EFFECTS OF SPRAY CHILLING ON BEEF CARCASS YIELDS AND TRAITS, CUT-OUT YIELDS, VACUUM AGING PURGE LOSSES AND WARNER-BRATZLER SHEAR FORCE VALUES

by

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TABLE OF CONTENTS

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LIST OF TABLES

REVIEW OF LITERATURE

Spray chilling effects on carcass shrink.

Spray chilling refers to the chilling of carcasses by intermittently spraying them with chilled water during the first hours of postmortem chilling. The use of spray chilling of carcasses has increased over the last few years in the United States. The primary reason for this increased usage is the economic advantage realized during the chilling from reduced carcass shrink. Carcass shrink is the difference between hot carcass weight and chilled carcass weight which is caused primarily by moisture evaporation during chilling. Koch _et al_., (1976) reported that after a 24 h chill carcass shrink averaged 3.2%. Fisher and Bayntum (1983), reported that in the first 24 h postmortem carcasses lost approximately 2% of their weight. When two rapid chilling methods, one utilizing ammonia and the other utilizing a cryogenic system were compared versus the conventional system (a nonspray carcass chill), Watt and Herring (1974) found that rapid chilled sides shrank from .11 to 1.28%, while conventionally chilled sides shrank .78 to 1.37%. Kastner (1981) stated that after an overnight, conventional chill shrouded beef carcasses typically shrank from .75 to 2.0%.

Smith _et al_., (1976) reported that wrapping lamb carcasses with polyvinyl chloride film as a shroud reduced shrink from 6.3 to 3.2% when stored at 0C. They also reported that waiting 2h postmortem to shroud the carcasses still had a significant effect in reducing shrink. Heitter (1975) stated that one of the main reasons for using the Chlor-chill system was to reduce shrink. He reported that with the use of the Chlor-chill system 24 h shrink could be reduced to .5 to 1.25%.

Allen et al., (1987) reported that spray chilled sides shrank .32% while their companion sides that were conventionally chilled had a shrink of 1.46% after a 24 h chill. The manner in which carcasses were spaced in the spray chill cooler had an effect on carcass shrink. Carcasses that were placed in the cooler on the same rail with foreshanks aligned in the same direction, but with a 15 cm space between sides shrank .05%. Those placed on the same rail but with foreshanks aligned in opposite directions shrank .08%, while those placed on the same rail with foreshanks aligned in the same direction, but with the sides crowded together, shrank .31%. They reported that the carcasses with the foreshanks aligned, but with the sides crowded together, shrank significantly more than the other spacing treatment.

Allen et al., (1987) also determined that spray chilling had mixed effects on primal and subprimal weight loss during their vacuum aging. They found that ribs from spray chilled sides had slightly more purge (1.37 vs. 1.56%) than conventionally chilled sides, but these differences were not significant. Furthermore, they determined that inside rounds from conventionally chilled sides had significantly less purge and weight loss than did their counterparts from spray chilled sides.

The effects of spray chilling on USDA grade factors of beef carcasses.

Because spray chilling is relatively new to the beef packing industry limited research has been reported on its effects on USDA grade factors. Allen *et al.*, (1987), in a study done in a commercial packing plant, found that skeletal maturity of beef sides that had been spray chilled was more youthful in appearance, than that of sidemates that had been conventionally chilled. This difference showed up in the appearance of less ossification of the chine buttons on the thoracic vertebra. He reported that this skeletal maturity difference translated into a younger overall carcass maturity and a slight advantage, for the spray chilled sides, in final USDA quality grade. The greatest advantage was for carcasses whose physiological maturity was in the interface of the B and C maturity groups (Allen *et al.*, 1987). These same workers in this study reported that spray vs conventional chilling had no effect on carcass yield grade factors.

Effects of chilling rate and muscle pH decline on physical and sensory characteristics of beef.

For many years it has been known that muscle pH and temperature postmortem affect the physical and sensory attributes of meat. Glover *et al.*, (1977), found that when beef carcasses where chilled at 3C and -2C that there was little effect on Warner-Bratzler Shear (WBS) values when the two treatments were compared. However, he felt that a bigger differential in chilling temperature or external fat thickness differences (fat vs lean) of carcasses may show some discrepancies in shear value.

Lochner et al., (1980) wrote that if we were to develop a close relationship, relating cooling rate to meat tenderness, then we must recognize that many factors affect the rate at which muscles chill. He listed among these variables size, shape and fatness of the carcass, plus the flow pattern of air in the cooler along with cooler temperature and the relative humidity of the cooler. Lean beef carcasses in a cooler with fast air movement 90m/min and temperature of -2C chilled the fastest when compared with fat carcasses chilled in the same manner and fat and lean carcasses chilled in a cooler at 9C and no forced air (Lochner et al., 1980). They also found that the carcasses of the lean group that chilled the fastest were less tender than the carcasses that chilled slower. He reported that when evaluated by either taste panel or WBS the fat carcasses chilled in rapid air movement were more tender when compared with the other groups in the study.

Marsh (1983) stated that it was a high pH and high carcass temperature early postmortem that was responsible for the rapid tenderizing of beef rather than either of them separately.

Honikel et al., (1983) concluded that in unrestrained muscle, shortening occurred at any temperature between freezing and physiological temperature. He stated that the shortening starts at different pH values at different temperatures. At temperatures >15C, shortening starts at a pH of 6.3, with the pH being lowest at 20C and this shortening stops at a pH as low as 5.6 (Honikel _et al._, 1983).

Petaja _et al._, (1985) working with adductor muscle excised at 40 to 50 min postmortem and incubated for 4 or 6 h at 10, 30, 37 and 40C, determined that muscle incubated at 37C for 6 h and for both time periods at 40C were more tender, when evaluated by WBS and sensory, than any of the other treatments. Yu and Lee (1986) concluded and were in agreement with Marsh, that early postmortem pH and temperature had significant effects on structural changes and final tenderness of beef.

Effects of electrical stimulation of beef carcasses on the incidence of heat ring (cold ring).

Heat rings are dark coarse areas that form along the outer surface of the beef carcasses ribeye (longissimus dorsi muscle) during the chilling process (Orcutt _et al._, 1984). Heat rings are formed when the outer surface of the longissimus dorsi is chilled to rapidly and before the pH has had time to drop to a point at which normal color would develop when the carcass is ribbed (Stiffler _et al._, 1982). Savell _et al._, (1978) reported that stimulation of beef carcass sides reduced the incidence of heat ring at 24 h postmortem. He stated that electrical stimulation speeds up the rate of postmortem glycolysis, thereby causing a rapid pH decline, this might explain why the incidence of heat rings was reduced in sides that were electrically stimulated compared with sides that were not stimulated. McKeith _et al._, (1981) when working with whole carcasses, versus sides had a similar reduction in heat ring incidence. Orcutt _et al._, (1984) found that electrical stimulation greatly reduced the incidence of heat ring and reduced the severity of those that did appear. Furthermore, he reported that after 48 h postmortem the heat rings that had formed during the chilling process, were not noticeable in either stimulated or non-stimulated carcasses. Electrical stimulation was effective in reducing the incidence of heat rings, after a 24 h chill, in steer carcasses, but had no influence in bull carcasses (Stiffler *et al.*, (1986).

Effects of electrical stimulation on beef muscle color and USDA quality grade.

Savell *et al.*, (1978) found that in three comparisons of electrical stimulation, lean color was improved when beef sides were electrically stimulated. He concluded that this improvement consisted of brighter more youthful appearing lean in electrically stimulated sides versus non-electrically stimulated sides. However, he cautioned, that if carcasses were held for long periods (>48h) these differences might become nonexistent.

Similar studies on electrical stimulation have confirmed that it has an affect on lean color and that electrical stimulation improved lean color (McKeith *et al.*, 1981; Crouse *et al.*, 1983; Orcutt *et al.*, 1984).

It has also been reported that electrical stimulation has the ability to improve marbling scores and thereby influence the final quality grade . Savell *et al.*, (1978) found that when sides of beef carcasses were electrically stimulated there was an increase in the perceivable amount of marbling in the longissimus dorsi. When the sides that had been stimulated were compared with non-stimulated sides they were higher in marbling and quality grades. Stiffler _et al._, (1982) reported in a technical bulletin, covering the history and use of electrical stimulation, that when beef was electrically stimulated, it appeared to have more marbling when ribbed at 24 h. He compared electrical stimulation's affect to the phenomena that happens to weekend cattle, in that when these cattle are ribbed on Monday after a weekend chill there tends to be higher percent of carcasses that grade Choice.

When the effect of electrical stimulation on bull and steer carcasses was studied, the use of electrical stimulation did not improve the marbling scores (Crouse _et al._, 1983; Stiffler _et al._, 1984). These findings would disagree with the findings reported by Savell _et al._, (1978) and McKeith _et al._, (1981). This disagreement would suggest that the consistency of quality grade improvement using electrical stimulation is suspect.

Vacuum aging effects on yield or weight loss of beef sub-primals.

Over the past twenty years vacuum packaging and aging of beef primals and sub-primals has become the norm in the beef industry. There are many reasons for this among which are:

1) A reduction in shrink or weight loss.

2) Less spoilage due to aerobic microbial growth.

3) Transportation efficiencies brought on by shipping less non-usable product.

I) Shrink Reduction: One of the primary reasons the meat industry is using vacuum packaging and aging is the reduction in shrink. Minks and Stringer (1972) found that when beef was aged in a vacuum package it had less weight loss than beef aged naturally. They reported that beef aged in a vacuum package lost only .9% during the aging period while the unpackaged or naturally aged beef lost 4.37%. They also reported that there was no significant weight loss difference between vacuum packaged beef cuts aged 7d vs those aged 15d, but when compared with non-packaged cuts aged the same lengths of time there were significant differences. Loins and ribs aged non-packaged for 7 days lost 2.44% more weight than their vacuum packaged counter parts while those aged for 15d lost 5.12% more than their vacuum packaged counterpart. Hodges et al. (1974) determined that when vacuum aging was used, weight loss was reduced over the aging period when weights were averaged over a 3, 7, 14 and 28d under vacuum.

Effects of vacuum aging on the palatability of beef.

From the start, questions have been raised about the effects of vacuum aging on meat flavor and tenderness characteristics. Some people feel that flavor is altered by vacuum aging while others feel flavor differences are not altered when compared to natural aging.

Hodges *et al*., (1974) compared loin steaks from two different quality grades, vacuum packaged at 1 d or 15d postmortem and stored up to 29d postmortem. He found that steaks from high grade loins packaged 15d postmortem had better flavor scores than those from low grade loins. They also reported that the lower grade loin steaks tended to have a greater incidence of off-flavor when compared with the other treatments. Mink and Stringer (1972) found that aging in vacuum packages for 7d and 15d increased tenderness as determined by WBS and taste panel scores. They stated that taste panels showed a greater amount of tenderization occurred during the first 7d of aging while WBS showed it to occur during the 7-15d period.

Hodges et al., (1974) in a study in which loins from beef carcasses were either vacuum packaged 1d postmortem or aged naturally for 15d postmortem then vacuum packaged reported that length of vacuum packaged storage time greatly increased the tenderness of loin steaks. They found a significant increase in tenderness when steaks removed from the carcass and frozen 1d postmortem were compared with steaks aged for 15d postmortem before freezing. Furthermore, they compared steaks from carcasses that were vacuum packed 1d postmortem and stored for 14d to steaks from those carcasses that were naturally aged for those same 15d and found that the comparison approaches significance, but when these steaks were compared at the same age of 29d postmortem there was a nonsignificant difference. Hodges et al., (1974) stated that if any shortening occurred from breaking some of these carcasses at 1d postmortem the toughening effects were less pronounced as postmortem time increased.

Gutowski et al., (1979) found that WBS forces were reduced when steaks were vacuum aged for 21d and then frozen and also for those steaks that were aged for 21d and then displayed for 5d. Bidner et al., (1985) found that at 21d of aging WBS values were reduced when compared to nonaged steaks, and that when steaks were tested by a sensory panel this tenderness was confirmed. Oreskovich et al., (1986) stated that vacuum aging vs natural aging did not make any difference in palatability characteristics of loin steaks as determined by WBS.

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CHAPTER 1

THE EFFECTS OF SPRAY CHILLING ON BEEF CARCASS YIELDS AND TRAITS,CUT-OUT YIELDS, VACUUM AGING PURGE LOSSES AND WARNER-BRATZLER SHEAR FORCE VALUES

Introduction

The use of spray chilling for the purpose of cooling beef carcasses is currently in wide spread use in the meat industry. By using spray chilling, beef packers realize a weight savings which has resulted in it's increased use in the slaughter plants. This weight savings appears in the form of less carcass shrink during the initial chill period.

Because this chilling method is relatively new to the packing industry, limited research on the total effects of spray chilling on the product have been conducted. Furthermore, there is no information on spray chilling effects on carcasses from cattle of different biological types or on spray cycles of different time lengths.

Therefore the objectives of this experiment were to determine the effects of two spray chilling regimes on carcass weight loss and on carcass characteristics of two biological types (or fat thicknesses) of slaughter cattle.

Experimental Procedure

Source of animals. Fifty-six carcasses were selected at a large commercial slaughter plant; twenty-eight of these were beef type steer carcasses with a mean external fat thickness of 1.61 cm and 28 were Holstein (dairy type) steer carcasses with a mean external fat thickness of .45 cm. An attempt was made to select similar weight carcasses, of approximately 341 kg, to try and keep weight variance to a minimum.

Treatment allocation: For two consecutive days 14 beef carcasses and 14 dairy carcasses were selected on the slaughter floor just after the carcass wash. Immediately after selection, individual side weights were obtained. Alternate right and left sides from each carcass were placed in a spray chill cooler with their side mates being placed in a conventional air chill cooler. Seven sides from each carcass type were placed in a 6h spray cycle and 7 more of each type in a 3h spray cycle.

Spray-chilled sides were sprayed for 60 sec every 8 min with water chilled to 1C for either 3 or 6h dependent upon the respective cycle treatments. During the spray period and for 4h after completion of the spray chilling cooler temperature was held at 3.3C after which it was lowered to -5.6C for the duration of the chilling time. Those carcasses sprayed 3h were chilled for a total of 19h while the 6h sprayed carcasses were chilled for 22h at which time all spray chilled sides and their respective conventionally-chilled sidemates were again individually weighed.

USDA Grade factors and lean characteristics scores: After the chilled weights were taken all sides were ribbed and USDA quality and yield grade factors (USDA, 1976) were evaluated for each individual side. A scale of 0 to 500 was used to score lean, skeletal and final maturity (A = 0 to 100; B = 101 to 200; C = 201 to 300; D = 301 to 400; E = 401 to 500). Marbling scores were assigned on a 0 to 900 scale (0 to 100 = Practically Devoid, Abundant = 801 to 900). The AMSA (1977) guidelines were used to score lean color, firmness and texture. Heat ring was scored from 1 to 5 with 1 = no heat ring to 5 = severe heat ring.

Carcass Cut-out: For the two consecutive days of the study five sides from the 6h spray-chilled beef group and their conventionally-chilled sides were selected for complete side cut-out comparisons. Each side of these five carcasses was individually fabricated and complete side fabrication data was collected. All cuts were trimmed to an average of .95cm external fat, with no more than 1.27 cm of fat in any one location.

The primal chuck was separated into a shoulder clod (IMPS 114), chuck roll (IMPS 116A), lean trim, fat, and bone. The primal rib was separated into a lip-on rib (IMPS 112A), lean trim, fat, and bone. The primal loin was separated into a boneless strip loin (IMPS 176), peeled tenderloin (IMPS 190A), top sirloin butt (IMPS 184), lean trim, fat, and bone. The primal round was separated into a top (inside) round (IMPS 168), bottom (outside) round (IMPS 171B), eye of round (IMPS 171C), peeled knuckle (IMPS 167A), lean trim, fat, and bone. The brisket was separated into a boneless brisket (deckle-off) (IMPS 120), lean trim, fat, and bone. The flank was separated into a flank steak (IMPS 193), lean trim, fat, and bone. The lean trim was divided into two categories either 75:25 trim or 50:50 trim. The total weight of all cuts, a combination of total cut weights plus 75:25 trim called combination 1, and combination 1 plus the 50:50 trim called combination 2 were analyzed for differences comparing spray versus conventional chilling.

Vacuum aging weight loss or purge: The chuck roll (IMPS 116A), boneless brisket (deckle-off) (IMPS 120), strip loin (IMPS 176), flank steak (IMPS 193), top sirloin butt (IMPS 184) and the top (inside) round (IMPS 168) from the 20 sides used in the carcass cut-out study were promptly vacuum packaged and boxed. They were then stored at 0C for 14d and then the packages were opened and the cuts removed. The cuts were allowed to drip on wire racks for 10 min and then individually weighed. The initial weight minus the weight taken after the 14 d storage period was used to determine the weight loss due to purge during the 14 d vacuum aging period.

Warner-Bratzler Shear Evaluation: A 7cm section was removed from the 11th and 12th rib area of 40 carcasses, vacuum packaged and transported to Kansas State University for Warner-Bratzler Shear (WBS) force determination. These sections were aged in a cooler at 3 to 4 C for 7 d then a 2.54 cm slice was removed from the 12th rib end for WBS. Each steak was trimmed to .64cm fat depth and then frozen until WBS analysis. These steaks were weighed frozen, thawed 16h at 4C and re-weighed. Then thermal couples were placed in the center of each steak and they were cooked to an internal temperature of 70C according to AMSA (1978) guidelines. Eight 1.27cm cores were removed from each steak and WBS determined using a WBS device on an Instron 4200.

Statistical Analyses: The statistical analysis was carried out using the Analysis of Variance procedure (SAS,1982). The main effects of carcass type, spray-cycle length, and their interaction were analyzed using a difference value calculated by finding the difference between the value of the trait of the spray-chilled side and that of the conventional-chilled side.

Results and Discussion

Effects of spray chilling on carcass weight loss:

Hot carcass weights for all main effects were similar for spray and conventionally chilled sides, with the dairy-type sides being slightly heavier than the beef types. Chilled carcass weights were heavier for those sides that were spray chilled than for those that were conventionally chilled. Therefore, carcass shrink which is calculated by subtracting chilled carcass weight from hot carcass weight was less for the spray-chilled sides than for the conventionally-chilled sides.

Carcass type had no effect ($p>.05$) on carcass weight loss difference (table 1). This difference in weight loss was 1.7 kg for beef type carcasses and 1.99 kg for dairy type carcass when comparing the mean difference in shrink of sidemates chilled using spray vs conventional chilling methods. Conventionally chilled beef-type sides lost an average of 1.93 kg while their spray-chilled sidemates lost .23 kg (table 1). Dairy-type carcasses chilled conventionally lost 2.15 kg with those chilled using spray chilling only lost .16 kg. Although there was no statistical signifince the fact that the spray chilled sides, for both carcass types, lost less weight than their conventionally chilled mates is economically significant.

Table 2 shows the mean weights for carcasses in the two spray cycle regimes. The mean difference for the 3 h spray cycle is less ($p< .05$) than the mean difference for the 6 h spray cycle (-1.29 vs -2.41 kg). However, sides that were chilled using the 6 h spray cycle gained .27 kg while the sides

Table 1: EFFECTS OF CARCASS TYPE ON CARCASS WEIGHT LOSS OR GAIN COMPARING SPRAY VERSUS CONVENTIONAL CHILLING

	Beef type		Dairy type	
	Conventional	Spray	Conventional	Spray
Item				
Number	28	28	28	28
Hot carcass weight, kg	170.24	170.52	172.33	172.33
Chilled carcass weight, kg	168.31	170.29	170.18	172.17
Shrink or gain, kg	-1.93	- .23	-2.15	- .16
Difference[a]	-1.70		-1.99	

[a]Difference = Shrink weight of spray side minus shrink weight of conventional side.

TABLE 2: EFFECTS OF CYCLE LENGTH ON CARCASS WEIGHT GAIN OR LOSS

	3 H Spray		6 H Spray	
Item	Conventional	Spray	Conventional	Spray
Number	28	28	28	28
Hot carcass weight, kg	171.02	171.14	171.55	171.71
Chilled carcass weight, kg	169.07	170.48	169.41	171.98
Shrink or gain, kg	-1.95	- .66	-2.14	.27
Difference[a], kg	-1.29[b]		-2.41[c]	

[a]Difference = Shrink weight of spray side minus shrink weight of conventional side.

[b,c]Means in same row witha different superscript are significantly ($p<.05$) different.

chilled in the 3 h spray cycle lost .66 kg. Sidemates that were chilled without the 3 and 6h spray lost 1.95 kg and 2.14 kg, respectively. Thus, the longer 6 h spray cycle was more effective in preventing weight loss during spray chilling.

Table 3 shows the effects of carcass type by spray cycle length interactions on side weight gain or loss during the chilling process. Though the difference betweeen spray and conventionally-chilled sides of this interaction are non-significant, these differences in weight loss could be of economic importance especially in large volume plants. The negative values for differences between spray and conventionally-chilled sides, show that the spray-chilled sides lost less weight than their conventionally-chilled sidemates for both the 3 h and 6 h cycle lengths regardless of carcass type. These findings are in agreement with Heitter (1975) and Allen et. al., (1987) who found that when sides were spray chilled they lost less weight than did their conventionally-chilled sidemates.

Effects of spray chilling on USDA grade factors and lean characteristics: Table 4 shows the effects of spray chilling on USDA grade factors. Spray vs conventional chilling of sides showed that skeletal maturity differences in dairy type carcasses was affected less ($p<.05$) than those in beef type carcasses. Spray-chilled dairy type carcass had maturity scores that were an average of 8.57 percent younger than their conventionally-chilled sidemates while the same difference in beef type carcasses was 28.04 percent. Allen et. al., (1987)

TABLE 3: EFFECTS OF CARCASS TYPE X CYCLE LENGTH ON CARCASS WEIGHT LOSS OR GAIN.

	Beef type				Dairy type			
	3 H Cycle		6 H Cycle		3 H Cycle		6 H Cycle	
	Conv.	Spray	Conv.	Spray	Conv.	Spray	Conv.	Spray
Number	14	14	14	14	14	14	14	14
Hot carcass weight, kg	171.35	171.80	169.14	169.24	170.70	170.47	173.96	174.19
Chilled carcass weight, kg	169.64	171.05	166.98	169.53	168.50	169.90	171.85	174.43
Weight gain or loss, kg	-1.71	- .75	-2.16	.29	-2.20	- .57	-2.11	.24
Difference[a], kg	- .96		-2.45		-1.63		-2.35	

[a]Difference = Weight loss or gain of spray side minus weight loss or gain of conventional side.

TABLE 4: EFFECTS OF CATTLE TYPE ON USDA GRADE FACTORS

Item	Beef type			Dairy type		
	Conventional	Spray	Difference	Conventional	Spray	Difference*
Number	28	28	28	28	28	28
Skeletal maturity[a]	95.18	67.14	-20.04[d]	50	41.43	- 8.57[e]
Lean maturity[a]	57.50	52.50	- 5.00	49.32	50.00	.68
Final maturity[a]	78.54	60.89	-17.65[d]	49.65	45.71	- 3.93[e]
Marbling[b]	328.39	334.68	6.29	361.86	368.29	6.43
Quality grade[c]	GD^{90}	GD^{98}	8	Ch^{13}	Ch^{18}	5
Final yield grade	3.13	3.17	.04	2.43	2.47	.04

*Difference = Post-chilled weight of spray side - post chill weight of conventional side.

a - A maturity = 0 to 99, B = 100 to 199, C = 200 to 299
b - Small Marbling = 301 to 400
c - Quality Grade - 0 to 100 as a percent grade
d,e - Means in same row with different super scripts differ signigicantly ($p<.05$)

reported that spray chilling seemed to influence skeletal maturity to a greater extent as overall skeletal maturity advanced. The dairy type carcasses in this study were more youthful than were the beef type carcasses (Table 4), thus spray versus conventional chilling had less effect on this trait in the more youthful dairy type carcasses. Lean maturity scores were not influenced by either carcass type or spray versus conventional chilling of sidemates. Due to the obvious influence of skeletal maturity on final maturity scores, dairy type carcasses showed significantly ($p<.05$) less difference in final maturity scores between spray versus conventional chilled sides (-3.93) than the same difference in beef type sides (-17.65). These findings agree with those of Allen et. al., (1987) who reported that skeletal and thus final maturity appears more youthful in sides that are spray chilled versus conventionally chilled. When comparing the differences between spray versus conventionally-chilled sides, carcass type had no influence on these difference between sides for marbling and USDA quality or yield grade (Table 4).

Carcass type, spray cycle length and their interactions for differences between spray versus conventional chilled sides were analyzed for all USDA quality and yield grade factors and for 12th rib longissimus muscle characteristics of color, firmness, texture and heat ring. Except for the effect of carcass type on skeletal and final maturity, no other significant effects were noted for any of these differences.

Effect of Spray Versus Conventional Chilling on Carcass Fabrication Yields.

Spray chilling had no effect (p>.05) on fabrication weights of individual cuts or on total weight of all cuts (table 5). The cut weights from the spray chilled sides were slightly heavier in most comparisons excepts for the brisket (IMPS 120), knuckle (IMPS 167A) and outside round (IMPS 171B). Of the individual cuts, the top sirloin butt (IMPS 184) had the greatest difference in weight yields between the spray and conventionally chilled sides (5.46 vs 5.21 kg). When the weight of the 75:25 trim was included with total major cut weights and also 75:25 trim, 50:50 trim plus total major weights no significant difference in weight yields were noted for spray versus conventional-chilled sidemates. Again, there were slight advantages in weight yields noted for the sides that were spray chilled versus those chilled conventionally (combination 1 = 75.95 vs 75.71 kg, and combination 2 = 93.09 vs 92.37 kg). Johnson et al., (1987) found that fat from spray-chilled carcasses had significantly more moisture than their non-spray chilled counterparts. Therefore, the close trimming of these cuts may have eliminated the moisture in the outer portion of the fat and thereby eliminated the weight advantage for the spray-chilled sides over the conventionally-chilled sides.

Effect of spray versus conventional chilling on vacuum aging purge loss: After a 14d vacuum aging period, purge was found

TABLE 5: EFFECTS OF SPRAY VERSUS CONVENTIONAL CHILLING[a] ON MAJOR CARCASS CUT WEIGHTS (KG) FOR PRIMALS, TOTAL WEIGHT AND COMBINATIONS OF CUT WEIGHTS

IMPS	Cuts	Spray	Conventional
119	Chuck roll	13.03	12.96
114A	Shoulder clod	9.33	9.24
120	Brisket	4.37	4.45
112A	Rib	5.37	5.29
189	Peeled tenderloin	2.65	2.63
175	Strip loin	5.41	5.37
184	Top sirloin butt	5.46	5.21
167A	Knuckle	4.30	4.42
171C	Eye of round	2.45	2.41
168	Inside round	9.71	9.70
171B	Flat round	6.39	6.45
	Total weight	68.47	68.13
	Combination 1*	75.98	75.71
	Combination 2**	93.09	92.87

[a]Ten sides per treatment
*Combination 1 = Total Wt + 75:25 Trim
**Combination 2 = Total Wt + 75:25 Trim + 50:50 Trim

not be different (p>.05) for primals that had been spray chilled when compared with those that had been conventionally chilled (Table 6). The chuck roll (IMPS 116) and top round (IMPS 168) of the spray-chilled side lost .01 kg more weight than did those from conventionally-chilled sides (purge loss = .08 vs .07 kg) for both cuts (Table 6). Conversely, the strip loin (IMPS 175) and top sirloin butt (IMPS 184) had more purge on the conventionally-chilled side by .01 kg than the spray-chilled sides (.07 vs .06 kg, strip loin and .08 vs .07 kg, top sirloin butt). Equal amounts of purge were found in both spray and conventional chilled sides for the brisket (IMPS 120) and flank steak (IMPS 193). Because of the varying effects on the cuts themselves there was no difference found in the total purge lost for the spray versus conventional chilled sides.

Allen et. al., (1987) found that (IMPS 107) ribs from spray-chilled sides lost more weight than the conventionally-chilled sides, but the loss was not significant. Inside rounds (IMPS 168) from the spray-chilled sides, however, had significantly more purge on a weight and percentage basis than did those from the conventionally-chilled sides. These results agree with the findings from this experiment in the fact that spray chilling had differing effects on different cuts from a carcass.

Thaw and cooking losses: The effects of carcass type, spray cycle length and the interaction of the two on thaw and cooking loss differences of rib steaks were analyzed. Carcass type and cycle length had no effect on the steak weight loss difference

TABLE 6: EFFECTS OF SPRAY VERSUS CONVENTIONAL CHILLING ON 14d VACUUM AGING WEIGHT LOSS OR PURGE

Cuts		Initial weight, kg		14d Vacuum Aged weight, kg		Purge[a] weight, kg	
	N	Conv.[b]	Spray	Conv.	Spray	Conv.	Spray
Chuck roll	10	12.96	13.03	12.89	12.95	0.07	0.08
Brisket	10	4.43	4.35	4.40	4.32	0.03	0.03
Strip loin	10	5.35	5.39	5.28	5.33	0.07	0.06
Top sirloin butt	10	5.21	5.44	5.13	5.37	0.08	0.07
Flank steak	10	0.83	0.83	0.82	0.82	0.01	0.01
Inside round	10	9.69	9.70	9.62	9.62	0.07	0.08
Total weight	10	38.47	38.74	38.14	38.41	0.33	0.33

[a]Purge Weight = Initial Weight - 14d vacuum aged weight.
[b]Conv= conventionally chilled

between spray and conventionally-chilled sidemates for weight lost during thawing and cooking (tables 7 and 8). Table 9 shows the steak weight loss for the spray cycle length by carcass type interaction. This interaction had an effect ($p<.05$) on the difference between the total amount of weight lost during the thawing and cooking process, but no effect on the weight lost during thawing process alone. Steak weight loss difference for beef carcasses under the 6 h spray cycle was significantly different from the same carcass type sprayed 3 h and from dairy carcasses sprayed 6 h, but not from the dairy carcasses sprayed for 3 h. The general trend was for steaks from spray-chilled sides to loose slightly more weight than those from conventionall-chilled sides.

Because the steaks were trimmed to an external fat thickness of .64cm, any losses that may have been found due to spray chilling may have been eliminated by this trimming.

Warner-Bratzler Shear force: Table 10 contains the mean shear force values for the spray and conventionlly chilled sides and their mean difference value for carcass types. Carcass type had no effect on WBS value differences. Tables 11 and 12 also show no spray cycle length or carcass type by spray cycle interaction effects on these same WBS mean value differences between steaks from spray vs conventionally-chilled sides. This would indicate that spray chilling in this study did not noticeably alter tenderness as measured by the Warner-Bratzler Shear in either beef or dairy-type carcasses or when carcasses were sprayed for 3 or 6 h regardless of carcass type. Position of cores on the steak, whether located on the outside or inside

TABLE 7: EFFECTS OF CARCASS TYPE ON FROZEN, THAWED AND COOKED WEIGHTS COMPARING SPRAY VERSUS CONVENTIONAL CHILLING

	Beef type		Dairy type	
Item	Conventional	Spray	Conventional	Spray
Number	20	20	20	20
Frozen wt,g	328.63	334.26	301.77	311.09
Thawed wt,g	320.61	326.29	294.59	303.43
Cooked wt,g	260.55	264.38	234.06	240.86
Thaw loss[a],g	8.02	7.97	7.18	7.66
Cook loss[b],g	68.08	69.88	67.71	70.23
Difference[c]	-1.80		-2.52	

[a]Thaw Loss = Frozen wt - Thawed wt.
[b]Cooked = Frozen wt - Cooked wt.
[c]Difference = Cook losses of steaks from conventionally-chilled sides minus cook losses of steaks from spray-chilled sides.

TABLE 8: EFFECTS OF CYCLE LENGTH ON FROZEN, THAWED AND COOKED WEIGHTS COMPARING SPRAY VERSUS CONVENTIONAL CHILLING

	3h Cycle		6h Cycle	
Item	Conventional	Spray	Conventional	Spray
Number	20	20	20	20
Frozen wt,g	311.59	316.26	319.32	329.34
Thawed wt,g	305.29	309.26	310.44	320.75
Cooked wt,g	246.75	245.33	249.31	260.14
Thaw loss[a],g	6.30	7.00	8.88	8.59
Cook loss[b],g	64.84	70.93	70.01	69.20
Difference[c]	-6.09		- .81	

[a]Thaw Loss = Frozen wt - Thawed wt.
[b]Cooked = Frozen wt - Cooked wt.
[c]Differnce = Cook losses of steaks from conventionally-chilled sides minus cook losses of steaks from spray-chilled sides.

TABLE 9: EFFECTS OF CARCASS TYPE BY CYCLE LENGTH ON FROZEN, THAWED AND COOKED WEIGHT OF STEAKS FROM SPRAY AND CONVENTIONAL-CHILLED SIDES

	Beef Type				Dairy Type			
Item	3 H Cycle		6 H Cycle		3 H Cycle		6 H Cycle	
	Conv.[f]	Spray	Conv.	Spray	Conv.	Spray	Conv.	Spray
Number	10	10	10	10	10	10	10	10
Frozen wt,g	317.97	330.32	339.30	338.18	304.49	300.62	299.34	320.50
Thawed wt,g	311.78	324.02	329.43	328.56	298.08	292.86	291.44	312.94
Cooked wt.g	258.36	260.27	262.74	268.49	233.85	228.72	235.88	251.79
Thaw loss[a],g	6.19	6.03	9.87	9.62	6.41	7.76	7.90	7.56
Cook loss[b],g	59.61	70.05	76.56	69.69	70.64	71.90	63.46	68.71
Difference[c]	-10.44[d]		6.87[e]		-1.26[d,e]		-5.25[d]	

[a]Thaw Loss = Frozen Wt - Thawed Wt.
[b]Cook Loss = Frozen Wt - Cooked Wt.
[c]Difference = Conventional-Chilled Cook Loss - Sprayed Chilled Cook Loss
[d,e]Means in the same row with a different superscript are significantly ($p<.05$) different.
[f]Conv. = Conventionally chilled.

TABLE 10: EFFECTS OF CARCASS TYPE ON WARNER-BRATZLER SHEAR FORCE COMPARING STEAKS FROM SPRAY VERSUS CONVENTIONAL CHILLING

	Beef Type			Dairy Type		
Item	Conv[a]	Spray	Diff*	Conv	Spray	Diff*
Number	20	20		20	20	
WBS,[b] kg	3.44	3.40	-.04	3.40	3.46	.06
Outside WBS[c], kg	3.60	3.56	-.04	3.53	3.65	.12
Inside WBS[d], kg	3.27	3.23	-.04	3.28	3.26	-.02

*Difference = Spray-chilled WBS - Conventional-chilled WBS.
[a]Conv = Conventional Chilled
[b]WBS = Warner-Bratzler Shear
[c]Mean of 4 cores taken from outer portion of the Longissimus Dorsi just below sub cutaneous fat and epimisial tissue.
[d]Mean of 4 cores taken from lower portion of Longissimus Dorsi just above the rib.

TABLE 11: EFFECTS OF CYCLE LENGTH ON WARNER-BRATZLER SHEAR FORCE COMPARING STEAKS FROM SPRAY VERSUS CONVENTIONAL CHILLING

	3h Cycle			6h Cycle		
Item	Conv[a]	Spray	Diff*	Conv	Spray	Diff*
Number	20	20		20	20	
WBS[b], kg	3.51	3.48	−.03	3.34	3.38	.04
Outside WBS[c], kg	3.73	3.83	.10	3.39	3.39	.00
Inside WBS[d], kg	3.26	3.13	−.13	3.29	3.36	.07

*Difference = Spray-chilled WBS - Conventional-chilled WBS.
[a]Conv = Conventional chill.
[b]WBS = Warner-Bratzler Shear.
[c]Mean of 4 cores taken from outer portion of the Longissimus Dorsi just below sub cutaneous fat and epimisial tissue.
[d]Mean of 4 cores takes from lower portion of Longissimus Dorsi just above the rib.

Table 12: EFFECTS OF CARCASS TYPE BY CYCLE LENGTH ON WARNER-BRATZLER SHEAR FORCE VALUE OF STEAKS FROM SPRAY AND CONVENTIONAL CHILLED SIDES

	Beef type						Dairy type					
	3h Cycle			6h Cycle			3h Cycle			6h Cycle		
Item	Conv[a]	Spray	Diff*	Conv	Spray	Diff*	Conv	Spray	Diff*	Conv	Spray	Diff*
Number	10	10		10	10		10	10		10	10	
WBS[b], kg	3.37	3.28	-.09	3.50	3.51	.01	3.66	3.71	.05	3.18	3.24	.06
Outside[c] WBS, kg	3.59	3.58	-.01	3.61	3.54	-.07	3.92	4.12	.20	3.18	3.24	.06
Inside[d] WBS, Kg	3.15	2.98	-.17	3.40	3.49	.09	3.39	3.28	-.11	3.18	3.24	.06

*Difference = Spray-chilled WBS - conventional-chilled WBS.
[a]Conv = Conventional Chill.
[b]WBS = Warner-Bratzler Shear.
[c]Mean of 4 cores taken from outer portion of the Longissimus Dorsi just below sub cutaneous fat and epimisial tissue.
[d]Mean of 4 cores taken from lower portion of Longissimus Doris just above the rib.

portion of the longissimus dorsi, did not effect WBS values.

Summary

Spray chilling compared to conventional chilling results in a reduction in carcass shrink during the initial 24h postmortem chilling. This reduction of shrink is sufficient to be of tremendous economic importance to high-volume slaughter plants. Spray chilling is more effective in reducing shrink when carcasses are sprayed for 6h rather than 3h. Spray chilling reduces skeletal maturity and final maturity as scored by USDA quality grading standards especially in carcasses with more advanced maturity scores. Spray chilling had a greater influence on skeletal maturity and final maturity in beef carcasses than in dairy carcasses.

Spray vs conventional chilling had no effects on cut-out weights or purge loss of closely trimmed sub-primal cuts used in this study. Also, when rib steaks from spray and conventionally-chilled sidemates were cooked there was no difference in the amount of weight lost during thawing and cooking. Tenderness of rib steaks taken from spray and conventionally-chilled sidemates as measured by Warner-Bratzler Shear values were not different.

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EFFECTS OF SPRAY CHILLING ON BEEF CARCASS YIELDS AND TRAITS, CUT-OUT YIELDS, VACUUM AGING PURGE LOSSES AND WARNER-BRATZLER SHEAR FORCE VALUES.

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Abstract

The purpose of this experiment was to determine the effects of spray chilling using two carcass types and two cycle lengths. Twenty-eight beef-type carcasses and 28 dairy-type carcasses were selected at a large commercial slaughter plant and their alternate right and left sides were allotted to a spray or conventional chilled treatment. One-half of the spray-chilled sides of each carcass type were sprayed for 3h during the initial chilling period and the remaining one-half for 6h.

Spray cycle length had a significant effect on the mean weight loss difference between spray and conventionally-chilled sidemates. The weight loss difference was greater for carcasses sprayed 6h than for those sprayed 3h, suggesting that the 6h cycle was more effective at reducing shrink. Carcass type nor the carcass type by cycle length interaction had an effect on this weight loss differences. Spray-chilled sides of this study generally lost less weight than did their sidemates that were conventionally chilled.

Carcass type had a significant (P<.01) effect on skeletal maturity. The difference between spray and conventional chilled sidemates was smaller for the dairy-type carcasses compared to the beef carcasses. Dairy carcasses were more youthful than beef-type carcasses in skeletal maturity score.

Final maturity was also significantly (P<.01) effected by carcass type. This effect was mainly due to differences in skeletal maturity as lean maturity scores were not different. Spray cycle

length or the cycle length x carcass type interaction showed no effect on 12th rib lean characteristics or any other USDA quality or yield grade traits.

Ten of the beef type sides sprayed for 6h and their conventionally chilled sidemates were fabricated and complete yield data were collected. Spray versus conventional chilling had no effect on cut-out weights nor on the purge loss of 6 major cuts after a 14d vacuum aging period.

The difference in cook losses between rib steaks from the 12th rib region, taken from spray and conventionally chilled sides were not effected by spray cycle length or by carcass type. The effects of the interaction of cycle length and carcass type on this difference was significant ($p < .05$). The difference value for steaks from the beef-type carcasses sprayed for 6h was different from those of the beef type sprayed for 3h and the dairy type sprayed for 6h, but not from those of the dairy type sprayed for 3h.

Warner-Bratzler shear force value differences were not influenced by carcass type, cycle length or by the interaction of these two.