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Heat penetration patterns of outside round, loin strip and eye round muscles cooked by electric broiler, electric belt grill, or forced-air convection oven

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Abstract

We used an electric belt grill, a forced air convection oven, and an electric broiler to cook steaks from three beef muscles; outside round (biceps femoris), loin strip (longissimus lumborum) and eye round (semitendinosus). Belt grill cookery gave the fastest heat penetration into steaks regardless of temperature interval. Eye round had the slowest heat transfer rate for each cooking method perhaps partially explained by its fiber orientation. Heat penetration rate into outside round and loin strip was not different (P>0.05) for cooking method within a given temperature range. Heat penetration into muscles between 140 and 158°F was slowest because energy-expensive reactions (collagen and protein denaturation) occur in that temperature and temperature differential between the heat source and meat is less. Heat penetration also was slow between 122 and 140°F due to the denaturation of contractile proteins.

Keywords

Cattlemen's Day, 2001; Kansas Agricultural Experiment Station contribution; no. 01-318-S; Report of progress (Kansas State University. Agricultural Experiment Station and Cooperative Extension Service); 873; Beef; Heat penetration; Belt grill; Forced-air convection oven; Electric broiler

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HEAT PENETRATION PATTERNS OF OUTSIDE ROUND, LOIN STRIP AND EYE ROUND MUSCLES COOKED BY ELECTRIC BROILER, ELECTRIC BELT GRILL, OR FORCED-AIR CONVECTION OVEN

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Summary

We used an electric belt grill, a forced air convection oven, and an electric broiler to cook steaks from three beef muscles; outside round (biceps femoris), loin strip (longissimus lumborum) and eye round (semitendinosus). Belt grill cookery gave the fastest heat penetration into steaks regardless of temperature interval. Eye round had the slowest heat transfer rate for each cooking method perhaps partially explained by its fiber orientation. Heat penetration rate into outside round and loin strip was not different (P>0.05) for cooking method within a given temperature range. Heat penetration into muscles between 140 and 158°F was slowest because energy-expensive reactions (collagen and protein denaturation) occur in that temperature and temperature differential between the heat source and meat is less. Heat penetration also was slow between 122 and 140°F due to the denaturation of contractile proteins.

(Key Words: Heat Penetration, Belt Grill, Forced-Air Convection Oven, Electric Broiler.)

Introduction

Heat penetration into meat is affected by many factors. The energy supply rate, heat conduction within the meat, shape and size of the meat, meat composition, changes induced in meat by heat, for example, protein and collagen denaturation and melting of fat affect heat penetration. Heat penetration is faster when heat is applied parallel to product fibers. The rate of heat penetration is generally most rapid between 50 and 104°F because energy-expensive processes such as protein denaturation have not occurred. On the other hand, heating rate between 140 and 158°F is the slowest due to collagen and protein denaturation and a smaller temperature differential between the heat source and meat. Contact cooking equipment such as a belt grill should result in the fastest heat penetration because of its very high heat transfer coefficient. The heat loss from the open surface of an electric broiler causes heat transfer into meat to be slower than contact cooking. Forced-air convection ovens give effective but slow heat penetration. Air has low thermal conductivity, so heat transfer between air and meat product in a forced-air convection oven is slower than in a belt grill.

Experimental Procedures

We purchased USDA Select subprimals [(beef strip loin, boneless (NAMP 180) and beef round, bottom (gooseneck) (NAMP 170)] (n=17 or 18 each) and removed outside round (biceps femoris, BF, n=17), loin strip (longissimus lumborum, LL, n=18), and eye round (semitendinosus, ST, n=17). Muscles were vacuum packaged and held at 34°F for 14 days, then frozen and stored at -35°F.

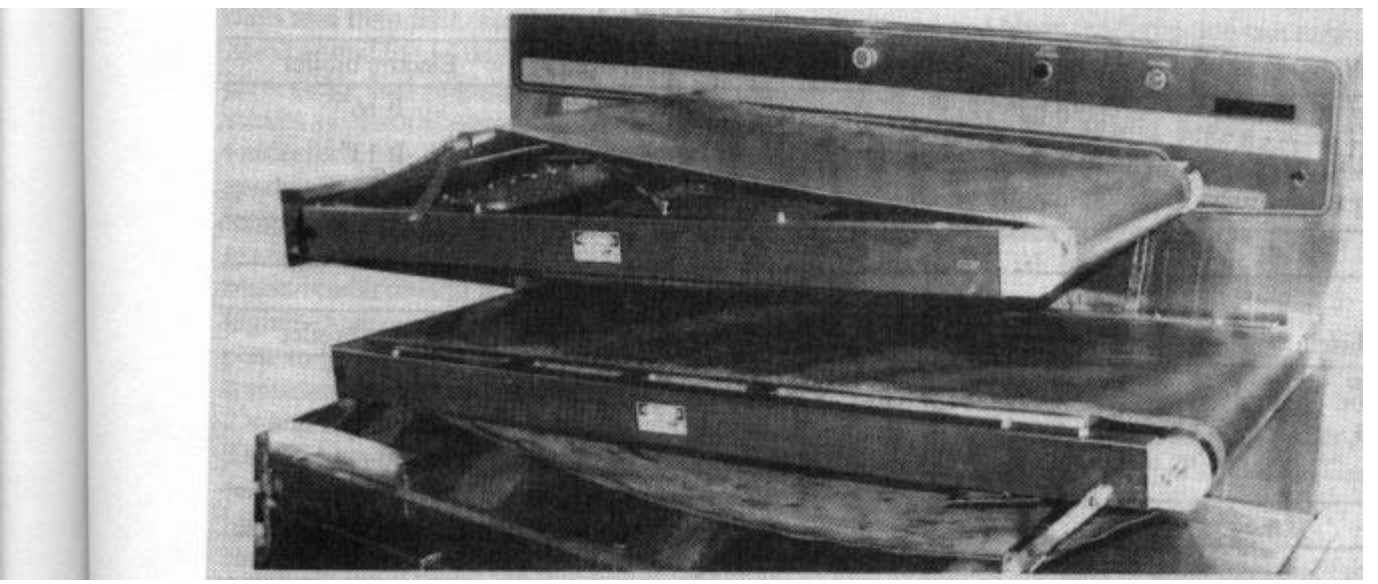
Frozen muscles were sawed into 1-inch thick steaks, which were vacuum packaged and stored. We thawed steaks at 39°F for 24 hours before cooking and cooked them by one of three cooking methods: electric belt grill at 325°F, forced-air convection oven at 325°F, or electric broiler (no temperature control). We cooked all steaks to the end-point temperature of 158°F. The center temperature of steaks was monitored using copper-constantan thermocouples. Temperature was recorded and heat penetration rate for each muscle was calculated as minutes/°F.

Results were analyzed in a completely randomized design using the General Linear Model procedure (SAS, 1998).

Results and Discussion

Belt grill cookery gave the fastest heat penetration rate for muscles studied (Table 1). Forced air convection oven and electric broiler gave similar results in most cases. Heat penetration rate into any given muscle decreased above 104°F since denaturation of contractile proteins, which starts at about 104°F, leads to slower heat penetration. The slowest heating rates occurred in the 140-l 58°F interval, followed by 122-140°F interval. At all temperature intervals, eye round required more energy. Heat penetration for eye round muscle between 50 and 68°F was almost three times faster than between 140 and 158°F, when cooked by either forced-air convection oven or electric broiler. Although loin strip and outside round showed the same trend both required less heat between 140 and158°F than eye round. Belt grill cookery resulted in no differences in heat transfer rate due to muscle in any temperature interval studied because heat transfer was very fast.

Different heat penetration rates for the three muscles may be explained by differences in fat, collagen water, and elastin content and fiberorientation.



Steaks enter the belt grill on the right and exit on the left. During operation the distance between the two belts is adjusted so that the hot belts touch both the top and bottom of the steaks.

Table 1. Heat Penetration (min/°F) Cooking Treatment × Muscle Interaction Means

50 to 68°F			
	Cooking Method		
Muscle	Belt grill	Forced-air convection oven	Electric broiler
BF	$0.04^{a,x}$	$0.13^{b,x}$	$0.12^{b,x}$
LL	$0.04^{a,x}$	$0.14^{b,x}$	$0.15^{c,x}$
ST	$0.04^{a,x}$	$0.16^{b,y}$	$0.16^{b,y}$
68 to 86°F			
	Cooking Method		
Muscle	Belt grill	Forced-air convection oven	Electric broiler
BF	$0.04^{a,x}$	$0.13^{b,x}$	$0.12^{b,x}$
LL	$0.04^{a,x}$	$0.12^{b,x}$	$0.14^{c,x}$
ST	$0.04^{a,x}$	$0.17^{b,y}$	$0.17^{b,y}$
86 to 104 °F			
	Cooking Method		
Muscle	Belt grill	Forced-air convection oven	Electric broiler
BF	$0.04^{a,x}$	$0.17^{b,x}$	$0.19^{b,x}$
LL	$0.04^{a,x}$	$0.15^{b,x}$	$0.13^{b,y}$
ST	$0.04^{a,x}$	$0.22^{b,y}$	$0.17^{c,xy}$
104 to 122°F			
	Cooking Method		
Muscle	Belt grill	Forced-air convection oven	Electric broiler
BF	$0.04^{a,x}$	$0.21^{b,x,y}$	$0.16^{b,x}$
LL	$0.04^{a,x}$	$0.18^{c,x}$	$0.13^{b,x}$
ST	$0.04^{a,x}$	$0.26^{b,y}$	$0.25^{b,y}$
122 to 140°F			
	Cooking Method		
Muscle	Belt grill	Forced-air convection oven	Electric broiler
BF	$0.05^{a,x}$	$0.23^{b,x}$	$0.26^{b,y}$
LL	$0.06^{a,x}$	$0.22^{c,x}$	$0.18^{b,x}$
ST	$0.05^{a,x}$	$0.32^{b,y}$	$0.33^{b,z}$
140 to 158°F			
	Cooking Method		
Muscle	Belt grill	Forced-air convection oven	Electric broiler
BF	$0.07^{a,x}$	$0.33^{b,x}$	$0.38^{b,y}$
LL	$0.07^{a,x}$	$0.37^{b,x}$	$0.31^{b,x}$
ST	$0.07^{a,x}$	$0.46^{b,y}$	0.47^{b}

^{a,b,c}Within a row, means lacking a common superscript letter differ ($P<0.05$).
^{x,y,z}Within a column, means lacking a common superscript letter differ ($P<0.05$).