The superior tenderness of the posterior part of *Longissimus lumborum* from farmed deer was no longer evident after aging

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Abstract— **The objective was to investigate the effects of aging time and sampling location on meat quality parameters of venison short-loin (*Longissimus lumborum*) produced, processed and aged under commercial conditions. Pasture-fed deer (n = 79; 41 male & 38 female) aged 12-14 mo from two farms were commercially processed over two consecutive days. The left short-loin (*L. lumborum* between the last rib and pelvic bone) was removed from the carcass 24h *post mortem*, halved, and anterior and posterior halves were allocated alternately to either a 3d or 42d aging period. Eating quality parameters including Warner-Bratzler shear force, pH_{ult}, purge, water-holding capacity, cooking loss, sarcomere length, and L*a*b* colour were measured at both aging times. Samples from the anterior half within *L. lumborum* had significantly higher shear force values at 3d aging ($p < 0.001$), but not after 42d aging. Venison at the anterior end of the short-loin was lighter, redder, and more yellow than that of anterior samples after 3d aging ($p < 0.001$), either with or without adjustments for pH_{ult}, but differences disappeared after aging for 42d. Aging venison for 42d significantly affected all traits except sarcomere length and cooking loss. Both location and aging affected most quality traits measured in this study, so both require consideration when seeking to optimise venison quality parameters.**

Keywords— **Venison, Meat Quality, Deer**

I. INTRODUCTION

Tenderness is an important factor contributing to a positive eating quality experience in red meat [1]. In the case of venison, a low fat content and high iron content add to its perception as a high-value product in many markets [2,3]. The majority of farmed venison produced in New Zealand is destined for EU markets. Vacuum-packaged venison is shipped to the EU in either a chilled or frozen form via sea freight which takes up to 6 weeks, however the effect of this process on product quality is not well characterized.

The aim of this experiment was to investigate the effects of aging time and sampling location on eating quality parameters of venison short-loin (*L. lumborum)* produced, processed and aged under commercial conditions.

II. MATERIALS & METHODS

A. Animals

The 79 deer (*Cervus elaphus*) for the experiment were processed under commercial conditions in two batches. The first batch were slaughtered on Monday the 14th of December 2009 and consisted of 18 red hinds and 20 red stags, and the second batch were slaughtered on Wednesday the 16th of December 2009 and consisted of 20 red-wapiti hybrid hinds and 21 red-wapiti hybrid stags. The two batches originated from different farms so a genotype comparison was not possible due to the confounding effects of genotype and farm.

B. Abattoir protocol

Deer were immobilized by a captive bolt pistol. Low voltage electrical stimulation was applied (72V for 62 seconds with 7.5ms stimulations at intervals of 70mS). Carcasses were exsanguinated immediately after stunning and dressed according to normal commercial practice. The dressing and subsequent grading/inspection process before entry to the chiller took approximately 16 minutes. Carcasses were chilled overnight at 1 ± 1°C.

Short-loin samples from 1 side of the carcass were recovered at approximately 24h *post mortem*. Each

short-loin sample was halved and the two halves were weighed, vacuum-packaged and the anterior and posterior halves were allocated alternatively to a 3d or 42d aging period. Samples were aged at 1 ± 1°C under commercial conditions for the designated aging time prior to freezing at –30°C for at least 1 week.

C. Meat quality assessment

Samples were defrosted in batches of 8 at 1 ± 1°C for 22h, removed from vacuum packs, and blotted dry using paper towels before the thawed weight was recorded. Purge was calculated by subtracting the weight of the sample upon opening from the weight at packing and expressing the difference as a percentage of the packing weight.

A 25mm steak was cooked for 90 minutes at 70°C within plastic bags that were suspended in a water bath [4]. Following cooking, samples were stored overnight at 1 ± 1°C, and then 5 13x13mm cores were prepared in such a way that muscle fibres ran longitudinally in the core. Measurements were made with a Warner-Bratzler device (crosshead speed of 230 mm•min^{-1}; G-R Electric Mfg. Co., Manhattan, KS) fitted with a square blade and a 30-kg load cell [4]. Two shears perpendicular to the muscle fiber axis were made per core. Parameters recorded for each shear were the average initial yield force (IYF), the peak force (PF), and the average shear force through the duration of the shear as an index of the work done (WD). The difference between the peak shear force and the initial yield has been linked to the connective tissue component of meat toughness [5] so this difference was also calculated (PF–IYF).

The remainder of the short-loin sample was used for measuring sarcomere length, pH and colour. The cranial portion was halved laterally; one half was frozen at –30°C for subsequent colour analysis and the other half retained on ice for pH and sarcomere length measures.

The sections for colour analyses, which included the half where the epimysium was thinnest, were defrosted for 12h at 1 ± 1°C, then cut across the fibres and allowed to bloom for 20 minutes at room temperature. Preliminary trials indicated that 20 mins was sufficient bloom time for venison. Two measures of L*, a* and b* were made using a Minolta Chromameter (CR-200, 8 mm measured area diameter, standard illuminant C, white tile calibration; Ramsey, NJ) and the average calculated.

Ultimate pH (pH_{ult}) was assessed on a homogenate prepared from 2 to 2.5 g of meat in 10 mL of distilled water using a combination pH electrode (Jenway 3020 pH meter with automatic temperature compensation).

Sarcomere length was assessed by laser diffraction [6]. The average diameter of 1st order diffraction patterns was calculated for 12 patterns [7].

Water-holding capacity (WHC) was evaluated using filter paper press method based on that described by [8]. A 500 ± 10mg sample of thawed venison was removed from the centre of the short-loin sample, placed on a sheet of Whatman No 1 filter paper. The paper and sample were placed between two Perspex plates and a force of 10 kg applied for 5 minutes. After removal from the plates, the outline of the meat was marked on the underside of the filter paper. Samples were set aside to dry before the area of the juice-stained region was measured using a planimeter. Expressed juice (EJ) was calculated by dividing the area by the sample weight yielding a value in cm^{2}g^{-1}.

D. Statistical methodology

The effect of aging was determined using the paired t-test procedure of SAS (SAS Inst. Inc., Cary, NC) by calculating the difference between 3d and 42d to form a new variable for each trait. Dependent variables including genotype, sex and short-loin sampling location were tested for significance using a general linear model. The location effect was investigated for both 3d and 42d aging times. Furthermore, pH_{ult} was fitted as a quadratic covariate for comparison in a second model. Significant interactions ($p \leq 0.05$) were retained in the appropriate models.

III. RESULTS & DISCUSSION

E. Effect of aging venison short-loin for 42d

Aging venison short-loin for 42d had significant effects on most measured traits (Table 1). Venison became more tender with PF (Figure 1), IYF and WD significantly lower at 42d; ($p < 0.001$), and with an increased amount of liquid purged after thawing ($p < 0.001$). Additionally, expressed juice decreased ($p < 0.001$), pH_{ult} increased slightly, and sarcomere length

decreased ($p < 0.05$) with aging. Venison was significantly lighter, redder and more yellow after aging for 42d ($p < 0.001$).

Table 1 Aging effects on venison short-loin characteristics in terms of the difference between values at 3 and 42d aging

Trait [abbreviation]	Difference (3 – 42 d)	p value
Peak Force [PF] (kg)	2.49 ± 0.16	<0.001
Initial Yield Force [IYF] (kg)	2.39 ± 0.14	<0.001
PF-IYF (kg)	0.10 ± 0.05	0.06
Work Done [WD] (kg)	0.63 ± 0.05	<0.001
Purge (%)	-1.97 ± 0.20	<0.001
Expressed Juice [EJ] (cm^2g^{-1})	4.68 ± 0.38	<0.001
Cooking Loss [CL] (%)	0.39 ± 0.23	0.10
Sarcomere Length [SL] (µm)	0.02 ± 0.01	0.023
pH_{ult}	-0.02 ± 0.01	0.001
Lightness [L*]	-2.10 ± 0.30	<0.001
Redness [a*]	-0.61 ± 0.16	<0.001
Yellowness [b*]	-0.32 ± 0.08	<0.001

F. Effect of sampling location on aging (3 – 42d)

The extent to which aging affected meat quality parameters of *L. lumborum* differently between anterior and posterior sections is shown in Table 2 as the difference between the aging times (3d – 42d) for each trait. The aging effect was significantly greater in the anterior section of the short-loin for shear force traits including PF (Figure 1), IYF, PF-IYF, WD, purge, a* and b* ($P < 0.05$). In contrast, there were no significant differences between the anterior and posterior for CL, pH_{ult}, SL or L* (data not shown).

Table 2 Effects of sampling location (sample assessed at 3d as either anterior or posterior) on changes with aging (3d – 42d)

Trait	Anterior (n = 41)	Posterior (n = 36)	p value	R^2	RSD
PF (kg)	3.04 ± 0.20	1.85 ± 22	< 0.001	20.1	1.26
IYF (kg)	2.90 ± 0.18	1.81 ± 0.20	< 0.001	19.0	1.17
PF-IYF (kg)	1.02 ± 0.07	0.79 ± 0.08	0.03	14.6	0.47
WD (kg)	0.78 ± 0.06	0.46 ± 0.33	< 0.001	22.3	0.36
Purge (%)	-2.56 ± 0.25	-1.32 ± 0.27	0.001	18.2	1.62
EJ (cm^2g^{-1})	4.33 ± 0.52	5.15 ± 0.57	0.30	4.3	3.29
CL (%)	0.69 ± 0.30	0.00 ± 0.33	0.13	15.7	1.93
a*	-1.04 ± 0.21	-0.16 ± 0.23	0.006	16.9	1.34
b*	-0.62 ± 0.09	0.00 ± 0.10	< 0.001	25.4	0.60

G. Location effects at 3 and 42d aging

Table 3 lists the traits where short-loin sampling location had a significant effect ($p \leq 0.05$) following aging for 3d. This is consistent with the finding that the extra 39 days aging had different effects on the anterior and posterior samples as shown in Table 2 and Figure 1. Table 4 shows results for the same traits as Table 3 with pH_{ult} fitted as linear and quadratic covariates. Inclusion of pH_{ult} increased the coefficient of determination (R^2) and reduced the residual standard deviation (RSD) in all cases (Table 3 vs. Table 4). At 3d aging, venison from the posterior section of the short-loin had significantly lower shear values, including PF (Figure 1), than the anterior section ($p < 0.001$). Posterior samples aged for 3d were also lighter ($p = 0.03$), more red and yellow than anterior samples at 3d aging ($p < 0.01$). None of the location effects shown in Table 3 were significant following aging for 42d e.g. 42d PF (see Figure 1).

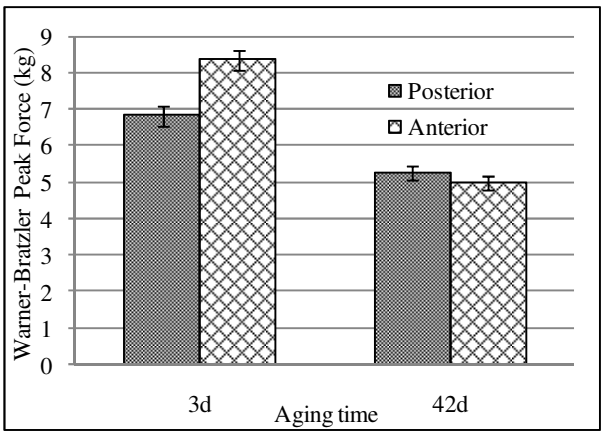

Figure 1 Least Squares means (±SE) of sampling location showing that posterior samples had significantly lower PF at 3d ($p < 0.001$), but this was no longer apparent after aging for 42d at 1 ± 1°C

Longitudinal variation in *L. dorsi* tenderness has been previously reported in pork [9], beef [10] and lamb [11]. In pork, the tenderness decreased towards the posterior end of the muscle [9]. In beef, the anterior and posterior ends of the *L. lumborum* were significantly tougher than the middle [10] and in lamb, *L. lumborum* was significantly tougher in the anterior part of the muscle after 14d aging [11].

Table 3 Location effects on characteristics of venison short-loin aged for 3d (n = 78)

Trait	Anterior (n = 41)	Posterior (n = 37)	p value	R^2	RSD
PF (kg)	8.35 ± 0.26	6.82 ± 0.27	< 0.001	21.6	1.63
IYF(kg)	7.26 ± 0.23	6.09 ± 0.24	< 0.001	24.4	1.43
WD (kg)	2.47 ± 0.07	2.10 ± 0.07	< 0.001	28.0	0.45
PF-IYF (kg)	1.03 ± 0.07	0.80 ± 0.08	0.034	14.6	0.47
L*	34.88 ± 0.32	35.90 ± 0.34	0.032	31.0	2.02
a*	11.26 ± 0.24	12.23 ± 0.26	0.008	9.5	1.55
b*	2.65 ± 0.12	3.29 ± 0.13	< 0.001	16.8	0.79
Purge (%)	2.59 ± 0.16	3.38 ± 0.17	< 0.001	14.8	0.99

Table 4 Location effects on characteristics of venison short-loin aged for 3d after adjusting for differences in pH_{ult}

Trait	Anterior	Posterior	p value	pH,pH^2	R^2	RSD
PF	8.17 ± 0.23	7.05 ± 0.25	0.002	**, **	39.0	1.46
IYF	7.14 ± 0.22	6.25 ± 0.23	0.008	*, *	35.2	1.34
WD	2.42 ± 0.06	2.16 ± 0.07	0.009	*, **	44.8	0.40
PF-IYF	0.97 ± 0.06	0.87 ± 0.07	0.29	ns, ns	41.7	0.39
L*	35.01 ±0.31	35.71 ± 0.32	0.13	ns, ns	39.9	1.92
a*	11.44 ± 0.20	11.98 ± 0.21	0.077	ns, ns	41.5	1.27
b*	2.76 ± 0.09	3.14 ± 0.10	0.010	*, ns	53.6	0.59
Purge	2.63 ± 0.15	3.32 ± 0.16	0.003	ns, ns	22.8	0.96

(ns = $p > 0.05$, * = $p \leq 0.05$, ** = $p \leq 0.01$)

The lower shear values for the posterior section of the short-loin remained significant after inclusion of pH_{ult} as a covariate, but the magnitude of the effect was smaller. There were no significant differences in IYF, lightness or redness after inclusion of pH_{ult}.

The amount of purge was also significantly greater in the posterior half of the short-loin with or without the covariate (pH_{ult}), suggesting that increased purge is not associated with poorer tenderness.

IV. CONCLUSIONS

This study showed that aging venison short-loin for 42d relative to 3d affected many meat quality traits, but the size of changes with aging was greater in the anterior section of the muscle. The differential tenderness within the short-loin at 3d aging may be of particular importance when venison is frozen with little aging. As a result, frozen, unaged short-loin tenderness may be less consistent than the chilled aged product.

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