



## Short Communication

# Freezing Temperature and Frequency Influence Purge But Not Tenderness of Beef *Semitendinosus*

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**Abstract:** Our objective was to test the effects of freezing temperature and frequency on purge loss and tenderness of eye of round steaks. Commercially sourced USDA Choice beef *semitendinosus* ( $n = 10$ ) were aged 24 d postmortem. Twelve steaks were cut from each muscle and randomly assigned to 1 of 12 treatments in a  $4 \times 3$  factorial treatment structure (unfrozen control at 2.2°C or initial freezing at  $-17.8^\circ\text{C}$ ,  $-26.1^\circ\text{C}$ , or  $-34.4^\circ\text{C}$  followed by secondary freezing at  $-17.8^\circ\text{C}$ ,  $-26.1^\circ\text{C}$ , or  $-34.4^\circ\text{C}$ ). Steaks were weighed after cutting and after thawing following each freezing treatment to determine purge losses. Tenderness was assessed via Warner-Bratzler shear force (WBSF); all data were analyzed via mixed models. Lower total purge losses (6.27%) were observed for steaks initially unfrozen ( $P < 0.001$ ), whereas those initially frozen at  $-34.4^\circ\text{C}$ ,  $-26.1^\circ\text{C}$ , and  $-17.8^\circ\text{C}$  lost 8.04%, 8.80%, and 8.53%, respectively. No difference ( $P > 0.501$ ) in WBSF was detected among the freezing treatments. These results suggest that freezing temperature and thus freezing rate impact purge loss of eye of round steaks, but mechanical tenderness was not influenced.

**Key words:** beef, purge, semitendinosus, tenderness

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## Introduction

Tenderness, juiciness, and flavor are widely considered the 3 primary factors affecting the palatability of cooked meat, leading to overall consumer satisfaction (Goodson et al., 2002). To preserve and maintain palatability while also ensuring food safety and prolonging shelf life, meat is commonly frozen (Zhang et al., 2019). However, when meat is frozen, ice crystals form within muscle fibers, piercing the sarcolemma and allowing water to transfer from myofibrils into extracellular space upon thawing (Martino and Zaritzky, 1988). This results in loss of water-holding capacity and increases sarcoplasm purge losses (Ali et al., 2015), which in turn has been reported to decrease juiciness and overall palatability (Lagerstedt et al., 2008). However, prior research has suggested that freezing meat at colder temperatures, and thus at a quicker rate,

yields smaller ice crystals (Dang et al., 2021), which results in less purge losses (Zhang and Ertbjerg, 2019).

During the COVID-19 pandemic, customers went into a “panic buying frenzy,” bulk-purchasing meat in fear of a food shortage (Tonsor et al., 2021). United States cold storage reports indicate that 400 to 525 million pounds of beef remain in frozen inventory at any month during the last 4 years (USDA, 2023). Additionally, few consumers are aware that the meat they are buying could have previously been frozen prior to retail sale, even though they are purchasing it unfrozen. Unknown quantities of meat may have been in frozen storage commercially, then thawed and offered in a retail market, purchased, and refrozen in the home.

Thus, the objective of this experiment was to determine the effects of freezing temperature and double-freezing upon purge loss and tenderness of eye of round steaks. Our hypothesis was that steaks

frozen twice would have greater water loss (purge) and shear force values than those remaining unfrozen or only frozen once and that steaks frozen at colder temperatures would have less purge and greater shear force values than those frozen at warmer temperatures.

## Materials and Methods

### *Muscle source and steak preparation*

Ten USDA Choice eye of round roasts (*M. semite-ndinosus*) were sourced from a commercial processing facility in the Midwest. Vacuum-packaged roasts were held for 24 d at 2.2°C prior to slicing and treatment allocation. Individual roasts were sliced into steaks, 25 mm thick, using an auto-slicing and portion cutter (model LION F; TREIF, Oberlahr, Germany). Eye of round steaks were trimmed into squares approximately 65 cm<sup>2</sup> to improve homogeneity of steak surface area and mass (150 ± 16 g). Steaks were weighed (±0.001 g; model t1450, American Scientific Products, Denver, CO) to record mass initially and after each freezing cycle. Temperature decline during the freezing procedure was monitored via a 10-channel benchtop thermometer (model MDSSi8-TC; Omega Engineering, Norwalk, CT) connected to thermocouples (copper-constantan, Type T, Omega Engineering) placed into the geometric center of the steaks and manually recorded every 15 min. Steaks were placed into vacuum pouches (19 × 23 cm, UltraSource, Kansas City, MO) and sealed using a vacuum sealer (Ultravac, model UV2100, UltraSource). Vacuum was monitored using a Kennedy gauge; vacuum pressure was below 277 torr.

### *Treatment randomization and application*

Twelve steaks per roast were randomly allocated, each to 1 of 12 treatment regimens in a 4 × 3 factorial treatment structure. Initial treatments were 2.2°C (unfrozen) or blast freezing for 4 h at −17.8°C, −26.1°C, or −34.4°C (Figure 1). After initial freezing periods were completed, steaks were placed in a cooler at 2.2°C to thaw. Steaks were allowed to thaw for 24 h and were removed from the vacuum package, dried with absorbent cloths, and reweighed. Initial percentage purge loss was calculated as described by Bekhit et al. (2014) using the following formula: initial purge loss (%) = 100 − (sample weight after first freeze thaw cycle ÷ initial sample weight × 100). Steaks were then repackaged into vacuum pouches and placed back in a cooler at 2.2°C for 14 h. Secondary treatments were blast freezing for 4 h at −17.8°C, −26.1°C, or −34.4°C (Figure 1), upon which steaks were thawed a second time for 24 h in a cooler at 2.2°C.

### *Steak cooking*

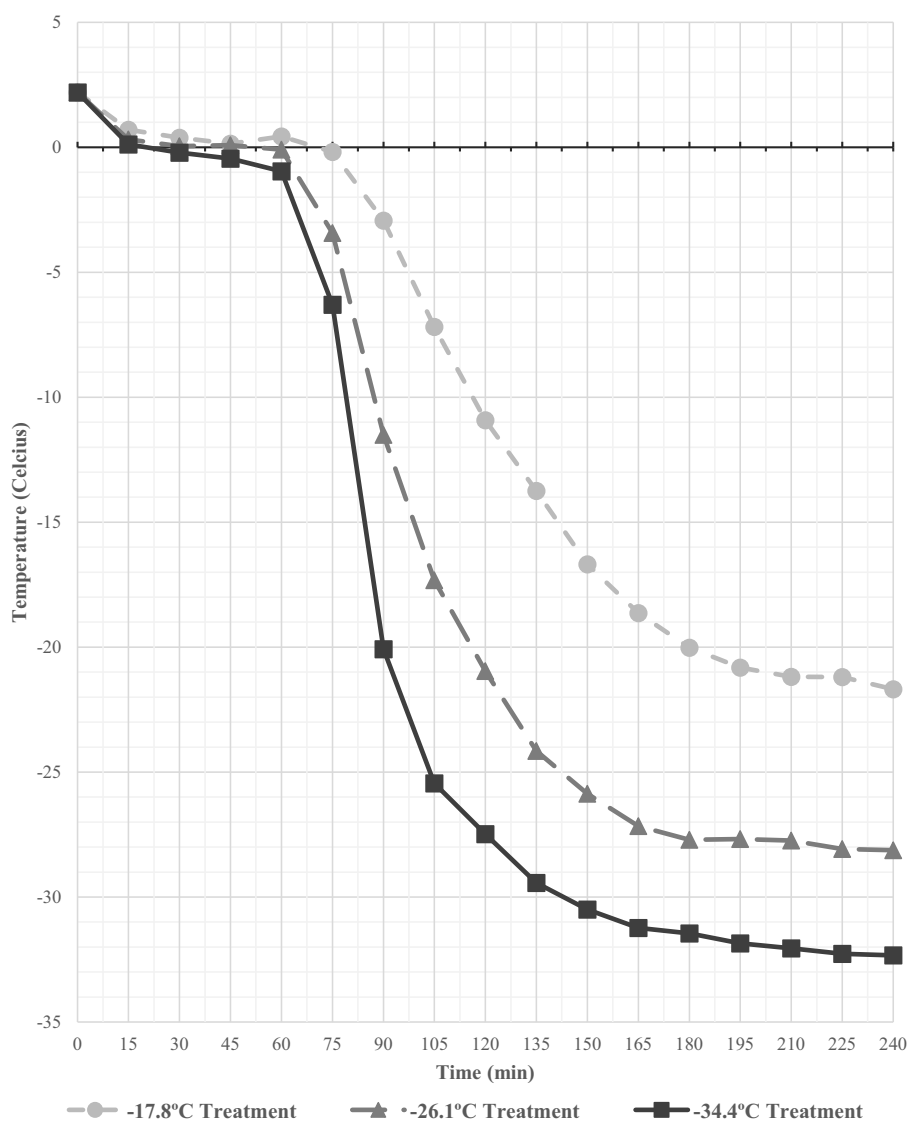
Steaks were removed from the cooler 24 h after the second thawing, dried with absorbent cloths, and weighed to establish second freezing purge losses and precooked weight. Second purge loss was calculated as follows: second purge loss (%) = 100 − (sample weight after second freeze thaw cycle ÷ sample weight after first freeze thaw cycle × 100). Total purge loss was calculated as follows: total purge loss (%) = 100 − (sample weight after second freeze thaw cycle ÷ initial sample weight × 100). Thermocouple wires (copper-constantan, Type T, Omega Engineering) were inserted into the geometric center of each uncooked steak to monitor internal temperature. Temperature was monitored via a 10-channel benchtop thermometer (Omega Engineering, model MDSSi8-TC). Steaks were then placed into a forced-air convection oven (model DFG-100-3; Blodgett, Essex Junction, VT), where they were cooked at 177°C and removed at 69.5°C to reach a target 71°C endpoint temperature. Steaks were allowed to cool and drip for 5 min, then reweighed to establish cooked weight. Cooked steaks were wrapped in polyvinyl chloride film, placed into a refrigerator, and chilled for 24 h at 2.2°C. Percentage cooking loss was calculated as described by Ngambu et al. (2013) using the following formula: cooking loss % = ((uncooked weight − cooked weight) ÷ uncooked weight) × 100.

### *Warner-Bratzler shear force determination*

Objective tenderness was assessed according to the *Research Guidelines for Cookery, Sensory Evaluation, and Instrumental Tenderness Measurements of Meat* (American Meat Science Association, 2016). Six cores (1.27-cm diameter) were mechanically (Power Glide 5-Speed 8-in. Drill Press, model 6070150; Central Machinery, Camarillo, CA) removed parallel to the long axis of the muscle fibers from each chilled steak sample using a 1.27-cm-diameter core drill attachment (GR Electric, Manhattan, KS). Cores were then sheared at a crosshead speed of 250 mm/min using an Instron universal testing machine (model 6800, Norwood, MA) with a 2 kN load cell attached to a Warner-Bratzler shear force (WBSF) blade; peak force (kilograms) of cores were averaged to determine mean steak WBSF.

### *Statistical analysis*

The 4 × 3 treatment structure was utilized within a complete block experimental design structure. Individual *semite-ndinosus* muscle represented a block; 12 steaks were cut per block. Data were analyzed using the



**Figure 1.** Temperature decline of *M. semitendinosus* steaks frozen at  $-17.8^{\circ}\text{C}$ ,  $-26.1^{\circ}\text{C}$ , or  $-34.4^{\circ}\text{C}$ .

GLIMMIX procedure of SAS (v. 9.4, SAS Institute, Cary, NC). Fixed effects included initial storage/freezing treatments, secondary freezing treatments, and interaction of initial  $\times$  secondary treatments; random effects included blocks. Means were generated via the LSMEANS statement and separated when significant ( $\alpha = 0.05$ ) using the PDIF statement.

## Results and Discussion

### Purge loss

The main effect of initial storage/freezing temperature affected ( $P < 0.001$ ) percentage purge loss (Table 1); unfrozen steaks had the lowest purge loss followed by steaks frozen at  $-34.4^{\circ}\text{C}$ ,  $-26.1^{\circ}\text{C}$ , and  $-17.8^{\circ}\text{C}$ . Previous research suggests that freezing muscle tissue causes a decrease in water-holding

capacity, resulting in greater purge and drip loss (Lagerstedt et al., 2008). The decrease in water-holding capacity is the direct result of ice crystal formation, which ruptures cellular membranes, thus allowing increased purge upon thawing (Zhang and Ertbjerg, 2019). Freezing meat at lower temperatures, and thus at a faster rate, lessens purge losses (Kim et al., 2015).

Percentage purge loss after the second round of freezing treatments was not affected by the interaction of initial storage/freezing temperature  $\times$  second freezing temperature ( $P = 0.976$ ). Additionally, second freezing temperature alone also did not alter percentage purge loss ( $P = 0.564$ ). However, temperature of the initial storage/freezing treatment affected ( $P = 0.048$ ) the percentage of purge lost during the second freezing period; steaks initially frozen at  $-26.1^{\circ}\text{C}$  or  $-34.4^{\circ}\text{C}$  had more purge than those that were unfrozen, with

**Table 1.** Least-squares means for the effects of freezing treatments and frequency on purge losses, cooking losses, and mechanical tenderness of eye of round steaks

	Initial storage/freezing treatment				Second freezing treatment			SEM	P value		
	2.2°C	-17.8°C	-26.1°C	-34.4°C	-17.8°C	-26.1°C	-34.4°C		First freeze	Second freeze	Freezing interaction
<b>Initial purge loss (%)</b>	2.56 <sup>c</sup>	4.52 <sup>a</sup>	4.44 <sup>a</sup>	3.78 <sup>b</sup>	—	—	—	0.25	<0.001	—	—
<b>Second purge loss (%)</b>	3.71 <sup>b</sup>	4.02 <sup>ab</sup>	4.36 <sup>a</sup>	4.26 <sup>a</sup>	4.22	4.04	4.00	0.20	0.048	0.564	0.976
<b>Total purge loss (%)</b>	6.27 <sup>b</sup>	8.53 <sup>a</sup>	8.80 <sup>a</sup>	8.04 <sup>a</sup>	8.28	7.64	7.80	0.40	<0.001	0.347	0.968
<b>Cooking loss (%)</b>	33.2	32.9	32.5	32.5	32.9 <sup>ab</sup>	31.9 <sup>b</sup>	33.6 <sup>a</sup>	0.60	0.701	0.021	0.198
<b>WBSF (kg)</b>	4.20	4.23	4.35	4.21	4.25	4.18	4.32	0.15	0.660	0.501	0.629

SEM = standard error of the mean; WBSF = Warner-Bratzler Shear Force.

<sup>a-c</sup>Within a row, means without a common superscript differ ( $P < 0.05$ ).

steaks frozen at  $-17.8^{\circ}\text{C}$  being intermediate for second freezing period purge loss. Moreover, total percentage of purge lost differed ( $P < 0.001$ ) only because of the initial storage/freezing temperature; steaks exhibited less total purge loss when initially unfrozen compared with steaks initially frozen at  $-17.8^{\circ}\text{C}$ ,  $-26.1^{\circ}\text{C}$ , or  $-34.4^{\circ}\text{C}$ .

### Cooking losses

The outcome of percentage of weight lost during the cooking procedure did not result in an interaction ( $P = 0.198$ ), nor did steaks differ ( $P = 0.701$ ) in cooking losses as a result of the initial storage/freezing temperatures (Table 1). However, cooking losses differed ( $P = 0.021$ ) as a result of second freezing temperatures. Steaks frozen at  $-34.4^{\circ}\text{C}$  had the greatest cooking losses, whereas those frozen at  $-26.1^{\circ}\text{C}$  had the lowest cooking losses, with steaks frozen at  $-17.8^{\circ}\text{C}$  being intermediate. Previous literature suggests that freezing muscle tissue increases cooking loss and total exudation loss (Locker and Daines, 1973; Crouse and Koohmaraie, 1990; Grayson et al., 2014). Furthermore, freezing meat decreases juiciness of the cooked product, which results in inferior palatability (Lagerstedt et al., 2008).

### Warner-Bratzler shear force

WBSF of eye of round steaks was not altered by initial storage/freezing temperature ( $P = 0.660$ ) or second freezing temperature ( $P = 0.501$ ) or their interaction ( $P = 0.629$ ) and averaged 4.25 kg of force (Table 1).

Research results conflict on the expected outcome of freezing upon tenderness; some research suggests freezing *longissimus dorsi* resulted in loss of tenderness (Lagerstedt et al., 2008), whereas others have reported that freezing improves *sternomandibularis* tenderness (Locker and Daines, 1973) as well as *longissimus dorsi* and *semitendinosus* tenderness (Grayson et al., 2014).

The lack of tenderness differentiation in the current study is likely due in part to the background toughness of the *M. semitendinosus* muscle originating from intramuscular connective tissue (Purslow, 2018).

## Conclusion

This study evaluated the effects of freezing temperature and repeated freeze-thaw cycles upon purge losses, cooking losses, and mechanical tenderness of eye of round steaks. Total purge losses were least for unfrozen steaks but did not differ between the 3 freezing temperatures tested. Freezing a second time did not cause further losses; thus, the initial freezing treatment was more influential than the second regarding purge losses. Mechanical tenderness of eye of round steaks was not altered by purge losses caused by the freeze-thaw cycles tested in this experiment.

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