturated FA (TUSFA), de novo FA, mixed FA, preformed FA, C14:0, C16:0, C18:0 and C18:1 concentrations and somatic cell counts (SCCs) were determined at a milk-testing laboratory (Northern Region Branch, MOA, Miaoli, Taiwan, Republic of China) using the FT-MIR devices MilkoScan™ FT⁺ and Fossomatic™ FC (FOSS, Denmark), respectively. FA analysis was performed using the Foss FA Origin package (Schwarz *et al.,* 2018), which divides the milk FAs into three groups: de novo, mixed and preformed. The de novo FA group includes butyric acid (C4:0), caproic acid (C6:0), caprylic acid (C8:0), capric acid (C10:0), lauric acid (C12:0), C14:0 and myristoleic acid (C14:1). The mixed FA group includes C16:0 and palmitoleic acid (C16:1). The preformed FA group includes pentadecylic acid (C15:0), margaric acid (C17:0), C18:0, C18:1, linoleic acid (C18:2), linolenic acid (C18:3), arachidic acid (C20:0), eicosadienoic acid (C20:2), behenic acid (C22:0) and lignoceric acid (C24:0). Twelve raw milk samples were analyzed annually using wet chemistry GC to calibrate the FA module for the FT-MIR analysis. The GC was conducted at Eurofins Modern Testing Services (Taiwan).

Statistical analyses

The evaluated variables included environmental, dietary and milk data. Milk data were compiled according to three seasons: hot (June-September), warm (April, May, October and November) and cold (January-March and December). The yearly averages for milk yield and composition were used to analyze the seasonal variation and dietary effects. All milk data were analyzed using SAS software (version 9.4; SAS Institute Inc., Cary, NC, USA) with the model:

$$Y_i = \mu + T_i + \varepsilon_i$$

Where:

Y_i= Dependent variable (e.g., milk yield, milk fat and FA).

μ= Total mean.

T_i= Effect of the i^{th} season (*i* = cold, hot and warm) or i^{th} farm diet (*i* = A, B and C).

ε_i= Residual error.

Table 1: Variations in temperature, humidity and THI in different seasons[1] in Taiwan.

Item	Season				
	Cold	Hot	Warm	Overall	SEM
Temperature	19.37^{c}	28.95^{a}	25.02^{b}	24.45	0.254
Humidity	75.89^{ab}	77.59^{a}	75.03^{b}	76.17	0.563
THI[2]	65.65^{c}	80.88^{a}	74.42^{b}	73.65	0.391

[1]Cold: January, February, March and December; Warm: April, May, October and November; Hot: June, July, August and September.

[a,b,c] Means in the same row without the same superscript indicates a significant difference between seasons (*P*<0.05).

[2]THI- Temperature-humidity index.

The least squares means were calculated and multiple comparisons were made, with *P*-values adjusted according to Tukey's procedure. A $P<0.05$ was considered statistically significant.

RESULTS AND DISCUSSION

Variations in milk composition are associated with the season

Table 1 shows the average THI in the cold, hot and warm seasons during the studied period, which were 65.65, 80.88 and 74.42, respectively; only the cold season had a THI below 72. The THI is a valuable and easy way to assess the risk of heat stress. Animals experience mild heat stress at THIs from 72 to 79 and moderate heat stress at THIs from 80 to 89 (NRC, 2001). In our study, the THI markedly exceeded 72 in the hot and warm seasons.

Variations in milk production and the composition of bulk tank milk samples in different seasons are shown in Table 3, while the FA profiles are shown in Table 4. Milk production (kg/day), fat (%), CP (%), true protein (%), lactose (%) and solids-not-fat (%) were significantly higher in the cold season than in the hot and warm seasons over the studied period ($P<0.05$). In contrast, the SCCs were significantly lower in the cold season than in the hot and warm seasons ($P<0.05$).

Climatic factors, such as ambient temperature, radiation, relative humidity, wind speed and their interactions, have been reported to affect animal performance (Sharma *et al.,* 1983). In our study, the highest average milk yield

Table 2: The dietary data for milking cows at the three selected dairy farms.

	Farm A
Major ingredient	concentrate[1], oat grass, Alfalfa
Crude protein (%)	15.49
Ether extract (%)	3.91[c]
Neutral detergent fiber (%)	36.67[ab]
Non-fiber carbohydrate (%)	37.94[a]
Starch	21.08[a]
	Farm B
Major ingredient	concentrate, oat grass, corn silage
Crude protein (%)	15.90
Ether extract (%)	4.45[b]
Neutral detergent fiber (%)	37.26[a]
Non-fiber carbohydrate (%)	35.73[b]
Starch	20.07[b]
	Farm C
Major ingredient	concentrate, oat grass, Alfalfa, *Pennisetum* grass, corn silage
Crude protein (%)	15.83
Ether extract (%)	6.09[a]
Neutral detergent fiber (%)	35.14[b]
Non-fiber carbohydrate (%)	37.15[a]
Starch	22.01[a]

[1]Concentrate: Milking cow concentrate and soybean hull.

[a,b,c]Means in the same item without the same superscript indicates a significant difference between farms ($P<0.05$).

Table 3: Variations in milk yield and the composition of bulk tank milk samples in different seasons[1].

Milk component	Season				SEM
	Cold	Hot	Warm	Overall	
Milk yield (kg/day)	24.65[a]	22.56[c]	23.73[b]	23.65	0.168
Fat (%)	3.87[a]	3.79[c]	3.84[b]	3.83	0.007
Crude protein (%)	3.34[a]	3.30[b]	3.30[b]	3.31	0.005
True protein (%)	3.16[a]	3.12[c]	3.13[b]	3.14	0.005
Lactose (%)	4.78[a]	4.74[b]	4.78[a]	4.77	0.005
Solids-not-fat (%)	8.84[a]	8.74[c]	8.80[b]	8.79	0.006
SCC[2] ($\times 10^4$ cells /mL)	19.9[c]	22.7[a]	20.8[b]	21.1	0.29

[1]Cold: January, February, March and December; Warm: April, May, October and November; Hot: June, July, August and September.

[a,b,c]Means in the same row without the same superscript indicates a significant difference between seasons ($P<0.05$).

[2]SCC: somatic cell count.

was recorded in the cold season (January, February, March and December), while the lowest yield was recorded in the hot season (June, July, August and September), confirming the inverse correlation between milk yield and heat stress effects modeled with the THI (Table 3).

Significant seasonal effects have been observed in milk yield, fat, true protein and SCC contents (Allore *et al.,* 1997). In our study, fat (%), CP (%), true protein (%), lactose (%) and solids-not-fat (%) were significantly higher in the cold season than in the hot and warm seasons. These results are similar to Giannone *et al.* (2023). Milk protein content is decreased in heat-stress cattle due to the specific downregulation of protein synthesis in the mammary glands (Cowley *et al.,* 2015). In our study, the true protein concentration differed significantly between the hot and warm seasons ($P<0.05$). Bhakat *et al.* (2022) pointed out that tropical climate had adverse influence on SCC.

Nutrient intake and nutrient uptake by the portal-drained viscera are expected to decrease high-temperature conditions. West (2003) stated that blood flow shifts to the peripheral tissue for cooling under high environmental temperature conditions and contributes less to milk synthesis. Specifically, high temperatures and humidity adversely affect milk production and protein content (Johnson *et al.,* 1963). For example, milk protein content was lower at temperatures above 30°C than below 15°C. Additionally, protein content was higher in November and December than during the rest of the year in the same region (Karlsson *et al.,* 2017; Priyashantha *et al.,* 2021). Seasonal variations in FA concentrations may also result from stress factors, such as lower feed intake and temperature fluctuations.

Since variations in FA content are related to changes in milk yield, this study examined bulk tank milk FA concentration (g/100 g of milk) instead of the FA proportion (g/100 g of FA). The FA composition of the bulk tank milk is shown in Table 4. The mean percentages of TSFA, TUSFA, de novo FA, mixed FA, preformed FA, C14:0, C16:0, C18:0 and C18:1 in milk were 2.54%, 1.06%, 0.89%, 1.18%, 1.41%, 0.41%, 1.17%, 0.40% and 0.86%, respectively. The milk FA profile variations did not show the same trend as milk fat between seasons, except for TSFA and C14:0 (Table 4). Milk TSFA and C14:0 concentrations were significantly higher in the cold season than in the hot and warm seasons ($P<0.05$). In contrast, milk C18:1 concentrations were significantly higher in the hot and warm seasons than in the cold season ($P<0.05$). However, milk C18:0 concentrations did not differ significantly between seasons.

FT-MIR-based FA composition analysis of bulk tank milk samples from 90 farms revealed that C14:0 concentrations significantly decreased, but preformed FA concentrations, especially C18:1, significantly increased with the THI (Table 1). These results are consistent with the data reported by Liu *et al.* (2017), who described decreases in C4:0 to C15:0 concentrations and increases in C18:1 concentration in cows under moderate heat stress. In addition, TUSFA concentrations were significantly higher in the warm season than in the cold season ($P<0.05$). The de novo FA, mixed FA and C16:0 concentrations were significantly higher in the warm season than in the cold season ($P<0.05$).

Variations in milk FA concentrations between seasons were similar to those in SCCs, which were highest in the hot season. In our study, the warm season was defined as April, May, October and November, months that fall between the hot and cold seasons. Even if the THI exceeds 72, FA may be affected by the metabolic reactions in the animal body. Islam *et al.* (2021) observed that the rumen microbiota composition differed between winter and the other seasons and a seasonal shift in the rumen microbiome was observed between spring and summer. Ozcan *et al.* (2015) reported that saturated FA concentrations decreased in summer (March to July) and that monounsaturated FA concentrations were highest in the evening milk during summer. Moreover, ambient temperatures above 30°C have been shown to

Table 4: Variations in milk FA profile of bulk tank milk samples in different seasons[1].

Fatty acids (g/100 g of milk)	Season				SEM
	Cold	Hot	Warm	Overall	
TSFA[2]	2.59[a]	2.49[c]	2.55[b]	2.54	0.007
TUSFA	1.06[b]	1.06[ab]	1.07[a]	1.06	0.004
De novo FA	0.89[b]	0.85[c]	0.92[a]	0.89	0.004
Mixed FA	1.17[b]	1.18[b]	1.19[a]	1.18	0.004
Preformed FA	1.37[c]	1.44[a]	1.43[b]	1.41	0.006
C14:0	0.42[a]	0.40[c]	0.41[b]	0.41	0.001
C16:0	1.15[c]	1.17[b]	1.19[a]	1.17	0.004
C18:0	0.40	0.40	0.41	0.40	0.002
C18:1	0.84[b]	0.87[a]	0.87[a]	0.86	0.003

[1]Cold: January, February, March and December; Warm: April, May, October and November; Hot: June, July, August and September.

[a,b,c]Means in the same row without the same superscript indicates a significant difference between seasons ($P<0.05$).

[2]TSFA: total saturated fatty acid; TUSFA: total unsaturated fatty acid; de novo fatty acids: C4:0, C6:0, C8:0, C10:0, C12:0, C14:0 and C14:1; mixed fatty acids: C16 and C16:1; preformed fatty acids: C15:0, C17:0, C18:0, C18:1, C18:2, C18:3, C20:0, C20:2, C 22:0 and C24:0.

significantly increase the long-chain FA (C18:0 and C18:1) concentration in milk ($P<0.01$). The seasonal effects may be due to changes in management practices, diet and rumen metabolism during the year.

Selected dairy farms

The dietary data for milking cows at three selected dairy farms are shown in Table 2, with the major ingredients and nutritional composition. The average milk yield, fat composition and FA composition of bulk milk samples from three farms are summarized in Table 5. The milk yield did not differ significantly between the farms throughout the studied period. However, milk yields were higher at these three farms than the average of the 90 surveyed dairy farms in Taiwan (23.65 kg/day). Fat, TSFA, TUSFA, de novo FA, mixed FA, preformed FA, C14:0, C16:0, C18:0 and C18:1 concentrations varied significantly among the three farms ($P<0.05$).

Diet is a crucial factor affecting the FA composition of ruminant milk (Dewhurst *et al.,* 2003). Differences in the ratio of concentrate in the TMR may affect milk composition and processing properties (Priyashantha *et al.,* 2021). Aschalew *et al.* (2020) stated that dietary effective fiber content has a positive effect on milk fat content through prevention of rumen acidosis. De novo FA, mixed FA, C14:0 and C16:0 concentrations were higher and preformed FA and C18:1 concentrations were lower at Farm A than at Farms B and C. Dietary NDF content was lowest at Farm C and highest at Farm B. Therefore, the higher de novo FA concentration at Farm A is not due to a higher forage (NDF) content.

The typical EE content of the TMR for dairy cows is approximately 4%-5% of the dry matter (NRC, 2001). In our study, Farm A had the lowest EE content (3.91%) in the TMR and the highest de novo FA concentration (0.95 g/100 g) in the milk. Woolpert *et al.* (2016) also concluded that the dietary EE content was lower at farms with higher de novo FA concentrations. While outdoor/extensive grazing is not practiced at dairy farms in Taiwan, climatic differences may cause northern, central and southern dairy farmers to have different grass choices. For example, access to corn silage is harder for northern than southern farmers. Unlike the limited choice of northern dairy farms, southern dairy farms in Taiwan use fresh *Pennisetum alopecuroides* grass, forage maize and corn silage as major fodders. Farms B and C used corn silage or *P. alopecuroides* grass in their TMR and had significantly higher milk TUSFA concentrations than Farm A ($P<0.05$). Previous studies have shown that milk from cows fed fresh grass has higher polyunsaturated FA concentrations, while milk from silage-fed herds has lower saturated FA concentrations (Drackley *et al.,* 2001; White *et al.,* 2001).

Beckman and Weiss (2005) proposed the NDF to starch ratio as a critical indicator to evaluate the effect of carbohydrate composition on nutrient digestibility and milk production. The milk fat percentage increased with the NDF to starch ratio. The milk fat content was lower and the NDF to starch ratio was higher and dietary fat was intermediate at Farm B than at Farms A and C ($P<0.05$). Therefore, the lower milk fat at Farm B is unrelated to the dietary NDF to starch ratio and fat content. One possible explanation for the lower milk fat content at Farm B may be its highest milk yield.

The seasonal variations in milk yield, fat and FA profile of bulk tank milk samples among the three selected dairy farms are shown in Table 6. Milk fat only differed significantly among the three farms in the hot season, with Farm B having the lowest milk fat content ($P<0.05$). As milk production increases, metabolic heat production increases with the metabolism of large amounts of nutrients, making high-production cows more vulnerable to high THI than low-production cows (Giannone *et al.,* 2023). TSFA, de novo

Table 5: Average milk yield, fat and FA profile of bulk tank milk samples among the three selected dairy farms.

Item	Farm		
	A	B	C
Milk yield (kg/day)	28.5±3.06	30.1±2.48	28.2±2.21
Fat (%)	3.90±0.17^{ab}	3.78±0.19^{b}	3.96±0.07^{a}
TSFA[1] (%)	2.66±0.16^{b}	2.37±0.16^{c}	2.51±0.08^{a}
TUSFA (%)	0.95±0.10^{b}	1.04±0.09^{a}	1.11±0.06^{a}
De novo FA (%)	0.95±0.08^{a}	0.78±0.07^{b}	0.81±0.05^{b}
Mixed FA (%)	1.39±0.07^{a}	1.25±0.07^{b}	1.30±0.04^{b}
Preformed (%)	1.26±0.13^{b}	1.48±0.12^{a}	1.58±0.07^{a}
C14:0 (%)	0.37±0.02^{a}	0.32±0.02^{b}	0.33±0.01^{b}
C16:0 (%)	1.25±0.07^{a}	1.12±0.05^{c}	1.19±0.05^{b}
C18:0 (%)	0.34±0.04^{b}	0.37±0.04^{b}	0.40±0.02^{a}
C18:1 (%)	0.79±0.06^{b}	0.89±0.07^{a}	0.93±0.04^{a}

[a,b,c]Means in the same row without the same superscript indicates a significant difference between farms ($P<0.05$).

[1]TSFA: total saturated fatty acid; TUSFA: total unsaturated fatty acid; de novo fatty acids: C4:0, C6:0, C8:0, C10:0, C12:0, C14:0 and C14:1; mixed fatty acids: C16 and C16:1; preformed fatty acids: C15:0, C17:0, C18:0, C18:1, C18:2, C18:3, C20:0, C20:2, C 22:0 and C24:0.

FA, mixed FA and C16:0 concentrations were significantly higher at Farm A than at Farms B and C in different seasons (*P*<0.05). The variation in FA proportions could be due to differences in fermentation by the rumen microorganisms under varying fodder material.

Farm C had the highest preformed FA and C18:1 concentrations in different seasons (*P*<0.05). Energy deficiency can decrease C4:0, C6:0, C8:0, C10:0, C12:0 and C14:0 concentrations and increase C18:0, C18:1 and C18:2 concentrations in milk (Lindmark-Mansson *et al.,* 2003). Farm C is located more toward the south of Taiwan and has a greater chance of experiencing heat stress, which may lower feed intake more than at the other two farms. Another possible explanation for the higher preformed FA concentration in milk at Farm C is its higher dietary fat content, which may affect milk fat content and composition. Rumen inert fat is often used in the TMR to increase energy intake (Sarkar *et al.,* 2022) and the most popular rumen inert fat sources are C16:0 and C18:0. At Farm C, the rumen insert fat (EB100v) comprised 16:0 (68.2%), C18:0 (15.3%), C18:1 (6.65%), C18:2 (2.09%), C18:3 (0.15%), C20:0 (0.15%) and other FAs. Loften *et al.* (2014) reported that heat stress and fat supplementation could cause variations in the FA composition of bulk tank milk. Mixed and preformed

Table 6: Variations in milk yield, fat and FA profile of bulk tank milk samples among the three selected dairy farms within each season.

Items	Farm	Season[1]		
		Cold	Hot	Warm
Milk yield (kg/day)	A	30.6±1.96	25.8±3.19	29.2±2.03
	B	30.7±2.29	28.7±2.29	31.1±2.78
	C	30.1±0.75	26.0±1.79	28.6±1.65
Fat (%)	A	4.00±0.18	3.81±0.09[ab]	3.89±0.20
	B	3.95±0.09	3.61±0.10[c]	3.78±0.19
	C	4.01±0.02	3.92±0.06[a]	3.96±0.08
TSFA[2] (%)	A	2.78±0.16[a]	2.57±0.14[a]	2.63±0.14[a]
	B	2.52±0.10[b]	2.22±0.11[c]	2.38±0.13[b]
	C	2.57±0.10[ab]	2.49±0.06[ab]	2.48±0.07[ab]
TUSFA (%)	A	0.98±0.14	0.91±0.07[b]	0.96±0.10
	B	1.10±0.04	1.00±0.11[ab]	1.02±0.08
	C	1.13±0.07	1.07±0.01[a]	1.13±0.08
De novo FA (%)	A	1.01±0.09[a]	0.89±0.04[a]	0.94±0.03[a]
	B	0.86±0.02[b]	0.70±0.04[b]	0.77±0.06[bc]
	C	0.86±0.03[b]	0.76±0.01[bc]	0.80±0.03[b]
Mixed FA (%)	A	1.44±0.08[a]	1.35±0.07[a]	1.37±0.05[a]
	B	1.32±0.04[ab]	1.19±0.06[b]	1.25±0.04[bc]
	C	1.30±0.07[b]	1.31±0.03[a]	1.28±0.03[b]
Preformed FA (%)	A	1.26±0.17[c]	1.25±0.08[b]	1.28±0.16[b]
	B	1.53±0.05[ab]	1.42±0.16[ab]	1.50±0.13[ab]
	C	1.60±0.06[a]	1.54±0.03[a]	1.60±0.10[a]
C14:0 (%)	A	0.38±0.02[a]	0.37±0.03[a]	0.37±0.02[a]
	B	0.33±0.01[bc]	0.31±0.02[b]	0.32±0.02[b]
	C	0.33±0.01[c]	0.33±0.01[ab]	0.32±0.02[b]
C16:0 (%)	A	1.27±0.08	1.25±0.09[a]	1.24±0.06[a]
	B	1.16±0.04	1.09±0.04[b]	1.11±0.05[b]
	C	1.17±0.06	1.24±0.03[a]	1.16±0.03[ab]
C18:0 (%)	A	0.34±0.05[b]	0.33±0.03	0.34±0.06
	B	0.39±0.02[ab]	0.35±0.05	0.36±0.03
	C	0.41±0.02[a]	0.38±0.01	0.41±0.03
C18:1 (%)	A	0.81±0.08[c]	0.75±0.03[c]	0.80±0.06[b]
	B	0.93±0.05[ab]	0.85±0.07[ab]	0.90±0.07[ab]
	C	0.95±0.04[a]	0.90±0.02[a]	0.94±0.04[a]

[1]Cold: January, February, March and December; Warm: April, May, October and November; Hot: June, July, August and September.

[a,b,c]Means in the same row without the same superscript indicates a significant difference between farms in the same season (*P*<0.05).

[2]TSFA: total saturated fatty acid; TUSFA: total unsaturated fatty acid; de novo fatty acids: C4:0, C6:0, C8:0, C10:0, C12:0, C14:0 and C14:1; mixed fatty acids: C16 and C16:1; preformed fatty acids: C15:0, C17:0, C18:0, C18:1, C18:2, C18:3, C20:0, C20:2, C 22:0 and C24:0.

FA concentrations were higher at the three farms than the average of the 90 surveyed farms, possibly due to their higher milk yield.

To our knowledge, this study is the first to evaluate the effects of seasonal and dietary factors on variations in milk profiles in Taiwan. These results provide an overview of milk FA variation related to seasonal factors, dietary EE content and forage choice.

CONCLUSION

Milk production (kg/day), fat (%), CP (%), true protein (%), lactose (%) and solids-not-fat (%) were significantly higher in the cold season than in the hot and warm seasons over the studied period ($P<0.05$). In contrast, SCCs were significantly lower in the cold season than in the hot and warm seasons ($P<0.05$). Milk TSFA and C14:0 concentrations were significantly higher in the cold season than in the hot and warm seasons ($P<0.05$). In contrast, milk C18:1 concentrations were significantly higher in the hot and warm seasons than in the cold season ($P<0.05$). TSFA, de novo FA, mixed FA and C16:0 concentrations were highest at Farm A in different seasons ($P<0.05$), possibly due to its lower dietary fat content and use of hay instead of fresh forage or silage. Preformed FA and C18:1 concentrations were highest at Farm C in different seasons ($P<0.05$), possibly due to its higher dietary fat content.

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Conflict of interest

The authors declare no conflict of interest.

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