The Effects of Rigor Temperature, Electrical Stimulation, Storage Duration and Packaging Systems on Drip Loss in Beef

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INTRODUCTION

Evaporation and drip loss during carcass chilling accounts for an approximately 3% reduction in carcass weight. This loss can be considere a reduction in potential profit. The subsequent formation of drip in retail packaging is unsightly and reduces the sales appeal of the product (Mal and James, 1983), and represents a portion of the product that cannot be used by the consumer. The amount of drip loss from meat is influenc by several factors including the shape of the sample, treatment before the onset of rigor, temperature and duration of storage and the intact structu of cell membranes (Honikel, 1988). Other factors such as pre-slaughter animal stress (Malton and James, 1983), electrical stimulation, process and packaging can also effect the amount of drip loss from a meat cut. A series of three trials was conducted: (a) to assess the effects of electri stimulation, temperature during rigor onset, packaging systems and storage times on drip loss from hot-boned beef *muscularis longissi lumborum* (LL); (b) to confirm with cold-boned beef LLs that elimination of the vacuum cycle from a packaging system would reduce drip los and (c) to investigate the apparent disparity in drip loss reduction achieved with non-vacuum packaging of hot- and cold-boned beef arising fro trial (b).

MATERIALS AND METHODS

(a) Effect of electrical stimulation, rigor temperature and packaging system

Prime beef LLs were obtained from a local hot-boning plant. Animals were stunned with a captive bolt and bled by a thoracic stick. The dress carcases were split and one side was electrically stimulated (1130 V peak, 2 A peak, 14.28 alternating pulses per s) for 60 s within 15 min slaughter. The unstimulated side was used as a control. The LLs were removed (hot-boned) within 30 min of slaughter, so the muscle temperatu could be controlled as the muscles entered rigor. Each LL was wrapped in a polyethylene bag and placed at either 5, 10 or 25°C for 48, 32 or hours respectively, to enter rigor. Following rigor onset, samples were placed at 2°C until all had attained rigor. The LLs were then divided into four pieces, weighed, and the pieces were either placed into a polyethylene bag (overwrapped) or were packag using a standard vacuum system or a standard saturated carbon dioxide controlled atmosphere system which involves a vacuum cycle (CA Samples were stored at -1.5°C for various times up to 4 weeks. After storage, the samples were gently blotted dry with paper towels and weigh

(b) Non-vacuum packaging of cold-boned beef LLs

Cold-boned LLs were obtained from a local processor. Although these LLs had been processed in accordance with the processor's norm procedures, no information was available concerning the temperature at rigor onset. The LLs were divided into six pieces, which were weigh and packaged in foil laminate bags using either a vacuum system or a novel non-vacuum system. Briefly, a simple water immersion procedu was used to expel air from the packs, which contained a proprietary oxygen absorber to remove any residual oxygen, immediately before sealin All packs were stored at -1.5°C for 4 weeks. Following storage, the samples were blotted dry with paper towels and weighed.

(c) Non-vacuum packaging of hot- and cold-boned beef LLs

For the hot-boned samples, unstimulated LLs, obtained from a local processor, were divided into six pieces, which were weighed and placed into polyethylene bags at either 10, 25 or 37°C for 24, 20, and 8 hours respectively to enter rigor. Unstimulated LLs were used in this experiment to allow time to manipulate the rigor temperature. After rigor onset, samples were transferred to 2°C until all had attained rigor. Before packaging, the samples were blotted dry with paper towels and weighed. The samples were packaged in foil laminate bags using either a vacuum system or our non-vacuum system. For cold-boned samples, LLs were obtained from the same commercial processor as in (b), but their temperature and pH were monitored during cooling. The LLs were divided into six pieces, which were weighed, packaged and stored as described in (b). After storage both hot- and cold-boned samples were blotted dry with paper towels and weighed. Also, after 4 weeks storage, the tenderness of the samples was determined by cooking the meat to 75°C, chilling it on ice, then shearing 1cm x 1cm cross section samples with a MIRINZ tenderometer. Tenderness was expressed in kgF.

RESULTS AND DISCUSSION

(a) Effect of electrical stimulation, rigor temperature and packaging system

In this multifactorial trial, meat derived from the electrically stimulated sides had significantly less ($p<0.05$) total drip loss (2.3%, mean of drip loss for all rigor temperatures and packaging treatments), than samples from non-stimulated sides (2.6%). Rigor temperature had a significant effect ($p<0.001$) on drip loss, with samples held at 5°C having less drip loss (1.6%) than those held at 10°C (2.5%) and 25°C (3.3%). This positive effect of electrical stimulation is likely to arise from shorter protein denaturation potential for stimulated muscle which entered rigor early when the temperatures are controlled. The packaging system had a significant effect ($p<0.05$) on the amount of drip produced, with the drip loss from overwrapped samples (1.6%) being lower than that from either the vacuum (2.8%) or CAP (3.0%) samples. Drip loss increased with storage time, with differences becoming significant ($P<0.05$) after 4 weeks of storage. These results suggest that drip loss would be minimised by low rigor temperature and by packaging systems that do not include drawing a vacuum. From these baseline measurements, we investigated the factors influencing drip loss due to packaging. In these experiments (not shown), we found that versions of a non-vacuum packaging system could significantly reduced drip loss in beef LL, while still giving a shelf-life of up to 16 weeks and maintaining a comparable meat quality, as compared to the CAP and vacuum systems.

(b) Non-vacuum packaging of cold-boned beef LLs

Using commercial cold-boned LLs for which the processing conditions were unknown (Table 1), there was no difference in total drip loss between conventional vacuum and non-vacuum processes after 4 weeks storage at -1.5°C. Surprising and disappointing as this result was, attention was drawn not just to packaging, but to the entire meat production process. The unknown in this trial was the temperature at which the meat went into rigor, which was demonstrated in the previous trial to have a marked influence on total drip loss.

(c) Non-vacuum packaging of hot- and cold-boned beef LLs

Temperature and pH measurements of cooling beef sides indicated that the cold-boned LLs went into rigor in approximately 5 hours at a temperature of 15°C, producing tender meat (4.1 kgF). These samples showed significant differences ($p<0.05$) in the amount of drip loss using the two packaging systems, with the non-vacuum system producing less drip (Table 1). However, there was a significant ($p<0.05$) inter-animal variation, with some samples having smaller differentials between the two packaging processes. Nevertheless without exception, the non-vacuum process produced the lower amount of drip for each animal. We interpret this inter-animal variation situation as arising in part from much larger variations in temperature across various parts of the carcass to influence the LL muscle temperature The samples from the unknown processing conditions (trial b) had higher levels of drip loss than those we found with cold-boned meat that went into rigor at 15°C (trial c). However, according to the meat plant, the processing conditions in trials (b) and (c) were the same, with the animals being electrically stunned, then immobilised by applying a current, totalling 14 s and then further stimulated for up to 20 s. The carcasses were dressed in a 10°C processing room, then the carcasses were put into a 4°C chiller with low air velocity, to produce a pH of less than 6.0 in about 3 hours post-slaughter. In the repeat trial, these conditions produced a rigor temperature of 15°C and subsequently a lower drip loss than for the previous samples. The drip loss from the unknown processing conditions was quite high, and we suggest that these samples went into rigor at a higher temperature, perhaps above 25°C, due to different processing conditions, such as electrical input, chain speed and chilling rate. Even so, the effect of animal/carcass cooling variation cannot be ruled out as one factor resulting in the lack of packaging effect in trial (b).

For the hot-boned samples (Table 1), rigor drip loss was significantly ($p<0.001$) higher when the samples were held at 37°C during rigor onset than for the 10 or 25°C samples. Although, the 25°C samples had higher rigor drip than the 10°C samples, the difference was not statistically significant. Drip loss during storage (packaging drip) was significantly ($p<0.05$) lower in those samples packaged using the non-vacuum system than those using the vacuum system (Table 1). For total drip loss from samples (the sum of rigor, packaging and storage loss), there were significant ($p<0.05$) effects for both rigor temperature and packaging system (Table 1), with the 37°C vacuum packed samples having the greatest total drip loss and the 10°C non-vacuum samples having the least. The deleterious effects of drip are also mirrored in the ultimate tenderness reached after 4 weeks storage (aging): hot-boned muscle that entered rigor at 10°C was much more tender (3.5 kgF) than muscle going into rigor at higher temperatures (5.0 kgF at 25°C and 7.3 kgF at 37°C). This effect was independent of hot- or cold-boning, although shortening effects can result in a further increase in toughness at high temperatures (Devine *et al.*, 1996).

If the meat is subjected to high temperatures during rigor onset, it will lose more drip than meat entering rigor at lower temperatures. Thus, processing factors such as electrical stimulation and chilling rates need to be controlled both to ensure a consistent product and to reduce drip loss. Non-vacuum packaging systems can only consistently reduce the amount of drip loss during storage if the meat has been processed appropriately in respect to electrical stimulation and rigor temperature. The packaging system can do little to reduce drip loss that has been ordained by inappropriate pre-packaging processing. The best that a packaging system can do is not to exacerbate the situation and minimise the amount of drip loss during storage. We have shown that vacuum-based packaging systems increase the amount drip loss and that non-vacuum systems can reduce this loss while maintaining meat quality and product safety. Further experimentation is, however, required to confirm that our non-vacuum process works consistently in reducing drip loss with cold-boned meat. Nevertheless, our non-vacuum system is certainly no worse than existing systems and is simpler, requiring less mechanical input. If commercialised, it is likely to be both less expensive and easier to operate than either conventional vacuum or carbon dioxide packaging systems.

CONCLUSION

Many factors influence the amount of drip loss from meat. While some factors are unavoidable and their effects cannot be modified, such as storage time, other factors can be controlled to minimise their effects on drip loss. High rigor temperature has a major detrimental effect on both drip loss and tenderness, but can be controlled through electrical stimulation and chilling regime. Packaging system selection can minimise drip loss. However, if non-packaging processing factors are not controlled to minimise their adverse effects, it is unrealistic to expect a packaging system to restrict drip loss to a low level. In this situation, the best that can be expected of a packaging system is that it will not exacerbate the inherent drip loss problem. The optimum rigor temperature appears to be between 10°C and 15°C in respect to both minimising drip loss and assuring tenderness.

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Table 1: Effects of Processing, Rigor Temperature and Packaging on Drip Loss From Beef LL Stored for 4 Weeks at -1.5°C.

Processing	Rigor temperature (°C)	Rigor drip†# (%)	Packaging drip (%) Vacuum	Packaging drip (%) Non-vacuum	Total drip†¥ (%) Vacuum	Total drip†¥ (%) Non-vacuum
Cold-boned	Unknown	na	na	na	5.5±0.7	5.5±0.2
Cold-boned	15	na	na	na	4.1±0.2	3.1±0.2
Hot-boned	10	1.3±0.1	3.1±0.2	2.7±0.2	4.9±0.2	3.5±0.2
Hot-boned	25	1.6±0.1	4.4±0.2	3.5±0.2	5.9±0.2	5.1±0.2
Hot-boned	37	4.8±0.1	4.2±0.2	2.9±0.2	9.0±0.2	7.4±0.2

† - % drip loss mean ± s.e.m., # - rigor drip loss is calculated for all samples at each rigor temperature, ¥ - total drip loss was calculated from the difference in prerigor and post-packaging weights, na - not available due to cold-boning process