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Effect of cattle marketing method on beef quality and palatability

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Abstract. This study was conducted to determine the effect of direct consignment compared with saleyard marketing on beef quality and palatability. A total of 258 cattle (mean carcass weight 227 ± 19 kg) from nine vendor properties in Victoria, Australia were used. From each vendor group (about 30 cattle/vendor), half were either: (1) processed through a saleyard and then sent to the abattoir or (2) directly consigned to the abattoir. All cattle were slaughtered at the same abattoir and the lairage and postslaughter management of the cattle and their carcasses was standardised. The cattle that had been directly consigned were slaughtered the day after dispatch from the property, whereas saleyard cattle were slaughtered 2 days after dispatch. Striploin (*longissimus lumborum*) samples were evaluated 1 day postslaughter and after 14 days aging. Overall, marketing method had only a small impact on the various meat quality measures and palatability. A significant vendor × marketing method interaction was found for most traits including muscle glycogen (*semimembranosus* and *semitendinosus*), pH (1, 3 and 24 h postslaughter), L^*, a^* and b^* colour values and consumer panel scores [tenderness, flavour and combined score (MQ4)]. Juiciness scores were unaffected by marketing method but were significantly influenced by vendor group ($P < 0.001$). For MQ4 score, there was a general trend showing that steaks from cattle that had been marketed through the saleyard had marginally lower MQ4 scores than those that had been directly consigned in five of the eight groups. However, this trend was only significant for two of the five groups. A significant three-way interaction between vendor group × marketing method × aging duration was found for shear force ($P < 0.001$) and cooking loss percentage ($P < 0.001$). The effect of marketing method on shear force was generally small and not always statistically significant but there was a trend indicating that saleyard marketing resulted in slightly higher shear forces at either 1 or 14 days postslaughter for the majority of the vendor groups. It was concluded that marketing method had a small but variable impact on palatability and meat quality.

Introduction

Despite the fact that the proportion of cattle sold through saleyards has declined in the last decade, it still remains the most common method for marketing cattle in Australia, accounting for 44% of the total turnoff in 2003–04 (ABARE 2004). Saleyard marketing is particularly prevalent in the southern states of Australia. For example, ABARE (2004) estimated that 62% of all cattle were marketed through saleyards in Victoria. Although direct consignment marketing or 'over the hooks' trading, offers advantages over saleyard selling (ACIL 1991), it is unlikely that there will be a rapid swing towards this marketing alternative in the short-term, particularly in southern Australia.

A major issue confronting saleyard marketing of slaughter cattle is the perception that it is not conducive to the delivery of high quality beef. Furthermore, at the time of the present study, saleyard cattle were ineligible for inclusion within the Meat Standards Australia (MSA) grading scheme (http://www.msagrading.com, verified 17 April 2007). The marketing of cattle for slaughter invariably exposes the animals to several stressors that can potentially lead to losses in beef quality. The magnitude of any loss will ultimately depend on the intensity and duration of the stressor and the susceptibility of the animals to stress (Ferguson *et al*. 2001). In this context, the major difference between direct consignment and saleyard marketing is that cattle subjected to saleyard selling are typically exposed to more handling and transport and longer delays between the farm and slaughter, and consequently, longer periods of time off feed before slaughter. There is also the increased likelihood of the mixing of unfamiliar mobs of cattle when saleyard marketing is used. Studies examining the impact of these individual stressors have generally shown that increased exposure to stress will increase the risk of muscle glycogen loss and, therefore, high ultimate pH (pH_u) meat or losses in eating quality (see reviews by Wythes 1990 and Ferguson *et al*. 2001). In general, however, there is a paucity of literature dealing specifically with the effects of marketing method on beef quality. This is not surprising given the fact that marketing method represents a combination of stressors of differing intensities that are often not easily reproducible experimentally.

Of the studies that have been undertaken, most have been surveys that have examined the association between marketing method and the incidence of the dark-cutting condition (Shorthose and Wythes 1988; Warner *et al*. 1988; Stevenson *et al*. 1996). To date, the effect of marketing method on beef

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palatability has not been studied. In view of the perceptions against saleyard marketing and the lack of corroborating data, the present study was undertaken to compare the quality and palatability of beef from cattle that had been marketed either through a saleyard or by direct consignment.

Materials and methods

Sample

Cattle destined for the domestic market (0–2 teeth) were sampled from nine commercial beef properties in Victoria, Australia between May and November 1999. A total of 258 cattle were used comprising 167 steers and 91 heifers. The cattle were predominantly British breeds or crossbreds and were grown and finished on pasture. Eight of the nine groups had access to supplements before turnoff, which included turnips (group 1), silage (groups 2, 3 and 4) and grain (groups 5, 6, 7 and 8).

Marketing treatments

The saleyards selected for the study (Wodonga and Camperdown saleyards) were chosen because both had achieved quality assurance accreditation under the National Saleyards Service Operators Organisation. Both saleyards had covered holding yards with ‘soft-standing’ or dirt floors.

On-farm, the slaughter cattle (~30 head/vendor group) were mustered on the day of transport (day 1). Half the group was unloaded at one of the saleyards, whereas the other half remained on the truck and were transported to the abattoir. The directly consigned cattle were placed in abattoir lairage pens overnight and slaughtered the following morning (day 2). Cattle had access to water at all times during lairage. The distance between the beef properties and the abattoir ranged from 140 to 370 km. One abattoir was used for all slaughters.

On arrival at the saleyard, cattle were placed in one of the soft-standing pens with access to water. These cattle remained in their groups throughout the sale (i.e. were not mixed with other groups of cattle). On day 2, the cattle were weighed and placed in sale pens adjacent to other groups that were sold. The cattle were transferred to holding pens after the sale and transported to the abattoir where they were treated in the same manner as those that had not been directly consigned. The cattle processed through the saleyards were slaughtered on the morning of day 3. The only exception to this treatment occurred for group 9 where, due to circumstances beyond our control, the saleyard-marketed cattle were not trucked from the saleyards until day 3. Rather than rest the cattle another night, a decision was made to slaughter the cattle soon after arrival at the abattoir.

In this study, the effect of marketing method was confounded by the day of slaughter. If the treatment groups were slaughtered on the same day, then the effect would still be confounded by a difference in the day of transport. After considering both options, the decision was made to slaughter the groups on different days.

Slaughter

The cattle were moved quietly from the lairage area and maintained in the marketing treatment groups on the morning of slaughter. Slaughter involved captive bolt stunning followed immediately by exsanguination.

The rates of pH and temperature decline in the *longissimus lumborum* (LL) were monitored at the abattoir before the study. Although low voltage stimulation was available at the abattoir, it was not required as the electrical immobilisation received during hide-pulling was sufficient to ensure that the rate of pH decline relative to temperature decline complied with the MSA pH and temperature window (Ferguson *et al*. 1999).

The pH and temperature of the LL were measured at 1 and 3 h after slaughter using a Jenco 6007 pH meter with an Ionode IJ42S electrode and automatic temperature-compensating probe.

Within 5–10 min after slaughter, muscle samples (~1 g) were taken from the *semitendinosus* (ST) and *semimembranosus* (SM) for determination of muscle glycogen and lactate levels. On removal, the tissue samples were trimmed of fat and connective tissue and immediately frozen in liquid nitrogen. The glycogen and lactate concentrations were determined according to the methods of Chan and Exton (1976) and Noll (1985), respectively. The glycogen level in the muscle immediately after slaughter (expressed as μmol/g of wet muscle tissue) was derived from the glucose concentration + (2 × lactate concentration).

AUS-MEAT carcass measurements including hot standard carcass weight, P8 fat depth, dentition and bruise score were also recorded.

After splitting, the sides were identified and chilled overnight. Cooling rates were not recorded but temperature was measured during pH measurement to provide an indication of cooling rate.

Sample preparation

The striploin (LL) from the right side of each carcass was collected ~24 h after slaughter and cut into three portions. Two portions were vacuum packaged and aged for 14 days at 0–1°C. The remaining portion (aged 1 day) was transferred to the laboratory for objective measurement of meat quality. One of the samples aged for 14 days was allocated for objective meat quality evaluation, whereas the sensory attributes of the other were determined using MSA consumer taste panels (Polkinghorne *et al*. 1999).

Objective meat quality determination

The objective measurements of pH_u, shear force and cooking loss were conducted on samples aged for either 1 or 14 days. Muscle colour (L^*, a^* and b^*) was measured on the samples aged 1 day only. pH_u was determined using the equipment described above. L^*, a^* and b^* measurements were made using a Minolta Chromameter (Model CR-200) on a freshly cut surface after the striploin samples were allowed to bloom for 30 min at room temperature. A 100 ± 2 g section of each striploin sample was cut for determination of cooking loss and tenderness. After weighing, the sections were placed in plastic bags and cooked in a water bath at 80°C for 60 min. The samples were dried, weighed and stored at 2°C for 24 h. Cooking loss was expressed as the percentage of weight lost during cooking. From each cooked sample, five 1-cm^2 strips were cut parallel to the orientation of muscle fibres for measurement of tenderness. Tenderness was measured using a Warner–Bratzler shear blade fitted to an Instron Universal Testing Machine Model 4465 with a 5 kN load cell.

Sensory evaluation

Detailed descriptions of the development and methodology of the sensory evaluation protocol are provided by Polkinghorne *et al*. (1999). Briefly, at the completion of the aging period, the striploin samples were cut into five 25 mm steaks, allocated a unique code number and frozen and stored at –20°C. Steaks were thawed (2–5°C) for 24 h before cooking on a Silex griller. Steaks were cooked to an internal temperature of 70°C, halved and allocated to panellists. Untrained panellists who prefer meat cooked to a medium degree of doneness and who consume beef at least once a week were used in the study. Consumers were allocated seven half steaks and were asked to score tenderness, juiciness, flavour and overall liking by marking their assessment on 100-mm lines, which were anchored with words very tender–very tough for tenderness, very juicy–very dry for juiciness and extremely like–extremely dislike for flavour and overall liking. These scores (1–100) were weighted to derive the overall acceptability of each steak, which was defined as the MQ4 score. Two panellists evaluated each steak. This meant that 10 consumers assessed each striploin sample.

Statistical analyses

The GLM procedure of SAS (SAS 1999) was used to analyse the pH, meat colour (L^*, a^* and b^*) and consumer sensory data. Vendor group, marketing method and their interaction were fitted as fixed effects in the model. For the analysis of glycogen concentration, muscle was added to the model as a fixed effect along with vendor group, marketing method and first and second order interactions. For the objective meat quality measurements of shear force and cooking loss, SAS's mixed model procedure was used. The model comprised vendor group, marketing method and aging period and all first and second order interactions. The aging period effect was tested on the random term of animal (vendor group × marketing method). For all analyses, non-significant interaction terms ($P > 0.05$) were sequentially removed until the simplest significant model was obtained. In these analyses, the animal was used as the experimental unit rather than the treatment group. It was recognised that statistically, this meant that the model was more sensitive to differences due to the main effects and their interactions compared with the alternative of using the treatment group as the experimental unit.

Results

Carcass traits

The means and range in carcass weight and fat depth for each marketing method within vendor group are presented in Table 1. The average carcass weight and fat depth for the two marketing methods were 227.2 kg and 8.0 mm and 226.6 kg and 8.1 mm for direct consignment and saleyard marketing, respectively.

Glycogen concentration and pH decline

The main effects of vendor group, marketing method and muscle were all significant ($P < 0.001$). A significant three-way interaction between vendor group × marketing method × muscle ($P < 0.05$) was found for glycogen concentration (Table 2). The differences in muscle glycogen concentration due to marketing method were relatively small and generally inconsistent. The mean glycogen concentrations were 71.07 ± 0.83 and 66.5 ± 0.82 µmol/g for the directly consigned and saleyard treatments, respectively. The concentration of glycogen was higher in the SM than the ST ($P < 0.001$) but the difference between muscles varied in magnitude among the vendor group × marketing method subgroups.

The data for the second vendor group was excluded from the analyses of some of the meat quality measurements. This was necessary because the group that was directly consigned received no electrical stimulation due to a failure of the immobiliser on the hide-puller at slaughter. Consequently, the rate of pH decline was considerably slower (pH at 3 h postslaughter = 6.60) than that observed for all other slaughter groups (mean pH at 3 h postslaughter = 6.03). As a result, higher shear force values and lower sensory panel scores (data not shown) were evident for this group which was most likely due to cold shortening. Therefore, it was felt that the inclusion of this group (group 2) within the dataset would unduly bias the results.

Similar rates of pH declines (pH about 6.0 at 3 h postslaughter) were achieved in all slaughters (Table 2). The analysis of the pH data revealed that differences between the marketing methods were not significant but a highly significant ($P < 0.001$) vendor group × marketing method interaction at 1 and 3 h post mortem was apparent (Table 2). At both time points, there was a general tendency for the muscle pH to be slightly lower in the LL of the carcasses from the saleyard group compared with those from the directly consigned group. The exceptions to this trend were observed for group 3 (pH 1 and 3 h) and groups 7 and 8 (pH 1 h only). The difference in pH due to marketing method was statistically significant ($P < 0.05$) for groups 1, 7, 8 and 9 (pH at 1 h) and groups 1, 4 and 9 (pH at 3 h).

Table 1. Numbers of cattle and mean (± s.d.) hot carcass weight and P8 fat depth for each vendor group × marketing method in 1999

Vendor	*n*	Slaughter date	Carcass weight (kg)	P8 fat depth (mm)
		Direct consignment		
1	13	18 May	229.4 ± 14.0	5.9 ± 2.1
2	15	28 June	200.3 ± 5.6	6.4 ± 2.1
3	14	20 August	226.6 ± 10.9	4.9 ± 1.7
4	14	7 September	207.3 ± 7.6	4.6 ± 1.8
5	13	14 September	229.3 ± 10.6	8.1 ± 2.6
6	15	12 October	242.5 ± 12.1	9.1 ± 2.3
7	15	26 October	242.3 ± 18.0	12.4 ± 4.9
8	15	26 October	227.9 ± 14.9	12.1 ± 3.4
9	14	30 November	238.8 ± 18.8	7.3 ± 2.9
		Saleyard		
1	13	19 May	213.2 ± 16.3	7.5 ± 2.6
2	13	29 June	199.8 ± 10.4	5.2 ± 2.2
3	16	21 July	233.9 ± 11.2	4.7 ± 1.9
4	14	8 September	201.7 ± 13.8	4.2 ± 1.9
5	14	15 September	236.8 ± 5.3	8.8 ± 2.2
6	15	13 October	237.2 ± 14.3	10.4 ± 2.1
7	15	27 October	234.4 ± 14.0	12.9 ± 5.2
8	15	27 October	243.2 ± 14.7	9.4 ± 4.8
9	14	1 December	232.8 ± 16.7	9.1 ± 1.4

Table 2. Means (and s.e.d.) for muscle glycogen concentration (μmol/g), pH_{1h}, pH_{3h} and muscle colour (L^*, a^* and b^* values) for the interactions between vendor group × marketing method × muscle (glycogen concentration) and vendor group × marketing method (pH_{1h}, pH_{3h}, pH_{24h} and muscle colour)

DC, direct consignment; SY, saleyard; SM, *semimembranosus*; ST, *semitendinosus*. *P*-values for the terms in the model are also shown

Group	Marketing method	Glycogen SM	ST
1	DC	60.49	48.42
	SY	59.48	43.63
2	DC	75.33	72.88
	SY	78.40	74.99
3	DC	73.36	58.91
	SY	74.07	50.75
4	DC	79.42	70.77
	SY	85.95	69.74
5	DC	91.91	64.30
	SY	58.00	57.00
6	DC	90.61	72.06
	SY	78.67	60.99
7	DC	69.79	62.58
	SY	66.34	62.68
8	DC	76.24	75.17
	SY	72.34	66.15
9	DC	75.62	61.40
	SY	76.00	61.82
s.e.d.			
Group × marketing method × muscle = 4.81–5.07			
P-values			
Group			<0.001
Marketing method			<0.001
Muscle			<0.001
Group × marketing method			<0.001
Group × muscle			<0.01
Marketing method × muscle			n.s.
Group × marketing method × muscle			n.s.

Group	Marketing method	pH_{1h}	pH_{3h}	pH_{24h}	L^*	a^*	b^*
1	DC	6.31	6.09	5.55	34.5	13.8	5.6
	SY	6.08	5.79	5.43	35.5	14.8	6.0
2	DC	–	–	–	–	–	–
	SY	–	–	–	–	–	–
3	DC	6.29	5.92	5.48	35.9	13.2	5.5
	SY	6.45	5.99	5.50	36.3	13.4	6.0
4	DC	6.45	6.12	5.54	34.0	15.3	6.6
	SY	6.32	5.89	5.33	34.5	15.3	6.9
5	DC	6.30	6.00	5.39	33.6	17.0	7.1
	SY	6.21	5.97	5.42	32.5	18.4	7.9
6	DC	6.44	6.00	5.39	32.0	16.5	6.6
	SY	6.35	5.83	5.47	30.6	19.1	8.4
7	DC	6.29	6.22	5.38	29.8	20.4	9.4
	SY	6.57	6.21	5.47	30.1	16.6	7.2
8	DC	6.32	6.13	5.37	30.4	20.3	9.1
	SY	6.52	6.07	5.39	31.4	17.7	7.6
9	DC	6.57	6.24	5.55	31.3	16.8	7.4
	SY	6.33	5.94	5.42	31.2	17.4	7.6
s.e.d.							
Group × marketing method		0.06	0.07	0.04	0.62	0.56	0.32
P-values							
Group		<0.001	<0.001	<0.001	0.001	<0.001	<0.001
Marketing method		n.s.	n.s.	<0.05	n.s.	n.s.	n.s.
Group × marketing method		<0.001	<0.001	<0.001	<0.05	<0.001	<0.001

Objective and sensory beef quality traits

pH_u (24 h) was also significantly influenced by the interaction between vendor group × marketing method (Table 2). However, the differences were quite small as highlighted by the fact that the means were within a very narrow band from 5.33 to 5.55. All groups were in the normal pH_u range (i.e. pH_u <5.7) and only five carcasses from each marketing method treatment had a pH_u in excess of 5.7. Of these, only four (two from each selling method) would be classed as genuine dark-cutters (i.e. $pH_u \geq 5.9$).

A significant vendor group × marketing method interaction was also observed for the colour values (Table 2). Although not consistent across the vendor groups, there was a trend for increased redness and decreased blueness in the colour of muscle from the saleyard group. The notable exceptions to this trend were observed for groups 7 and 8. Overall, the marketing method differences in a^* and b^* values were only significant ($P < 0.05$) for groups 6, 7 and 8.

The interaction between vendor group × marketing method was also significant for consumer panel tenderness, flavour and the MQ4 scores (Table 3). This interaction was not significant in the case of panel juiciness scores. Significant differences in juiciness scores were still observed between the vendor groups but not between the marketing methods. Of note here was the similar pattern across the vendor groups for each of the palatability traits. This indicates that if the steak was rated high or low for one palatability dimension (e.g. tenderness), the other traits were also scored similarly. Not surprisingly, the correlations among tenderness, juiciness and flavour scores were high ($r = 0.8$–0.9). In view of this, the discussion of results will be limited to the MQ4 score.

Considerable variation in MQ4 score was observed across the nine vendor groups with LL steaks from groups 1 and 5 rated the highest overall. The effect of marketing method on the MQ4 scores was significant, however, the magnitude of the effect varied across the vendor groups. For five of the eight groups, saleyard marketing had a slight negative impact on the MQ4 scores. Statistically, this was only significant ($P < 0.05$) in the case of groups 3 and 8. For these two groups, the differences due to marketing method on the MQ4 scores were 14 and 11 units, respectively. For vendor groups 1, 5 and 9, the opposite trend ($P > 0.05$) between marketing methods was observed. With regard to vendor group 9, it is worth remembering that the saleyard cattle were transported from the

Table 3. Means (and s.e.d.) for Meat Standards Australia (MSA) panel tenderness, juiciness, flavour and MQ4 scores (0–100), shear force and cooking loss percentage for the interactions between vendor group × marketing method (MSA panel scores) and vendor group × marketing method × aging (shear force and cooking loss %)

DC, direct consignment; SY, saleyard. *P*-values for the terms in the model are also shown

Group	Marketing method	Tenderness	Juiciness	Flavour	MQ4	Shear force		Cooking loss (%)	
						1 day	14 days	1 day	14 days
1	DC	70.1	63.2	64.0	66.2	10.6	5.9	34.8	36.6
	SY	70.6	64.5	65.4	67.6	8.0	5.6	35.8	37.2
2	DC	–	–	–	–	–	–	–	–
	SY	–	–	–	–	–	–	–	–
3	DC	62.8	59.0	60.9	60.9	10.4	5.8	37.4	38.0
	SY	45.8	48.1	50.4	46.8	11.7	6.6	36.2	38.0
4	DC	58.9	63.3	60.2	59.2	10.0	4.5	33.1	36.4
	SY	56.5	61.0	58.2	57.4	11.3	6.0	35.4	37.2
5	DC	67.3	64.8	66.4	66.3	6.8	4.7	25.4	34.6
	SY	73.5	70.4	70.6	72.2	7.7	5.6	27.3	33.5
6	DC	54.2	59.1	59.6	56.1	10.5	5.8	35.2	33.7
	SY	49.7	55.6	59.1	53.8	10.2	7.0	36.5	34.7
7	DC	64.7	62.6	63.1	63.6	9.8	5.4	34.1	34.4
	SY	60.9	58.6	58.8	59.5	11.2	6.1	33.7	34.1
8	DC	71.7	67.5	68.3	69.1	8.6	5.6	33.2	33.2
	SY	55.6	60.0	61.6	58.4	11.3	5.7	34.9	35.7
9	DC	55.5	52.1	54.5	54.3	11.6	4.8	36.2	34.0
	SY	61.0	54.2	60.5	60.2	12.6	5.2	35.7	35.2
s.e.d.									
Group × marketing method		4.74	4.05	3.04	3.89				
Group × marketing method × aging						0.64		0.67	
P-values									
Group		<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	
Marketing method		<0.05	n.s.	n.s.	0.08	<0.001		<0.001	
Aging						<0.001		<0.001	
Group × marketing method		<0.01	0.09	<0.01	<0.01	<0.01		<0.01	
Group × aging						<0.001		<0.001	
Marketing method × aging						n.s.		n.s.	
Group × marketing method × aging						<0.001		<0.001	

saleyard the day after the sale and slaughtered on arrival at the abattoir without any recovery period. Rather than having an adverse effect, this resulted in an improvement ($P > 0.05$), in eating quality compared with the results for the direct consigned subgroup.

For the objective measurements of shear force and percent cooking loss, the three-way interaction between vendor group × marketing method × aging was highly significant (Table 3). The change in least square means for shear force (Fig. 1) indicates that the reduction in shear force from 1 to 14 days varied depending on the vendor group and marketing method. The smallest and largest reductions in shear force were observed for vendor groups 5 and 9, respectively. Of note, shear force on day 1 and percent cooking loss values for vendor group 5, were the lowest overall and this group also received the highest MQ4 scores when assessed by the consumer panel. With respect to marketing method, the reduction in shear force following aging was significantly greater ($P < 0.05$) for the direct consignment treatment in two vendor groups (groups 1 and 6), whereas the opposite was observed for vendor group 8. For the remaining vendor groups, the reductions in

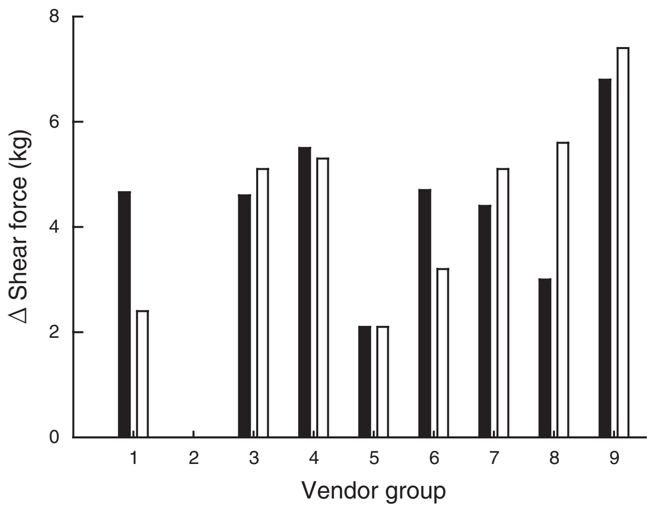

Fig. 1. The change in shear force (kg) from 1 to 14 days aging for the different vendor group × marketing method treatments (solid bars, direct consignment; open bars, saleyard).

shear force due to aging were similar between the marketing methods.

For six of the eight groups, the shear force values after 14 days aging were lower for the direct consignment group than for the saleyard group. However, this was only statistically significant ($P < 0.05$) in the case of groups 4 and 6 where the mean difference was 1.5 and 1.2 kg, respectively.

A significant three-way interaction between vendor group × marketing method × aging was also found for cooking loss (Table 3). Cooking loss percentage generally increased with aging but the magnitude differed between the vendor groups and marketing method. Cooking loss was higher for saleyard groups then for directly consigned groups at both 1 and 14 days postslaughter in groups 1, 4, 5, 6 and 8.

Postslaughter pH decline

The results presented in Table 2 clearly showed that the interaction between vendor group × marketing method had an influence on the postslaughter pH at 1 and 3 h in the LL. The differences in glycolytic rate, particularly during the early post mortem period, may also underpin the significant interactions between vendor group × marketing method and vendor group × marketing method × aging for MQ4 scores and shear force, respectively. To determine whether differences in the rate of pH decline could account for the results for shear force and eating quality, an analysis of covariance was performed where the covariate representing the rate (dx/dt) of pH decline (pH 1 h–pH 3 h)/120 during the early post mortem period was fitted. After adjusting for the rate of pH decline, the overall significance of the interaction terms vendor group × marketing method × aging and vendor group × marketing method was reduced but still significant for shear force ($P < 0.05$) and MQ4 score ($P < 0.01$), respectively.

Discussion

Historically, the primary issue studied with respect to the effect of marketing method on meat quality has been the incidence of dark cutting (e.g. Shorthose and Wythes 1988; Warner *et al*. 1988, Stevenson *et al*. 1996). In the present study, marketing method did not affect the incidence of high pH_u meat (i.e. pH_u >5.9). Indeed, the proportion of carcasses with an LL pH_u >5.7 was very low at 3.8%. This is not surprising given the high muscle glycogen levels found in the study. The levels were higher than those reported by Pethick *et al*. (1999) for cattle receiving a grain-based supplement at pasture (SM: 44.4–72.2 μmol/g; ST: 38.9–61.1 μmol/g). Although the cattle in the present study would be classed as pasture finished, silage or grain based supplements were also provided to cattle in eight of the nine groups.

In general, cattle sold through saleyards are typically exposed to additional stress before slaughter due largely to the increased time off feed and additional exposure to novel environments, handling and transport. The results of studies comparing saleyard and direct consignment marketing certainly support this view based on behavioural and physiological criteria (Jarvis *et al*. 1996; Warner *et al*. 1998). Despite the additional stress, there was a negligible impact on muscle glycogen levels in the present study. The largest differences were observed for vendor groups 5 and 6. This tends to contrast with the results of Warner *et al*. (1998) who showed that marketing method had a highly significant effect on muscle glycogen levels and that this was exacerbated by the nutritional status of the cattle before slaughter. In their case, the difference in muscle glycogen levels between directly consigned cattle and saleyard cattle was substantially larger in cattle that were on poor quality pasture before slaughter. The cattle in the present study were on high quality nutrition before slaughter and this may have been a factor in the minimal effect of marketing method on muscle glycogen concentration. Another factor is that best practice was applied in the management and handling of the saleyard groups, which may have mitigated some of the cumulative stressors.

As expected, the glycogen content was lower in the ST than in the SM and this is a reflection of the differences in fibre morphology of the two muscles. The ST has a higher proportion of glycolytic fibres relative to the SM (Totland and Kryvi 1991) and is more sensitive to stress induced depletion of muscle glycogen (Pethick *et al*. 1999).

Marketing method influenced several of the objective and sensory meat quality measurements; however, the effect was inconsistent across the vendor groups and in some cases, quite small. Therefore, it is difficult to draw firm conclusions about the impact of marketing method on beef quality. Suffice to say, there was a trend in favour of direct consignment particularly for the important measurements of shear force and MQ4 score for five of the vendor groups. In stark contrast, the differences among vendor groups in the various meat quality measurements were far greater than those associated with marketing method. This result was unexpected since the cattle had similar backgrounds (i.e. breed, age and production history) and the postslaughter conditions were standardised. These groups would be considered the same from an MSA grading viewpoint but clearly, consumers would not agree. We can only speculate that there are uncharacterised on-farm or preslaughter factors, which underpin these large vendor differences in eating quality. Moreover, these results suggest that there is scope for further improvement in beef eating quality if these factors can be identified and controlled.

It is well documented that the rate of post mortem pH decline relative to temperature decline is pivotal in relation to the two key biophysical changes that govern tenderness (Bendall 1973). Notably, these are the degree of myofibrillar shortening (Locker and Hagyard 1963; Bendall 1973; Devine *et al*. 1999) and the rate and extent of post mortem proteolysis (Dransfeld 1994; Simmons *et al*. 1996). Small differences in the early post mortem rate of pH decline (i.e. pH at 1 and 3 h) were evident between the marketing methods in the present study. However, these differences could not completely account for the significance of the interactions between vendor group × marketing method and vendor group × marketing method × aging time on MQ4 scores and shear force, respectively.

The small differences in muscle pH at 1 and 3 h post-slaughter between the marketing methods could be linked to variations in electrical inputs on the slaughter-floor (i.e. efficacy of the hide-puller immobiliser) between slaughter days. However, it would be expected that if there was a day of slaughter effect, then it was more likely to be a random rather than a consistent effect, over the nine pairs of different slaughter days. Given the consistency of the trend in pH at 1 and 3 h post mortem between the marketing methods, it is unlikely that this was due to differences in the postslaughter conditions on the different slaughter days. Although it is impossible to completely discount any day of slaughter effect, the differences in pH decline are more likely to be associated with differences in the preslaughter treatment of the cattle. The results of Simmons *et al*. (1997) and Butchers *et al*. (1998) lend support here because they showed that post mortem glycolytic rate was altered by the preslaughter treatment of lambs and cattle, respectively. Unfortunately, the reasons for this effect have yet to be elucidated.

Meat colour was influenced by the interaction between vendor group × marketing method; however, it is unlikely that these changes would be perceptible by consumers.

The observed interaction between vendor group × marketing method × aging on shear force indicates that the aging potential of the meat, as measured by the change in shear force, differed between the vendor groups and the method by which the cattle were marketed. However, the reduction in shear force after 14 days aging varied considerably across the vendor groups and there was no clear trend with respect to marketing method. Similarly, cooking loss percentage was also influenced by this interaction. As expected, cooking loss increased with aging but the magnitude varied among the vendor × marketing method subgroups.

Conclusion

The results of this study lead us to conclude that marketing method had a small but variable impact on beef quality and palatability. For the majority of the vendor groups, saleyard marketing resulted in a small loss in eating quality and tenderness. However, the caveats here are that the magnitude of the loss varied depending on the origin of the cattle and additionally, the direct consignment advantage in MQ4 score was only statistically significant in two of the eight groups. It is also worth noting that the saleyard selling treatment used in this study was industry best practice and, therefore, any deviation from it may result in larger and more consistent losses in beef eating quality.

The differences observed in all meat quality traits between the vendor groups, was not unexpected. However, the magnitude of them was. Ostensibly, these groups would be considered the same from an MSA viewpoint. That is, they were young cattle of British origin growing well at pasture, which was enhanced by the provision of supplements, and highly suitable for the Victorian domestic market. Clearly, further examination of the origins of these vendor differences is required in interests of maximising consumer acceptability of beef.

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