Musk Ox Harvest: Ensuring Consistent Meat Quality

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Introduction

The development of viable industries to provide employment for Inuvialuit in Canada's far north is socially and economically desirable. The world's largest population of musk oxen (*Ovibos moschatus*, Figure 1), estimated at 65,000 breeding animals, exists on Banks Island, NT. That population may provide an opportunity to supply unique products to the world. The inner wool or qiviut of musk oxen, which is finer than cashmere and eight times warmer, weight for weight, than lamb's wool, is a highly prized and valuable product used for making garments. There is an established market eager for qiviut, and harvesting of some animals is seen as a management tool to provide a balanced, healthy environment for the animals as well as other species on the island. However, to develop sustainable markets for musk ox meat, a consistently high quality product is essential. Agriculture and Agri-Food Canada researchers from the Lacombe Research Centre have been involved in a multi-year program to assist in the development of *ante mortem* and *post mortem* protocols to maximize animal welfare and ensure consistently high meat quality. For that work, travel to Sachs Harbour, the only habitation on the island, has been necessary. The work has been undertaken in collaboration with the Inuvialuit Development Corporation's Musk Ox Harvest Team, the NT Department of Resources Wildlife and Economic Development, and the people of Sachs Harbour. This report discusses a couple of concerns researchers had with the commercial musk ox harvest and some of the work undertaken to address those concerns in a study completed in 2002.

Unique concerns

The harvest of musk oxen at Sachs Harbour during winter months entails the slaughter and processing of animals in a tent, followed by the outdoor chilling of dressed carcasses, consequently, carcass cooling rates far exceed those typical for carcasses from domestic species, at commercial slaughtering plants. Under these circumstances there are two phenomena, both well documented in scientific literature, which may have a profound influence on the ultimate quality of the meat. One is cold toughening, which may result from cold shortening of the myofibrils and/or rapid activation and inactivation (degradation) of calpains, the calcium-dependent enzymes that are largely responsible for *post mortem* proteolysis leading to tenderization. Muscle which has been toughened by cold shortening undergoes little or no tenderization during subsequent aging.. The rate of temperature decline is so severe as to freeze the muscles of the carcasses early in the pre-rigor state. That is, freezing occurs before *post mortem* glycolysis has been allowed to go to completion and ATP depletion has proceeded to the point of loss of extensibility of the muscle. That can lead to the second phenomenon of muscle shortening and toughening brought about by the development of rigor during thawing. While much of the work done on cold shortening and thaw shortening phenomena has been completed on excised beef or lamb muscle, it has been demonstrated that both cold shortening and thaw shortening are independently capable of producing excessive toughness in intact lamb carcasses. Other work has shown that in blast-frozen lamb the effects of cold shortening and thaw shortening "can be cumulative and devastating to tenderness" (Locker, 1985).

Cold shortening

Cold shortening in beef can be avoided by ensuring the muscle is not cooled below 10°C during the first 10 h after slaughter while the pH is still relatively high, i.e. pH>6.0. The severity of cold shortening is pH dependent, being greater at the higher pH levels which can occur with fast chilling rates. However, in the musk ox harvest on Banks Island the carcasses are subjected to extremely fast cooling rates which freeze the muscles at an early stage of rigor development while there are still relatively high levels of muscle glycogen and ATP. In two early trials (November, 1997 and February, 2001) it was observed that carcass sides were beginning to freeze solid within 2 h of the start of chilling (less than 3 h *post mortem*). Where very high rates of heat extraction can be achieved, meat can be frozen fast enough to prevent cold shortening. When musk oxen carcasses were suspended in blowing air at -30 to -35°C, as in the current study, the rate of chilling in the longissimus muscle of the back was so rapid that the time the muscle was in the "cold-shortening zone" (10°C to -2°C) was too short for substantive shortening to occur. Research has demonstrated that cold shortening in pre-rigor lamb carcasses could be prevented by freezing carcasses very rapidly in less than 4 hours. Experimentation with ultra-rapid chilling of lamb carcasses has produced tender loins. The system used was to chill the lamb carcasses for 3.5 h at -20°C with an air speed of 1.5 m/s followed by 7 days of aging. The mechanism for preventing cold toughening by ultra-rapid chilling proposed was that skeletal restraint was imposed by crust hardening of the outer surface of the carcass. However, crust hardening may not be solely responsible for production of tender longissimus muscle by ultra-rapid chilling and the mechanism has not been fully elucidated. Shear values obtained for longissimus samples thawed so as to prevent shortening due to thaw rigor indicated that cold toughening was not a significant factor in the current trial.

Thaw shortening

When pre-rigor muscle is frozen below about -20°C, utilization of glycogen and depletion of ATP with consequent development of rigor mortis are arrested. Upon thawing, rigor development (thaw rigor) will proceed rapidly, generally accompanied by intense, irreversible shortening (thaw shortening)..The rate of rigor development is known to affect the tenderness/toughness of meat. The rate of thawing critically affects the rate of development of rigor mortis and the extent of contraction. The rate of rigor development in thawing muscle also affects the recoverable activity of μ-calpain, loss of m-calpain and, consequently, the extent of post-thaw aging of pre-rigor frozen muscle. Rapid rigor and severe contraction may occur when pre-rigor frozen muscle is thawed above 0°C. Below 0°C, the rate of development of rigor mortis actually increases to a maximum at about -3°C. However at temperatures just below 0°C, even though rigor proceeds rapidly, the presence of ice prevents contraction. At lower temperatures, the rate of rigor development declines rapidly and is arrested below about -20°C. Pre-rigor frozen lamb benefits from post-thaw aging by subsequent storage at 4°C for up to 7 d. Consequently, in this experiment, different thawing/aging combinations were investigated to determine the most efficacious system for reducing shear values and variability in tenderness of pre-rigor frozen musk ox meat. The results can be summarized as follows:

1) Cooking pre-rigor frozen musk ox longissimus muscle directly from the frozen state without thawing or rapid thawing over 25 min resulted in severe shrinkage, sample contortion (Figure 2), and excessive loss of moisture, and was detrimental to the quality (decreased tenderness) of the cooked product. Both the average shear value (Table 1) and the frequency of tough or probably tough cores were higher for samples thawed rapidly either by direct cooking or immersion in warm water compared to all other thawing/aging treatments. Decreased tenderness is likely caused by contraction during development of thaw rigor, lack of post-thaw conditioning, and loss of moisture. The average purge loss in steaks thawed rapidly (35 min in warm water) was 13.4%, ranging from 7.2% to as high as 19.5% of the original weight of the frozen steak. In contrast, purge loss in steaks thawed for approximately 23 h at 2°C was less than 3% on average. Shortening to 50% to 72% of initial length and distortion following thawing of pre-rigor frozen muscle, along with high drip production, has been reported by other researchers. The degree of shortening and amount of drip is dependent on the muscle pH at the time of freezing.

2) Thawing musk ox longissimus muscle at ei-

ther -1.5 or 2°C combined with some additional post-thaw aging reduced average shear values by 1.5 kg and decreased within-sample variation as compared with rapid thawing (Table 1). All slow thawing treatments reduced non-conformity (tough or probably tough samples) to less than 5%. The expected benefit to tenderness of slowly thawing (-1.5°C) pre-rigor frozen muscle compared to a more moderate thawing regime (+2°C) was not realized. The purpose of the very slow thawing is to allow for the depletion of ATP while the muscle is still rigid enough, because of the ice crystals present, to prevent thaw contraction: and, to prevent the loss of activity of the calpains responsible for *post mortem* proteolysis. It is likely that the thawing of our steak samples at 2°C was in itself sufficiently slow to prevent thaw shortening. The extensive shrinkage and excessive thaw purge observed in rapidly thawed samples was not manifest in samples thawed at 2°C. In contrast, when earlier researchers froze strips of lamb longissimus muscle without delay and then thawed them at 16-20°C, they observed an average shortening of 72% with a 27% drip. However, when the frozen muscle was thawed at -3°C for 4 d, it did not shorten or exude significant drip.

3) Post-thaw aging of pre-rigor frozen musk ox muscle was effective in reducing average shear value and within animal variation in tenderness (Table 1) compared to cooking directly from the frozen state, cooking rapidly thawed samples or cooking samples thawed for 1d without further aging. Similarly, pre-rigor frozen beef diaphragm muscle which had been thawed at -3°C further decreased in toughness when aged at 4°C for 5 days. The mean shear force value for striploins from pre-rigor frozen lamb carcasses also improved after storage of the carcasses for 2 to 7 days at 4°C.

Conclusion

Results obtained in this study indicate that, provided the ultra-rapid chilling of musk ox carcasses is fast enough to prevent cold toughening, and the conditions of thawing and post-thaw aging are carefully controlled so as to avoid the potentially severe contraction of thaw rigor and provide some degree of conditioning, it is possible to produce consistently tender meat within current commercial musk ox harvest practices. Recommended temperatures for thawing of pre-rigor frozen musk ox are 0 to 2°C. Temperatures much above this may lead to thaw rigor contraction and toughening. Holding the meat at this temperature for 3 to 7 d would improve tenderness and reduce variability in the texture of the cooked product.

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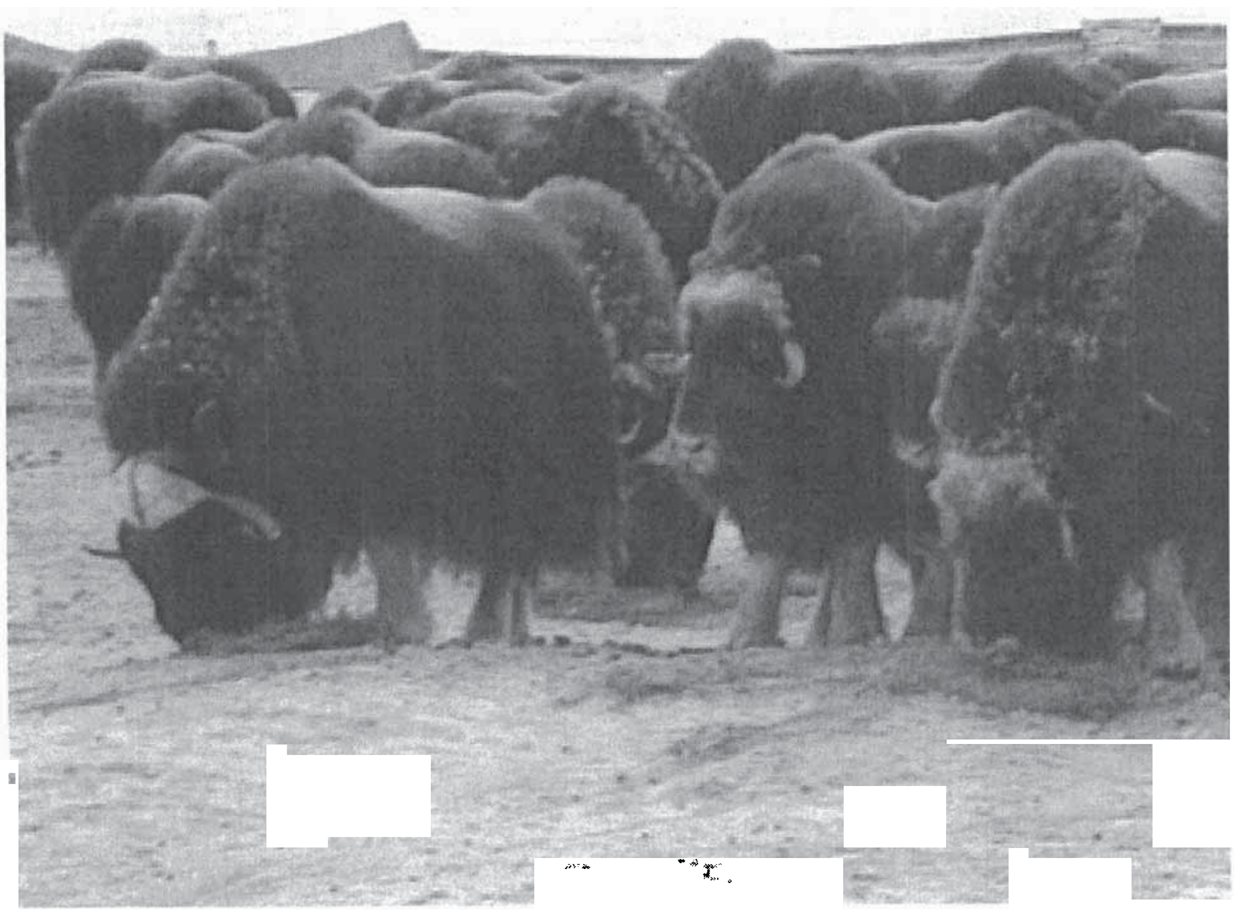

Figure 1: Musk-ox (*Ovibus moschatus*) feeding

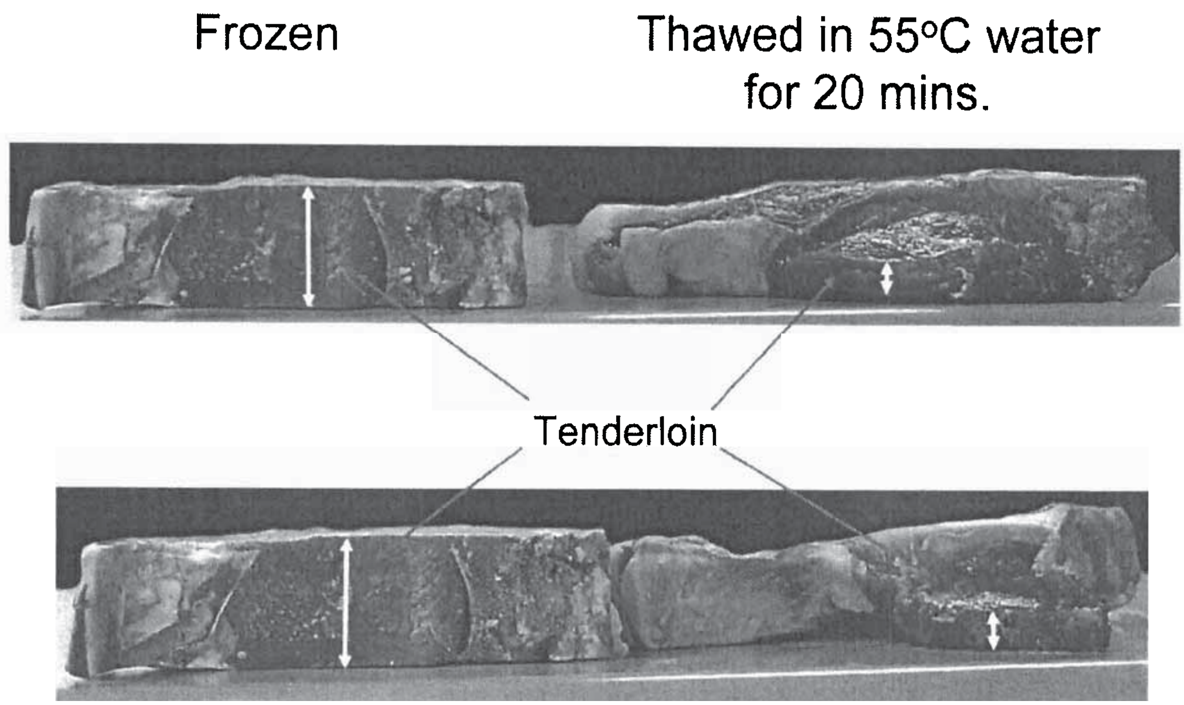

Figure 2: Shrinkage of 1" thick muscle, on rapid thawing

Table 1. Effect of thawing/aging treatments of pre-rigor frozen musk ox longissimus muscle on average shear value; and frequencies of tough or probably tough steaks[1]

Thawing temperature /aging treatment (days)	Average shear (kg)	Variation (Std. deviation)	% Tough or Probably Tough
NT or rapid thawing[2]/0 d	7.090*c*	2.021*c*	
2°C, 1 d	6.179*b*	1.640*b*	
2°C, 3 d	5.528*a*	1.292*a*	1.2
2°C, 7 d	5.390*a*	1.420*ab*	4.9
-1.5°C, 5 d	5.487*a*	1.225*a*	1.2
-1.5C, 8 d	5.680*a*	1.301*a*	4.9

[1] Tenderness categories based on beef shear value categories established by Aalhus *et al.* (2002).
[2] NT, Not Thawed or Thawed for 25 min in warm water with a starting temperature of 55°C.
a,b,c Means by column with unlike letters are significantly different ($P<0.05$).