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Effect of the transport duration time and season on some physicochemical properties of beef meat

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Abstract

The objective of this study was to examine the effect of season and transport time on beef quality. The study was conducted during 12 months of 2009 on 480 bulls and 480 heifers of Simmental breed. The cattle were divided into 2 transport groups and then into 4 season groups according to the journey. Quality indicators pH, electrical conductivity (EC) and meat colour values were measured 24 h *post mortem* on *m. longissimus dorsi*. Heifer beef compared to bull beef had better values of quality indicators (P<0.05). Differences in quality indicators were found between cattle slaughtered in the spring and summer seasons and between cattle slaughtered in the autumn and summer seasons (P<0.05). Bull beef had poorer colour, pH and EC values in the summer and winter seasons compared to the spring season, whereas heifer beef had poorer pH, EC and colour values in the summer period compared to other seasons (P<0.05). In the summer season, poorer pH, EC and colour (L* and h*) values were obtained in groups of heifers transported for a longer time compared to heifers transported for a shorter time (P<0.05). In groups of bulls transported for a shorter time during the winter period poorer pH, EC and colour values were obtained (P<0.05). This study suggests that the quality of Simmental beef was associated with the season and that environmental factors should be considered when deciding about the time of cattle transport, since this can reduce beef colour in a very short period of time.

Keywords: beef, stress, pH_{24}, electrical conductivity, colour

Introduction

Beef is a very valuable animal product. In recent years, producers have encountered problems with beef distribution, related primarily to frequent occurrence of dark, firm, dry meat (DFD). Consumers place high emphasis on food quality, and their decision on purchasing a product is mainly based on colour. Bright red colours are acceptable and desirable, while dark purple colours create a negative connotation to consumers, who believe that such meat comes from old and sick animals. When cattle are stressed, there is a rapid release of catecholamines (norepinephrine, epinephrine, dopamine), which results in glycogen depletion (Lacourt & Tarrant 1985) causing a lower rate of *post mortem* lactic acid synthesis and high ultimate pH. Abnormally high pH (>6.0) increases the light-absorption and water-binding abilities and results is undesirable colour (Lister 1988).

During transfer to the slaughterhouse cattle can be exposed to various stressors such as fast or forced movements, exertion, jostling, breakdown of the social group, strange environment, rough treatment (during loading and unloading), novelty, track movement, noise, vibrations, centrifugal force, climatic conditions, shortage of food and water (Grandin 1997, Swanson & Morrow-Tesch 2001, Broom 2003). Shorter transport may lead to weight reduction, drop in glycogen reserves and increased muscle temperature, which is not always reflected in ultimate pH (Agnes *et al.* 1990, María *et al.* 2003). Prolongation of transport time from the farm to the slaughterhouse has commonly an adverse effect on beef quality but little is known about its direct influence on the texture or colour of beef (Grandin 2000). Transport period to the slaughterhouse is relatively short in some parts of Europe, and in Croatia it is typically less than 6 h.

Further, adverse seasonal conditions can potentially stress meat animals and consequently influence carcass and meat quality characteristics. Cattle are considered more sensitive to hot than to cool temperatures (Baker *et al.* 1981). During warm weather, cattle show signs of stressful behaviour, impaired physiological functions and increased incidence of morbidity (Hahn & Mader 1997), while cold weather combined with precipitation increases the rate of body-heat loss and elicits shivering (Smith *et al.* 1993).

The objective of the present study was to examine the effect of transport time and season on meat quality of Simmental bulls and heifers.

Materials and methods

Four hundred and eighty Simmental bulls, aged 14-16 months, and four hundred and eighty Simmental heifers, aged 13-15 months, were used in the study during 12 months of 2009. Cattle production system (housing, feeding management and nutritional status) used was the same on both farms. Cattle were kept in large partially shaded multiple pens (approximately 10 cattle in 61 m^2 pen) with appropriate feedlot. Bulls and heifers were kept in pens separately. The cattle were fed *ad libitum* with same diet, based on maize silage and concentrates, and also had *ad libitum* access to water during whole fattening period. The average nutritional content of the feeds was approximately 7.6 MJ ME/kg dry matter and 950 g crude protein.

Cattle were divided into two transport time groups; the first group included 240 bulls and 240 heifers transported from the farm to the slaughterhouse precisely 92 min and the second group included 240 bulls and 240 heifers transported from the farm to the slaughterhouse precisely 265 min. Transport times corresponded to approximately 110 km and 300 km, respectively. Cattle groups were transported unmixed. For each journey, 10 cattle were led to the truck which had 2 pens of equal size at the front and back (5 cattle in each pen). The stocking density was 1.5 m^2/cattle (one deck lorry with a surface area of $6.00\,m \times 2.50\,m = 15\,m^2$). The loading and unloading were timed and negative behavioral events were noted according to the scoring system of María *et al.* (2004).

According to season, cattle were divided into 4 groups of 240 animals each (120 bulls and 120 heifers). Cattle were transported from the farm to the slaughterhouse in winter (December to February), spring (March to May) summer (June to August) and autumn (September to November). Temperature and relative humidity data were collected twice a month - on the days of transport, during loading at the farm and during unloading at the slaughterhouse with a Kestrel 4000 Pocket Weather Tracker (Nielsen-Kellerman, Boothwyn, PA, USA).

The cattle were slaughtered according to the standard procedure, immediately after being unloaded. Carcasses were chilled under commercial conditions at 4 °C for 24 h. On the following day, the concentration of hydrogen ions (pH) was measured at 24 h *post mortem* with a Eutech CyberScan pH 310 instrument (Eutech Instruments Pte Ltd, Singapore). Measurements were made on the right side of *m. longissimuss dorsi* removed from the area between the 6th and 7th ribs. Electrical conductivity (EC) was measured 24 h after slaughter with a LF-Control System Instrument (Würthinger, Pettenbach, Austria) in miliSiemens per centimeter (mS/cm). Meat colours were measured at 24 h *post mortem* plus 80 min after bloom time (80 min after cutting, exposing *m. longissimuss dorsi* to air). In order to evaluate the colour pattern, CIE (Commission International de l'Éclairage) 1976 values (L*: lightness, a*: redness, b*: yellowness, c*: chroma, h: hue) were measured with a Minolta Chroma Meter CR-410 colorimeter (Minolta Co., Ltd., Japan), with a 50-mm-diameter measurement area using D65 illumination. Statistical analysis was carried out using the SAS General Linear Model procedures (SAS Institute Inc., Cary, NC, USA) with a fixed effect of sex, transport time and season. Mean separations were performed using the Tukey (HSD) multiple range test for significant main effect at $P<0.05$.

Results and discussion

Table 1
Environmental conditions, loading and unloading time and carcass traits of Simmentals breed per season

	Season			
	Winter	Spring	Summer	Autumn
Environmental conditions				
Ta, °C	3.63^{a}	14.13^{b}	23.00^{c}	14.50^{b}
Td, °C	3.93^{a}	8.17^{b}	7.99^{b}	8.75^{b}
Tt, °C	3.29^{a}	6.79^{b}	6.96^{b}	4.50^{a}
Relative humidity, %	78.58^{a}	67.38^{b}	62.54^{b}	80.04^{a}
Loading and unloading time, minutes per animal				
Loading time	1.68	1.58	2.04	1.71
Unloading time	0.83	0.81	0.88	0.77
Carcass traits				
Warm carcass weight of bulls, kg	357.26^{a}	362.33^{ab}	371.28^{b}	355.74^{a}
Net weight gain of bulls, kg	0.751^{a}	0.776^{ab}	0.794^{b}	0.758^{a}
Bulls' age, months	15.66	15.38	15.43	15.49
Warm carcass weight of heifers, kg	268.22	269.83	273.13	274.92
Net weight gain of heifers, kg	0.617	0.626	0.633	0.629
Heifers' age, months	14.31	14.22	14.24	14.41

^{a,b,c}different letters in the same row indicate significant difference ($P<0.05$), Ta: average daily temperature, Td: difference between maximum and minimum daily temperatures according to the Croatian Metrological and Hydrological Service, Tt: difference between loading and unloading temperatures

As shown in Table 1, average daily temperatures (Ta) in the winter season were significantly lower and those in the summer season significantly higher compared to other seasons ($P<0.05$). Differences between maximum and minimum daily temperatures (Td) were significantly lower in the winter season than in other seasons. Differences between loading and unloading temperature (Tt) were significantly higher in the summer and spring seasons compared to the winter and autumn seasons. Average relative humidity was significantly higher in autumn and winter than in other seasons ($P<0.05$). Loading and unloading times were not significantly different between different seasons and quite short with few negative behavioural events (falls and slips). According to the results of carcass traits, bulls slaughtered in summer had significantly higher warm carcass weight and net weight gain compared to bulls slaughtered in the winter and autumn seasons ($P<0.05$). No significant differences were found between heifers slaughtered in different seasons.

The effects of sex and season on pH, electrical conductivity and muscle colour are shown in Table 2. In the presented study, heifers had significantly lower muscle pH, EC values and higher L* and b* values, while bulls had significantly higher pH, EC and a* values ($P<0.05$). Our findings agree with Page *et al.* (2001) and Wulf & Wise (1997), who also reported that bulls produced beef with higher pH values and lower L* and b* values. Tatum *et al.* (2007) maintained that the differences between sexes were associated with endogenous hormone levels, differences in temperament and reactions to pre-harvest stress. Gruber *et al.* (2006) found that cattle exhibiting calm behaviour immediately following transport had the lowest blood lactate levels, whereas behaviour of agitated cattle could have affected their pH values. In our study, heifers produced significantly lighter beef with lower electrical conductivity than bulls. Some authors (Voisinet *et al.* 1997, Wulf *et al.* 1997, Page *et al.* 2001, Tatum *et al.* 2007) found that heifers typically produced carcasses with higher marbling score, which affected the L* and b* values. Swantek *et al.* (1992) and Aldai *et al.* (2006) reported that animals with higher intramuscular fat content (marbling) had lower results for juice loss and electrical conductivity. In the presented study (Table 2), the groups of cattle slaughtered during the summer and winter periods had poorer pH, EC and colour values compared to cattle slaughtered in spring and autumn. Significant differences in parameters pH, EC and colour values were found between cattle slaughtered during the spring and summer seasons and between cattle slaughtered during the autumn and summer seasons ($P<0.05$). Significant differences in parameters pH, b* and h* ($P<0.05$) were found between cattle slaughtered in the spring and winter seasons. Comparison between the winter season and the summer season showed that significantly better values were obtained for parameters pH, EC and colours (a*, b*, C*) in cattle slaughtered in the winter season ($P<0.05$). There were no significant differences between cattle slaughtered in the winter and autumn seasons and between cattle slaughtered in the autumn and spring seasons. This result seems to indicate that meat colours differ in dependence on seasonal conditions. Our result is in agreement with several groups, who also found that the season had an adverse effect on beef quality (Baker 1981, Grandin 1996, Kladim *et al.* 2004, Mounier *et al.* 2006). In this study, bull beef had a significantly poorer colour, pH and EC values during the summer and winter seasons compared to the spring season ($P<0.05$) and slightly poorer compared to autumn, whereas heifer beef had significantly poorer pH, EC and colour (a*, b*, C*) values in the summer period compared to other seasons ($P<0.05$). Similarly, Yong *et al.* (2003) reported that bull beef was significantly darker in summer and winter. Tarrant & Sherington (1980) reported that October and December were the peak months for dark cutting beef. In contrast to this study, Fabiansson *et al.* (1984) found that the highest incidence of dark cutting beef was from May to August. Jones & Tong (1989) reported that the frequency of dark cutting beef was higher in March and April and the lowest in December. Warriss (1992) concluded that the seasonal effect on beef quality was not large.

Table 2
Effect of season and sex on meat colour, pH and electrical conductivity (n=120/season)

	Season	Sex		Mean[2]
		Bulls	Heifers	
pH	Winter	5.60^{aA}	5.55^{bA}	5.58^{A}
	Spring	5.56^{aB}	5.55^{aA}	5.55^{B}
	Summer	5.60^{aA}	5.61^{aB}	5.61^{C}
	Autumn	5.58^{aAB}	5.55^{bA}	5.56^{AB}
	Mean[1]	5.59^{a}	5.56^{b}	
EC	Winter	7.17^{aA}	4.71^{bA}	5.94^{A}
	Spring	7.52^{aB}	4.77^{bA}	6.15^{A}
	Summer	7.07^{aA}	4.34^{bB}	5.70^{B}
	Autumn	7.32^{aAB}	4.78^{bA}	6.05^{A}
	Mean[1]	7.27^{a}	4.65^{b}	
L*	Winter	42.06^{aA}	43.89^{bA}	42.98^{AB}
	Spring	42.76^{aB}	43.93^{bA}	43.34^{B}
	Summer	41.99^{aA}	43.41^{bA}	42.70^{A}
	Autumn	42.42^{aAB}	43.88^{bA}	43.15^{B}
	Mean[1]	42.31^{a}	43.78^{b}	
a*	Winter	29.19^{aA}	29.03^{aA}	29.11^{A}
	Spring	29.64^{aB}	28.96^{bA}	29.30^{A}
	Summer	29.11^{aA}	28.37^{bB}	28.74^{B}
	Autumn	29.38^{aAB}	28.89^{bA}	29.13^{A}
	Mean[1]	29.33^{a}	28.81^{b}	
b*	Winter	11.35^{aA}	11.89^{bA}	11.62^{A}
	Spring	11.77^{aB}	11.91^{aA}	11.84^{B}
	Summer	11.32^{aA}	11.49^{aB}	11.40^{C}
	Autumn	11.57^{aAB}	11.88^{aA}	11.73^{AB}
	Mean[1]	11.50^{a}	11.80^{b}	
C*	Winter	31.33^{aA}	31.33^{aA}	31.33^{A}
	Spring	31.91^{aB}	31.30^{bA}	31.60^{A}
	Summer	31.25^{aA}	30.61^{bB}	30.93^{B}
	Autumn	31.59^{aAB}	31.24^{aA}	31.41^{A}
	Mean[1]	31.52^{a}	31.12^{b}	
h*	Winter	21.20^{aA}	22.27^{bA}	21.74^{AC}
	Spring	21.63^{aB}	22.35^{bA}	21.99^{B}
	Summer	21.20^{aA}	22.02^{bA}	21.61^{C}
	Autumn	21.46^{aAB}	22.35^{bA}	21.90^{AB}
	Mean[1]	21.37^{a}	22.25^{b}	

[1]mean of four seasons within the same sex (n=480), [2]mean of two sex groups within the same season (n=240), ^{a,b}Different letters in the same row indicate significant difference ($P<0.05$). ^{A,B,C}Different letters in the same column indicate significant difference ($P<0.05$).

As shown in Table 3, transport time over the whole year had no significant influence on beef quality indicators in the studied sample. No significant influence of transport on beef quality was observed in some earlier research either (Fernandez *et al.* 1996, María *et al.* 2003). In this study, bulls transported for a shorter time had slightly poorer pH, L*, a*, b* and

C* values compared to bulls transported for a longer time. Heifers subjected to a shorter journey had slightly better pH, EC, L*, b*, C* and h* values compared to heifers transported for a longer time. Jones *et al.* (1988) noted an insignificant adverse effect of transport time on beef quality. Villarroel *et al.* (2003) observed that longer journey, up to 6 h, slightly increased pH and decreased colour parameters (L*, a*, b*). Some other studies found that longer journey significantly increased the pH value, and decreased colours (Poulanne & Aalto 1981, Brown *et al.* 1990). Borell (2000) reports that transport is considered as a major stressor for farm animals and might have deleterious effects on health, well-being, performance and ultimately on product quality. Sanz *et al.* (1996) concluded that shorter journey gave animals less time to adapt to a new situation and animals arrived to the slaughterhouse with lower glycogen reserves, causing lower post-mortem rate of lactic acid synthesis, high ultimate pH and undesirable colour. In this study, significantly poorer pH, EC and colour (L* and h*) values were observed during the summer season in groups of heifers transported for a longer time compared to heifers transported for a shorter time (P<0.05). In groups of bulls subjected to a shorter journey from the farm to the slaughterhouse significantly poorer pH, EC and colour parameters were observed during the winter period compared to bulls transported for a longer time (P<0.05). Tarrant (1989) observed that due to colder temperatures, transport was more stressful in the winter season than transport in summer seasons. Grandin (1992) reported that the incidence of DFD was high during very cold weather combined with precipitation and during very warm weather or when large temperature fluctuations occurred over a short period of time. Murray (1989) reported that the mean incidence of dark meat was significantly affected by minimum and maximum daily temperatures. Mounier *et al.* (2006) found that the journey was physically demanding for bulls when the external temperature was above 18 °C. Morrison & Lofgreen (1979) reported that temperature stress in cattle was observed when the air temperature was above 20.3 °C. Scanga *et al.* (1998) reported that when average temperatures were below 0 °C, 2 days to 1 day before harvest, incidence of DFD in heifers was higher (P<0.05) than when temperatures were above 0 °C. During our survey, temperatures were high in summer (23 °C on average, with peaks at 29 °C), while winter temperatures were low (3.63 °C on average, with peaks at –12 °C); hence we suppose that at external temperatures above 23 °C and below 3 °C the journey was physically demanding for Simmental bulls and heifers, resulting in increased pH value and a decrease in colour parameters.

In conclusion, under optimal weather conditions during spring and autumn period transport time had slight effects on some physicochemical properties of beef quality. Under sub-optimal weather conditions during winter and summer period the effects of transport on some physicochemical properties of beef quality were higher. The study shows that pre-slaughter journey along with season conditions can have significant deleterious effects on some physicochemical beef quality traits. There is a need in the future to broaden research focus on truck equipment designed to reduce as much as possible the negative effects of extreme environmental conditions in terms of optimising cattle welfare and minimising losses in production yield and quality. What was left unexplored but deserves to be further pursued and evaluated is the effective temperature like temperature-humidity and wind chill index in order to more precisely determine cattle discomfort index. The results show that the effect of pre-slaughter acute stress should never be underestimated, since it can reduce beef quality in very short period of time.

Table 3
Effect of transport time and season on pH, electrical conductivity and CIE colour values of Simmental bulls and heifers (n=60/transport time/season)

	Sex	Transport	Season				Mean[1]
			Winter	Spring	Summer	Autumn	
pH	Bulls	Short journey	5.63^{aA}	5.56^{bA}	5.59^{cA}	5.57^{bcAB}	5.59^{A}
		Long journey	5.57^{abB}	5.56^{bA}	5.61^{aAB}	5.58^{abA}	5.58^{A}
	Heifers	Short journey	5.56^{aB}	5.55^{aA}	5.59^{bA}	5.55^{aB}	5.56^{B}
		Long journey	5.56^{aB}	5.55^{aA}	5.63^{bB}	5.55^{aB}	5.57^{B}
EC	Bulls	Short journey	6.97^{aA}	7.59^{bA}	7.19^{acA}	7.40^{bcA}	7.29^{A}
		Long journey	7.37^{aB}	7.46^{aA}	6.95^{bA}	7.24^{abA}	7.25^{A}
	Heifers	Short journey	4.74^{aC}	4.79^{aB}	4.39^{bB}	4.78^{aB}	4.68^{B}
		Long journey	4.68^{aC}	4.76^{aB}	4.29^{bB}	4.78^{aB}	4.63^{B}
L*	Bulls	Short journey	41.68^{aA}	42.79^{bA}	42.19^{acA}	42.56^{bcA}	42.30^{A}
		Long journey	42.44^{aB}	42.73^{aA}	41.78^{bcA}	42.29^{acA}	42.31^{A}
	Heifers	Short journey	43.87^{aC}	44.02^{aB}	43.71^{aB}	43.87^{aB}	43.87^{B}
		Long journey	43.91^{aC}	43.84^{aB}	43.12^{bC}	43.89^{aB}	43.69^{B}
a*	Bulls	Short journey	28.82^{aA}	29.70^{bA}	29.26^{cA}	29.42^{bcA}	29.30^{A}
		Long journey	29.57^{aB}	29.58^{aA}	28.96^{bA}	29.34^{abA}	29.36^{A}
	Heifers	Short journey	28.99^{aA}	28.96^{aA}	28.45^{bB}	28.84^{abB}	28.81^{B}
		Long journey	29.06^{aA}	28.97^{aB}	28.28^{bB}	28.93^{aB}	28.81^{B}
b*	Bulls	Short journey	11.11^{aA}	11.80^{bA}	11.44^{cA}	11.65^{bcAB}	11.50^{A}
		Long journey	11.60^{aB}	11.73^{aA}	11.20^{bA}	11.49^{abA}	11.51^{A}
	Heifers	Short journey	11.87^{aB}	11.94^{aA}	11.62^{aA}	11.85^{aB}	11.82^{B}
		Long journey	11.92^{aB}	11.88^{aA}	11.36^{bA}	11.91^{aB}	11.77^{B}
C*	Bulls	Short journey	30.89^{aA}	31.95^{bA}	31.42^{cA}	31.66^{bcA}	31.48^{A}
		Long journey	31.76^{aB}	31.86^{aA}	31.07^{bA}	31.52^{aA}	31.55^{A}
	Heifers	Short journey	31.33^{aA}	31.33^{aB}	30.73^{aAB}	31.18^{abA}	31.14^{B}
		Long journey	31.34^{aA}	31.28^{aB}	30.49^{bA}	31.29^{aA}	31.10^{B}
h*	Bulls	Short journey	21.01^{aA}	21.66^{bA}	21.32^{abA}	21.56^{bA}	21.39^{A}
		Long journey	21.40^{abB}	21.60^{aA}	21.08^{bA}	21.35^{abA}	21.36^{A}
	Heifers	Short journey	22.26^{aC}	22.41^{aB}	22.19^{aB}	22.33^{aB}	22.30^{B}
		Long journey	22.29^{aC}	22.30^{aB}	21.84^{bC}	22.37^{aB}	22.20^{B}

^{a,b,c}Different letters in the same row indicate significant difference ($P<0.05$), ^{A,B,C}Different letters in the same column indicate significant difference ($P<0.05$), [1]mean of four seasons within the same sex and transport time (n=240)

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