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Abstract

We used an electric belt grill, a forced-air convection oven, and an electric broiler to cook 170 bottom round, 142 brisket, 177 top sirloin, 176 strip loin, and 136 eye of round steaks from USDA Select carcasses to determine the effects of cooking method and muscle on shear force values, cooking traits, and repeatability of duplicate measurements. All cooking treatments allowed differences to be detected ($P<0.05$) in Warner-Bratzler shear force, although the differences were inconsistent. Shear force values of strip steaks and eye of round steaks were similar across cooking treatments; however, shear force values of bottom round, brisket, and top sirloin steaks were different ($P<0.05$) among cooking treatments. Based on poor repeatability, shear force values for top sirloin steaks appear unreliable. Poor repeatability for shear force values from steaks cooked by the forced-air convection oven are a result of drastic temperature changes that occur when the doors are opened to remove steaks. We do not recommend using a forced-air convection oven to test treatment effects on shear force values when cooking multiple steaks simultaneously. Belt grill cooking resulted in the highest shear force repeatability ($R = 0.07$ to 0.89) of strip steaks. Electric broiling resulted in acceptable ($R = 0.60$) repeatability of shear force measurements for all classes of steaks. The electric broiler and electric belt grill are both satisfactory cooking methods when measuring shear force of bottom round, brisket, strip loin, and eye of round steaks.

Keywords

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TENDERNESS AND COOKING CHARACTERISTICS OF BEEF COOKED BY ELECTRIC BELT GRILL, FORCED-AIR CONVECTION OVEN, OR ELECTRIC BROILER

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Summary

We used an electric belt grill, a forced-air convection oven, and an electric broiler to cook 170 bottom round, 142 brisket, 177 top sirloin, 176 strip loin, and 136 eye of round steaks from USDA Select carcasses to determine the effects of cooking method and muscle on shear force values, cooking traits, and repeatability of duplicate measurements. All cooking treatments allowed differences to be detected ($P<0.05$) in Warner-Bratzler shear force, although the differences were inconsistent. Shear force values of strip steaks and eye of round steaks were similar across cooking treatments; however, shear force values of bottom round, brisket, and top sirloin steaks were different ($P<0.05$) among cooking treatments. Based on poor repeatability, shear force values for top sirloin steaks appear unreliable. Poor repeatability for shear force values from steaks cooked by the forced-air convection oven are a result of drastic temperature changes that occur when the doors are opened to remove steaks. We do not recommend using a forced-air convection oven to test treatment effects on shear force values when cooking multiple steaks simultaneously. Belt grill cooking resulted in the highest shear force repeatability R = 0.07 to 0.89) of strip steaks. Electric broiling resulted in acceptable R = 0.60) repeatability of shear force measurements for all classes of steaks. The electric broiler and electric belt grill are both satisfactory cooking methods when measuring shear force of bottom round, brisket, strip loin, and eye of round steaks.

(Key Words: Beef, Cooking, Repeatability, Tenderness.)

Introduction

Cooking method is one of the most important factors influencing the tenderness of beef. Cooking methods used for research should give highly repeatable results; and should neither mask nor enhance treatment effects. Previous research has suggested the use of an electric belt grill instead of an electric broiler for steak tenderness research, based on increased precision and repeatability of duplicate measurements. Other research has suggested not using forced-air convection cooking because of inconsistent cooked product characteristics. Our objectives were: (1) to determine if differences in Warner-Bratzler shear force (WBSF) can be detected among steaks from five muscles cooked on an electric belt grill, in a forced-air convection oven, or on an electric broiler; and (2) to determine the repeatability of WBSF values and cooking traits.

Experimental Procedures

We cut one-inch thick steaks from 18 briskets (NAMP 120), 18 top sirloin butts (NAMP 184), 18 loin strips (NAMP 180), 17 bottom rounds (NAMP 170), and 17 eye of rounds (NAMP 170) from USDA Select carcasses. Identification of subprimal and steak location within subprimal were maintained. All steaks were aged 14 days at 34°F. Consecutive pairs of steaks were randomly assigned to one of five cooking treatments: electric belt grill (TBG-60 Magigrill, MagiKitch'n Inc., Quakertown, PA) at 200, 242, or 325°F; forced-air convection oven (Blodgett, model DFG-102 CH3, G.S. Blodgett Co., Burlington, VT) at 325°F; or electric broiler (Open Hearth electric broiler, Farberware, Yonkers, NY). The electric broiler had no temperature control. All

steaks were cooked to an internal temperature of 158°F and then removed from the cooking device. Total cooking loss, cooking time, and endpoint temperature (maximum temperature reached after removal from the cooking device) of each steak was recorded. After cooking, steaks were refrigerated overnight (39°F). We removed six round cores (1/2 inch in diameter) parallel to the muscle fiber direction and sheared each one once through the center with a V-shaped WBSF attachment on an Instron Universal Testing Machine. We analyzed the data by two-way analysis of variance with five levels of each factor. Our model included the fixed effects of muscle, cooking treatment, and muscle × cooking treatment interaction as well as the random effects of subprimal, steak location within subprimal, and replication. Muscle × cooking treatment interaction means were generated and separated when significant ($P<0.05$). Repeatability for consecutive steaks within cooking treatments was calculated as follows: (variance of subprimal + variance of steak location within subprimal) ÷ (variance of subprimal + variance of steak location within subprimal + error variance).

Results and Discussion

All cooking treatments allowed detection of differences ($P<0.05$) in WBSF values across the five muscles (Table 1); however differences were inconsistent. Bottom round and eye of round steaks had similar WBSF values when cooked by the belt grill at 200°F, the forced-air convection oven, or the electric broiler; however, bottom round steaks were tougher ($P<0.05$) than eye of round steaks when cooked on the belt grill at 325°F. Top sirloin steaks were tougher ($P<0.05$) than strip steaks when cooked in the forced-air convection oven; however, they were similar for all other cooking treatments. Top sirloin steaks were more tender ($P<0.05$) than eye of round steaks for all cooking treatments except for the belt grill at 325°F.

Endpoint temperatures were similar for all muscles within a cooking treatment (Table 2). Cooking loss was higher ($P<0.05$) for eye of round steaks than for all other muscles when cooked by the belt grill at 200°F or the forced-air convection oven (Table 3). Cooking times were similar across the five muscles when cooked in the belt grill at any temperature; however, differences ($P<0.05$) in cooking times were detected for the forced-air convection and electric broiler cooking treatments (Table 4). In the forced-air convection oven, strip steaks cooked faster ($P<0.05$) than bottom round and top sirloin steaks, which cooked faster ($P<0.05$) than eye of round steaks. In the electric broiler, strip steaks cooked faster ($P<0.05$) than brisket steaks, which cooked faster ($P<0.05$) than bottom round or eye of round steaks.

WBSF values for bottom round, brisket, and top sirloin steaks were not consistent ($P<0.05$) across the five cooking treatments (Table 1); however, values for strip steaks and eye of round steaks were consistent across all cooking treatments. Bottom round steaks were tougher ($P<0.05$) when cooked by the belt grill at 325°F than by any other cooking treatment. Brisket steaks were tougher ($P<0.05$) when cooked by the electric broiler than when cooked by the belt grill at 200 or 242°F. Top sirloin steaks were tougher ($P<0.05$) when cooked by the forced-air convection oven than when cooked by the belt grill at 200°F.

Belt grill cooking at 325°F resulted in the highest post-cooking temperature rise for all five muscles, which were higher than for the belt grill at 200°F, the forced-air convection oven, or the electric broiler (Table 2). Electric broiling did not result in a significant post-cooking temperature rise, whereas the belt grill at 325°F resulted in a consistent 7°F post-cooking temperature rise for all muscles. Cooking losses for bottom round, brisket, top sirloin, and strip steaks tended to be higher for the electric broiler treatment than any other (Table 3), while the lowest ($P<0.05$) cooking losses resulted from belt grill cooking at 200°F. Cooking time was longest for the electric broiler followed by the forced-air convection oven and belt grill cooking at 200, 242, and 325°F, respectively (Table 4).

Repeatability of shear force values was acceptable (repeatability ≥ 0.60) for bottom round and eye of round steaks cooked by all treatments (Table 5). Strip steak repeatability was highest when cooked by the belt grill at 242 or 325°F and unacceptable for the forced-air convection oven. Only the electric broiler provided acceptable repeatability for top sirloin steaks. Repeatability was unacceptable for brisket steaks cooked by the belt grill at 242°F. The electric broiler was the only cooking method that provided acceptable shear force repeatability for all muscles. The forced-air convection oven provided poor shear force repeatability, which can best be explained by the drastic temperature changes that occur when the oven is opened to remove steaks. Endpoint temperature repeatability was not acceptable for any steak cooked by any treatment (Table 5). Cooking time repeatability was acceptable only for bottom round steaks cooked in the forced-air convection oven and top sirloin steaks cooked by the belt grill at 242°F. Cooking time range was 3.7 minutes for bottom round, 7.4 for brisket, 5.8 for top sirloin, 3.8 for strip, and 7.0 for eye of round steaks. Repeatability of cooking losses was acceptable only for brisket steaks cooked by the belt grill at 200°F, top sirloin cooked by the belt grill at 242°F or electric broiler, and eye of round steaks cooked in the forced-air convection oven. Endpoint temperature, cooking time and cooking loss repeatabilities are important because variations in each can affect repeatability and reliability in WBSF.

Table 1. Warner-Bratzler Shear Force Measurements (Least Squares Means, lb) of Steaks from Five Muscles and Five Cooking Treatments

Cooking Treatment	Bottom Round	Brisket	Top Sirloin	Strip	Eye of Round
Belt grill (200°F)	$10.21^{r,w}$	$13.51^{q,x}$	$8.29^{s,w}$	8.31^{s}	9.57^{r}
Belt grill (242°F)	$10.32^{r,w}$	$14.02^{q,w,x}$	$8.38^{s,v,w}$	8.07^{s}	-
Belt grill (325°F)	$11.84^{r,v}$	$14.99^{q,v,w}$	$9.17^{s,t,v,w}$	8.55^{t}	9.81^{s}
Forced-air convection (325°F)	$10.25^{q,r,v}$	-	$9.35^{r,v}$	8.20^{s}	10.56^{q}
Electric broiler	$10.78^{r,v}$	$15.92^{q,v}$	$8.62^{s,v,w}$	8.33^{s}	10.47^{r}

n = 32-36 per cell.
^{q,r,s,t}Within a row, means lacking a common superscript letter differ (P<0.05).
^{v,w,x}Within a column, means lacking a common superscript letter differ (P<0.05).

Table 2. Endpoint Temperature (Least Squares Means, °F) of Steaks from Five Muscles and Five Cooking Treatments*

Cooking Treatment	Bottom Round	Brisket	Top Sirloin	Strip	Eye of Round
Belt grill (200°F)	161.3^{w}	160.5^{w}	161.3^{x}	161.3^{w}	161.9^{w}
Belt grill (242°F)	164.1^{v}	164.6^{v}	$165.8^{v,w}$	165.3^{v}	-
Belt grill (325°F)	165.7^{v}	166.2^{v}	166.1^{v}	166.1^{v}	166.8^{v}
Forced-air convection (325°F)	160.7^{w}	-	$161.7^{w,x}$	$160.2^{w,x}$	$160.6^{w,x}$
Electric broiler	158.8^{x}	159.8^{w}	159.4^{y}	159.2^{x}	159.1^{x}

n = 32-36 per cell
^{v,w,x,y}Within a column, means lacking a common superscript letter differ (P<0.05).
*No muscle differences were found within a cooking method.

Table 3. Percentage Cooking Loss (Least Squares Means) of Steaks from Five Muscles and Five Cooking Treatments

Cooking Treatment	Bottom Round	Brisket	Top Sirloin	Strip	Eye of Round
Belt grill (200°F)	19.86^{r,x}	20.78^{r,x}	20.98^{r,x}	21.54^{r,w}	25.34^{q,x}
Belt grill (325°F)	27.42 ^{q,r,w}	26.49^{r,w}	27.08^{q,r,w}	26.17^{r,v}	28.69^{q,w}
Forced-air convection (325°F)	28.03^{r,w}	-	29.63^{r,v}	25.89^{s,v}	33.40^{q,v}
Electric broiler	30.63^{q,v}	30.18^{q,v}	30.63^{q,v}	27.60^{r,v}	31.66^{q,v}

n = 32-36 per cell
*Cooking loss of the Belt grill (242°F) was excluded due to a mechanical malfunction.
^{q,r,s}Within a row, means lacking a common superscript letter differ (P<0.05).
^{v,w,x}Within a column, means lacking a common superscript letter differ (P<0.05).

Table 4. Cooking Time (Least Squares Means, Minutes) of Steaks from Five Muscles and Five Cooking Treatments

Cooking Treatment	Bottom Round	Brisket	Top Sirloin	Strip	Eye of Round
Belt grill (200°F)	10.64^{x}	10.53^{w}	10.48^{w}	10.87^{x}	10.80^{w}
Belt grill (242°F)	8.33^{y}	7.45^{x}	7.64^{x}	8.04^{y}	-
Belt grill (325°F)	7.13^{y}	6.40^{x}	6.72^{x}	6.93^{y}	6.67^{x}
Forced-air convection (325°F)	25.32^{r,w}	-	26.44^{r,v}	21.09^{s,w}	32.80^{q,v}
Electric broiler	31.78^{q,v}	26.28^{r,v}	26.07^{r,s,v}	25.23^{s,v}	31.33^{q,v}

n = 32-36 per cell
^{q,r,s} Within a row, means lacking a common superscript letter differ (P<0.05).
^{v,w,x,y} Within a column, means lacking a common superscript letter differ (P<0.05).

Table 5. Repeatability of Warner-Bratzler Shear Force Measurements and Cooking Traits

Variable	Belt Grill (200°F)	Belt Grill (242°F)*	Belt Grill (325°)	Forced-Air Convection (325°F)	Electric Broiler
			Bottom Round		
Endpoint temperature (°F)	0.44	0.00	0.00	0.00	0.38
Cooking loss (%)	0.37	-	0.16	0.37	0.38
Cooking time (min)	0.36	0.06	0.00	0.67	0.39
Shear force (lbs)	0.79	0.66	0.83	0.87	0.89
			Brisket		
Endpoint temperature (°F)	0.41	0.13	0.26	-	0.08
Cooking loss (%)	0.77	-	0.43	-	0.31
Cooking time (min)	0.01	0.16	0.00	-	0.18
Shear force (lbs)	0.62	0.55	0.76	-	0.68
			Top Sirloin		
Endpoint temperature (°F)	0.39	0.26	0.18	0.21	0.00
Cooking loss (%)	0.38	-	0.00	0.14	0.70
Cooking time (min)	0.56	0.71	0.00	0.18	0.53
Shear force (lbs)	0.35	0.58	0.09	0.09	0.66
			Strip		
Endpoint temperature (°F)	0.00	0.10	0.05	0.27	0.30
Cooking loss (%)	0.07	-	0.12	0.13	0.44
Cooking time (min)	0.06	0.51	0.35	0.08	0.19
Shear force (lbs)	0.70	0.89	0.83	0.50	0.63
			Eye of Round		
Endpoint temperature (°F)	0.45	-	0.04	.030	0.00
Cooking loss (%)	0.48	-	0.24	0.60	0.40
Cooking time (min)	0.26	-	0.04	0.34	0.04
Shear force (lbs)	0.83	-	0.86	0.79	0.67

n = 32-36 per cell
*Cooking loss excluded due to a mechanical malfunction.