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The effect of "kiwi fruit solution" on the meat quality of beef topside

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Background

Whilst conducting an in-plant demonstration at Australian Country Choice (ACC) a request was made to examine the impact of a ‘kiwi fruit’ based brine on the meat quality of beef topsides. The active enzyme in ‘kiwi fruit juice’ is actinidin and recent work published by Han et al. (2009) showed that lamb carcasses infused with kiwi fruit juice extract produced more tender meat.

Contents

Materials and Methods

Eight female cattle with no permanent incisors and a BI of 110 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 then carcases were suspended from the obturator foramen hence tenderstretched. The carcases weighed between 230-250kg and both the topsides from each animal were boned out cold the day after slaughter. The abductor was removed from the *semimembranosus* (SM) and discarded. Each topside portion was allocated randomly to one of three treatments; Injected with kiwi fruit solution, injected with water and control non-injected, in a balanced manner. Ageing treatments were subsequently applied to sub-portions at either 1 or 14 days of ageing and samples held frozen at -20°C until measurement.

Injection process

All cuts were injected with 'kiwi' brine through a Formaco machine using needles 4mm thick. The samples were injected at a rate of approximately 25% initial weight. A representative from Earlee Product (who makes the brine solution) was present at ACC to mix the brine according to the manufacturers requirements. To examine how much brine was lost a number of measurements were taken including; Pre-injection weight, post-injection weight and post-smart shape weight.

Warner Braztler shear force

Shear forces samples were cut from the frozen SM muscles using a band saw to a weight of 65 g. Samples were cooked from frozen in plastic bags at 70°C for 35 min in a water bath, removed and cooled under running water and stored chilled until testing. The samples were allocated in a balanced design to cooking batches (1, 2 or 3). Samples with a cross-sectional area of 1 cm^2 were prepared for testing by cutting strips along the grain of the muscle, with 6 replicates tested per sample using a method adapted from that described by Thompson et al. (2005) and a Lloyd Texture analyser.

Compression

Samples for measurement of compression were prepared as those for shear force. Six replicates were tested using a rod 6.3mm in diameter. The rod travels 8mm into the meat sample for each compression.

Cooking loss

Samples taken for Warner Braztler shear force and compression testing were used to measure the amount of cooking loss. An initial weight was recorded to two decimal places then the samples were cooked for 35 minutes at 70ºC. Once the samples were cooled (for 20 minutes in a cold water bath) they were patted dry using paper towelling and re-weighed, then a cooking loss percentage was calculated using the following formula;

Cooking loss (%) = 100 * (Initial weight - Final weight) / Initial weight

Colour stability

Slices of frozen SM (3 cm thick) were taken from sample, 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 meter (Models 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 once a day for 4 days. Each sample was measured twice at each measurement time and the values averaged.

Statistical analysis

Linear mixed models using restricted maximum likelihood (REML) with the statistical package ASReml (Gilmour et al. 2006) were used to analyse the data. The model fitted for Y (shear force and compression) was;

Y = Mean + Ageing + ModTrt + Treatment + Ageing:ModTrt + Ageing:Treatment **+ *CookBatch + Animal + Animal:Side + Animal:Side:Portion + Number + error***

Here terms in bold/italic are fitted as independent random effects. The error variance (i.e. variation within samples) was allowed initially to differ across combinations of treatment × ageing. The ModTrt term corresponds to treatment, but with the levels No Inject and Water combined into one level. This allowed for the testing of differences between No Inject and Water. Number corresponds to each unique sub-portion tested via six replicates. The model fitted for cooking loss of samples used for shear and compression testing was as follows;

Cooking loss = Mean + Treatment + Ageing + Treatment:Ageing +
CookBatch + Animal + Animal:Side + Animal:Side:Portion + error

Here terms in bold/italic are fitted as independent random effects.

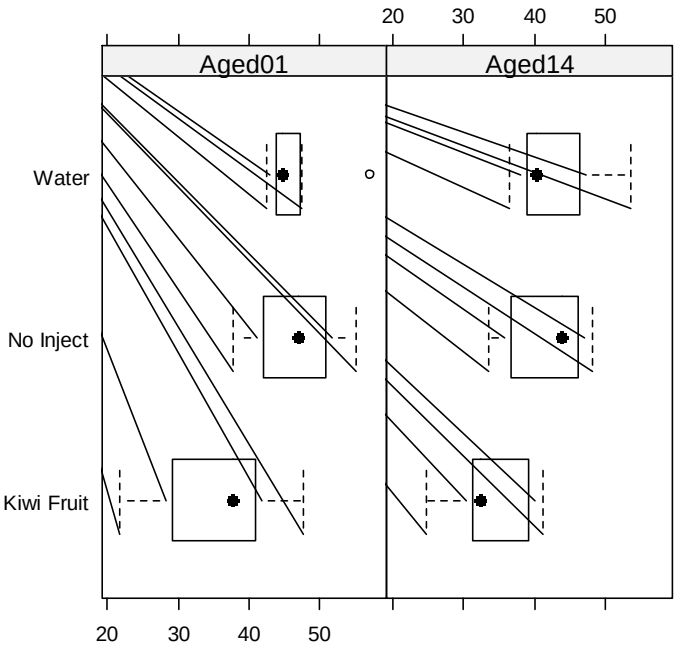
For each of the four colour response variables, L*, a*, b* and 630/580 ratio (Ratio) the following model, with Y denoting L*, a*, b* or log (Ratio), was fitted;

Y = Mean + Treatment:Ageing + Treatment:Ageing:time +***Animal + ASP + Treatment:Animal + Ageing:Animal + Treatment:Ageing:Animal + Animal:time + ASP:time + FTime + Ftime:Animal + error***

If the either of the two main effects were significant the effects for Treatment:Ageing were decomposed into ModTrt + Treatment + Ageing + ModTrt:Ageing + Treatment:Ageing and model re-fitted. Here ASP corresponds to combinations of Animal×Side×Portion, ModTrt is as for shear force and compression analyses, Ftime is a factor version of time (i.e. treats the four times as four unique non-quantitative values); error is the residual variation. Hence this model allowed initially a separate regression for each Treatment × Ageing combination. Terms in bold/italic are independent random effects.

Results

Topsides injected with kiwi fruit solution increased in weight by an average of 23.5% and those injected with water by 19.9%. After subjection to the Smart/shape technology the increase in weight was 16.5 and 12.7% respectively. A trellis plot containing box-plots of the averages for shear force (in Newtons) for each combination of treatment and days aged is given below. This indicates a reduced shear force for the "Kiwi Fruit" treatment.

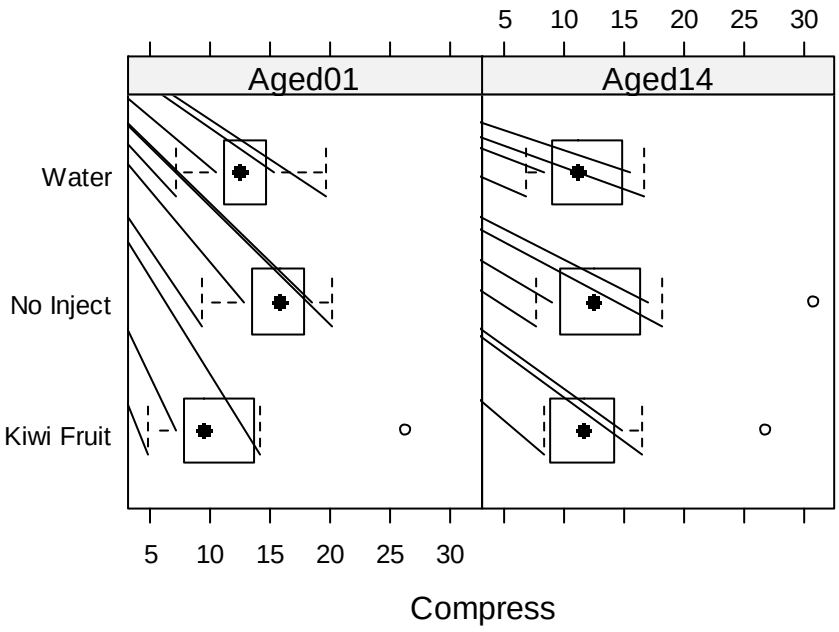


Analysis revealed that the error variation only differed significantly across the two levels of ModTrt (i.e. “Kiwi Fruit” and “No Inject or Water”). There was no significant ($P > 0.05$) variation due to Animal:Side or Animal:Side:Portion. Of the fixed effects only ageing and ModTrt main effects were significant ($P < 0.05$). The predicted means are shown in Table 1. This indicates that the ageing effect was the not significantly different between treatments.

Table 1. Shear force results (Newtons).

Treatment/Days ageing	Mean	Standard error	LSD
Kiwi fruit – 1 day aged	36.5	1.74	b
Kiwi fruit – 14 days aged	32.8	1.74	a
Water or no injection – 1 day aged	46.2	1.46	d
Water or no injection – 14 days aged	42.6	1.48	c

For compression none of the fixed effects were significant ($P < 0.05$) which is illustrated in the trellis plot below. The average compression was estimated as 13.17 ± 0.96 Newtons.



There was a treatment effect ($P < 0.001$) on cooking loss for samples used for both shear force and compression and for those used for shear force there was a significant interaction ($P < 0.05$) between treatment and ageing (Table 2). No variance was attributable to CookBatch and Animal:Side:Portion and these were removed from the model for cooking loss from shear force samples. For cooking loss from compression samples none of the random terms accounted for variance and they were removed from the model.

Table 2. Effect of treatment and ageing on cooking loss (%).

Treatment	Days aged	Mean	Standard error	LSD	Mean	Standard error	LSD
	Shear force cooking loss				*Compression cooking loss*		
Kiwi fruit	1	25.4	0.70	c	25.2	0.60	b
Kiwi fruit	14	22.9	0.70	b			
No Injection	1	20.3	0.66	a	21.6	0.57	a
No injection	14	20.8	0.69	a			
Water	1	26.3	0.72	c	27.0	0.60	c
Water	14	25.5	0.72	c			

There was no effect ($P < 0.05$) of treatment on pH, measured after injection of the samples and before ageing was applied. There was no significant effect ($P < 0.05$) of ageing or time on *L** values or interaction between treatment and ageing, but there was a significant ($P > 0.001$) treatment effect. Of the random terms, animal and variation in the interaction effects between treatment and ageing across Animals, explained the most variation. Samples not injected (control) were the lightest (lowest L* values) at 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 significant effects of treatment, ageing and time ($P < 0.05$). Of the random terms animal×side×portion explained the most variation. The pattern of change in *a** values remained the same across time, such that the non injected samples had the highest values at time 0 and after 3 days of display irrespective of whether the samples had been aged for 1 or 14 days (Table 3). Over time the *a** values decreased (Table 3).

There was both an ageing and time effect ($P < 0.05$) but no significant treatment effect on b* values, with the treatment x animal and treatment x ageing x animal terms being the dominant random effects. Samples aged for 14 days had lower b* values than those aged for 1 day and over time the values decreased (Table 4).

Table 3. Effect of treatment, ageing and time on *a and ratio (log) values.**

Treatment	Days aged	Mean a*	Standard error	LSD	Mean ratio	Mean (log) ratio	Standard error	LSD
				Time = 0 days				
Kiwi fruit	1	17.2	0.70	bc	3.7	1.31	0.08	bc
Water	1	16.1	0.68	b	3.5	1.25	0.08	c
No injection	1	18.2	0.66	c	4.4	1.48	0.07	d
Kiwi fruit	14	13.7	0.70	a	2.6	0.96	0.08	a
Water	14	15.0	0.68	a	3.1	1.14	0.08	b
No injection	14	17.0	0.67	b	3.9	1.36	0.07	c
				Time = 3 days				
Kiwi fruit	1	15.3	0.72	bc	3.0	1.11	0.08	bc
Water	1	14.2	0.69	b	2.6	0.94	0.08	ab
No injection	1	16.3	0.67	c	3.2	1.17	0.07	c
Kiwi fruit	14	11.8	0.72	a	2.3	0.82	0.08	a
Water	14	13.0	0.70	a	2.4	0.89	0.08	a
No injection	14	15.1	0.68	b	3.1	1.12	0.08	bc

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 3). There was also a significant interaction ($P < 0.05$) between the composite term where water and no injection were combined and ageing. This composite also significantly interacted with time on display and there was a significant interaction of time on display and ageing. In general the samples not injected had higher ratio values indicating less formation of metmyoglobin.

Table 4. Effect of ageing and time on *b values.**

Time (days)	Days aged	Mean	Standard error	LSD
0	1	20.0	0.46	h
0	14	18.8	0.46	dfg
1	1	19.5	0.44	g
1	14	18.2	0.45	ce
2	1	18.9	0.45	ef
2	14	17.7	0.45	b
3	1	18.4	0.47	bcd
3	14	17.2	0.48	a

Discussion

The treatment of cold boned topsides with 'kiwi fruit solution' gave a clear improvement in tenderness of the order of 28%. Given there was no effect of injection with water then the improvement in tenderness can be attributed to an increase in proteolysis and thus protein degradation as opposed 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 that 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. Actinidin is a cysteine protease and it appears from the results of Han et al. (2009) that this enzyme was directly responsible for the degradation of myofibrillar proteins, but some effect on the calpains was not ruled out, and this is an area of study requiring further elucidation.

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 and not dissimilar to the levels reported by Geesink and 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 and 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 given the results found 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 again this requires further elucidation. Given the increase in sample weight from injection it was not surprising that the injected samples lost more moisture during cooking, with samples injected with Kiwi fruit solution losing less than those injected with water, even though the increase in sample weight was greater after injection with Kiwi fruit solution.

Both a* and ratio (630/580 nm) values indicate that meat injected with kiwi fruit solution is less colour stable and would therefore be less acceptable at the retail counter. Recent data in lamb (Khilji and Hopkins unpublished data) says that when ratio values fall below 3.3 consumers will on average regard the meat as unacceptably brown (excessive metmyoglobin formation). The effect was worse for meat aged for 14 days and after 3 days of display a high proportion of the samples would have been unacceptable. This aspect does not appear to have been considered in previous work.

Conclusions

Injection of kiwi fruit solution clearly provides an improvement in tenderness, but the increased discolouration would limit the treated product to the food service sector. The extent of moisture loss (purge) on thawing was not determined in this study and this also needs to be considered as this may detract from the appearance of the product. Obviously more moisture will be lost from injected meat. Linked to this the optimum level of injection must also be determined to avoid the potential to over tenderise the product causing a loss of form. SmartShape technology provides an ideal process for the injected solution to be retained in the sample during ageing at the same time providing a uniform product form.

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