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Seasonal and Regional Effects on Milk Composition of Dairy Cows in South Korea

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ABSTRACT

For a period of over 6 years, more than 160,000 milk samples were collected and analyzed to determine the influence of different seasonal temperatures and geographic regional location on milk composition in South Korea. Fat, protein, lactose, non fat milk solids (NFMS) and total solids (TS) contents were significantly higher among dairy cows milked in winter season than other seasons ($p<0.05$). In contrast, freezing point (FP), milk urea nitrogen (MUN) and somatic cell count (SCC) were significantly higher in summer season than other seasons ($p<0.05$). The average SCC in the autumn season was 358×10^3/ml, which was lower than any other seasons ($p<0.05$). These results may be due to the changes in temperature during different seasons. Meanwhile, milk produced by dairy cows in central region had higher fat, protein, lactose, NFMS, TS and MUN and had lower SCC compared to other regions ($p<0.05$). Fat, TS, FP, MUN and citric acid in northeast region were lower than other regions ($p<0.05$). The SCC was significantly higher in southeast region than those of other regions ($p<0.05$). As a result, it might be possible that the differences in feeding management in each different region may affect the milk composition. In conclusion, present results indicated that milk composition is clearly influenced by both season and regional location. Therefore, based on these results, development of different feeding systems, according to season and region is needed to produce high quality and satiable milk production.

(**Key words :** Milk composition, Seasonal variation, Regional difference, Dairy cow, South Korea)

INTRODUCTION

South Korea has a moderate continental type of climate that is characterized with clear four different seasons of spring, autumn, cold winter, and hot and humid summer. The average temperature in January ranges from -3.6ºC in the extreme north to 2ºC in the southeast, and to 4.4ºC in southernmost region, Jea-ju Island. However, during the summer season, the average temperature especially in July ranges from 25ºC to 27ºC in the south down to 21ºC in the northeast. Daily temperatures during winter and summer seasons are highly fluctuating. The hot and humid summers brought by air pollution and East Asian monsoons are expected to extend for over six-month period of heat each year as a result of global climate change (The Government of the Republic of Korea, 2003).

Holstein cows are more sensitive to the effects of heat stress than non-lactating cattle (Araki et al., 1984). High ambient temperature is indirectly related to the heat stress among dairy cows, thus, it is one of the major factors that can negatively affect milk yield and milk composition of dairy cows (Sharma et al., 1983; National Research Council, 1989). It has been well documented that heat stress due to exposure of dairy cows in high temperature results in a decreased dry matter (DM) intake (Coppock, 1978). Therefore, heat stress becomes major production challenge among dairy farmers in South Korea.

At present, around 60 million tons of raw milk is produced from around 7,000 dairy farms all over Korea. It has been known that changes of milk compositions are strongly influenced by nutritional management (Fuquay, 1981), genetic ability (Sharma et al., 1983), and climatic factors (Thatcher, 1974; Johnson, 1976). However, there is an apparent lack of information about seasonal and geographical changes on milk composition in Korea. The objective of this study was to analyze the influence of seasonal changes of temperatures and regional location on composition and

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quality of milk produced by dairy cows in South Korea.

MATERIALS AND METHODS

1. Milk sample collection and analysis

Over one hundred sixty thousand of milk samples used in this study were collected from Holstein-Friesian lactating cows located in all over places of South Korea. As soon as 30 mL of milk was sampled in plastic container, about 20 mg of antioxidant (Broadspectrum Microtabs®.II; D&F Control System, Inc.) was added. Samples were stored at 4ºC in cold storage box and delivered within a day. The samples were divided into four areas such as central, northeast, southwest and southeast according to consideration of regional location and environmental temperatures of South Korea. Each milk sample was analyzed by automatic milk analyzer (Automatic IR 4000/5000 Milk Analyzer, Foss Electric) for fat, protein, lactose, NFMS, TS, FP, MUN, citric acid, and SCC. The experimental analysis was conducted for a period of over 6 years between March, 2000 and December, 2006. The changes of environmental temperatures in central, northeast, southwest and southeast area, during experimental period, are shown in Table 1.

2. Statistical analysis

Statistical analysis was carried out using the Statistical Analysis System (SAS Version 9.1, 2002). The effects of seasons (spring, summer, autumn, and winter) and regional locations (central, northeast, southwest and southeast area) on milk composition (fat, protein, lactose, NFMS, TS, FP, MUN, citric acid, and SCC) were tested by ANOVA. The differences between treatment means were determined by using Duncan's multiple range test.

RESULTS

1. Seasonal and regional temperatures in South Korea

The average temperatures according to region and season are shown in Table 1. The data were retrieved from Korea meteorological administration from March, 2000 to December, 2006. The average seasonal temperatures in northeast region were 10.5ºC in spring, 22.2ºC in summer, 12.4ºC in autumn and −1.5ºC in winter. Southeast region showed highest temperature in spring, summer and winter season. It was observed that difference between minimum and maximum temperature was the least in summer season than any other seasons regardless of regional differences. The highest maximum temperature was found in southeast region (27.4ºC)in summer and the lowest minimum temperature in northeast region in winter (−8.9ºC).

2. Effect of season on milk composition in South Korea

The effect of spring, summer, autumn and winter seasons on fat, protein and lactose contents in milk are shown in Table 2. Average milk fat, protein and lactose contents were significantly higher during the winter season than other seasons ($p<0.05$). On the contrary, dairy cows produced milk with significantly lower fat and lower protein contents in summer season than any other seasons ($p<0.05$). Lactose content was lowest in the spring season. Average fat, protein and lactose contents of the milk produced by lactating cows in South Korea were 3.793%, 3.245% and 4.739%, respectively. The NFMS, TS and FP of milk in different seasons are presented in Table 3. The NFMS and TS contents were significantly higher during the winter season as compared to spring, summer and autumn ($p<0.05$). In the summer season, NFMS and TS decreased with increasing FP ($p<0.05$). The mean NFMS, TS contents and FP of milk in South Korea were 8.685%,

Table 1. Average and range of temperatures (°C) according to region and season in South Korea[1),2)]

Region[3)]	Seasons[4)]			
	Spring	Summer	Autumn	Winter
Central	11.4 (17.5, 5.5)	23.6 (27.0, 19.6)	13.4 (19.2, 8.0)	−0.9 (5.6, −7.6)
Southeast	12.5 (18.1, 6.7)	23.6 (27.4, 19.3)	14.5 (20.2, 9.6)	1.6 (7.5, −4.3)
Southwest	11.8 (17.5, 6.4)	23.7 (26.8, 20.1)	14.9 (20.3, 9.9)	1.6 (8.0, −4.1)
Northeast	10.5 (17.3, 3.9)	22.2 (26.6, 17.8)	12.4 (18.6, 7.0)	−1.5 (5.0, −8.9)

1) Retrieved from Korea Meteorological Administration (March, 2000 to December, 2006)
2) Values in parenthesis represent the maximum and minimum temperatures for each season.
3) Region: Central−Gyeonggi-do + Chungcheong-do; Southeast−Gyeongsang-do; Southwest−Jeolla-do; and Northeast Gangwon-do.
4) Seasons: Winter−December to February; Spring−March to May; Summer−June to August; and Autumn−September to November.

Table 2. Effect of season on fat, protein and lactose contents of milk collected from Holstein-Friesian lactating cows in South Korea[1)]

Season[2)]	Fat	Protein	Lactose
	……… % ………		
Spring	3.817 ± 0.0042[b]	3.242 ± 0.0014[c]	4.729 ± 0.0010[d]
Summer	3.610 ± 0.0048[d]	3.166 ± 0.0017[d]	4.737 ± 0.0013[c]
Autumn	3.786 ± 0.0058[c]	3.274 ± 0.0021[b]	4.748 ± 0.0014[b]
Winter	3.967 ± 0.0056[a]	3.317 ± 0.0019[a]	4.752 ± 0.0014[a]
Total Mean	3.793 ± 0.0025	3.245 ± 0.0009	4.739 ± 0.0006

[1)] Values are presented as mean ± SE. Values in the same column with different superscript are significantly different ($p<0.05$); wherein, n = 166,080 (60,958 in spring; 40,295 in summer; 30,494 autumn; 35,055 in winter season).
[2)] Seasons: Winter－December to February; Spring－March to May; Summer－June to August; and Autumn－September to November.

Table 3. Effects of season on NFMS, TS contents and FP of milk collected from Holstein-Friesian lactating cows in South Korea[1)]

Season[2)]	NFMS[3)]	TS[4)]	FP[5)]
	……… % ………	……… % ………	……… ℃% ………
Spring	8,672 ± 0.0018[c]	12.489 ± 0.0049[c]	0.541 ± 0.00036[c]
Summer	8.603 ± 0.0022[d]	12.213 ± 0.0058[d]	0.548 ± 0.00052[a]
Autumn	8.722 ± 0.0026[b]	12.508 ± 0.0069[b]	0.545 ± 0.00061[b]
Winter	8.770 ± 0.0024[a]	12.736 ± 0.0065[a]	0.538 ± 0.00046[d]
Total Mean	8.685 ± 0.0011	12.480 ± 0.0030	0.543 ± 0.0023

[1)] Values are presented as mean ± SE. Values in the same column with different superscript are significantly different ($p<0.05$); wherein, n = 166,080 (60,958 in spring; 40,295 in summer; 30,494 autumn; 35,055 in winter season).
[2)] Seasons: Winter－December to February; Spring－March to May; Summer－June to August; and Autumn－September to November.
[3)] NFMS: non-fat milk solids
[4)] TS: total solids
[5)] FP: freezing point

Table 4. Effect of season on MUN, citric acid contents and SCC of milk collected from Holstein-Friesian lactating cows in South Korea[1)]

Season[2)]	MUN[3)]	Citric acid	SCC[4)]
	……… mg/L ………	……… % ………	……… × 10^3/ml ………
Spring	14.80 ± 0.027[c]	0.1717 ± 0.00013[c]	376 ± 3.27[a]
Summer	16.63 ± 0.036[a]	0.1692 ± 0.00016[d]	384 ± 4.25[a]
Autumn	15.52 ± 0.038[b]	0.1787 ± 0.00034[a]	358 ± 4.30[b]
Winter	14.75 ± 0.039[c]	0.1730 ± 0.00017[b]	376 ± 4.22[a]
Total Mean	15.36 ± 0.017	0.1726 ± 0.00009	374 ± 1.97

[1)] Values are presented as mean ± SE. Values in the same column with different superscript are significantly different ($p<0.05$); wherein, n = 166,080 (60,958 in spring; 40,295 in summer; 30,494 autumn; 35,055 in winter season).
[2)] Seasons: Winter－December to February; Spring－March to May; Summer－June to August; and Autumn－September to November.
[3)] MUN: milk urea nitrogen
[4)] SCC: somatic cell count

12.48% and 0.543ºC, respectively. The MUN and SCC were highest during summer, whereas citric acid concentration was highest during autumn (Table 4). Average somatic cell count in the autumn season was 358 × 10^3/ml which was lower than other seasons ($p<0.05$). The citric acid concentration was significantly lower in milk produced by dairy cows during summer season ($p<0.05$).

3. Milk composition in different region of South Korea

The fat, protein and lactose contents of milk produced by dairy cows in different regional location in South Korea are shown in

Table 5. Milk fat and lactose were significantly higher in central region than in southeast, southwest and northeast regions of South Korea ($p<0.05$). Milk protein content was significantly higher in central and southwest regions than other regions ($p<0.05$). Lower fat content was observed in northeast region compared to other regions ($p<0.05$). Lactose was lower in both southeast and southwest regions than central and northeast regions ($p<0.05$). As shown in Table 6, it has been observed that NFMS and TS contents of milk were higher in central region, while FP was significantly higher in both southeast and southwest than other regions ($p<0.05$). In contrast, NFMS was lower in southeast, whereas TS contents and FP were lower in northeast ($p<0.05$).

Table 5. Effect of regional location on fat, protein and lactose contents of milk collected from Holstein-Friesian lactating cows in South Korea[1)]

Region[2)]	Fat	Protein	Lactose
	··· % ···		
Central	3.832 ± 0.0031[a]	3.252 ± 0.0011[a]	4.748 ± 0.0008[a]
Southeast	3.752 ± 0.0053[b]	3.225 ± 0.0019[b]	4.722 ± 0.0014[c]
Southwest	3.740 ± 0.0077[b]	3.251 ± 0.0025[a]	4.726 ± 0.0018[c]
Northeast	3.466 ± 0.0168[c]	3.234 ± 0.0052[b]	4.740 ± 0.0037[b]
Total Mean	3.793 ± 0.0025	3.245 ± 0.0009	4.739 ± 0.0006

1) Values are presented as mean ± SE. Values in the same column with different superscript are significantly different ($p<0.05$); wherein, n = 166,080 (105,827 in central area; 35,279 in southeast area; 20,832 southwest area; 4,864 in northeast area)
2) Region: Central－Gyeonggi-do + Chungcheong-do; Southeast－Gyeongsang-do; Southwest－Jeolla-do; and Northeast－Gangwon-do.

Table 6. Effect of regional location on NFMS, TF contents and FP of milk collected from Holstein-Friesian lactating cows in South Korea[1)]

Region[2)]	NFMS[3)]	TS[4)]	FP[5)]
	··· % ···		··· ℃% ···
Central	8,699 ± 0.0014[a]	12.531 ± 0.0037[a]	0.541 ± 0.00029[b]
Southeast	8.647 ± 0.0024[c]	12.399 ± 0.0063[b]	0.549 ± 0.00050[a]
Southwest	8.677 ± 0.0031[b]	12.418 ± 0.0088[b]	0.549 ± 0.00070[a]
Northeast	8.673 ± 0.0066[b]	12.139 ± 0.0191[c]	0.515 ± 0.00093[c]
Total Mean	8.685 ± 0.0011	12.480 ± 0.0030	0.543 ± 0.0023

1) Values are presented as mean ± SE. Values in the same column with different superscript are significantly different ($p<0.05$); wherein, n = 166,080 (105,827 in central area; 35,279 in southeast area; 20,832 southwest area; 4,864 in northeast area)
2) Region: Central－Gyeonggi-do + Chungcheong-do; Southeast－Gyeongsang-do; Southwest－Jeolla-do; and Northeast－Gangwon-do.
3) NFMS: non-fat milk solids
4) TS: total solids
5) FP: freezing point

Table 7. Effect of regional location on MUN concentration, citric acid content and SCC of milk collected from Holstein-Friesian lactating cows in South Korea[1)]

Region[2)]	MUN[3)]	Citric acid	SCC[4)]
	··· mg/L ···	··· % ···	··· $\times 10^3$/ml ···
Central	15.88 ± 0.022[a]	0.1726 ± 0.00010[b]	346 ± 2.34[d]
Southeast	14.78 ± 0.036[b]	0.1753 ± 0.00030[a]	444 ± 4.88[a]
Southwest	14.31 ± 0.046[c]	0.1698 ± 0.00024[c]	401 ± 5.62[b]
Northeast	12.84 ± 0.089[d]	0.1660 ± 0.00061[d]	375 ± 11.3[c]
Total Mean	15.36 ± 0.017	0.1726 ± 0.00009	374 ± 1.97

1) Values are presented as mean ± SE. Values in the same column with different superscript are significantly different ($p<0.05$); wherein, n = 166,080 (105,827 in central area; 35,279 in southeast area; 20,832 southwest area; 4,864 in northeast area)
2) Region: Central－Gyeonggi-do + Chungcheong-do; Southeast－Gyeongsang-do; Southwest－Jeolla-do; and Northeast－Gangwon-do.
3) MUN: milk urea nitrogen
4) SCC: somatic cell count.

The effects of regional location on MUN, citric acid and SCC in milk were shown in Table 7. The mean of MUN concentration in central region was 15.88 mg/L, which was significantly higher than the rest of the regions ($p<0.05$). Northeast was recorded as the region with the lowest MUN concentration ($p<0.05$). Highest citric acid content was observed in southeast region ($p<0.05$). The SCC was lower in central region (346 x 10^3/ml) but higher in southeast region (444 × 10^3/ml). The mean MUN, citric acid and SCC in milk in South Korea were 15.36 mg/L, 0.1726 % and 374 × 10^3/ml, respectively.

DISCUSSION

Climatic factors such as air temperature often limit animal performance (Sharma et al., 1983), like reduction in milk yield (McDowell et al., 1976), feed intake (Collier et al., 1982), intestinal metabolisms (Aganga et al., 1990), milk composition (Allore et al., 1997) and reproduction (Berman et al., 1985). Depending on the region, South Korea is characterized by having high range of maximum and minimum temperature. The hot and humid weather in summer can be attributed to its geographical location in East Asia. Therefore, we should look at seasonal and regional effects on milk composition to produce high quality and satiable milk production.

Dairy cows need suitable temperatures of between 5 and 25ºC (Roenfeldt, 1998). At temperatures above 26ºC, the cow reaches a point where she can not cool herself and suffers from heat stress (Kadzere et al., 2002). A study with Jersey cows exposed to either 15 or 30ºC air temperatures (Bandaranayaka and Holmes, 1976) found that the fat and protein contents of milk decreased significantly at 30ºC when intake was equalized at both temperatures. Bandaranayaka and Holmes (1976) also reported that the decrease in milk fat content was positively correlated to reductions in proportions of acetate in the rumen contents and to a small reduction in ruminal pH at 30ºC. The decrease in energy intake and increased water intake during hot season might have resulted in the reduction of fat content in milk (Emery, 1978). Lu et al. (2003) reported that the reduction of lactose content in milk demonstrates regression of mammary function and unfavourable physiological conditions in heat stressed cows. Some works have definitely pointed out that NFMS can be lowered by high environmental temperature. In controlled climatic chamber, Cobble and Herman (1951) found that NFMS content decreased as the temperature rose above 90ºF. During winter, the increase of milk NFMS and TS may be due to the decreased water intake as the temperature decreases to about 0^oC. The increase of milk fat, NFMS and TS contents during winter reflects on the decrease in FP as a result of low moisture contents in the milk, which can be due to decreased water intake (Henno et al., 2008).

The MUN concentration in milk can also be affected by environmental temperature. Nishibu (1998) and Wittwer et al. (1999) found that the decline in MUN might have resulted from decrease in rumen microbial synthesis and low level of soluble protein in the rumen, such as ammonia in hot environment. The SCC is also influenced by seasonal temperature. Allore et al. (1997) reported that SCC in milk decreased in summer season. However, many studies have shown that SCC increased during summer season (Harmon, 1994; Green et al., 2006). In this study, the SCC was lowest during autumn and higher during summer, spring and winter. The study of Green et al. (2006) suggested that the higher SCC during summer is due to long-term infection (chronic) rather than an increase in number of infected individuals. The most plausible reason for the seasonal variation in SCC is the possible decrease in immune system during stressful weather conditions.

It has been shown in previous studies and demonstrated in this study that there is strong relationship between environmental temperatures and some milk composition. However, we believe that there might be other reasons for differences in milk composition such as nutritional management (Fuquay, 1981) and regional genetic ability of dairy cows (Sharma et al. 1983).

This study shows that milk composition of dairy cows is strongly related with seasonal differences and regional location in South Korea. In order to alleviate the detrimental effects of extreme temperatures and regional variations, the development of different feeding management systems according to season and region is needed to achieve the goal of high quality and satiable milk production.

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