S3P07.WP

FACTORS AFFECTING THE QUALITY AND SPOILAGE OF MEAT FROM SPRAY-CHILLED BEEF CARCASSES

G.G. GREER and S.D.M. JONES

Agriculture Canada, Lacombe Research Station, Lacombe, Alberta, Canada

Please refer to Folio 11A.

INTRODUCTION

The traditional, air-chilling of carcasses (2°C, 24 hours) has implicit economic consequences. That is, weight losses of up to 2% for beef carcasses (Allen *et al.*, 1987; Johnson *et al.*, 1988; Jones and Robertson, 1988a; 1988b) and 2.6% for pork carcasses (Jones *et al.*, 1988) have been determined. Evaporative losses in pig sides as great as 3.5% have been noted in the United Kingdom (Gigiel *et al.*, 1989).

In Canada, annual losses associated with this "shrinkage" have been estimated at 48 million dollars for chilled pork carcasses (Jones *et al.*, 1988). Losses of 32 million dollars would be expected for beef carcasses.

In an effort to abate these losses, the North American industry has developed the innovative technology termed, spray-chilling (Allen *et al.*, 1987; Jones *et al.*, 1988; Hippe *et al.*, 1991) and this practice has become commonplace in western Canadian beef processing abattoirs over the past five years.

The process constitutes an intermittent, water, spray-mist which is deposited upon the carcass surface in timed cycles during the initial four to 12 hours of chilling. Depending on cycle and spray duration, beef carcass shrinkage has been reduced by up to 1.5% after 24 hours of chilling (Allen *et al.*, 1987; Jones and Robertson, 1988a; 1988b; Greer *et al.*, 1990). Thus, the potential to completely negate shrink losses has become a reality.

Apart from the economic benefits, research was necessary to assure that spray-chilling was not detrimental to carcass and muscle quality and beef storage life. There is some evidence that spray-chill and vacuum packaging can slightly increase purge losses from beef (Allen *et al.*, 1987) and increase bacterial numbers during vacuum storage (Hippe *et al.*, 1991).

Despite evidence to the contrary (Jones and Robertson, 1988a; 1988b; Greer *et al.*, 1990) there have been complaints from beef processors of increased purge losses, undesirable appearance and accelerated spoilage, concomitant with the use of water spray-chilling in the abattoir. In view of the controversy, there was a need for additional data on some of the factors which may influence the quality and bacteriology of spray-chilled beef.

The present study was proposed to determine the effects of the duration of intermittent water sprays and vacuum storage temperature on carcass shrink, muscle quality, purge losses and the bacterial spoilage of vacuum-packaged beef. Vacuum-packaged beef was selected for study since the Canadian industry is moving towards the production of this type of product and it constitutes a storage extreme which should accentuate any deleterious effects of spray-chill.

MATERIALS AND METHODS

At 45 minutes post-slaughter and following weighing and shrouding, alternate beef carcass sides were assigned to one

of two identical coolers (1 °C, 95%rh, 0.5m/s air velocity) and subjected to two chilling treatments. The average carcass side weight was 143kg.

Control sides were air-chilled while spray-chilled sides were sprayed with an intermittent water mist at 1 °C in four, 60s cycles/h. The water spray was applied at a rate of 6.5L/min/nozzle and nozzles were spaced at 90cm intervals along the rail.

Both control and water-sprayed sides were chilled for 24-hour post-mortem (1 °C). At this time the *longissimus dorsi* (LD) muscle was removed from the rib area of each carcass for bacteriological and case life studies and the LD muscle from the loin area was removed for muscle quality measurements. Muscles were trimmed to a commercial fat layer of 5mm. Carcass sides were weighed warm on the slaughter floor, immediately prior to shrouding and following 24 hours of chilling.

To determine the effects of the duration of spray-chill, treated carcass sides were sprayed for the initial 4, 8, 12 or 16 hours of cooler storage and the temperature of vacuum storage for the packaged LD muscle was 1 °C. To determine the effects of storage temperature and spray-chill a 12-hour spray-chill interval was selected and vacuum-packaged LD muscles were stored at 1, 4, 8 or 12 °C.

Muscles were vacuum packaged using a Multivac AG1 (Simonsen Industries Ltd., Rexdale, ON, Canada) using packaging films with an oxygen transmission rate of 40-50cc/m^2/24h (Winpak Ltd., Winnipeg, MB, Canada). Vacuum-packaged LD muscles were randomly assigned to storage treatments of 2, 16, 30 or 44 days.

After each interval of vacuum storage, rib-eye steaks were cut from the LD muscle, wrapped in an oxygen permeable (8000cc/m^2/24 h) film (Goodyear Canada Ltd., Toronto, ON, Canada) and placed in a retail cabinet operating to give a meat surface temperature approximating 10 °C. The appearance and bacteriological quality of steaks was determined at display intervals of 0, 3, 5, 7 and 11 days.

Carcass traits (weight loss, temperature, pH, colour) and muscle quality (moisture, sarcomere length, shear value, weight loss) were determined by methods previously described (Jones and Robertson, 1988b).

Steaks were subjectively evaluated for appearance by an experienced five-member sensory panel and retail case life was quantified by published methods (Greer *et al.*, 1990).

Bacteriological sampling and enumeration has been described elsewhere (Greer *et al.*, 1990). Total aerobic bacteria were determined on plate count agar (Difco Laboratories, Detroit, MI, U.S.A.) after incubation at 25 °C for two days. Total anaerobic bacteria were determined on MRS agar (Difco) after anaerobic incubation at 25 °C for three days.

The significance of treatment differences were determined following analysis of variance according to the General Linear Model Procedure of the SAS Institute (1985). Carcass and muscle traits and bacterial numbers on LD muscle were analyzed in a split plot design while bacterial growth on steaks and retail case life were analyzed using a completely randomized design.

RESULTS AND DISCUSSION

The data in Table 1 show the effects of chilling treatment on beef carcass quality traits. In comparison to air-chilling, spray-chilling produced a slightly greater reduction in the temperature of the LD muscle which was statistically significant ($P \leq 0.05$) after eight and 16 hours of spray-chill only. This difference in temperature amounted to about 1 °C in the LD muscle and 2 °C in the *semitendinosus* muscle (data not shown) after 24 hours of chilling.

Chilling treatment had no significant effect ($P > 0.05$) on the ultimate pH (24 hours) at any spray duration from four to 16 hours (Table 1).

Although spray-chilling had no significant effect ($P>0.05$) upon lean colour, there were some significant changes ($P\leq0.05$) in fat colour (Table 1). Fat L* values were consistently higher on spray-chilled carcasses and this effect was significant ($P\leq0.05$) after spray-chill durations of 4, 8 and 12 hours. After 12 or 16 hours of spray-chilling, fat a* values and b* values were significantly lower ($P\leq0.05$) on spray-chilled carcasses.

Figure 1 shows the effects of spray-chill duration on carcass weight changes. The data show a positive linear relationship between 0 and 16 hours of spray-chill ($r^2=0.874$). The relationship was defined by the equation $y=-1.08+0.08x$, where y=carcass weight change (g/100g) and x=spray duration (h).

Chilling treatment had no significant effect upon percent moisture, sarcomere length, shear value or weight loss from LD muscles (data not shown). This result was similar at spray-chill durations of 4, 8, 12 and 16 hours. Similar treatment effects on carcass traits and muscle quality were found with the *semitendinosus* muscle.

The data in Table 2 show the effect of spray-chilling on bacterial numbers and retail case life. Total anaerobic bacteria found on vacuum packaged LD muscle were only significantly affected ($P\leq0.05$) by chilling treatment after 16 hours of carcass spray-chill. At this time, anaerobic populations were slightly lower on muscle from spray-chilled carcasses.

Total aerobic bacterial counts were also significantly lower ($P\leq0.05$) on retail steaks derived from vacuum packaged LD muscles after carcass spray-chill duration of 4, 8 and 12 hours.

Also in Table 2, carcass chilling treatment had no significant effect ($P>0.05$) upon the retail case life of steaks derived from vacuum packaged LD muscles. These results were confirmed at spray-chill intervals of 4, 8, 12 and 16 hours.

The results in Table 3 show the effects of chilling treatment and LD vacuum storage temperature on bacterial counts and retail case life. With the exception of the 12°C storage temperature, significantly less ($P\leq0.05$) anaerobic bacteria were found on vacuum packaged LD muscle derived from spray-chilled carcasses.

Total aerobic bacterial counts on steaks during display were only significantly affected by temperature after LD vacuum storage at 8°C, where bacterial numbers were slightly higher on steaks derived from spray-chilled carcasses.

Chilling treatment had a significant effect ($P\leq0.05$) on the case life of steaks after LD vacuum storage at temperatures of 1 and 4°C but not 8 or 12°C. At those lower storage temperatures, spray-chilling produced about a 0.5 day reduction in retail case life in comparison to air-chilling (Table 3).

Previous research, conducted under both commercial processing conditions (Jones and Robertson, 1988a) and in a research abattoir (Jones and Robertson, 1988b; Greer *et al.*, 1990) demonstrated that spray-chilling regimes of up to 12 hours had negligible deleterious effects upon carcass traits and muscle quality. The current work extends these studies by determining that water spray-chilling for periods extending to 16 hours did not effect deep muscle pH, lean colour, percent moisture, sarcomere length, shear value or weight loss during the vacuum storage of sub-primal cuts.

In a recent comparison of beef from lean and fatter carcasses, Hippe *et al.* (1991) also found that spray-chilling did not increase purge losses from vacuum-packaged top round during 10 weeks of storage.

Spray-chilling did have a limited effect on deep muscle temperature. Thus, there was about a 1°C advantage in the loin and a 2°C advantage in the round in comparison to conventional air-chilling. From a commercial perspective, a more rapid temperature decline may expedite carcass fabrication.

As found in an earlier study (Jones and Robertson, 1988b), fat colour became brighter with a higher reflectance as the spray-chilling period increased from four to 16 hours. Also, once spray-chilling exceeded 12 hours, there was a shift in a* and b* values with fat becoming more washed out with a grey appearance. Spray-chilling beyond 12 hours is therefore not recommended.

Bacterial populations found on vacuum-packaged LD muscles and retail steaks were similar for beef derived from air-

chilled or spray-chilled carcasses. These observations were independent of spray-chill duration (four to 16 hours) and vacuum storage temperature (1 to 12°C). Despite the statistical significance of some treatment differences, the magnitude of these differences was always considerably less than 1log cycle and therefore of limited practical relevance. Others have also found that spray-chilling had only marginal effects upon bacterial populations developing on vacuum-packaged beef (Hamby *et al.*, 1987; Hippe *et al.*, 1991).

The retail case life of beef was largely unaffected by chilling treatment. This was confirmed after carcass spray durations of four to 16 hours and LD vacuum storage temperatures from 1 to 12°C. These findings complement previously published data where spray-chilling in conjunction with vacuum storage did not compromise the storage life of beef (Hamby *et al.*, 1987; Greer *et al.*, 1990).

A most commercially-relevant aspect of the present study was the beneficial effects of spray-chilling upon carcass weight losses. Linear regression indicated that each one hour period (four cycles spray/h) of spray-chilling resulted in a decrease of 0.08g/100g in carcass shrinkage. In an average plant slaughtering 1000 cattle a day, spray-chilling for eight hours would reduce carcass shrinkage from 1.08 to 0.44g/100g. Assuming an average carcass weight of 320kg, spray-chilling would result in a daily shrinkage saving of 2048kg of beef valued at $7,230 per day.

CONCLUSIONS

Under the conditions defined herein, the industry could continue to use water spray-chilling for up to 12 hours (four cycles spray/h) for an economically beneficial decrease in carcass shrinkage without concern for compromising quality or increasing spoilage losses. Based on an average carcass shrinkage of 1.1g/100g, the optimum time for spray-chilling would range between eight and 12 hours to achieve low and consistent carcass shrinkages.

ACKNOWLEDGEMENTS

The authors are grateful for the financial assistance of the Alberta Agriculture Farming for the Future Research Program. The technical assistance of Wayne Robertson and Bryan Dilts and the clerical assistance of Julie Smith and Anna Alexander are also appreciated.

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Table 1. The effect of spray-chill duration on beef carcass traits[1].

Spray/chill duration (h); Treatment	Temp. (°C)	pH	Lean colour L*	a*	b*
4h					
Conventional	6.2	5.50	36.3	21.7	9.0
Spray	5.7	5.50	36.9	21.8	9.1
P	0.052	0.848	0.221	0.887	0.803
8h					
Conventional	7.5	5.55	36.6	22.8	9.9
Spray	6.3	5.61	36.1	22.2	9.9
P	0.003	0.093	0.387	0.453	0.938
12h					
Conventional	3.6	5.57	36.0	20.6	9.2
Spray	3.2	5.58	35.8	19.4	8.3
P	0.090	0.791	0.889	0.483	0.464
16h					
Conventional	4.1	5.64	34.9	22.5	10.1
Spray	3.0	5.66	34.6	22.0	9.7
P	0.003	0.541	0.889	0.211	0.501

Spray/chill duration (h); Treatment	Temp. (°C)	pH	Fat colour L*	a*	b*
4h					
Conventional	6.2	5.50	68.5	4.5	11.7
Spray	5.7	5.50	75.6	5.0	12.2
P	0.052	0.848	0.007	0.618	0.150
8h					
Conventional	7.5	5.55	64.1	4.9	11.0
Spray	6.3	5.61	77.2	2.2	10.1
P	0.003	0.093	0.029	0.219	0.336
12h					
Conventional	3.6	5.57	73.7	5.0	12.5
Spray	3.2	5.58	79.9	1.0	9.6
P	0.090	0.791	0.042	0.038	0.010
16h					
Conventional	4.1	5.64	72.8	4.3	12.8
Spray	3.0	5.66	81.6	0.6	10.1
P	0.003	0.541	0.074	0.0004	0.042

[1] All measurements taken on *longissimus dorsi* muscle after 24 hours of post-mortem chilling at 1°C. Data are least squares means for 10 alternate carcass sides.

Table 2. The effect of spray-chill duration on bacteriology and beef case life[1].

Spray/chill duration (h); Treatment	Anaerobic bacteria on LD (log CFU/cm^2)2	Anaerobic bacteria on steaks (log CFU/cm^2)[3]	Retail case life (d)[4]
4h			
Conventional	2.64	4.77	4.8
Spray	2.86	5.42	3.8
P	0.209	0.001	0.087
8h			
Conventional	2.66	6.58	4.1
Spray	2.85	6.32	3.6
P	0.122	0.003	0.085
12h			
Conventional	4.93	6.91	3.3
Spray	4.85	6.66	3.0
P	0.565	0.006	0.199
16h			
Conventional	5.65	6.98	3.9
Spray	5.35	6.89	3.3
P	0.001	0.236	0.312

[1] Data are least squares means.
[2] Ten *longissimus dorsi* (LD) muscles pooled over four vacuum storage times.
[3] Five rib-eye steaks pooled over four vacuum storage times and five display times.
[4] Five rib-eye steaks pooled over four vacuum storage times.

Table 3. The effect of vacuum storage temperature and spray-chill on bacteriology and beef case life[1].

Storage temperature; Treatment	Anaerobic bacteria on LD (log CFU/cm^2)[2]	Anaerobic bacteria on steaks (log CFU/cm^2)[3]	Retail case life (d)[4]
1°C			
Conventional	5.69	7.00	2.9
Spray	5.40	6.97	2.5
P	0.009	0.898	0.016
4°C			
Conventional	4.45	6.82	3.8
Spray	4.18	6.94	3.3
P	0.010	0.108	0.012
8°C			
Conventional	5.51	6.12	4.4
Spray	5.02	6.75	3.7
P	0.001	0.001	0.102
12°C			
Conventional	6.49	7.05	2.2
Spray	6.46	7.05	2.5
P	0.810	0.999	0.069

[1] Data are least squares means and spray duration was 12 hours.
[2] Ten *longissimus dorsi* (LD) muscles pooled over four vacuum storage times.
[3] Five rib-eye steaks pooled over four vacuum storage times and five display times.
[4] Five rib eye steaks pooled over four vacuum storage times.