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EFFECTS OF END-POINT TEMPERATURE, REHEATING, HOLDING TIME, AND HOLDING TEMPERATURE ON BEEF TENDERNESS

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Summary

We cooked steaks from two muscles; outside round (*biceps femoris*), and strip loin (*longissimus lumborum*) with an electric belt grill. *Biceps femoris* steaks had higher Warner-Bratzler shear force (WBSF), connective tissue force (WB C-force), and myofibrillar force (WB M-force) values than *longissimus lumborum* steaks. Holding *biceps femoris* steaks at 144°F after cooking increased WB C-force ($P<0.05$) and WB M-force ($P<0.01$) as compared to holding them at 135°F. Holding *biceps femoris* steaks for 15 min decreased shear force by 12%, whereas the decrease was only 3% from holding for 30 min, likely because more moisture was lost with the longer holding time. Reheating had the only significant effect on *longissimus lumborum* steaks' WB measures because low collagen content of this muscle is not affected by holding time or temperature.

(Key Words: Cooking, Belt Grill, Shear Force.)

Introduction

Cooking meat can tenderize connective tissue due to collagen solubilization and can toughen myofibrillar proteins (muscle cells) due to water loss. Tenderness will decrease with increased end-point temperature. To optimize tenderness, the influence of low-temperature/long cooking time has been investigated. In other research, meat became more tender and cooking losses decreased with lower cooking temperatures. Additionally, post-cooking holding time at 135-140°F internally was correlated ($r^2 = 0.53$) with tenderness. Minimum shear force values (maximum tenderness) were reported after heating eye round (*semitendinosus*) cores and holding to 140-147°F for 30-60 min. Holding meat below the collagen shrinkage temperature (≈149°F) should benefit tenderness because collagen solubilization will occur before collagen shrinkage has a negative effect. However, at the same time, dehydration may cause toughening. Therefore, our objectives were to study the effects of endpoint temperature, reheating, holding time, and holding temperature on beef tenderness.

Experimental Procedures

Sub-primals from a commercial processing plant were aged for 19 days postmortem at 34°F, then frozen and held at –20°F. We sawed one-inch thick steaks from 24 outside rounds (NAMP 171B), and 24 strip loins (NAMP 170) from USDA Choice carcasses. Steaks were numbered from 1 to 12 for each outside round or strip loin to identify anatomical location. Paired steaks (#3 to 8) were cooked on an electric belt grill (TBG-60 Magigrill, MagiKitch'n, Inc., Quakertown, PA) at 200°F to internal temperatures of either 129 or 138°F, then held in a water-bath at 135 or 144°F (to allow for a post-cooking temperature rise of about 5°F) for 0, 15, or 30 min. One

steak from each pair was immediately reheated on the electric- belt grill to 158°F.

Steaks were held overnight at 39°F before we removed six round cores (0.5 inch diameter) parallel to muscle fiber orientation. Each core was sheared once using an Instron Universal Testing Machine. A 110-lb load cell and 10 inches/min cross-head speed were used. WBSF, WB M-force, and WB C-force values were calculated from the shear curves obtained from Instron software. The statistical design was a split-split plot. Treatment differences were evaluated by Statistical Analysis System software using the PROC MIXED procedure.

Results and Discussion

For cooking loss (Tables 1 and 2), an interaction for holding temperature × holding time was found for *biceps femoris*. At a holding temperature of 135°F no difference was noted between a 15 or 30 minute holding time, but at 145°F the longer holding time caused increased cooking loss.

Both muscles had an interaction between reheating and holding time effects on cooking loss. In *longissimus* muscle with no reheating, increasing holding time increased cooking loss, but when muscles were reheated, a longer holding time did not affect cooking loss.

The reheating × holding temperature interaction showed increased cooking loss with both reheating and with warmer holding temperature. In summary, all three variables—holding time, holding temperature and reheating—can increase cooking loss.

For *biceps femoris* steaks, WBSF, WB M-force, and WB C-force increased with higher holding temperature. Holding *biceps femoris* steaks for 15 min decreased shear force by 12%, whereas the decrease was only 3% for 30 min holding time. This was likely caused by greater moisture loss with longer holding time. Reheating *biceps femoris* steaks increased WBSF and WB M-force, but did not significantly change WB C-force (Table 1). WB C-force was always higher than WB M-force for *biceps femoris* steaks, while the opposite was true for *longissimus lumborum* steaks. With *longissimus lumborum* steaks, reheating increased WBSF and WBM-force, but did not influence WB C-force. This is because of the low collagen content of the *longissimus lumborum*.

Table 1. Effects of Holding Temperature, Holding Time, and Reheating on WBSF, WB M-Force, WB C-Force, and Cooking Loss for Biceps Femoris Steaks

Source of Variation	WBSF (lb)	WB M-Force (lb)	WB C-Force (lb)	Cooking Loss (%)
Holding temperature (°F)				
135	8.40[a]	5.41[a]	7.35[a]	16.88
144	9.88[b]	6.89[b]	9.13[b]	21.29
P- value	0.054	<0.0001	0.026	<0.0001
Holding time (min)				
0	9.61[b]	5.90	8.95[b]	14.14
15	8.50[a]	5.96	7.48[a]	20.17
30	9.31[a,b]	6.58	8.25[a,b]	22.94
P-value	0.038	0.14	0.02	<0.0001
Holding temperature/holding time				
135/0	9.28	5.5	8.45	13.13[a]
135/15	7.57	5.08	6.09	17.95[c]
135/30	8.34	5.7	7.48	19.55[c]
144/0	9.97	6.29	9.48	15.14[b]
144/15	9.42	6.86	8.88	22.39[d]
144/30	10.25	7.48	9.02	26.33[e]
P-value	0.28	0.31	0.19	0.0007
Reheating				
No	8.71[a]	5.72[a]	8.25	16.81
Yes	9.55[b]	6.58[b]	8.23	21.35
P-value	0.016	0.004	0.98	<0.0001
Reheating × holding time				
No/0	9.04	5.04	8.51[a,c,d]	10.75[a]
Yes/0	10.21	6.73	9.42[b,d]	17.52[b]
No/15	7.96	5.57	7.30[a]	17.66[b]
Yes/15	9.02	6.36	7.66[a]	22.68[c]
No/30	9.15	6.53	8.91 [b,c]	22.04[c]
Yes/30	9.46	6.64	7.61[a]	23.84[c]
P-value	0.43	0.07	0.047	0.0003
Reheating × holding temp				
No/135	7.85	4.91	7.22	13.95[a]
Yes/135	8.95	5.94	7.48	19.81[b]
No/144	9.59	6.53	9.28	19.69[b]
Yes/144	10.16	7.22	8.98	22.88[c]
P- value	0.53	0.53	0.44	0.007

[a,b]Within columns, means sharing the same letter are not significantly different (P>0.05).

Table 2. Effects of Holding Temperature, Holding Time, and Reheating on WBSF, WB M-Force, WB C-Force, and Cooking Loss for Longissimus Lumborum Steaks

Source of Variation	WBSF (lb)	WB M-Force (lb)	WB C-Force (lb)	Cooking Loss (%)
Holding temperature (°F)				
135	5.81	5.35	4.66	17.74
144	5.70	5.43	4.84	20.13
P- value	0.70	0.77	0.60	0.027
Holding time (min)				
0	5.70	5.13	4.64	14.03
15	5.74	5.39	4.64	20.25
30	5.79	5.65	4.97	22.53
P-value	0.90	0.36	0.48	<0.0001
Holding temperature/holding time				
135/0	5.85	5.13	4.77	13.61
135/15	5.81	5.39	4.73	18.68
135/30	5.74	5.32	4.47	20.94
144/0	5.54	5.10	4.51	14.45
144/15	5.70	5.21	4.53	21.82
144/30	5.83	5.98	5.48	24.13
P-value	0.54	0.39	0.11	0.20
Reheating				
No	2.39[a]	4.91[a]	4.53	16.78
Yes	2.83[b]	5.87[b]	4.97	21.09
P-value	<0.0001	0.0006	0.07	<0.0001
Reheating × holding time				
No/0	5.17	4.49	4.29	11.20[a]
Yes/0	6.23	5.74	4.97	16.86[b]
No/15	5.30	5.06	4.40	18.26[c]
Yes/15	6.20	5.72	4.88	22.23[e]
No/30	5.32	5.17	4.88	20.88[d]
Yes/30	6.25	6.14	5.08	24.19[f]
P-value	0.90	0.60	0.72	0.04
Reheating × holding temp				
No/135	5.30	4.88	4.44	15.13[a]
Yes/135	6.29	5.79	4.88	20.35[c]
No/144	5.21	4.91	4.60	18.43[b]
Yes/144	6.16	5.96	5.08	21.83[d]
P- value	0.85	0.79	0.95	0.02

[a,b]Within columns, means sharing the same letter are not significantly different (P>0.05).