



Seasonal Variation in Carcass Characteristics of Korean Cattle Steers

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ABSTRACT: Climate temperature affects animal production. This study was conducted to evaluate whether climatic conditions affect beef carcass characteristics of Korean cattle steers. The monthly carcass characteristics of Korean cattle steers ($n = 2,182,415$) for 8 yr (2006 through 2013) were collected from the Korean Institute for Animal Products Quality Evaluation. Daily climate temperature (CT) and relative humidity (RH) data were collected from the Korean Meteorological Administration. Weather conditions in South Korea during summer were hot and humid, with a maximum temperature of 28.4°C and a maximum RH of 91.4%. The temperature-humidity index (THI), calculated based on CT and RH, ranges from 73 to 80 during summer. Winter in South Korea was cold, with a minimum temperature of -4.0°C and a wind-chill temperature of -6.2°C. Both marbling score (MS) and quality grade (QG) of Korean cattle steer carcasses were generally best ($p < 0.05$) in autumn and worst in spring. A correlation analysis showed that MS and QG frequencies were not associated ($p > 0.05$) with CT. Yield grade (YG) of Korean cattle steer carcasses was lowest ($p < 0.05$) in winter (November to January) and highest in spring and summer (May to September). A correlation analysis revealed that YG frequency was strongly correlated ($r \geq 0.71$; $p < 0.01$) with CT and THI values. The rib eye area, a positive YG parameter, was not associated with CT. Backfat thickness (BT), a negative YG factor, was highest in winter (November and December). The BT was strongly negatively correlated ($r \leq -0.74$; $p < 0.01$) with CTs. Therefore, the poor YG during winter is likely due in part to the high BT. In conclusion, YG in Korean cattle steer carcasses was worst in winter. QGs were not associated with winter or summer climatic conditions. (**Key Words:** Beef, Climate Temperature, Yield Grade, Quality Grade, Korean Cattle Steers)

INTRODUCTION

Korea is a highly urbanized country that is experiencing one of the highest rates of temperature increase in the world as a consequence of global warming. Temperatures on the Korean peninsula increased by approximately 2°C from 1992 to 2004 (Ho et al., 2006), and hotter summers as well as colder winters are expected.

Climatic conditions affect animal performance (Birkelo et al., 1991). Hot weather can strongly affect animal bioenergetics, with adverse effects on the performance and wellbeing of livestock. Heat-stressed ruminants generally decrease dry matter intake to reduce metabolic heat

production and maintain a constant body temperature (Hahn, 1985; Beede and Collier, 1986; Collier et al., 2006; Bernabucci et al., 2009; O'Brien et al., 2010). Exposure to cold temperatures often reduces performance and efficiency in animals (Young, 1981). Several studies have reported that feed-to-gain ratios and weight gain in beef cattle decrease during cold winters in southern California and the Midwest USA (Elam, 1970), as well as in several areas of Canada (Webster et al., 1970; Hidirolou and Lessard, 1971; Milligan and Chrisfison, 1974).

Thermal stress resulting in increased energy maintenance requirements and reduced growth rates can result in sizable economic losses to producers of intensively managed beef cattle. However, no information is available on seasonal variations in beef cattle production traits, including quality grade (QG) and yield grade (YG), in Korea. This study was performed to evaluate whether carcass characteristics of Korean cattle steers vary

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seasonally and whether they are associated with climatic conditions. Carcass data of Korean cattle steers for the most recent 8 years were collected from the Korea Institute for Animal Products Quality Evaluation (KAPE), and climatic data of the corresponding years were collected from the Korean Meteorological Administration (KMA). Monthly and seasonal trends in the carcass characteristics were analyzed, and the correlations between carcass characteristics and climate data were analyzed.

MATERIALS AND METHODS

Institutional Animal Care and Use Committee approval was not required because no live animals were involved in this study.

Climate temperature, relative humidity, and the temperature humidity index

Climate temperature (CT) data for 8 years (2006-2013) were collected from the KMA for 75 cities in South Korea. Regional CT data were collected from all representative cities of each province: two southern areas, 9 cities in Gyeonggi-do and 12 cities in Gangwon-do; and two northern areas, 11 cities in Gyeongsangnam-do and 9 cities in Jeollanam-do. Mean, minimum, and maximum CT values for each month and each season were calculated from the corresponding daily data.

The CT and relative humidity (RH) measurements are recorded every 1 h by the KMA. Maximum CT and minimum CT were selected, and the RH at the corresponding CT was selected to calculate maximum and minimum temperature humidity index (THI), respectively.

The following equation was used for the THI calculation (Bohmanova et al., 2007):

$$\text{THI} = (1.8 \times \text{CT} + 32) - (0.55 - 0.0055 \times \text{RH}) \times (1.8 \times \text{CT} - 26)$$

Wind chill temperature (WCT) was calculated based on following equation:

$$\text{WCT} (\text{°C}) = 13.12 + 0.6215\text{CT} - 11.37\text{V}^{0.16} + 0.3965\text{TV}^{0.16}$$

(Osczevski and Bluestein, 2005),

where V (wind speed) = km/h.

Carcass data of Korean cattle steers

Slaughter weight (SW) and carcass data of Korean cattle steers, including carcass weight (CW), QG frequency (QGF), marbling score (MS), YG frequency (YGF), backfat thickness (BT), rib eye area (REA), and yield index (YI) were obtained for 2006 through 2013 from the KAPE. Monthly carcass data of each year were compared using 2,182,415 steers with an average of 272,802 steers/yr. Monthly data were sub-grouped into four seasons for the

seasonal comparison: spring (March to May), summer (June to August), autumn (September to November), and winter (December to February). In addition to the national data, regional data were collected from four provinces located in the north (Gyeonggi-do [n = 516,645], Gangwon-do [n = 123,443]) and south (Gyeongsangnam-do [n = 182,256], Jeollanam-do [n = 116,165]) of South Korea.

The following guidelines are used for slaughter in Korea: upon arrival at the abattoir, the animals are kept off feed but are given free access to water. Slaughter weights are determined immediately before slaughter. The animals are slaughtered after undergoing captive bolt stunning. After slaughter and a 24-h chill, cold CW is measured, and the left side of each carcass is cut between the last rib and the first lumbar vertebrae to determine QG. The nine MS (MS1 being lowest and MS9 being highest) are evaluated according to the Korean Beef Marbling Standard. The QG of the carcass is determined based on the MS, lean meat color, fat color, and maturity. Five QGs (1++ as the best QG and 3 as the lowest QG) based mainly on the MS are assigned as follows: QG 1++, BMS 8 or 9; QG 1+, BMS 6 or 7; QG 1, BMS 4 or 5; QG 2, BMS 2 or 3; and QG 3, BMS 1.

Carcass YI was determined based on the adjusted BT, REA, and the CW. The BT was evaluated in terms of fat thickness over the *longissimus dorsi* muscle measured perpendicular to the outside surface at a point two-thirds the length of the rib eye from its chin bone end. The REA was determined at the surface using a grid. The YI was calculated using the following formula:

$$\text{YI} (\%) = 71.414 - [0.625 \times \text{BT} (\text{mm})] + [0.130 \times \text{REA} (\text{cm}^2)] - [0.024 \times \text{CW} (\text{kg})]$$

Three YGs (A is the best YG and C is the lowest) were assigned based on the YI, as follows: the YG A, >67.5% of YI; YG B, 62.0% to 67.5% of YI; and YG C, <62.0% of YI.

Statistical analyses

The monthly, seasonal, and regional variations in climatic data, THI, and beef carcass data were subjected to analysis of variance using SAS (SAS Institute, Cary, NC, USA), and the data were tested for significance using the SAS General Linear Model Procedure (Proc GLM). The SAS PDIFF option of LSMEANS was used to compare differences among mean values. Correlation coefficients were analyzed using the SAS CORR procedure. A $p < 0.05$ was considered to indicate significance.

RESULTS

South Korea climatic data

Average values of the climate parameters are shown in Tables 1 and 2. Average minimum, mean, and maximum CT

Table 1. Monthly temperature, relative humidity, and temperature-humidity index (THI) values for 8 years (2006 through 2013) in South Korea

Item	Month												SEM	p-value
	1	2	3	4	5	6	7	8	9	10	11	12		
Temperature (°C)														
Mean	-1.2 ⁱ	1.6 ^h	6.0 ^g	11.3 ^e	17.3 ^c	21.4 ^b	24.5 ^a	25.7 ^a	20.8 ^b	15.0 ^d	7.9 ^f	1.2 ^h	0.94	<0.001
Maximum	4.0 ^j	7.0 ⁱ	11.6 ^h	17.3 ^f	23.3 ^d	26.6 ^c	28.5 ^b	30.1 ^a	25.8 ^c	21.3 ^e	13.3 ^g	6.1 ⁱ	0.92	<0.001
Minimum	-5.7 ⁱ	-3.3 ^h	0.8 ^g	5.7 ^e	12.0 ^c	17.1 ^b	21.5 ^a	22.3 ^a	16.8 ^b	10.0 ^d	3.2 ^f	-3.2 ^h	0.98	<0.001
Wind speed (km/h)	4.9 ^b	5.0 ^b	5.5 ^a								4.2 ^c	5.1 ^{ab}	0.10	0.004
Wind chill temperature (°C)	-8.0 ^d	-5.3 ^c	-0.9 ^b								2.4 ^a	-5.2 ^c	0.66	<0.001
Humidity (%)														
Mean	61.4 ^{ef}	60.3 ^f	59.8 ^f	59.9 ^f	65.5 ^d	72.9 ^c	81.3 ^a	78.9 ^{ab}	76.2 ^b	70.3 ^c	65.4 ^d	63.9 ^{de}	0.81	<0.001
Maximum	79.2 ^g	80.7 ^{fg}	81.7 ^f	83.8 ^e	87.2 ^d	89.9 ^{bc}	92.5 ^a	91.8 ^{ab}	91.3 ^{ab}	88.8 ^{cd}	84.1 ^e	81.4 ^f	0.51	<0.001
Minimum	40.3 ^{de}	37.4 ^{ef}	36.3 ^f	35.7 ^f	41.9 ^d	52.8 ^c	65.9 ^a	61.1 ^b	54.4 ^c	43.8 ^d	42.5 ^d	42.8 ^d	1.04	<0.001
THI														
Mean	36 ⁱ	40 ^h	46 ^g	54 ^e	62 ^c	69 ^b	74 ^a	76 ^a	68 ^b	59 ^d	49 ^f	39 ^h	1.38	<0.001
Maximum	45 ^j	48 ⁱ	54 ^h	61 ^f	68 ^d	73 ^c	78 ^b	80 ^a	73 ^c	66 ^e	56 ^g	47 ⁱ	1.22	<0.001
Minimum	27 ⁱ	31 ^h	37 ^g	45 ^e	54 ^c	63 ^b	70 ^a	72 ^a	62 ^b	51 ^d	40 ^f	31 ^h	1.55	<0.001

SEM, standard error of the mean.

n = 8.

Means with different letters within the same row differ at p<0.05.

values in South Korea during summer for 2006 through 2013 were 20.3°C, 23.9°C, and 28.4°C, respectively. Average minimum, mean, and maximum CT values in winter were -4.0°C, 0.5°C, and 5.7°C, respectively. Average CT in spring and autumn was 6.1°C to 20.2°C. Maximum THI was 73 to 80 during summer and averaged 77 in summer. Maximum RH values were 90% to 92.5% during summer. Maximum wind speed and WCT with minimum CT were 5.0 km/h and -6.2°C in winter, respectively. Minimum CT and WCT with minimum CT in winter were -3.2°C to -5.7°C and -5.2°C to -8.0°C,

respectively.

A regional comparison of the temperature data is shown in Table 3. Summer maximum temperature, THI, and winter WCT in Gyeongsangnam-do were 28.9°C, 77, and -3.9°C, whereas they were 27.5°C, 75, and -9.0°C, respectively, in Gangwon-do.

Monthly and seasonal variations in marbling score and quality grade frequency in Korean cattle steer carcasses

Means, standard deviations, and minimum and maximum values of the Korean cattle steer carcass data for

Table 2. Seasonal temperature, relative humidity, and temperature-humidity index (THI) values for 8 years (2006 through 2013) in South Korea

Item	Spring	Summer	Autumn	Winter	SEM	p-value
Temperature (°C)						
Mean	11.6 ^c	23.9 ^a	14.6 ^b	0.5 ^d	1.50	<0.001
Maximum	17.4 ^c	28.4 ^a	20.2 ^b	5.7 ^d	1.47	<0.001
Minimum	6.1 ^c	20.3 ^a	10.0 ^b	-4.0 ^d	1.57	<0.001
Wind speed (km/h)				5.0		
Wind chill temperature (°C)				-6.2		
Humidity (%)						
Mean	61.7 ^c	77.7 ^a	70.6 ^b	61.9 ^c	1.22	<0.001
Maximum	84.2 ^c	91.4 ^a	88.1 ^b	80.4 ^d	0.76	<0.001
Minimum	38.0 ^d	59.9 ^a	46.9 ^b	40.2 ^c	1.57	<0.001
THI						
Mean	54 ^c	73 ^a	58 ^b	38 ^d	2.22	<0.001
Maximum	61 ^c	77 ^a	65 ^b	47 ^d	1.95	<0.001
Minimum	45 ^c	68 ^a	51 ^b	30 ^d	2.46	<0.001

SEM, standard error of the mean.

n = 8.

Means with different letters within the same row differ at p<0.05.

Table 3. Regional temperature data for 8 years (2006 through 2013) in South Korea

Item	Spring				Summer				Autumn				Winter				SEM	Mean				SEM		
	GG	GW	GN	JN	GG	GW	GN	JN	GG	GW	GN	JN	GG	GW	GN	JN		GG	GW	GN	JN			
Temperature (°C)																								
Mean	10.7 ^c	10.3 ^d	12.8 ^a	11.8 ^b	23.7 ^c	22.8 ^d	24.4 ^a	23.9 ^b	13.9 ^b	12.7 ^c	15.9 ^a	16.0 ^a	-1.6 ^d	-1.9 ^c	2.5 ^a	2.6 ^a	11.7 ^b	11.0 ^c	13.9 ^a	13.9 ^a	0.24			
Maximum	16.3 ^c	16.2 ^c	18.7 ^a	17.2 ^b	28.1 ^b	27.5 ^c	28.9 ^a	27.9 ^b	19.2 ^c	18.4 ^d	21.7 ^a	20.9 ^b	3.4 ^c	3.6 ^c	8.3 ^a	7.1 ^b	16.7 ^c	16.4 ^d	19.4 ^a	18.2 ^b	0.23			
Minimum	5.7 ^b	4.8 ^c	7.3 ^a	7.2 ^a	20.2 ^b	19.0 ^c	21.0 ^a	21.0 ^a	9.5 ^c	8.0 ^d	11.3 ^b	12.0 ^a	-5.9 ^c	-6.8 ^d	-2.3 ^b	-1.2 ^a	7.4 ^c	6.2 ^d	9.3 ^b	9.8 ^a	0.26			
Wind speed (km/h)																								
														5.2 ^b	4.5 ^c	4.4 ^c	9.0 ^a	0.36						
Wind chill temperature (°C)																								
														-8.4 ^c	-9.0 ^d	-3.9 ^a	-4.5 ^b	0.48						
Humidity (%)																								
Mean	62.2 ^b	60.0 ^c	60.0 ^c	67.3 ^a	77.9 ^b	76.6 ^c	76.9 ^{bc}	82.9 ^a	70.0 ^b	70.8 ^{ab}	67.9 ^c	72.0 ^a	62.7 ^b	59.7 ^c	55.2 ^d	66.5 ^a	0.84	68.2 ^b	66.8 ^c	65.0 ^d	72.2 ^a	0.51		
Maximum	84.8 ^b	83.6 ^{bc}	82.7 ^c	87.1 ^a	91.6 ^b	91.3 ^{bc}	90.5 ^c	93.7 ^a	88.3 ^a	88.3 ^a	86.2 ^b	88.2 ^a	81.6 ^b	78.8 ^c	75.5 ^d	83.2 ^a	0.62	86.6 ^b	85.5 ^c	83.7 ^d	88.0 ^a	0.33		
Minimum	38.2 ^b	35.9 ^c	36.7 ^{bc}	44.7 ^a	60.3 ^b	57.7 ^c	59.5 ^b	67.9 ^a	46.6 ^b	46.2 ^b	44.1 ^c	51.0 ^a	41.1 ^b	36.7 ^c	33.2 ^d	47.1 ^a	1.00	46.5 ^b	44.2 ^c	43.4 ^c	52.7 ^a	0.69		
THI																								
Mean	53 ^c	52 ^d	56 ^a	54 ^b	72 ^b	71 ^c	73 ^a	73 ^a	57 ^b	55 ^c	60 ^a	60 ^a	35 ^c	35 ^c	42 ^a	41 ^b	0.62	55 ^c	54 ^d	58 ^a	57 ^b	0.35		
Maximum	59 ^c	58 ^d	62 ^a	61 ^b	76 ^b	75 ^c	77 ^a	77 ^{ab}	64 ^c	63 ^d	67 ^a	66 ^b	44 ^d	45 ^c	50 ^a	48 ^b	0.55	60 ^c	60 ^c	64 ^a	63 ^b	0.30		
Minimum	45 ^c	43 ^d	48 ^a	47 ^b	68 ^c	66 ^d	69 ^b	70 ^a	50 ^c	48 ^d	53 ^b	54 ^a	27 ^b	26 ^c	34 ^a	34 ^a	0.74	48 ^b	46 ^c	51 ^a	51 ^a	0.43		

GG, Gyeonggi-do; GW, Gangwon-do; GN, Gyeongsangnam-do; JN, Jeollanam-do; SEM, standard error of the mean; THI, temperature-humidity index. n = 8.

Means with different letters within the same row differ at $p < 0.05$.

2006–2013 are shown in Table 4. The MS was highest ($p < 0.05$) during autumn and lowest in spring and winter, with the exception of December (Tables 5 and 6). The QG 1++, QG 1+, QG 1++ plus 1+, and QG 1++ plus 1+ plus 1 frequencies were greater ($p < 0.05$) in autumn (August and September to December) than those in winter or spring (January or February to May) (Table 5; Figure 1). The seasonal comparison showed similar trends: the QG 1++, QG 1+, and QG 1++ plus 1+ plus 1 frequencies were greatest ($p < 0.05$) in autumn (15.3%, 31.5%, and 78.8%) and lowest in spring (13.8%, 29.7%, and 75.9%) (Table 6). In contrast, the QG 2 frequency was lowest ($p < 0.05$) in autumn (18.8%) and highest in spring (21.0%).

Mean summer and winter values of the QG 1++ and QG 1++ plus 1+ plus 1 frequencies were greatest ($p < 0.05$) in Gangwon-do, whereas all of those values were lowest in Gyeonggi-do (Table 7). Thus, regional variations in QGs were not related to temperature.

Monthly and seasonal variations in the carcass data associated with yield grade in Korean cattle steers

The SW and BT were higher ($p < 0.05$) in winter than those in other seasons (Tables 5 and 6). In contrast, the YI

Table 4. Means, standard deviations (SD), minimum, and maximum values of Korean cattle steer carcass data for 8 years (2006 through 2013) in South Korea

Trait	Mean	SD	Minimum	Maximum
Slaughter weight (kg)	683	22.3	633	716
Carcass weight (kg)	410	12.7	378	429
Fat thickness (mm)	12.6	0.64	11.2	13.7
Rib eye area (cm ²)	87.5	2.37	82.8	90.7
Yield index	65.1	0.43	64.3	66.1
Marbling score ¹	5.2	0.36	4.7	5.6

n = 96.

¹ Marbling score range = 1 (devoid) to 9 (highly abundant).

was lower ($p < 0.05$) in winter than that in other seasons. The CW and REA were not significantly different among seasons, although they showed some differences among months. The YG A and YG A plus B frequencies were greatest ($p < 0.05$) in summer (31.4% and 82.1%) and lowest in winter (28.0% and 78.4%), respectively (Tables 5 and 6; Figure 2). In contrast, the YG C frequency was lowest ($p < 0.05$) in summer (17.7%) and highest in winter (21.4%), respectively.

The mean and all four seasonal YG A frequency values were lowest in Gyeongsangnam-do ($p < 0.05$) and similar in the other three regions ($p > 0.05$; Table 7). The mean and all four seasonal YG A plus B frequency values were greater ($p < 0.05$) in Gangwon-do and Gyeonggi-do than those in Gyeongsangnam-do and Jeollanam-do. Therefore, regional differences in YGs were not related to temperature.

Overall, monthly and seasonal variations in YGF and the parameters associated with YG, including SW, BT, and YI were detected in Korean cattle steer carcasses.

Correlation between climate data and carcass characteristics

The correlation analysis showed that mean MS and all QG frequencies were not correlated ($p > 0.05$) with mean, maximum, or minimum CT and THI values over the 8 years (Table 8). Mean YG A and YG A plus B frequencies and the yield index for the 8 years were strongly ($r \geq 0.71$) positively correlated ($p < 0.01$) with mean, maximum, and minimum CT and THI values (Table 8). In contrast, YG C frequency, SW, and BT were strongly negatively ($r \leq -0.69$; $p < 0.05$) correlated with all CT and THI values. The CW showed a correlation trend ($p < 0.1$) with the CTs and THI. However, REA was not correlated ($p > 0.05$) with any CT or THI values. Overall, YGFs were associated with CT, but QGFs were not associated with CT.

The correlation analysis results for the carcass

Table 5. Monthly carcass characteristics, quality grade frequency, and yield grade frequency for 8 years (2006 through 2013) in Korean cattle steers

Item	Month												SEM	p value
	1	2	3	4	5	6	7	8	9	10	11	12		
Marbling score ¹	5.1 ^{cd}	5.1 ^d	5.1 ^{cd}	5.1 ^{cd}	5.1 ^{cd}	5.2 ^{bcd}	5.2 ^{bc}	5.2 ^{ab}	5.2 ^{ab}	5.3 ^a	5.3 ^a	5.3 ^a	0.03	0.001
Quality grade ² frequency (%)														
1++	14.1 ^{cdef}	13.6 ^f	13.9 ^{def}	13.8 ^{ef}	13.8 ^{ef}	14.2 ^{bcd}	14.6 ^{abc}	14.9 ^{abc}	15.1 ^{abc}	15.4 ^a	15.4 ^{ab}	15.1 ^{abcd}	0.27	0.015
1+	30.0 ^{cd}	29.4 ^e	29.8 ^{de}	29.6 ^e	29.7 ^e	30.1 ^{cde}	30.4 ^{bcd}	31.2 ^{abc}	31.1 ^{abcd}	31.9 ^a	31.4 ^{ab}	31.7 ^{ab}	0.23	0.004
1	31.9	32.5	32.3	32.4	32.4	32.4	32.4	32.3	32.2	32.1	31.9	32.1	0.14	0.949
2	20.9 ^{ab}	21.4 ^a	20.9 ^{ab}	20.9 ^{ab}	21.3 ^{ab}	20.5 ^{abc}	19.9 ^{bcd}	19.3 ^{cde}	19.2 ^{cde}	18.3 ^e	19.0 ^{de}	18.8 ^{de}	0.35	<0.001
3	2.9 ^{ab}	2.9 ^{ab}	2.9 ^{ab}	3.1 ^a	2.7 ^{abc}	2.6 ^{abc}	2.5 ^{bcd}	2.2 ^d	2.3 ^{cd}	2.2 ^{cd}	2.1 ^d	2.1 ^d	0.13	<0.001
1++ plus 1+	44.1 ^{de}	43.1 ^e	43.7 ^e	43.3 ^e	43.5 ^e	44.2 ^{cde}	45.0 ^{bcd}	46.1 ^{abcd}	46.2 ^{abc}	47.3 ^a	46.8 ^{ab}	46.8 ^{ab}	0.46	<0.001
1++ plus 1+ plus 1	76.1 ^{cd}	75.6 ^d	76.0 ^{cd}	75.8 ^{cd}	75.9 ^{cd}	76.7 ^{cd}	77.4 ^{bc}	78.4 ^{ab}	78.4 ^{ab}	79.4 ^a	78.7 ^{ab}	78.9 ^{ab}	0.48	<0.001
Slaughter weight (kg)	683 ^{cd}	687 ^{bc}	683 ^{cd}	680 ^{de}	680 ^{def}	683 ^{cd}	681 ^{de}	677 ^{ef}	675 ^f	685 ^{bcd}	690 ^b	696 ^a	2.27	<0.001
Carcass weight (kg)	411 ^{bc}	410 ^{bc}	408 ^c	408 ^c	409 ^c	410 ^{bc}	409 ^c	408 ^c	408 ^c	410 ^{bc}	413 ^{ab}	416 ^a	1.29	0.002
Rib eye area (cm ²)	87.1 ^c	87.3 ^c	87.4 ^c	87.3 ^c	87.4 ^c	87.5 ^{bc}	87.5 ^{bc}	87.3 ^c	87.2 ^c	87.5 ^{bc}	87.9 ^{ab}	88.2 ^a	0.24	<0.001
Backfat thickness (mm)	12.8 ^{bc}	12.7 ^{cd}	12.5 ^{de}	12.4 ^{ef}	12.3 ^{ef}	12.3 ^f	12.3 ^{ef}	12.3 ^{ef}	12.4 ^{ef}	12.8 ^c	13.0 ^{ab}	13.2 ^a	0.07	<0.001
Yield index	64.9 ^{cd}	65.0 ^{bc}	65.2 ^{ab}	65.2 ^a	65.3 ^a	65.3 ^a	65.3 ^a	65.2 ^a	65.2 ^a	65.0 ^{bcd}	64.8 ^{de}	64.7 ^e	0.04	<0.001
Yield grade ³ frequency (%)														
A	28.5 ^{cd}	29.5 ^{bc}	30.4 ^{ab}	30.9 ^{ab}	31.1 ^{ab}	31.7 ^a	31.5 ^a	31.2 ^{ab}	31.2 ^{ab}	28.5 ^{cd}	27.1 ^{de}	26.1 ^e	0.40	<0.001
B	50.4	50.2	50.1	50.5	50.7	50.5	50.7	50.8	50.6	50.7	50.9	50.4	0.31	0.991
C	21.0 ^{bc}	20.1 ^{cd}	19.3 ^{de}	18.3 ^{ef}	18.0 ^f	17.5 ^f	17.7 ^f	17.8 ^f	18.1 ^{ef}	20.6 ^c	21.9 ^b	23.2 ^a	0.46	<0.001
A+B	78.9 ^{de}	79.8 ^{cd}	80.5 ^{bc}	81.4 ^{ab}	81.8 ^a	82.3 ^a	82.1 ^a	82.0 ^a	81.7 ^a	79.2 ^d	78.0 ^e	76.5 ^f	0.46	<0.001

SEM, standard error of the mean.

n = 8.

¹ Marbling score range = 1 (devoid) to 9 (highly abundant). ² Quality grade range = 1++ (best), 1+, 1, 2, and 3 (worst).³ Yield grade range = A (highest), B, and C (lowest).Means with different letters within the same row differ at $p < 0.05$.

characteristics are shown in Table 9. CW was strongly positively correlated ($r \geq 0.83$; $p < 0.01$) with SW, REA, and BT, whereas YI was negatively correlated ($r \leq -0.58$; $p < 0.05$) with SW, CW, REA, and BT.

DISCUSSION

Heat stress (HS) or cold stress may affect food intake, heat production, and nutrient partitioning priorities and decrease animal performance. Weather conditions in South

Korea are hot and humid during summer (maximum temperature 28.4°C and maximum humidity 91.4%), as evidenced by the average climate data for the past 8 years. THI values were 73 to 80 in summer. Zimbleman et al. (2009) suggested that the THI categories for lactating dairy cows are stress threshold (68 to 71), mild HS (72 to 79), moderate HS (80 to 89), and severe HS (90 to 99). Thus, summer THI values in South Korea may be within the mild HS category for beef cattle. Only small differences in the summer maximum temperature (1.4°C) and THI (2) values

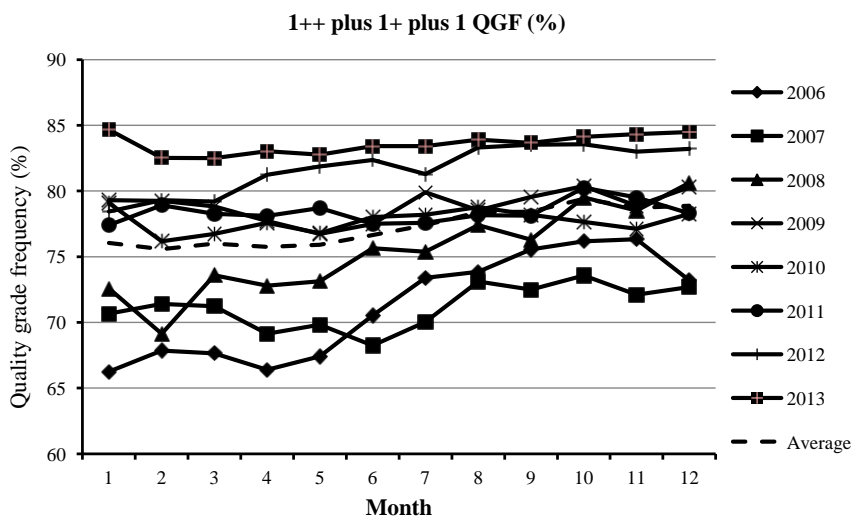
**Figure 1.** Monthly comparison of 1++ plus 1+ plus 1 quality grade frequency (QGF) in Korean cattle steers for 8 years.

Table 6. Seasonal carcass characteristics, quality grade frequency, and yield grade frequency for 8 years (2006 through 2013) in Korean cattle steers

Item	Spring	Summer	Autumn	Winter	SEM	p-value
Marbling score ¹	5.1 ^c	5.2 ^b	5.3 ^a	5.1 ^{bc}	0.04	0.001
Quality grade ² frequency (%)						
1++	13.8 ^b	14.5 ^{ab}	15.3 ^a	14.3 ^b	0.44	0.030
1+	29.7 ^b	30.6 ^{ab}	31.5 ^a	30.4 ^b	0.36	0.010
1	32.4	32.4	32.1	32.2	0.21	0.690
2	21.0 ^a	19.9 ^{ab}	18.8 ^b	20.4 ^a	0.59	0.006
3	2.9 ^a	2.4 ^{bc}	2.2 ^c	2.6 ^{ab}	0.23	0.004
1++ plus 1+	43.5 ^c	45.1 ^b	46.8 ^a	44.7 ^{bc}	0.74	0.003
1++ plus 1+ plus 1	75.9 ^c	77.5 ^{ab}	78.8 ^a	76.8 ^{bc}	0.80	0.003
Slaughter weight (kg)	681 ^b	680 ^b	683 ^b	689 ^a	3.85	0.003
Carcass weight (kg)	408	409	410	412	2.21	0.080
Rib eye area (cm ²)	87.4	87.4	87.5	87.5	0.42	0.820
Backfat thickness (mm)	12.4 ^b	12.3 ^b	12.7 ^a	12.9 ^a	0.11	<0.001
Yield index	65.2 ^a	65.3 ^a	65.0 ^b	64.8 ^b	0.07	<0.001
Yield grade ³ frequency (%)						
A	30.8 ^a	31.4 ^a	28.9 ^b	28.0 ^b	0.65	0.004
B	50.4	50.7	50.7	50.4	0.52	0.840
C	18.5 ^c	17.7 ^c	20.2 ^b	21.4 ^a	0.78	<0.001
A+B	81.2 ^a	82.1 ^a	79.6 ^b	78.4 ^c	0.77	<0.001

SEM, standard error of the mean.

n = 8.

¹ Marbling score range = 1 (devoid) to 9 (highly abundant). ² Quality grade range = 1++ (best), 1+, 1, 2, and 3 (worst).³ Yield grade range = A (highest), B, and C (lowest).

Means with different letters within the same row differ at p<0.05.

were observed between the southern and northern regions of South Korea.

The lower critical temperature (LCT) is defined as the effective ambient temperature at which energy intake increases to minimize the reduction in weight gain in growing cattle or to prevent weight loss in mature cattle. LCT and cold stress vary with cattle breed, hair coat condition, moisture conditions, age, cattle size, length of time exposed to the temperature difference, and wind speed (Young, 1981). As temperatures decrease in the fall, cattle

coat hair thickens to offer more protection. The estimated LCT for beef cattle is 7.2°C with a dry fall coat, 0°C with a dry winter coat, and -7.2°C with a dry heavy winter coat (<http://www.forestrywebinars.net/webinars/planning-and-design-of-livestock-watering-systems/>). Another study reported different LCT values of approximately 8°C for newborn calves, -5°C for 50 to 200 kg growing calves, -22°C for growing cattle, -28°C for dairy cows at peak lactation, and -35°C for finishing feedlot cattle (Young, 1981). The cattle cold stress index numbers are based on the

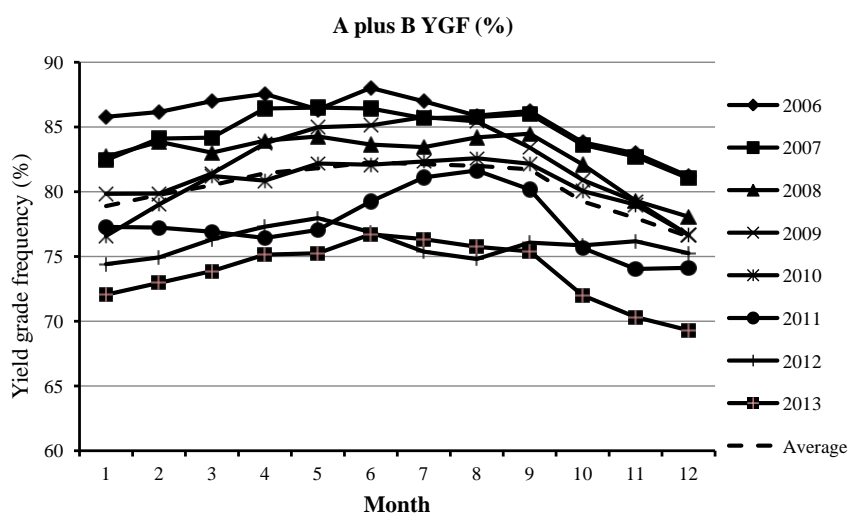
**Figure 2.** Monthly comparison of A+B yield grade frequency (YGF) in Korean cattle steers for 8 years.

Table 7. Regional comparison of average quality frequency and yield frequency for 8 years (2006 through 2013) in Korean cattle steer carcasses

Item	Spring				Summer				Autumn				Winter				Mean				SEM
	GG	GW	GN	JN	GG	GW	GN	JN	GG	GW	GN	JN	GG	GW	GN	JN	GG	GW	GN	JN	
Quality grade ¹ frequency (%)																					
1++	12.9 ^b	17.6 ^a	15.2 ^{ab}	14.0 ^b	14.1 ^b	15.9 ^a	16.4 ^a	14.2 ^b	14.8 ^b	16.4 ^a	17.3 ^a	16.0 ^{ab}	13.0 ^b	16.4 ^a	16.0 ^a	14.2 ^b	13.7 ^b	16.6 ^a	16.2 ^a	14.6 ^b	0.42
1+	29.7 ^c	33.7 ^{ab}	30.5 ^{bc}	36.9 ^a	30.2 ^c	34.5 ^b	31.5 ^c	37.9 ^a	31.8 ^b	34.0 ^b	32.2 ^b	39.7 ^a	30.4 ^c	33.3 ^b	30.5 ^{bc}	37.3 ^a	30.5 ^c	33.9 ^b	31.2 ^c	38.0 ^a	0.73
1	31.6 ^a	31.5 ^a	32.5 ^a	27.1 ^b	31.6 ^a	32.9 ^a	31.3 ^a	26.8 ^b	31.2 ^{ab}	32.8 ^a	31.0 ^b	25.5 ^c	31.3 ^a	31.9 ^a	32.4 ^a	26.7 ^b	31.5 ^a	32.3 ^a	31.8 ^a	26.5 ^b	0.51
2	22.6 ^a	15.5 ^b	18.0 ^b	17.5 ^b	21.4 ^a	15.1 ^c	16.9 ^{bc}	17.5 ^b	19.9 ^a	15.1 ^b	16.3 ^b	15.4 ^b	22.3 ^a	16.4 ^b	17.8 ^b	16.8 ^b	21.6 ^a	15.5 ^b	17.2 ^b	16.8 ^b	0.67
3	3.0 ^{ab}	1.7 ^b	3.2 ^a	3.6 ^a	2.5 ^a	1.5 ^b	3.1 ^a	3.0 ^a	2.2 ^b	1.6 ^c	2.6 ^{ab}	2.9 ^a	2.9 ^{ab}	1.9 ^b	2.8 ^b	3.9 ^a	2.6 ^a	1.7 ^b	2.9 ^a	3.3 ^a	0.27
1++ plus 1+	42.6 ^b	51.3 ^a	45.8 ^b	50.9 ^a	44.3 ^c	50.4 ^{ab}	47.9 ^b	52.1 ^a	46.6 ^c	50.4 ^b	49.4 ^{bc}	55.7 ^a	43.4 ^c	49.7 ^{ab}	46.5 ^{bc}	51.5 ^a	44.3 ^c	50.5 ^{ab}	47.4 ^{bc}	52.6 ^a	0.90
1++ plus 1+ plus 1	74.2 ^b	82.8 ^a	78.2 ^b	77.9 ^b	76.0 ^c	83.3 ^a	79.2 ^b	78.9 ^b	77.8 ^b	83.2 ^a	80.5 ^{ab}	81.2 ^a	74.7 ^c	81.7 ^a	78.9 ^{ab}	78.2 ^b	75.7 ^c	82.8 ^a	79.2 ^b	79.1 ^b	0.87
Yield grade ² frequency (%)																					
A	32.1 ^a	32.8 ^a	27.1 ^b	33.9 ^a	33.6 ^a	33.2 ^a	26.6 ^b	34.1 ^a	30.7 ^a	30.4 ^a	24.1 ^b	31.5 ^a	29.6 ^a	29.8 ^a	23.8 ^b	29.9 ^a	31.5 ^a	31.5 ^a	25.4 ^b	32.4 ^a	1.04
B	50.8 ^a	52.8 ^a	51.1 ^a	45.2 ^b	50.1 ^b	52.7 ^a	52.9 ^a	46.5 ^c	50.4 ^b	54.5 ^a	53.1 ^{ab}	46.2 ^c	51.0 ^b	53.3 ^a	51.9 ^{ab}	45.1 ^c	50.6 ^b	53.3 ^a	52.2 ^{ab}	45.7 ^c	0.76
C	17.0 ^b	14.4 ^c	21.2 ^a	20.0 ^a	16.1 ^b	14.0 ^c	19.6 ^a	18.8 ^a	18.8 ^b	15.1 ^c	22.2 ^a	21.8 ^a	19.4 ^b	16.8 ^c	23.8 ^a	23.9 ^a	17.8 ^b	15.1 ^c	21.7 ^a	21.1 ^a	1.00
A+B	82.9 ^b	85.5 ^a	78.2 ^c	79.1 ^c	83.8 ^b	85.9 ^a	79.5 ^c	80.5 ^c	81.1 ^b	84.9 ^a	77.2 ^c	77.7 ^c	80.5 ^b	83.1 ^a	75.7 ^c	75.0 ^c	82.1 ^b	84.9 ^a	77.7 ^c	78.1 ^c	1.00

GG, Gyeonggi-do; GW, Gangwon-do; GN, Gyeongsangnam-do; JN, Jeollanam-do; SEM, standard error of the mean.

n = 8.

¹ Quality grade range = 1++ (best), 1+, 1, 2, and 3 (worst). ² Yield grade range = A (highest), B, and C (lowest).

Means with different letters within the same row differ at p<0.05.

Table 8. Pearson's correlation coefficient values for marbling score, quality grade frequency, yield grade frequency, and carcass characteristics with temperatures and temperature-humidity index (THI)

Item	Climate temperature			THI		
	Mean	Maximum	Minimum	Mean	Maximum	Minimum
Marbling score	0.16	0.16	0.18	0.27	0.27	0.28
Quality grade frequency						
1++	0.25	0.24	0.27	0.23	0.23	0.24
1+	0.16	0.15	0.18	0.16	0.16	0.18
1	0.41	0.41	0.39	0.41	0.40	0.40
2	-0.24	-0.23	-0.26	-0.24	-0.25	-0.25
3	-0.30	-0.29	-0.33	-0.33	-0.32	-0.35
1++ plus 1+	0.19	0.18	0.21	0.19	0.19	0.20
1++ plus 1+ plus 1	0.27	0.25	0.28	0.26	0.27	0.28
Slaughter weight	-0.70*	-0.71**	-0.69*	-0.70*	-0.72**	-0.69*
Carcass weight	-0.55 ^a	-0.57 ^b	-0.53 ^c	-0.55 ^d	-0.57 ^e	-0.53 ^f
Rib eye area	-0.21	-0.22	-0.20	-0.22	-0.23	-0.21
Backfat thickness	-0.75**	-0.76**	-0.74**	-0.75**	-0.75**	-0.74**
Yield index	0.74**	0.75**	0.72**	0.74**	0.74**	0.72**
Yield grade frequency						
A	0.72**	0.73**	0.71**	0.73**	0.73**	0.72**
B	0.60*	0.61*	0.61*	0.60*	0.61*	0.59*
C	-0.79**	-0.79**	-0.77**	-0.79**	-0.79**	-0.78**
A+B	0.79**	0.79**	0.77**	0.78**	0.78**	0.77**

* p<0.05, ** p<0.01.

^a p = 0.062; ^b p = 0.053; ^c p = 0.076; ^d p = 0.062; ^e p = 0.053; ^f p = 0.074.**Table 9.** Pearson's correlation coefficients among carcass characteristics

Item	Slaughter weight	Carcass weight	Rib eye area	Backfat thickness
Carcass weight	0.90**	-	-	-
Rib eye area	0.80**	0.83**	-	-
Backfat thickness	0.88**	0.88**	0.65*	-
Yield index	-0.82**	-0.86**	-0.58*	-0.98**

* p<0.05, ** p<0.01.

human wind chill calculation. The combined effects of temperature and wind are often expressed as a wind chill index (WCI) or WCT. The WCI, rather than ambient temperature, is used to estimate effective temperature when considering cold stress severity. For example, under dry winter cattle coat conditions, cold stress is categorized as “mild” at 0°C to -6.7°C, “moderate” at -7.2°C to -13.9°C, and “severe” at <-13.9°C (<http://www.forestrywebinars.net/webinars/planning-and-design-of-livestock-watering-systems/>). In this study, minimum CT and WCT in winter ranged from -3.2°C to -5.7°C and -5.2°C to -8.0°C, respectively. Thus, winter WCI values in South Korea may be within the mild or moderate cold stress categories for beef cattle, depending on the location of the city. Winter WCI values in South Korea may affect productivity of ruminants. The WCT in Gangwon-do, the northern part of South Korea, was approximately 4°C or 5°C colder compared to that in Jeollanam-do or Gyeongsangnam-do, the southern parts of South Korea. Therefore, animals that raised in northern part may be more exposed to cold stress during winter compared to southern parts in South Korea. The LCT values should be considered only as indicators of cold susceptibility. In practice, the actual LCT may vary considerably depending on specific housing and pen conditions, breed type, nutrition, time after feeding, thermal adaptation history, behavior, and physiological status (Hamada, 1971; Young, 1981). Hamada (1971) estimated that LCTs for maintenance and production cows of 10 and 20 kg fat-corrected milk daily were 2°C, -4°C, and -10°C, respectively.

In this study, we analyzed whether Korean cattle steer carcass data varied seasonally and whether the data were associated with climate data. We found that both MS and QGs of Korean cattle steer carcasses were generally best in autumn and worst in spring. The correlation analysis showed that both MS and QGs were not associated with CT or THI values. Therefore, our results demonstrate that both hot summer and cold winter climatic factors have not significantly affected MS and QGs in South Korean cattle steer. Regional differences in QGs and YGs were observed; however, the regional differences were not associated with temperature.

We found that YGs of Korean cattle steer carcasses were worst in winter (November to January) and best in spring and summer (May to September). We revealed that YG was significantly correlated with CT. REA is an important positive parameter for YG; however, it was not associated with CT. The BT and CW were negative factors for YG, and both were highest in winter (November and December). We found that the BT was strongly negatively correlated with CTs and that the CW showed a trend to be correlated with the CTs. Therefore, one of reasons for the poorest YGs during winter may be the high BT. It has been

suggested that tissue insulation increases as a consequence of prolonged exposure and adaptation to cold (Webster, 1976). Greater ultrasound backfat is observed in growing beef cattle during colder periods (Mujibi et al., 2010). Therefore, it is possible that increased BT due to the insulation effect from cold exposure caused reduced YGs during winter.

Various studies have demonstrated that colder temperatures result in decreased feed efficiency and daily gain (Elam, 1970; Birkelo et al., 1991; Delfino and Mathison, 1991). Several studies have also indicated that the thermal environment of feedlot cattle influences animal production at effective ambient temperatures well above their estimated LCT (Webster et al., 1970; Young and Christopherson, 1974; NRC, 1981). In this study, both SW and CW were strongly positively correlated with REA. However, REA was not different among seasons, although SW was heaviest in winter. As described above, winter WCI values in South Korea may be within the mild-to-moderate cold-stress categories. Therefore, REA may not increase, even though CW was higher in winter due to decreased feed efficiency caused by cold stress.

We found regional differences in YGs. However, these regional differences were not related to CT: YGs in Gyeongsangnam-do were worse in winter compared to those in other regions (Gangwon-do and Gyeonggi-do in the northern part of South Korea).

In conclusion, summer THI values (range, 73 to 80) in South Korea may be within the mild HS category, and winter CT and WCI values may be within either the mild or moderate cold-stress categories for beef cattle. The YGs of Korean cattle steer carcasses were worst in winter (November to January). Our results demonstrate that winter cold weather may cause cold stress, resulting in decreased YGs. However, MS and QGs were not associated with climate conditions. Additionally, YG in summer was best among all seasons, indicating that the hot summer climate does not adversely affect YGs. We calculated THI and WCT values based on the weather conditions. Beef cattle in South Korea are generally grown on a feedlot with shelter, and ambient temperature and RH may differ from the weather conditions. Therefore, ambient temperature and corresponding RH values should be used to calculate THI and WCI values under beef cattle feedlot conditions in South Korea.

IMPLICATIONS

Animal productivity is maximized in the thermal neutral range, as energy and nutrients are diverted away from production toward maintaining normal body temperature when environmental conditions are not ideal. Heat or cold stress may affect nutrient partitioning priorities and

decrease animal performance. Therefore, temperature stress is a significant financial burden in most countries. We found that the YGs of Korean cattle steer were the worst in winter and were significantly correlated with temperature, although QG was not associated with climate conditions. Therefore, strategies to minimize the adverse effects of cold stress on YG are needed for beef cattle farms in South Korea.

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