The influence of carcass weight and external fat thickness on chilling rate of commercial beef carcasses

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The study evaluated beef carcass weight classes (thin, medium, and heavy) and 12th rib external fat depth classes (thin, average, fat) on the rate of temperature decline of the deep portion of the beef round during the initial 24 hours of carcass chilling and subsequent impacts on tenderness and water holding capacity. Carcass weight had the biggest influence on the rate of temperature decline where fat depth measured at the 12th rib only impacted temperature decline during early chilling. Meat quality differences were limited to water holding ability. The slower temperature decline in higher weight carcasses with more fat allowed for decreased purge loss in the sirloin, thus preventing yield loss during storage.

Summary

The objectives of this study were to; 1) evaluate carcass weight and external fat depth on the rate of temperature decline of the round on commercial beef carcasses and 2) analyze the impact of carcass weight and external fat depth on meat tenderness and water-holding capacity. Commercial beef carcasses (n = 60) were selected based upon carcass weight (light = less than 800 lbs.; medium = between 801 lbs. and 900 lbs.; and heavy = over 901 lbs.) and 12th rib external fat depth (thin = less than 0.4 in.; average = 0.5 in. and 0.69 in.; and fat = over 0.7 in.). The results indicated that heavy and fat carcasses took longer to cool than other classed carcasses. Fat depth also influenced ($P = 0.05$) the pH values after 24 hours of chilling. There was a carcass weight × external fat depth interaction for cook loss ($P = 0.007$) on top round steaks where medium-average carcasses and medium-fat weight carcasses had more cooking loss percentage than other classed carcasses. There was also a carcass weight × fat depth interaction for purge loss ($P = 0.01$) in sirloin where medium-fat weight carcasses and heavy-average carcasses, and heavy-fat carcasses had the least amount of purge.

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Introduction

In the U.S., over the past several decades, carcass weights have increased by at least 90 pounds (Maples et al., 2018) and fat thickness measured at the 12th rib has increased by 0.20 in. These changes have initiated questions on the influence of weight and fat depth on the rate of carcass chilling, meat quality, and the consistency of beef products.

Research has established that trim and light weight carcasses can be susceptible to cold shortening which happens when muscles are cooled too quickly before rigor mortis (Davey and Gilbert, 1974) causing a contraction or shortening of muscle fibers and subsequent reduction in tenderness. Conversely, an increased fat thickness has been indicated in insulating muscles from cooling, which can also result in decreased tenderness due to loss of protein functionality (Aalhus et., 2001) which lessens the ability of beef to age.

Limited data is available on how carcass weight and fat thickness influences the rate of chilling and meat quality characteristics of beef products. Therefore, the objectives of this study were to evaluate if carcass weight and fat depth impacted temperature decline in the beef round and to determine subsequent impacts on tenderness and water-holding capacity.

Experimental Procedures

At a large, commercial midwestern packing plant, beef carcasses (n = 60) were selected prior to entering the cooler after harvest based upon a 3 × 3 factorial scheme with three levels of carcass weight (thin, medium, and heavy) and three levels of 12th rib external fat depth (thin, average, and fat).

Carcasses were probed with a temperature logger (ThermoWorks THS-294-933, ThermoWorks, American Fork, UT) into the cushion of the round. The probe was angled towards the deep portion of the round and temperature points were recorded every 15 minutes for 24 hours while carcasses were in the chill cooler prior to grading and fabrication.

24 to 36 hours after cooling, carcasses were ribbed, and data was collected by USDA personnel. The data

consisted of hot carcass weight (HCW), 12th ribeye area, kidney, pelvic, and heart fat (KPH). Loin pH was measured by NDSU personnel between the 12th and 13th rib before entrance to the carcass cooler, and after 24 hours of chilling.

After grading, carcasses were fabricated into primal cuts. Beef top rounds (Institutional Meat Purchase Specification {IMPS} 169) and top sirloin butts (IMPS 184) were vacuum packaged and transported back to North Dakota State University's Meats Laboratory. The primal cuts were stored at approximately 35°F for 14 days (sirloins) and 21 days (rounds). Primal cuts were weighed with and without packaging, using the weight differences to calculate the percentage of purge. Each primal cut was measured for external fat depth and fabricated into 1-inch-thick steaks (IMPS 1169 and 1184) for cook loss and Warner-Bratzler shear force analysis.

Steaks were equilibrated to room temperature (68°F) prior to cooking and raw weight was collected. Steaks were cooked on an electric clam-shell grill (Cuisinart Electric Griddler GR5BP1, Cuisinart, Stamford, CT) preheated to 350°F to an internal temperature of 145°F. The internal temperature of the steaks was monitored with a thermocouple probe (Omega KHSS-18G-RSC-12, Omega Engineering, Inc., Norwalk, CT) placed in the center of each steak connected to a handheld thermometer (Omega HH801B, Omega Engineering, Inc., Norwalk, CT). Steaks were removed from the grill and allowed to cool for a minimum of 5 minutes. After the initial cooling period, cooked steaks were weighed and cooking loss percentage calculated. Warner-Bratzler shear force was conducted from a minimum of six cores (0.5 in. diameter) were removed from the center of each steak parallel with the muscle fibers. Each core was placed in the middle of a V-notched (60-degree-angle) cutting blade. All cores were perpendicularly sheared to the muscle fibers at the shear force machine (Tallgrass Solutions GF-151, Tallgrass Solutions, Inc., Manhattan, KS).

Statistical Analysis

Data collected were analyzed using the PROC MIXED procedures of SAS (SAS 9.4, SAS Institute Inc., Cary, NC) with the main effects of carcass weight and 12th rib external fat depth, and their interaction with carcass as the experimental unit. Least square means was separated using the PDIFF option in SAS 9.4. Significance levels were set at $P \leq 0.05$.

Results and Discussion

The rate of temperature decline was affected by carcass weight ($P < 0.05$; Figure 1a) where in the second hour of chilling, the heavy carcasses were cooling at a slower rate than the light carcass weights, and by the ninth hour, the heavy carcasses were chilling more slowly than the medium weight carcasses. These temperature differences were still apparent for the heavy carcass weights when the probes were removed at 24 hours. It is important to note that the inside rounds were not fully cooled at 24 hours and temperature was still decreasing. There was a tendency ($P < 0.10$; Figure 1b) for fat carcasses to have a higher temperature than thin carcasses between the second and seventh hour in the cooler but that tendency was not sustained beyond those times, which may be due to the lower number of thin carcasses in the analysis.

There were differences in KPH% for carcass weight and fat depth ($P < 0.001$; Table 1) which were expected outcomes due to selection criteria and the connection between weight, muscling, and fat. The interaction of carcass weight and 12th rib fat depth for REA was further investigated in Figure 2a. Light-thin and medium-thin carcasses had the smallest REA. As carcasses became heavier and developed more fat, the REA became larger. These results were expected due to the relationship with the development of weight, muscling, and fat. Loin pH was lower in the thin carcasses versus the average and fat after 24 hours ($P = 0.04$). The location of pH measurements was similar to the location of fat depth measurement, which allow a direct connection between fat depth and pH. The pH was not evaluated in the same muscle as temperature, making a connection between temperature and pH more difficult. However, Fevold et al. (2021) showed that the loin did cool more quickly than the top round, and light carcasses were colder than heavy carcasses at four hours into chilling.

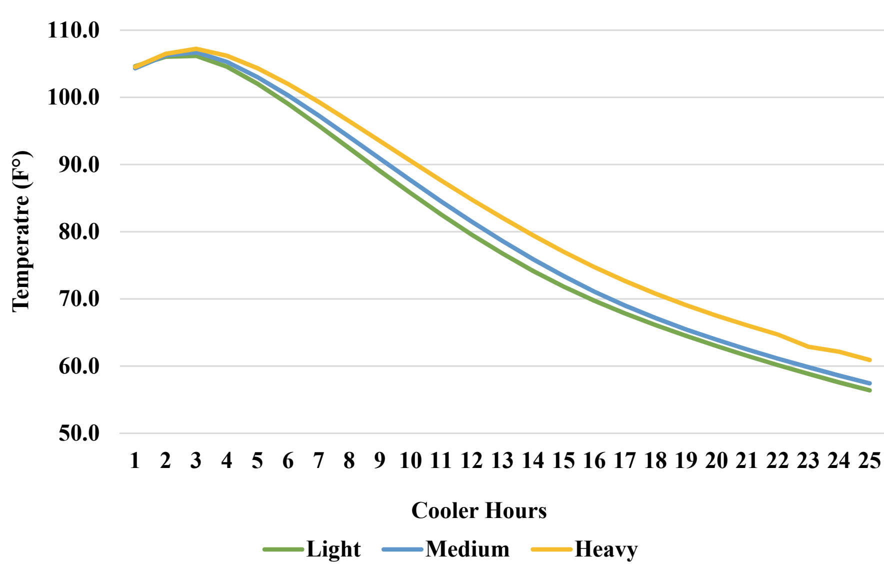

Figure 1a. Influence of carcass weight class on the rate of temperature decline.

Weight classes represents; Light = less than 800 lbs., Medium = 801 lbs. to 901 lbs., and Heavy = over 901 lbs.

McKenna et al. (2005) reported that the gluteus muscle and the semimembranosus muscle had similar pH values, which were lower than the pH in the longissimus.

Purge loss, cook loss, and shear force outcomes for top rounds and top sirloin butts are found in Table 1 and Figures 2b and 2c. For top rounds, carcass weight and 12th rib fat depth influenced cook loss ($P < 0.01$) where medium-average and heavy-fat carcasses had more cook loss than light-average. Top sirloin butts showed significant differences for purge loss ($P = 0.01$) based upon the interaction of carcass weight × fat depth, where medium-fat carcasses, heavy-average carcasses, and heavy-fat carcasses had the least amount of purge. Based on these results, fat depth plays an important role in water-holding ability within the sirloin. In the sirloin, the

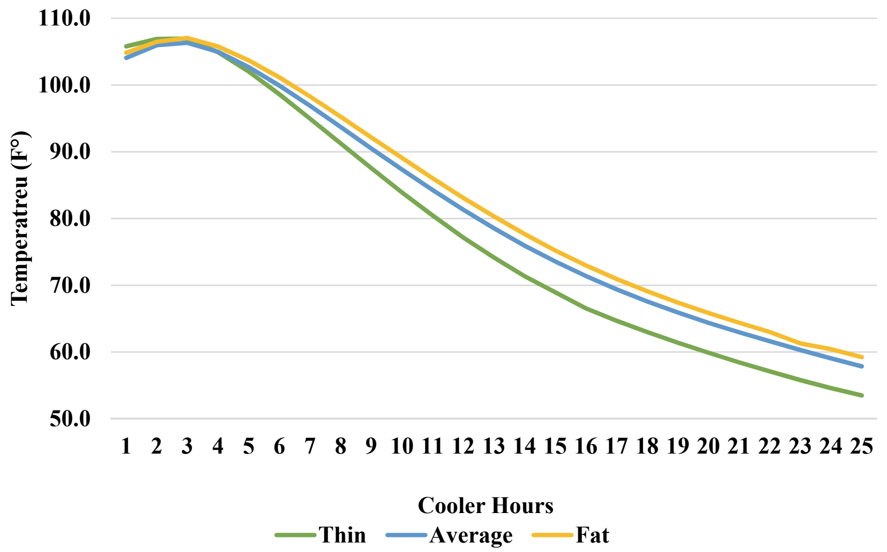

Figure 1b. Influence of 12th rib fat depth class on the rate of temperature decline.

Fat depth classes represents; Thin = less than 0.4 in., Average = 0.5 in. to 0.69 in., and Fat = over 0.7 in.

Table 1. Influence of carcass weight class, fat depth class, and weight class × 12th rib fat depth class interaction on carcass and meat quality

	Carcass Weight				12th Rib Fat Depth				*P*-Values		
Variable	Light	Medium	Heavy	SE	Thin	Average	Fat	SE	Weight	Fat Depth	Weight x Fat Depth
Carcasses (n)	21	15	24		6	20	25				
HWC (lbs.)	758^{c}	851^{b}	991^{a}	9.4	779	864	891	39.5	<0.001	0.708	0.625
12th Rib BF	0.57	0.67	0.70	0.03	0.45^{c}	0.60^{b}	0.88^{a}	0.03	0.11	0.002	0.378
REA (in.^{2})	12.83^{c}	13.97^{b}	15.03^{a}	0.27	13.15	14.13	13.93	0.36	<0.001	0.464	0.027
KPH (%)	2.14^{a}	2.13^{a}	1.83^{b}	0.05	1.54^{b}	1.91^{ab}	2.10^{a}	0.09	<0.001	<0.001	0.314
pH Before Cooling	6.68	6.74	6.73	0.05	6.78	6.76	6.67	0.07	0.653	0.293	0.808
pH After 24 hours	5.83	5.77	5.79	0.05	5.68^{b}	5.87^{a}	5.74^{a}	0.07	0.950	0.038	0.535

Top Rounds	Carcass Weight				12th Rib Fat Depth				*P*-Values		
Variable	Light	Medium	Heavy	SE	Thin	Average	Fat	SE	Weight	Fat Depth	Weight x Fat Depth
Rounds (n)	18	14	21		5	22	26				
Purge (%)	1.63	1.66	1.58	0.17	2.04	1.41	1.77	0.21	0.750	0.115	0.321
CL (%)	24.20	28.24	27.90	1.26	27.10	26.03	27.47	1.79	0.735	0.978	0.007
WBSF (kg)	2.46	2.50	2.43	0.09	2.27	2.47	2.47	0.13	0.574	0.548	0.062

Sirloins	Carcass Weight				12th Rib Fat Depth				*P*-Values		
Variable	Light	Medium	Heavy	SE	Thin	Average	Fat	SE	Weight	Fat Depth	Weight x Fat Depth
Sirloins (n)	18	14	21		5	22	26				
Purge (%)	1.01^{a}	0.82^{b}	0.82^{b}	0.09	0.96	0.94	0.83	0.13	0.049	0.302	0.012
CL (%)	18.79	19.06	18.24	1.52	19.59	18.40	18.82	2.93	0.950	0.945	0.917
WBSF (kg)	2.34	2.54	2.16	0.18	1.29	2.40	2.29	0.34	0.305	0.321	0.840

Means with different subscripts with a category within each row are significantly different ($P \leq 0.05$)
Carcass abbreviations; HWC = hot carcass weight, BF = backfat, REA = ribeye area, KPH = kidney, pelvic, and heart fat, CL = cook loss, and WBSF = Warner-Bratzler shear force.

combination of fat and weight appear to have different impacts depending on class as the medium weight carcasses had the least purge when fattest and the heavy weight carcasses had the least purge with average fat cover, indicating a moderate temperature decline is more ideal than either extreme. Heavier carcasses with more fat have a slower rate of temperature decline than lighter thinner carcasses. These differences appear to influence water-holding ability of cuts from the round and sirloin. Based on these outcomes, further comparisons should be completed on carcass weight and fat depth on other economically important cuts. This preliminary data indicate that carcass weights and fat depths do influence meat quality outcomes due to temperature decline differences. It may be possible to mitigate these temperature differences by making changes during the carcass chilling process through carcass sorting and cooler modifications.

Acknowledgments

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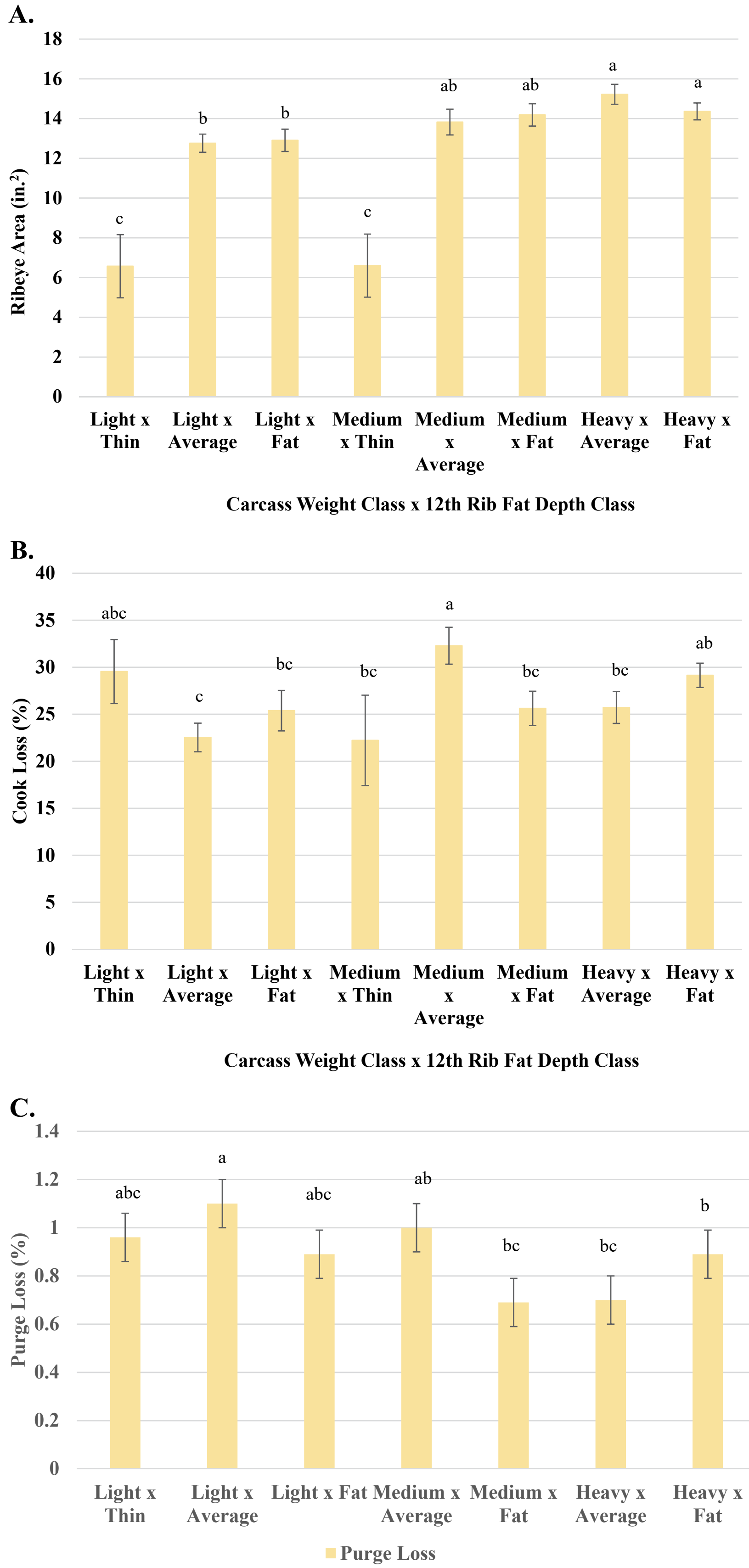

Figure 2. Interactive means ($P < 0.05$) of carcass weight x 12th rib fat depth on carcass ribeye area (A), round steak cook loss % (B), and sirloin purge loss % (C).

Means with different subscripts are significantly different ($P \leq 0.05$). Weight classes represents; Light = less than 800 lbs., Medium = 801 lbs. to 901 lbs., and Heavy = over 901 lbs. Fat depth classes represents; Thin = less than 0.4 in., Average = 0.5 in. to 0.69 in., and Fat = over 0.7 in.