PE4.87 Ageing Prior to Freezing Improves Waterholding Capacity in Beef and Venison 310.00

Mustafa Farouk (1) mustafa.farouk@agresearch.co.nz, Eva Wiklund(1), Adam Stuart 1, Peter Dobbie 1
(1)AgResearch MIRINZ

***Abstract* — This study tests the hypothesis that the waterholding capacity of frozen meat can be improved by ageing the meat prior to freezing. Beef *M. semimembranosus*, and beef and venison *M. longissimus dorsi et lumborum* were each divided into four portions and assigned to four ageing times: 0 (48 h post-mortem), 1, 3 and 9 (chilled-never-frozen) weeks prior to freezing, thawing and analyses. Purge, drip, and drying losses and exudates decreased with increased ageing time prior to freezing ($P < 0.01$). No significant changes were observed in cook loss and total moisture (purge loss + cook loss) loss due to ageing time. Moisture losses were lower in venison relative to beef. The improvement in waterholding capacity with ageing was attributed to the breakdown of meat structure post-rigor. Result in this study proves the hypothesis that the waterholding capacity of meat can be improved by ageing the meat until the meat structure has substantially broken down before the meat is frozen. The implications of the results have been discussed.**

Authors are with AgResearch MIRINZ, Ruakura Research Centre, Private Bag 3123, Hamilton 3240, New Zealand
*corresponding author; Phone: 64 7 838 5260; fax: 64 7 838 5625; e-mail: mustafa.farouk@agresearch.co.nz.

***Index Terms*— meat ageing, waterholding capacity. beef, venison**

I. INTRODUCTION

Meat is composed of about 75% water; the bulk of the water is held either within the myofibrils, between the myofibrils, between the myofibrils and the cell membrane (sarcolemma), between muscle cells or between muscle bundles [1]. The retention of this water throughout the supply chain is a measure of the eating and processing quality of meat. The ability of chilled meat to hold water (usually called waterholding capacity) is one reason it currently attracts a premium price over frozen meat. AC&A (accelerated conditioned and aged) meat is frozen within 48 h of slaughter [2]. The superiority of chilled-never-frozen (CNF) meat over AC&A meat in terms of waterholding ability could be due to the latter having a more intact muscle structure and thus more defined channels for moisture loss relative to the former [1]. Previous lamb [3] and beef (unpublished) storage studies in our laboratory indicate that meat waterholding capacity improves with long term chilled storage; the improvement was attributed to the breakdown of the muscle structure resulting in the disruption of the channels through which meat water could be lost. This study is part of a wider study designed to test the hypothesis that ageing of meat prior to freezing will narrow or eliminate the difference in the quality, including moisture loss, between chilled and AC&A meat.

II. MATERIALS AND METHODS

Two separate studies were conducted to determine the effect of ageing prior to freezing on the waterholding capacity of meat: (A) Used beef *M. semimembranosus*, (B) Compared beef and venison *M. longissimus dorsi et lumborum*. The meat samples were collected according to the following protocols:

A. Beef M. semimebranosus (SM)

Twelve young bulls (age 2-3 years) were included in the study. The animals were slaughtered according to standard procedure at a New Zealand beef export processing plant. All carcasses at this plant are hot-boned within 1 h post-mortem [4]. Meat samples (both SM muscles from each animal) were collected at boning and then transported chilled to AgResearch MIRINZ, stored at 10°C until in *rigor* and then transferred to 2°C. At 2 days post-mortem, the SM were cut in half and the resulting four sub-samples from each animal were weighed and then randomly assigned to one of the following four treatments: 1 = chilled storage at -1.5°C for 9 weeks, 2 = frozen storage at -18°C for 9 weeks, 3 = chilled storage at -1.5°C for 1 week then frozen storage at -18°C for 8 weeks, 4 = chilled storage at -1.5°C for 3 weeks then frozen storage at -18°C for 6 weeks.

B. Beef & venison M. longissimus dorsi et lumborum (LDL)

Eight young bulls (age 2-3 years) and eight red deer (*Cervus elaphus*) stags (< 2 years) were included in the study. The bulls were slaughtered according to standard procedure at a New Zealand beef export processing plant. All carcasses at this plant are hot-boned within 1 h post-mortem[4]. The deer were slaughtered according to standard procedure at a New Zealand specialized deer slaughter facility approved for

export. The deer carcasses were kept for approximately 6 hrs post-mortem at 10°C and then chilled down to 1°C. Carcasses were boned out 1 day post-mortem.

The beef samples (left-side LDL) were collected at hot-boning and transported chilled to AgResearch MIRINZ, stored at 10°C until in *rigor* and then transferred to 2°C. Venison samples (left-side LDL) were collected at boning 1 day post-mortem and transported chilled to AgResearch MIRINZ.

At 2 days post-mortem, all LDL samples (beef and venison) were cut into four pieces and the 4 sub-samples from each animal were weighed and then randomly assigned to one of four treatments; 1 = chilled storage at -1.5°C for 9 weeks, 2 = frozen storage at -18°C for 9 weeks, 3 = chilled storage at -1.5°C for 1 week then frozen storage at -18°C for 8 weeks and 4 = chilled storage at -1.5°C for 3 weeks then frozen storage at -18°C for 6 weeks.

All frozen samples were thawed at 2°C for 48 hours after the 9 weeks storage period.

C. pH

pH of the samples was measured after the 9 week storage period by inserting a calibrated pH probe (Mettler Toledo MP 125 pH meter with an Inlab 427 probe) directly into the meat. Duplicate readings were taken for analysis of each sample.

D. Moisture loss

Chilled and thawed beef and venison samples were removed from their packages, dabbed dry with a paper towel and then weighed.

E. Purge and thaw loss

Purge/thaw losses were calculated as the difference in the weight of the samples before and after vacuum packaging, storage and thawing expressed as a percentage of the original weight of the samples before packaging.

F. Drip loss

The Honikel bag method [5] was used to gravimetrically measure drip loss as an indication of waterholding capacity of meat. Samples approximately 100g were cut, weighed, suspended in a netting suspended over a plastic dish and then stored at 4°C for 48 h, removed from the netting, dabbed dry with a paper towel, and then weighed. Drip loss was calculated as the difference in the weight of the samples before and after storage expressed as a percentage of the original weight of the samples before storage.

G. Drying loss

Samples were sliced into 40mm x 40mm x 5mm (thick) slices, dried at 62°C in a Marford controlled temperature oven (C.W. Martin & Co. Ltd. Wellington, New Zealand) for 3 h, and then removed from the oven and weighed. Drying loss was calculated as the weight of the moisture lost during drying expressed as a percentage of the weight of slices before drying.

H. Cook loss and shear force measurements

Samples were cooked in a waterbath set at 95°C to an internal temperature of 75°C (measured by thermocouples) and then immediately placed in ice-water slurry. The weight of the meat was recorded before and after cooking. After cooking the meat samples were blotted dry and re-weighed. The cook loss was calculated as weight lost expressed as a percentage of the original sample weight. Shear force was measured using a MIRINZ Tenderometer. Once cooled, 10mm x 10 mm cross section samples (n=10 from each sample) were cut out from the cooked meat samples and sheared with the MIRINZ Tenderometer. The results were expressed as shear force (kgF).

Exudates = purge loss + drip loss

Total moisture loss = purge/thaw loss + cook loss

I. Statistical analysis

The designs for both studies were randomised block. The first study consisted of 12 animals. The two SM muscles from each animal were divided into two parts and the 4 subsamples from each animal were allocated to the 4 ageing times so that treatments and positions were as balanced as possible. For all data, the only significant positional effect was 'end of muscle', so data were analysed using the ANOVA directive of GenStat [6]. The second study consisted of 8 stags and 8 bulls. The left LDL muscle from each carcass was excised and each divided in 4 pieces. The 4 subsamples from each animal were then allocated to the ageing times. One animal was excluded from the analysis due to high pH. Data were analysed using the REML directive of GenStat [6]. Both species were included in the same analysis for all data except shear force, for which there was too great a difference between species.

III. RESULTS AND DISCUSSION

1. Effect of ageing time prior to freezing on pH and moisture loss in beef SM

The pH of beef SM did not change significantly ($P > 0.05$) with ageing time prior to freezing (Figure 1). Thus, any difference observed in the waterholding capacity of the meat with ageing time could not be pH related. Purge, drip and exudates losses in beef SM decreased linearly ($P < 0.001$) with the time of ageing prior to freezing (Figures 1a and b). In other words, the longer the meat was aged or held at chilled temperatures before being frozen and thawed, the less moisture was lost from that meat in the form of purge due to vacuum pressure or as drip due to the force of gravity. The least amount of moisture was lost in samples that were chilled-never-frozen compared to the frozen. This was expected as freezing of meat on its own causes higher moisture loss relative to chilling [7]. Nevertheless, within the frozen samples, thaw loss decreased with ageing time before freezing, indicating that the freezing process and the structural changes associated with it did not neutralize the positive effect ageing prior to freezing had on the waterholding capacity of the meat. The amount of moisture lost on drying did not differ with ageing time (Figure 1b). However, when frozen samples alone were compared, moisture loss on drying decreased significantly ($P < 0.001$) with ageing prior to freezing. There was no effect ($P > 0.05$) of ageing time on cook loss or total moisture loss (purge + cook loss, Figure 1b).

2. Effect of ageing time prior to freezing on pH and moisture loss in beef and venison LDL

Beef had higher ($P < 0.001$) pH at all the ageing periods compared to venison (Figure 2a). Ageing prior to freezing had no effect on the pH of beef and venison LDL (Figure 2a) for similar reasons as observed in the first study on beef SM. Purge/thaw loss was lower ($p < 0.03$) while drip loss ($P < 0.001$), exudates ($P < 0.03$) and cook loss were higher in beef relative to venison. The higher pH in beef relative to venison did not overall translate into a higher waterholding capacity. There were interactions between specie and ageing time for the moisture losses determined in this study ($P < 0.01$). Purge loss decreased in beef with ageing time while it decreased in the first three periods and then significantly increased in the fourth period in chilled-never-frozen venison (Figure 2a). Drip loss decreased with ageing time in meat from both species but the decrease was more pronounced in beef relative to venison (Figure 2b). Exudates (not shown) in beef decreased linearly with ageing time while in venison it decreased linearly in the first three periods then reached a plateau with no difference observed in exudates from venison aged for three weeks then frozen and CNF venison. As observed with beef SM, ageing time did not affect the cook loss or total moisture loss in meat from both species.

3. Basis for the improved waterholding capacity of aged meat

The improvement in the waterholding capacity of meat from the two muscles and meat species with ageing time prior to freezing – as determined by the moisture losses associated with vacuum pressure, gravimetric pull and mild heating of meat – could be attributed to the structural rather than biochemical changes taking place in meat post-mortem. The lack of an overall effect of pH on the waterholding capacity difference in beef and venison in this study is one proof that factors other than pH were playing a more important role in the waterholding capacity of post rigor meat. A review of previous studies [1] indicates that channels are formed in muscle soon post-mortem through which water from meat could be lost in the form of purge or drip. An earlier study [7] reported a decrease in exudates with chilled storage time, and a more recent study [8] demonstrated reduced moisture losses with structural protein breakdown in pork. Data from the current study support the structural basis for the improved waterholding capacity of meat in the following way: (1) pH in meat from two muscles and two species did not change with ageing time but moisture loss did; (2) structural changes took place in meat with ageing time before freezing as evidenced by the decrease in shear force with ageing time (Figure 3); (3) moisture loss in the form of exudates and drip decreased with increased meat structural breakdown; (4) venison being a fast tenderizing meat with potentially faster meat structural breakdown held its water better under vacuum pressure and atmospheric gravity relative to beef – a comparatively slower tenderizing meat; and (5) the waterholding advantages of venison over beef tended to reduce with ageing time as structural breakdown in the latter meat increased. We hypothesise that the structural improvement in waterholding capacity in meat happens in the following way: (a) The decrease in pH and the contraction of muscle due to rigor releases water and creates channels

for potential moisture loss; (b) the channels are well defined early post-mortem/post-rigor and given the right conditions water is lost through these channels; (c) as proteolysis occurs with time (faster in chilled versus frozen and in venison versus beef) and muscle structural proteins are broken, the channels for moisture loss are disrupted and become less defined thereby creating a sponge effect that physically entraps the water and reduces the water loss through gravity, mild pressure as in vacuum and mild heat as in drying at 62°C; (d) higher pressure as experienced by heating meat to higher temperatures could overcome the sponge effect and all the free water is expelled under this condition and hence there was no observable effect of ageing on cook loss and total moisture loss.

IV. CONCLUSION

Within the parameters of this study, the waterholding capacity of frozen meat can be improved by ageing the meat prior to freezing. The length of time of ageing should be ≥3weeks for beef and 1-2 weeks for venison at -1.5°C. The outcomes in this study have the following implications for the meat industry: (1) the waterholding capacity of frozen meat can be improved by the ageing of the meat prior to freezing; (2) value can be added to frozen meat relative to chilled by the improvement in the waterholding capacity of the meat; (3) the significant difference observed between beef and venison in the attributes measured in this study strongly suggest specie-specific tailoring of process inputs is required for beef and venison by the meat processors if the quality of these meats is to be optimised.

ACKNOWLEDGEMENT

The authors would like to thank the meat processing plants involved in the survey for their support and assistance in connection with the collection of the samples, and John Waller for statistical analysis of the data. Funding for this project was provided by the New Zealand Foundation for Research, Science and Technology (contract number C10X0708).

REFERENCES

[1] Huff-Lonergan, E. & Lonergan, S.M. (2005). Mechanisms of water-holding capacity of meat: The role of postmortem biochemical and structural changes. Meat Science, 71, 194-204.

[2] Hagyard, C.J. (1979). Aging regimes for electrically stimulated lamb. MIRINZ Publication No. RM 88.

[3] Farouk, M.M., Tavendale, M., Lane, G., Pulford, D. & Waller, J. (2007). Comparison of white clover, perennial ryegrass and the high tannin containing forage *Lotus pedunculatus* as finishing diets: Effect on sheepmeat quality. The Proceedings of the New Zealand Society of Animal Production 67, 426-430.

[4] Farouk, M. M. & Swan, J. E. 1998. Effect of rigor temperature and frozen storage on functional properties of hot-boned manufacturing beef. Meat Science 49, 233-247.

[5] Honikel, K.O. (1998). Reference methods for the assessment of physical characteristics of meat. Meat Science, 49, 447–457.

[6] Payne, R.W., Harding, S.A., Murray, D.A., Soutar, D.M., Baird, D.B., Welham, S.J., Kane, A.F., Gilmour, A.R., Thompson, R., Webster, R., & Tunnicliffe Wilson, G. (2008). *GenStat Release 11 Reference Manual, Part 1 Summary*. VSN International, Hemel Hempstead.

[7] Anon, M. C. & Calvalo, A. (1980). Freezing rate effects on the drip loss of frozen beef. Meat Science 4, 1-14.

[8] Z hang W.G., Lonergan S. M., Gardner M. A. and Huff-Lonergan E. (2006). Contribution of postmortem changes of integrin, desmin and _-calpain to variation in water holding capacity of pork. Meat Science 74, 578-585.

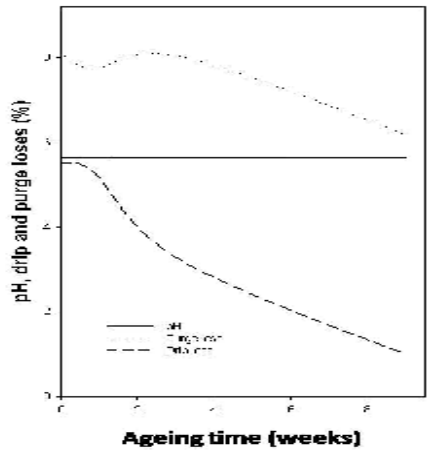

Fig. 1a. Changes in pH, drip and purge loses in beef *semimembranosus* with time of ageing

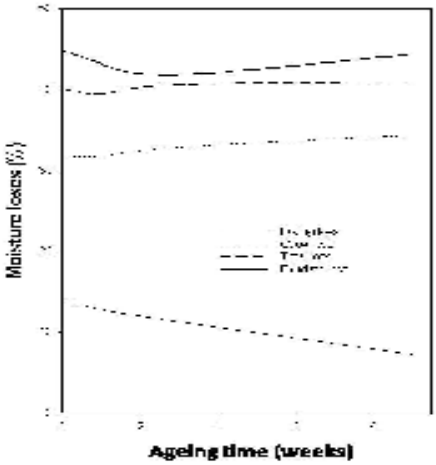

Fig. 1b. Changes in moisture loses in beef semimembranosus with time of ageing

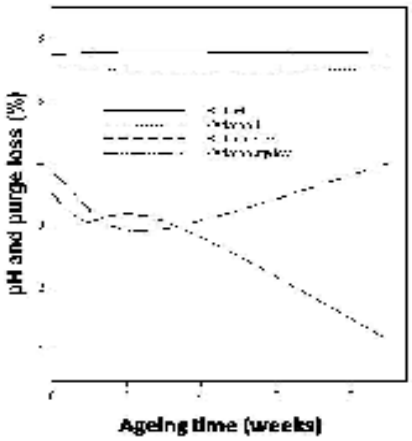

Fig. 2a. Changes in pH and purge loss in beef and venison with time of ageing

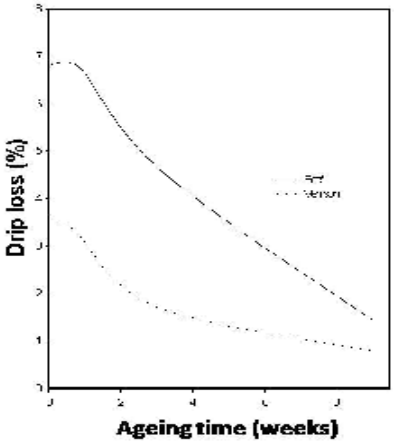

Fig. 2b. Changes in drip loss in beef and venison with time of ageing

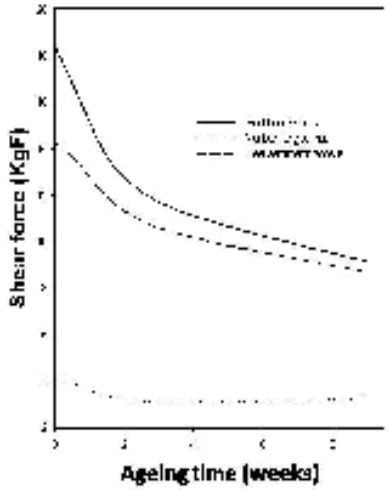

Fig. 3. Changes in shear force in cooked beef and venison with time of ageing