INFUSION OF KIWI FRUIT EXTRACT CONTAINING ACTINIDIN INTO *M. Longissimus dorsi AND M. Biceps femoris* IMPROVES CONSUMER SENSORY SCORES

Peter McGilchrist[1], Małgorzata Konarska[2], Judy Philpott[3] and Rod J. Polkinghorne[3]

[1] School of Veterinary & Life Sciences, Murdoch University, Perth, WA, 6150, Australia; [2] Division of Engineering in Nutrition, Warsaw University of Life Sciences, Warsaw, Poland; [3] "Merringanee", 461 Timor Rd, Murrurundi, NSW, 2338, Australia.

Abstract – This study measured the impact of infusing a kiwi fruit based solution on consumer sensory scores for tenderness, juiciness, flavor and overall liking. The striploin (*M. longissimus dorsi*) and outside flat (*M. biceps femoris*) were taken from 87 *Bos indicus* cross steers. Half of each muscle from each animal was infused with the kiwi fruit solution 6 days after slaughter, and the other half was the control. Each portion was then halved again and aged for 10 or 28 days (post-slaughter) and consumer sensory testing of grilling streaks was conducted. Ten consumers tested each portion. Infusion of kiwi extract significantly improved the palatability as reflected by the meat quality (MQ4) score of both muscles at both levels of ageing ($P<0.05$). With 10 days ageing, the tenderness, juiciness, flavour and overall liking scores of the kiwi infused meat was higher than the control product, but at 28 days ageing, only the tenderness and overall liking scores were higher. Infusion with Kiwi fruit solution is a simple way to improve the consumer palatability of beef for consumers and increase the predicted quality grade and the value of the cuts.

Key Words – Consumer sensory testing, Meat Standards Australia, Proteolysis.

I. INTRODUCTION

In order to predict the eating quality of Australian beef, Meat Standards Australia (MSA) incorporates inputs from all sectors of the beef supply-chain including production, processing and value adding (ageing and cooking method) [1, 2]. The techniques for value adding, preparing and cooking beef are continually growing, increasing the utilization of all muscles in the carcass. However at present the MSA model only predicts eating quality for the following cooking methods: grilling, roasting, slow-cooking, stir frying, shabu shabu, yakiniku and corning [3, 4]. There are many emerging techniques for value-adding beef but one technology that is showing particular promise is the infusion of beef with a Kiwi fruit (*Actinidia deliciosa*) based solution. Kiwi fruit contains a cysteine protease enzyme called Actinidin (EC 3.4.22.67)[5]. This product has been shown to improve the tenderness of both beef and lamb compared to non-treated or needled meat [6, 7]. Toohey et al. [7] showed that infusion with a commercially available kiwi fruit solution improved the sheer force of the *M. semimembranosus* in beef but did not alter the compression values. This may indicate that the action of Actinidin on the tenderness of beef is via proteolytic activity on the myofibrillar protein rather than the connective tissue [7]. Toohey et al. [7] also showed that beef treated with Kiwi fruit extract was more tender at 14 days than at 1 day post-slaughter, suggesting that the process of proteolysis continued in treated beef.

Sensory satisfaction of a consumer is based on more than just tenderness. The attributes of juiciness, flavor and overall liking are also important, and are combined within the MSA system to form an overall meat quality score (MQ4) [4]. At this stage there is little evidence showing the impact of Actinidin on juiciness and flavor sensory scores, however given the impact on tenderness it is anticipated that the overall MQ4 score will improve. Therefore is its hypothesized that infusion of the *M. longissimus dorsi* and *M. biceps femoris* with kiwi fruit extract will increase MQ4 score at different ageing times.

II. MATERIALS AND METHODS

This experiment used a total of 87 grass-fed yearling steers which were a range of cross bred cattle utilising Red Poll, Wagyu and Brahman bulls over crossbred cows bred from a Brahman base. These cattle were aged between 18 to 36 months with a live weight range from 489 to 790 kg.

A. Slaughter procedure, MSA grading and boning

The cattle were slaughtered after 8 hours in lairage at a commercial abattoir. Temperature and pH was recorded at hourly intervals commencing at chiller

entry and continuing until a pH of 6 was attained (between 3 and 5 hours) to ensure all passed through the appropriate pH/ temperature window. Spray chilling was used in the chillers. MSA graders collected full MSA grading data [8] from all carcasses 20 hours following slaughter. *Bos indicus* content was not assessed on individual live animals, but rather was estimated from the relationship between hump height and carcass weight [4].

The striploin and outside flat from each carcass was collected at boning. The left side was used for all carcasses. All primals were vacuum packed and chilled for 24 hours prior to collection from the abattoir.

B. Sample Preparation

The two primals from the 87 carcasses were transported by refrigerated transport at 1˚C for further processing. At day 6, the *M. longissimus dorsi* (LD) and *M. biceps femoris* (BF) were dissected from the primals, denuded removing all external fat and epimysium together with muscle portions other than the LD and BF. The LD and BF were cut in half and allocated in a balanced manner to the 2 treatments: (i) injected with commercial kiwi fruit solution or (ii) not injected. The Kiwi treated portions were injected at a rate of approximately 10% initial weight using a Fomaco Machine (Copenhagen, Denmark) with 4mm needles. The Kiwi fruit solution was a commercial product produced by Earlee Products Pty Ltd (Wunda Brine CFD 5000, Code: 044-224M, Batch No: 170727, Brisbane, Australia) mixed at the recommended rate of 10kg pre-mix to 72 litres of water until the mixture was fully dissolved. Each portion was then re-weighed.

The kiwi infused and control portions from the LD and BF were then allocated to the following cook by ageing treatments, balanced for position within the muscle in a randomized design: (i) Grill, 10 days ageing (ii) grill, 28 days ageing. Each portion was then cut into five 25mm thick steaks following MSA protocols [9]. Steaks were individually wrapped in freezer film prior to packing as a set of 5 per sample. Samples were then aged for 10 or 28 days from slaughter at which point they were frozen and stored at -20˚C until thawed for consumer testing.

C. Consumer sensory testing

Consumer testing was conducted using MSA grill protocols described in detail by Watson *et al* [3] and Anon [9]. Briefly, groups of 20 regular beef eating consumers, screened to include those preferring medium doneness, aged 18 to 65, were each served seven steaks with a broad range of eating quality. The first sample served was a starting sample and was not included in the subsequent analysis. The following six samples were drawn from six product groups with each product of presumed uniform quality and expected to differ from other products. A range of test products were included in each consumer test group (6 samples) to deliver high, medium and low eating quality scores. Presentation of the six test products was controlled by a 6x6 latin square ensuring that each product was presented an equal number of times in serving order from two to seven and an equal number of times before and after each other product, which effectively balanced potential order or halo effects. All samples were tasted by 10 consumers.

Consumers rated each sample by marking four 100 mm line scales representing tenderness, juiciness, flavour and overall satisfaction with the scales anchored by descriptions being not tender/very tender, not juicy/very juicy and dislike extremely/like extremely for both liking of flavour and overall satisfaction scores. The raw means of each sensory trait were calculated together with clipped means calculated by removing the highest and lowest 2 scores for each trait. An MQ4 (meat quality, 4 variable) score was calculated by summing sensory scores for tenderness, flavour and overall satisfaction weighted by 0.3 and juiciness by 0.1 to create a combined score between 0 and 100 for clipped results following procedures described by Watson [4].

D. Statistical analysis

Tenderness, Juiciness, flavor, overall liking, overall satisfaction and MQ4 score were analyzed using a linear mixed effects model [10]. Fixed effects included muscle (LD or BF), treatment (Kiwi or Control) and days aged (10 or 28), and carcass identification was used as the random term. All relevant interactions between fixed effects were tested, and non-significant terms ($P>0.05$) were removed in a step-wise manner. The final model for all sensory scores included significant terms ($P<0.05$) for muscle, treatment, ageing plus interactions for muscle by treatment and treatment by days aged.

Table 1. Predicted means ± standard errors for Meat Quality score (MQ4 score), tenderness, juiciness, flavor and overall Liking for the *M. biceps femoris* and *M. longissimus dorsi*, treated with kiwi fruit solution or control and aged for 10 or 28 days.

Muscle	Treatment	Days Aged	Tenderness	Juiciness	Flavour	Overall Liking	MQ4 score
M. biceps femoris	Control	10	28.1 ± 1.3a	43.2 ± 1.2a	42.0 ± 1.1a	35.4 ± 1.2a	36.4 ± 1.1a
M. biceps femoris	Control	28	34.5 ± 1.9b	47.3 ± 1.7b	46.8 ± 1.6b	41.0 ± 1.8b	41.5 ± 1.7b
M. biceps femoris	Kiwi	10	47.8 ± 1.8c	60.3 ± 1.7d	58.5 ± 1.5e	53.5 ± 1.7de	54.0 ± 1.6de
M. biceps femoris	Kiwi	28	43.2 ± 1.9c	48.7 ± 1.7b	49.7 ± 1.6bc	46.5 ± 1.7c	46.7 ± 1.6c
M. longissimus dorsi	Control	10	47.1 ± 1.3c	48.2 ± 1.2b	51.3 ± 1.1cd	50.2 ± 1.2cd	49.4 ± 1.1cd
M. longissimus dorsi	Control	28	55.1 ± 2.0d	53.0 ± 1.8c	55.6 ± 1.7de	55.6 ± 1.8e	55.2 ± 1.7e
M. longissimus dorsi	Kiwi	10	74.2 ± 1.9e	72.5 ± 1.8f	73.2 ± 1.6g	74.0 ± 1.8g	73.0 ± 1.6f
M. longissimus dorsi	Kiwi	28	72.1 ± 1.9e	67.3 ± 1.7e	67.4 ± 1.6f	69.2 ± 1.7f	68.9 ± 1.6f

Means (within each measure) with different letters are significantly different ($P<0.05$).

III. RESULTS AND DISCUSSION

Infusion of the LD and BF muscles with a commercial kiwi fruit solution containing Actinidin significantly increased the eating quality (MQ4 score) of both cuts at 10 and 28 days ageing (Table 1) when compared to the control, supporting the hypothesis. At 10 days of ageing, the infused BF had a 48.1% or 17.5 ± 1.9 higher MQ4 score ($P<0.01$) compared to the control product. Similarly with the LD, at 10 days ageing, the kiwi infused steaks were 47.8% or 23.6 ± 1.9 MQ4 score points higher ($P<0.01$) than the control LD steaks (Table 1).

At 28 days ageing, this difference had reduced to only 5.3 ± 2.2 MQ4 score points higher in the BF and 13.7 ± 2.2 MQ4 score points higher in the LD than the control steaks of the respective muscles ($P<0.05$).

At both aging periods the control BF steaks scored below 46.5 MQ4 score points (Table 1) deeming them as "unsatisfactory" under the MSA system [3]. The BF steaks infused with kiwi fruit solution scored above this threshold at both levels of ageing (Table 1). Infusion with kiwi effectively took the LD grills from a 3 star or "good everyday" product to a 4 star or "better than everyday" product at 10 and 28 days ageing.

When comparing within a muscle and treatment, increasing ageing from 10 to 28 days post-slaughter, elevated MQ4 scores of the control LD and BF muscles. The consumer scores for tenderness, juiciness, flavour and overall liking ($P<0.05$) were all higher at 28 than 10 days in the control steaks. The exception to this was for flavor in the LD, which did not improve between 10 and 28 days (Table 1). This shows that the ageing of meat improves consumer sensory scores aligning well with the predictions in the MSA model [4].

The MQ4 score of the LD infused with kiwi did not change from 10 to 28 days, but the MQ4 score of the BF decreased ($P>0.05$). For both kiwi infused muscles, the tenderness scores did not change from 10 to 28 days, yet the consumer ratings for tenderness, juiciness and overall liking were all significantly less at 28 days compared to 10 ($P<0.05$, Table 1). This indicated that Actinidin has an immediate and direct impact on tenderness, but its protease activity appears to be limited beyond the initial action, shown here 4 days post infusion. The infusion of moisture or the action of Actinidin also increased the juiciness and flavor scores of product at 10 days ($P<0.05$), but these scores decreased at 28 days (Table 2).

The increased quality achieved by infusion with kiwi fruit solution not only represents an improved palatability outcome for consumers but its utilization as a value-adding product would also lead to a more economically viable beef industry. Willingness to pay data presented by Lyford *et al.* [11] shows that a 3 star or "good everyday" beef product was worth almost double the amount of 2 star or "unsatisfactory" beef. Thus the infusion of outside flats or the BF muscle will theoretically double the value of that primal at both 10 and 28 days ageing in the Australian market place. Similarly, consumers in Australia are willing to pay around 50% more for 4 star or "better than everyday" product compared with 3 star product [11]. Once again this represents a massive increase in value of a loin cut helping to improve the profitability of the industry, whilst also improving the eating experience of consumers.

The mechanisms which deliver a decreased consumer score for flavour, juiciness and overall

liking at 28 days ageing compared with 10 days are not well understood, but the infused beef still had a higher rating than the control beef at 28 days ageing, justifying its use. To gain the largest benefit from the kiwi infusion, it would be recommended to cook and consume the product in a short time frame.

IV. CONCLUSION

The infusion of kiwi fruit based solution into the LD and BF significantly improves the eating quality scores of grilling steaks as assessed by consumers. In both muscles, the tenderness, juiciness, flavor and overall liking of the kiwi infused product was increased, raising the quality level as determined by MSA by 1 extra star rating which represents a much more palatable and profitable product to consumers and processors respectively.

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REFERENCES

1. Polkinghorne, R., J.M. Thompson, R. Watson, A. Gee, & M. Porter, (2008). Evolution of the Meat Standards Australia (MSA) beef grading system. Australian Journal of Experimental Agriculture. 48(11): p. 1351-59.
2. Polkinghorne, R., R. Watson, J.M. Thompson, & D.W. Pethick, (2008). Current usage and future development of the Meat Standards Australia (MSA) grading system. Australian Journal of Experimental Agriculture. 48(11): p. 1459-64.
3. Watson, R., A. Gee, R. Polkinghorne, & M. Porter, (2008). Consumer assessment of eating quality - development of protocols for Meat Standards Australia (MSA) testing. Australian Journal of Experimental Agriculture. 48(11): p. 1360-67.
4. Watson, R., R. Polkinghorne, & J.M. Thompson, (2008). Development of the Meat Standards Australia (MSA) prediction model for beef palatability. Australian Journal of Experimental Agriculture. 48(11): p. 1368-79.
5. Baker, E.N., M.J. Boland, P.C. Calder, & M.J. Hardman, (1980). The Specificity of Actinidin and Its Relationship to the Structure of the Enzyme. Biochimica Et Biophysica Acta. 616(1): p. 30-34.
6. Han, J., J.D. Morton, A.E.D. Bekhit, & J.R. Sedcole, (2009). Pre-rigor infusion with kiwifruit juice improves lamb tenderness. Meat Science. 82(3): p. 324-30.
7. Toohey, E.S., M.J. Kerr, R. van de Ven, & D.L. Hopkins, (2011). The effect of a kiwi fruit based solution on meat traits in beef m. semimembranosus (topside). Meat Science. 88(3): p. 468-71.
8. Anon, Meat Standards Australia, beef information kit, in Published by Meat and Livestock Australia Limited. 2011: North Sydney, NSW.
9. Anon, (2008). Accessory Publication: MSA sensory testing protocols. Australian Journal of Experimental Agriculture. 48: p. 1360 - 67.
10. SAS, Statistical analysis system. 2001, SAS Institute Incorporated: Cary, NC.
11. Lyford C, T.J., Polkinghorne R, Miller M, Nishimurae T, Neath K, Allen P & Belasco E, (2010). Is willingness to pay (WTP) for beef quality grades affected by consumer demographics and meat consumption preferences? . Australasian Agribusiness Review. 18: p. 1 - 17.