TENDERIZATION OF BEEF AND PORK WITH SHOCK WAVES PRODUCED WITH A CAPACITOR DISCHARGE SYSTEM

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ABSTRACT

Several experiments were conducted to determine the effects of exposing meat to hydrodynamic shock waves (HSW) that were electrically produced with a capacitor discharge system (CDS, Hydrodyne®. Fresh meat and enhanced meat were evaluated. Experiment 1 evaluated hot-boned strip loins (SL, n=10) from non-electrically stimulated beef carcasses. SL were exposed to single and multiple pulses of HSW. Tenderization was based on Allo-Kramer shear (AK) for steaks cooked to 71 C. Experiments 2 through 4 evaluated CDS on meat used to manufacture enhanced USDA Select beef (eye of rounds, ER, n=24; bottom rounds, BR, n=20; top rounds, TR, n=4). Experiment 5 tested CDS on boneless pork loins. Tenderness was determined with a Warner-Bratzler shear (WBS) instrument on product cooked to 71 C (Experiments 2-5). A marinade solution was prepared to provide 0.5% NaCl and 0.35% sodium tripolyphosphate (STP). The multineedle injector (model FGM 20s; Reiser Inc.) was set to deliver approximately a 12% injection. Once the injector level was set, no changes were made so that a direct comparison was made between the control (C) and CDS relative to marinade uptake. The average tenderization of CDS processed SL ranged from 18 to 24% (AK shear force reduction). In some cases, AK was reduced by 53%. CDS processed meat used to produce enhanced beef, facilitated marinade uptake (C vs. CDS; ER, 10.2% vs. 15.1%; BR, 9.9 vs. 14.0%) and reduction in drip percentage (C vs. CDS; ER, 5-day, 3.6 vs. 2.6%; BR, 4-day, 2.0 vs. 1.8%; TR, 6-day, 3.9 vs. 2.8%). Tenderization (WBS) favored the CDS processed beef (C vs. CDS; ER, 4.1 vs. 3.2 kg; BR, 6.0 vs. 5.5 kg; TR, 4.8 vs. 3.7 kg). Tenderization was likely due to fragmentation of the myofibrillar proteins in addition to the beneficial effects of elevated salt, STP, and moisture. The boneless pork loins tended to have lower shear force values and higher marinade uptake. Processing beef and pork with shock waves produced with a CDS can improve meat tenderness, moisture uptake, and moisture retention.

INTRODUCTION

Shock waves and Tenderization

Hydrodynamic shock waves (HSW) have been shown to tenderize meat. HSW can be produced using explosives (Long, 1993; 1994). Using an explosive-based system to generate shock waves, Solomon et al. (1997) reported a reduction in Warner-Bratzler shear (WBS) force of 49 to 72% for cooked longissimus dorsi steaks and Meek et al. (2000) reported a 28% decrease in the WBS values in chicken. With the explosive-based system, packaged meat was placed in the bottom of a water-filled vessel in which an explosive charge was detonated to create the shock wave.

Limitations of an explosive-based shock wave generating system

- Safety associated with handling and detonating explosives
- Product packaging requirements- avoid product contact with water, potential chemicals and detonation materials (wire insulation, wire). Absence of air bubbles, otherwise bag failure.
- System cost- a major capital expense

Electrically generate a shock wave

- High voltage arc discharge system (Long, 2000; 2001a, 2001b) based on pulsed-power plasma technology
- Capacitors discharge electricity across electrodes underwater creating an arc that produces a shock wave (Figure 1)

OBJECTIVES

- ➢Determine the effects of various Capacitor Discharge System (CDS) energy levels and pulses on the tenderization of beef.
- ➢Evaluate the effects of CDS shock wave treatment on meat used for enhanced beef and pork.

Figure 1

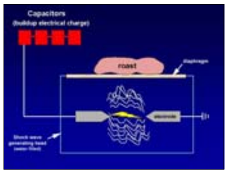
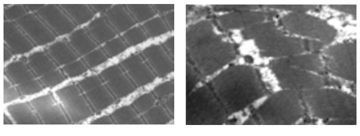


Photo 1



Non-shock wave processed beef

Shock wave processed beef

MATERIALS & METHODS

Muscles and treatments

Experiment 1- Nine non-electrically stimulated hot-boned strip loins (various quality grades, Emmpak Inc., chilled (2 C), stored (2 d), and frozen (-29 C). Thawed before treatment. Hardware: aluminum shock wave head. Round, flat-bottomed metal meat catcher (with diaphragm) mounted on r-shaped support structure.
Treatments: Steaks CDS pulsed three times (3X) at 53% energy, once (1X) at 68%. Roast pulsed 1X or 2X at 72% energy (Figure 2).

Experiments 2-5
Unfrozen, vacuum packaged cuts. USDA Select beef from IBP Incorporated. CDS processed and then injected. Hardware: aluminum shock wave head. Round, flat-bottomed metal meat catcher (w/o diaphragm) mounted on r-shaped support structure.

Experiment 2- Round eyes (n=24)- CDS processed 10 d postmortem. 12 randomly selected for CDS processing before injection. 12 pieces, injection only (control group). Standardized roast length (11 inches) before injected.
Treatment: pulsed once at 72% energy.

Experiment 3- Bottom rounds (n=20)- CDS processed 11 d postmortem. 10 randomly selected, designated for CDS processing before injection. 10 pieces, injection only (control group). Standardized roast length (11 inches) before CDS processed and injected.
Treatment: pulsed once at 76% energy.

Experiment 4- Top rounds (n=4)- CDS processed 12 d postmortem. Cut into halves (one half designated CDS, other control).
Treatment: pulsed once at 60% energy.

Experiment 5- Pork loins, boneless (n=18)- CDS processed 5 d postmortem. Cut into halves (one half designated CDS, other control).
Treatment: pulsed twice at 42% energy.

Marination

Multi-needle injector (model FGM 20s; Reiser).
~12% pump (0.5% sodium chloride; 0.35% sodium tripolyphosphate. Once injector dial set, not changed. Post-injected weight taken immediately exiting injector.

Color and drip loss measurement

Drip- steaks/chops placed on foam trays and over wrapped with oxygen permeable film. Stored (2 C) various days before drip measurement.
Color- measured with a white plate calibrated chroma meter (CR-200, Minolta).

Cookery

Convection oven cooked. Oven preheated (325 F). Steaks and chops flipped once at 104 F internal. Removed from oven at 158 F to achieve an internal temperature of 160 F.

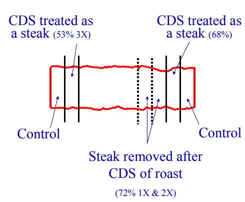
Tenderness methodology- shearing

Experiment 1- steaks cut into 1-cm wide strips (length 4 cm), weighed, and sheared (Allo-Kramer 10-bladed sheared).
Experiments 2 to 5- steaks and chops, room temp., 0.5 inch cores (n=8), Warner-Bratzler shear testing (G.R. Electric Co.), perpendicular to fibers.

Data Analysis

PROC GLM and PROC MIX programs of SAS (Version 8.1, Statistical Analysis System, Inc.).

Figure 2.



RESULTS & DISCUSSION

Electrically generated shock waves tenderized meat by physical disruption of the muscle fibers as previously reported for meat exposed to shock waves produced by the detonation of explosives (Photo 1).

Energy level and number of pulses on tenderization

Regardless of energy level or number of pulses, CDS post rigor processed hot boned beef strip loins were more tender than control steaks (Table 1).

Strip loins from different animals did not all respond the same. Depending on the energy level and number of pulses some muscles had lower shear forces up to 53%. Solomon et al. (1997) reported similar percentage changes with explosively generated shock waves. Differences in anatomical location and collagen may play a significant role.

Marinade uptake

CDS processed beef (round eyes, bottom rounds) picked up more marinade than controls (Tables 2 and 3). Top rounds were not different in marinade uptake (data not shown). CDS processed boneless pork loins tended to have higher marinade uptake (Table 4.).

Table 1. Allo-Kramer total energy per gram values for post-rigor, CDS[1] processed, hot-boned beef strip loins[2].

Animal	53%		68%		72%		Top
(Rep)	Control	3X	Control	1X	1X	2X	Improvement[3]
1	124.1	91.8	93.6	83.5	**52.9**	-	43.5%
2	127.9	112.3	143.7	103.9	72.2	**66.9**	53.4%
3	85.1	69.8	120.8	135.6	**89.3**	91.8	26.1%
4	121.4	100.7	127.8	106.3	115.1	**84.6**	33.8%
5	94.7	76.0	111.5	**87.8**	98.5	88.4	21.3%
6	128.9	102.7	102.9	**79.4**	-	133.1	22.8%
7	79.1	67.7	117.9	87.6	78.4	**75.4**	36.1%
8	117.1	93.3	76.5	**57.1**	69.0	72.2	25.3%
9	168.2	**124.0**	119.0	90.0	111.2	102.0	26.2%
Average	**116.3^{a}**	**93.2^{b}**	**112.6^{ax}**	**92.4^{b}**	**85.8^{y}**	**89.3^{y}**	
Change		19.9%		18.0%	23.8%	20.7%	

[1]CDS= capacitor discharge system, CDS set at 53%, 68% or 72% of machine's energy capacity and product pulsed once (1X), twice (2X), or three times (3X).
[2]Strip loins were processed as roasts (72%) or steaks (53%, 68%). Steaks were cooked to an internal temperature of 160 F. Allo-Kramer shear was performed on 4 cm long, 1 cm wide, nature thick strips from the center of the steaks.
[3]Top improvement= percentage change based on greatest shear reduction compared to control. Value used within a given row designated in bold.
^{ab}Values within a CDS energy level with unlike letters are different (P<0.05). S.E.= 7.84 for 53%, 6.89 for 68%.
^{xy}Values within 72% CDS energy level with unlike letters are different (P<0.05) than the control. S.E. = 7.24

Drip

CDS round eye muscles lower drip. CDS bottom round steaks equivalent to control steaks, despite higher marinade uptake. The ability to differentiate the effects of the shock wave (tenderization) versus higher levels of injected salt and phosphate was not possible in this experiment.

Enhanced meat tenderization

With the exception of the bottom rounds, the beef and pork muscles used were relatively tender to start. Enhanced steaks from CDS round eye muscles had lower shear values than control steaks.

Color

CDS muscles produced enhanced steaks that were less red (lower CIE a*) possibly due to higher incorporation of marinade diluting the pigments. A color difference of less than 5 CIE a* units may not be apparent to consumers.

Table 2. Effects of capacitor discharge system application on USDA Select **round eye** muscles

	Treatment		
Depend. var.	Control	CDS	S.E.
WBS			
Peak force (kg)	4.05^{a}	3.21^{b}	0.27
Injection uptake (%)	10.2^{b}	15.1^{a}	1.2
5 day drip (%)	3.6^{a}	2.6^{b}	0.4
CIE values			
5 day L*	39.29	38.40	1.28
5 day a*	20.43^{a}	17.54^{b}	0.52
5 day b*	12.44^{a}	10.77^{b}	0.36
Cook loss (%)	32.1	33.2	1.6
8 day drip (%)	3.8	3.2	0.4
CIE values			
8 day L*	39.02	38.25	1.32
8 day a*	17.57^{a}	14.87^{b}	0.66
8 day b*	11.56^{a}	10.19^{b}	0.27
pH	5.64^{a}	5.54^{b}	0.25

^{a,b}Row means bearing unlike superscripts are different (P<0.05). Row means without superscript letters are not different.

Table 3. Effects of capacitor discharge system application on USDA Select **bottom rounds** used to produce enhanced beef.

	Treatment		
Depend. var.	Control	CDS	S.E.
WBS			
Peak force (kg)	6.04	5.50	0.83
Injection uptake (%)	9.9^{a}	14.0^{b}	0.8
4 day drip (%)	2.0	1.8	0.3
CIE values			
4 day L*	38.57	38.07	0.69
4 day a*	22.07^{a}	19.69^{b}	0.33
4 day b*	11.56^{a}	10.91^{b}	0.24
Cook loss (%)	29.9	27.7	1.6
7 day drip (%)	2.7	2.7	0.2
CIE values			
7 day L*	39.49	38.39	0.96
7 day a*	19.21^{a}	16.92^{b}	0.37
7 day b*	11.86^{a}	11.26^{b}	0.20
pH	5.40	5.42	0.03

^{a,b}Row means bearing unlike superscripts are different (P<0.05). Row means without superscript letters are not different.

Table 4. Effects of capacitor discharge system application (2 pulses at 42%) on **pork loins** used to produce enhanced pork chops

	Treatment		
Depend. Var.	Control	CDS	S.E.
WBS			
Peak force (kg)	2.13	2.06	0.12
Injection uptake (%)	14.8	17.0	1.2
2 day drip (%)	1.8	1.5	0.2
CIE values			
2 day L*	42.35^{a}	41.48^{b}	0.23
2 day a*	6.98	7.02	0.30
2 day b*	4.79	4.63	0.26
Cook loss (%)	20.7	20.9	0.7
pH	5.72	5.72	n.a.

^{a,b}Row means bearing unlike superscripts are different (P<0.05). Row means without superscript letters are not different.

CONCLUSIONS

- Electrically generated shock waves produced with a high voltage arc capacitor discharge system tenderize beef.
- Roasts and steaks can be directly tenderized with electrically generated shock waves eliminating the need to age.
- Marinade uptake and retention can be increased.
- With the capability of this system to easily alter the energy level and number of pulses, this should provide the industry the opportunity to optimize the level of tenderization by type of cut.

Acknowledgements

Authors would like to acknowledge the Wisconsin Beef Council for providing funds for a portion of this research, Hydrodyne Incorporated for providing personnel and equipment. In addition, authors would like to thank IBP Incorporated and Emmpak Foods Incorporated relative to providing the beef for these experiments.