THE EFFECT OF "KIWI FRUIT SOLUTION" ON MEAT TRAITS IN BEEF TOPSIDE

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***Abstract*—Methods to improve tenderness include mechanical and chemical approaches and the latter category includes the use of proteolytic enzymes that degrade structural proteins. A study was undertaken to investigate the effectiveness of a 'kiwi fruit solution' for improving the tenderness of beef m. *semimembranous* (SM) and the effect on colour stability, where the solution contained the enzyme actinidain. Three treatments were applied; 1) Samples injected with the solution, 2) Samples injected with water and 3) Samples not injected. All samples were then packaged using a SmartShape™ prototype (licensed as SmartShape™) and aged for 1 or 14 days. There was a significant effect ($P < 0.001$) of the Kiwi fruit solution on shear force, with no difference between samples injected with water and those not injected. There was also a significant ($P < 0.05$) ageing effect with samples in all treatments exhibiting a decrease in shear force with ageing, but no significant interaction between treatment and ageing. For compression of the samples no fixed effects were significant ($P > 0.05$). Given there was no effect of injection with water the improvement in tenderness can be attributed to an increase in proteolysis and thus protein degradation rather than a physical effect associated with the injection process. Samples not injected (control) were the darkest (lowest L* values) with a mean (± s.e.) of 37.0 ± 1.02 with no difference between samples injected with water (43.0 ± 1.02) and those injected with kiwi fruit solution (43.2 ± 1.02). For a* (redness) values there was a significant interaction between treatment and ageing ($P < 0.05$) and a significant linear trend with time (days on display) ($P < 0.05$), such that injected samples had lower values than non-injected samples. In general the samples not injected had higher ratio (630/580 nm) values indicating less formation of metmyoglobin.**

***Index Terms*—kiwi fruit solution, meat colour, tenderness, topside**

I. INTRODUCTION

The active enzyme in the juice of kiwi fruit (*Actinidia deliciosa*) is actinidain (Barrett, Rawlings & Woessner, 2004) and recent work published by Han, Morton, Bekhit & Sedcole (2009) showed that lamb carcasses infused pre-rigor with kiwi fruit juice extract produced more tender meat. Actindain is a cysteine protease and has been shown in a purified form to increase the solubility of collagen (Wada, Suzuki, Yaguti & Hasegawa, 2002), making it attractive for improving the tenderness of m. *semimembranosus* (SM) the main muscle of the topside. This paper reports on the results of a study to investigate the effectiveness of a 'kiwi fruit solution' for improving the tenderness of beef SM when injected and packaged cold and the impact of the solution on other meat traits, specifically colour.

II. MATERIALS AND METHODS

Eight female cattle with no permanent incisors and with a carcase weight between 230-250kg were used for the experiment. The carcases were processed under normal conditions of the abattoir which meant that all carcases were head stunned, followed by low voltage stimulation and the carcases were then tenderstretched. Both topsides (Anon. 1998; HAM 2001) from each animal were removed the day after slaughter. The m. *adductor* was removed from the topside and discarded leaving the m. *semimembranosus* (SM) which was then split into two samples (equalling four samples/animal). Each portion (n = 32) was allocated randomly, in a balanced manner within animals, to one of three treatments: i) injected with kiwi fruit solution, ii) injected with water and iii) non-injected (control).

Both 'kiwi injected' and water injected treatments were injected at a rate of approximately 25% initial weight using a Formaco machine with needles 4mm thick. The 'kiwi fruit solution' was prepared according to the manufacturers guidelines. After injection each sample, including the control, was packaged using a SmartShape™ prototype (licensed as SmartShape™) under development by Meat & Livestock Australia and Meat & Wool New Zealand (Toohey & Hopkins, 2009). For injected samples pre-injection weight, post-injection weight and post-SmartShape weight were recorded. Each package was subsequently divided into sub-portions and one sub-portion of each portion was allocated, at random, to one of two ageing treatments, 1 or 14 days at 4°C. Following ageing samples were frozen and stored at -20°C until measurement.

Shear force (65 g) and compression (65 g) samples were cut from the frozen SM muscles using a band saw. Samples were cooked from frozen in plastic bags at 71°C for 35 min in a water bath, removed and cooled in cold water and stored chilled until testing. The samples were allocated in a balanced design to one of three cooking batches. Samples with a cross-sectional area of 1 cm^2 were prepared for shear force testing by cutting strips along the grain of the muscle, with 6 replicates tested per sample using a Lloyd Texture analyser. Samples for measurement of compression were prepared by cutting strips as those for shear force, with a depth of 10 mm. Six replicates were tested using a rod 6.3mm in diameter. The rod travels 8mm into the meat sample for each compression. Samples used for shear force testing were used to measure the amount of cooking loss. An initial weight was recorded prior to cooking and once the samples were cooled they were patted dry using paper towelling and re-weighed, and cooking loss percentage calculated as; Cooking loss (%) = 100 * (Initial weight - Final weight)/Initial weight.

Colour samples were cut from the frozen SM muscles 3cm thick using a band saw, placed on trays and allowed to thaw overnight in a chiller set at 3-4°C. The following day a fresh surface was cut on each sample and they were placed individually on black foam trays (13.5 cm x 13.5 cm) and over wrapped with PVC food film wrap (15 μm thickness). After a blooming period of 30-40 min, each sample was measured with a Hunter Lab Miniscan meter (Model 45/0-L) with an aperture size of 25 mm. The instrument was calibrated with black and white tiles using Illuminant D-65, with 10 degree standard observer. Samples were displayed in a chiller at 3-4°C under lighting (1000 lux) and measured over 4 days daily, in duplicate and results averaged on a daily basis.

Statistical Analyses

Data for each trait was analysed separately using linear mixed model (LMM) analysis. For shear force, where the replicate results for each sub-portion were included in the analysis, the model initially fitted included fixed effects for treatments (injection), ageing and an interaction between treatment and ageing. The random terms in the model were effects for cooking batch, carcase, side within carcase, portion within side, sub-portion within portion and finally random error. The random errors within treatments were fitted with different variances. For analysis of compression, where only the mean for replicates within sub-portion were analysed, the initial model was similar to that for shear force except for the exclusion of the random term sub-portion within portion, and here the random error variances were treated as homogeneous. The initial model for cooking loss (%), with only a single result for each sub-portion, was as for compression. Each of these models was subsequently simplified, including the removal of non significant fixed effect terms. Predicted means were then obtained and these were subsequently ranked based on pair-wise least significant differences.

Averages within sub-portions of the colour data L*, a* and 630nm/580nm ratio, recorded four times over a 72 hour period, were also analysed using LMM analyses. The initial model included as fixed effects separate linear regressions on time for each treatment by ageing combination. Random effects included terms for carcase, side within carcase, portion within side, interactions of each of these with linear time, deviations from linear time (i.e. time fitted as a factor with four levels), interactions of fixed effects with carcase, interactions of fixed effects and carcase with deviations from linear time, and finally a random error. Ratio was $\log_e$ transformed prior to analysis. All models were fitted using the statistical package ASReml (Gilmour, Gogel, Cullis & Thompson, 2006) which uses REML based methods and incorporates adjusted Wald statistics (Kenward & Roger, 1997) to test significance of fixed effects under small sample inference.

III. RESULTS AND DISCUSSION

Topsides injected with 'kiwi fruit solution' and water increased in weight by an average of 23.5% and 19.9% respectively. After subjection to the SmartShape™ technology the increase in weight was 16.5 and 12.7% respectively. There was a significant effect ($P < 0.001$) of the 'kiwi fruit solution' on shear force, with no difference between samples injected with water and those not injected (Table 1). There was also a significant ($P < 0.05$) ageing effect with samples in all treatments exhibiting a decrease in shear force with ageing, but no significant interaction between treatment and ageing. There was no significant ($P > 0.05$) variation due to side within carcase or portion within side. There was variation due to cooking batch, across carcasses and the random variation for kiwi-fruit juice injected samples differed (was larger) than for the other two treatments which had similar error variance. For compression no fixed effects were significant ($P > 0.05$; Table 1), and of the random terms, carcase, side within carcase and portion within side contributed to the variance. Cooking loss of compression samples differed significantly across treatments ($P < 0.001$; Table 1), but not significantly ($P > 0.05$) across the two ageing levels, either on average or within a treatment.

Table 1. Predicted means (standard errors) for shear force and compression (Newtons) and cooking loss (%).

	Shear force (N)		Compression (N)		Cooking loss (%)
Treatment	**Aged 1 day**	**Aged 14 day**	**Aged 1 day**	**Aged 14 day**	
Kiwi	36.5 (1.7) b	32.9 (1.7) a	11.5 (1.6) a	13.2 (1.6) a	25.2 (0.60) a
Water	46.9 (1.6) de	43.3 (1.7) cd	12.7 (1.5) a	12.0 (1.7) a	27.0 (0.60) b
No injection	45.7 (1.7) e	42.0 (1.6) c	15.4 (1.6) a	13.7 (1.5) a	21.6 (0.57) c

Means (within each test) having a letter in common are not significantly different (P = 0.05)

The treatment of cold boned topsides with 'kiwi fruit solution' gave a clear improvement in tenderness of the order of 20% irrespective of ageing treatment (Table 1). Given there was no effect of injection with water the improvement in tenderness can be attributed to an increase in proteolysis and thus protein degradation rather than to a physical effect associated with the injection process. Han *et al.* (2009) clearly showed that when lamb carcases were infused with a kiwi fruit juice solution there was an increase in proteolytic activity with the more rapid disappearance of proteins like desmin and myosin light chain. Wada *et al.* (2002) reported that a kiwi fruit juice based solution did lead to disorganization of myosin and actin filaments. Overall the absolute basal level of tenderness before treatment (46 N) indicated a relatively tender product to start with, reflecting the benefits of tender stretching employed by the company. The level was not dissimilar to the level reported by Geesink & Thompson (2008) for beef striploins at the same abattoir, whereas values around 70 N were reported when tender stretching was not used in beef striploins (Geesink & Thompson 2008). However in the current study when kiwi fruit solution treatment was applied this further improved the product and after 14 days of ageing a very acceptable product was produced (based on the results reported by Thompson (2002) where 45 N was the level which equated to a maximum level for consumer acceptability of beef). There is some evidence that kiwi fruit juice may increase the solubisation of collagen (Wada *et al.* 2002), but in the current study the lack of effect on compression does not support this finding and this requires further elucidation. As expected injection regardless of the composition of the solution led to greater loss of moisture during cooking, but the magnitude of the increase in the weight of the SM due to injection was such that a net benefit in weight was apparent for injected product.

There was no significant effect ($P < 0.05$) of ageing or linear trend with time on L* values, nor were interactions between treatment and ageing significant. There was a significant ($P < 0.001$) overall treatment effect. Of the random terms, carcase and variation in the interaction effects between treatment and ageing across carcases, explained the most variation. Samples not injected (control) were the darkest (lowest L* values) with a mean (± s.e.) of 37.0 ± 1.02 with no difference between samples injected with water (43.0 ± 1.02) and those injected with kiwi fruit solution (43.2 ± 1.02). For a* values there was a significant interaction between treatment and ageing ($P < 0.05$) and a significant linear trend with time (days on display) ($P < 0.05$). The linear trend with time (decreasing) was consistent across treatment x ageing combinations. Hence, for example, non injected samples which had the highest values at time 0 also had the highest values after 4 days on display, irrespective of ageing level (Table 2). Of the random terms carcase × side × portion explained the most variation. The data for ratio at 630/580 nm was log transformed for analysis and both treatment and ageing had a significant effect ($P < 0.05$) on this trait as did time on display (Table 2). In general the samples not injected had higher ratio values indicating less formation of metmyoglobin.

Table 2. Effect of treatment, ageing and time on display (0 days or 3 days) for *a and ratio values.**

Treatment	Days aged	Mean a*	Standard error	LSD	Mean ratio	Standard error	LSD
Time = 0 days							
Kiwi fruit	1	17.2	0.70	bc	3.82	0.29	bc
Water	1	16.1	0.68	b	3.61	0.27	c
No injection	1	18.2	0.66	c	4.52	0.32	d
Kiwi fruit	14	13.7	0.70	a	2.70	0.21	a
Water	14	15.0	0.68	a	3.20	0.24	b
No injection	14	17.0	0.67	b	4.00	0.29	c
Time = 3 days							
Kiwi fruit	1	15.33	0.72	bc	3.12	0.25	bc
Water	1	14.24	0.69	b	2.66	0.20	ab
No injection	1	16.25	0.67	c	3.33	0.25	c
Kiwi fruit	14	11.83	0.72	a	2.34	0.19	a
Water	14	13.04	0.70	a	2.51	0.19	a
No injection	14	15.06	0.68	b	3.15	0.24	bc

Means (within each time) having a letter in common are not significantly different (P = 0.05)

The results of Bekhit *et al.* (2007) showed that meat from lamb carcases infused with water had higher L* values than that of meat from non-infused carcases or that infused with a kiwi fruit in direct contrast to the results reported here where both infused groups showed higher L* values and thus lighter meat. Increasing the water content of meat does potentially increase spacing between muscle fibres so a lighter coloured meat is to be expected. Further to this Bekhit *et al.* (2007) reported some increase in a* values for leg meat from kiwi infused carcases, but the opposite effect was found in the current study, with control (non-injected) meat showing the highest a* values after 3 days on display and thus being more acceptable. Recent data in lamb (Khilji, van de Ven, Lamb, Lanza & Hopkins, 2010) show that when the a* value falls below 14.8 consumers will on average regard the meat as unacceptable. If the level is applicable to beef then **aged** meat injected with kiwi fruit solution would not be acceptable even at initial display.

In general the ratio (630/580 nm) values indicate that meat injected with kiwi fruit solution is less colour stable (lower values) hence having a shorter display life and would therefore be less acceptable at the retail counter especially

when aged for 14 days, although water injection also reduced colour stability. The study of lamb by Khilji *et al.* (2010) showed that when ratio values fall below 3.3 consumers will on average regard the meat as unacceptably brown (excessive metmyoglobin formation). If a 'kiwi fruit solution' was to offer an advantage for colour stability this would be likely due to the presence of antioxidants in the juice. However, the lack of positive effect on colour stability in the current study may well be due to the loss of the antioxidants during preparation filtration.

IV. CONCLUSION

It can be concluded that injection of a kiwi fruit solution will confer tenderness benefits, which appears to operate through the myofibrillar component of meat, but this requires confirmation. Despite improvements in meat tenderness gained by the 'kiwi fruit solution' the increased discolouration would limit the use of the treated product by the retail sector, whereas for the food service sector this is unlikely to be an issue.

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