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Intramuscular fat content of New Zealand lamb *M. longissimus lumborum*

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Abstract

The content of intramuscular fat (IMF%) in lamb is an important trait for the lamb-meat value chain. Not only is IMF% an important energy reserve for replacement stock, IMF% is an important driver of lamb-meat eating quality. A growing body of research shows an antagonistic relationship between muscle growth traits and fat content across the lamb carcass (including IMF%). The New Zealand sheep industry has selected for muscle growth traits for decades to improve production efficiency and reduce extremes of carcass fatness historically observed, but the impacts on IMF% levels in New Zealand lamb have not been widely investigated.

This paper aims to stimulate discussion on lamb IMF% by reporting on levels of IMF% observed in the *M. longissimus lumborum* (LL) of 1,705 progeny test lambs raised under extensive, pasture-based production systems across New Zealand, and investigates the relationship between IMF% and carcass weight, VIAscan®-predicted GR (VSGR) and lean-meat-yield percentage (VSYLD).

The average IMF% was 2.69%, (SD = 0.83%, and ranged between 0.91-6.42%). IMF% is positively correlated with carcass weight and VSGR and negatively correlated with VSYLD. Considerable variation exists in lamb IMF%, highlighting the opportunity to manage IMF% through genetic improvement and optimised on-farm management.

Keywords: intramuscular fat; lamb; meat quality

Introduction

Producing lamb with highly desirable meat-eating quality characteristics is a key goal of the New Zealand lamb industry. Lamb-meat eating quality can be considered the end result of production and processing factors, which form the value proposition of lamb products offered to consumers. Research has identified that meat eating quality is the determined by intrinsic factors such as the texture and flavour of the meat, and also by the extrinsic factors (Grunert et al. 2004) which include the mode of production and processing for example, whether the meat is organically produced or halal slaughtered. In terms of the intrinsic quality factors, intramuscular fat (IMF) content (%) and composition, which are driven by on-farm production factors, are also known to influence consumer acceptability of lamb meat particularly the juiciness and flavour (Frank et al. 2017, Sanudo et al. 2000, Oltra et al. 2015, Wood et al. 2003, Wood et al. 2008). Research has shown that IMF% actually accounts for a significant amount of the variation in consumer acceptability of red-meat products. In beef, IMF% was found to account for 15% of the variation in palatability (Dikeman 1987) while in lamb, IMF% was found to account for 11% of the variability in palatability as assessed by a trained sensory panel (Lambe et al. 2017).

The level of IMF% in lamb required to ensure consumer satisfaction with regard to palatability is a topic of some debate. A minimum of 5% IMF was proposed to ensure consumer acceptability of lamb meat (Hopkins et al. 2006). Recent research has found evidence that the relationship between IMF and texture and overall liking as perceived by a trained sensory panel is non-linear (Lambe et al. 2017) where the scores for texture and overall liking peaked between 4 and 5% IMF. The same authors also showed that lamb meat where computed tomography (CT) predicted IMF was above 3% scored significantly higher for sensory traits than products where CT-predicted IMF was lower than 3%.

The role of IMF in ensuring lamb palatability is important because eating experience is widely accepted as a key driver of repeat purchase consumer behaviour.

Recent research has shown that selection for leanness results in reduced levels of IMF in lamb *M. longissimus lumborum* (Pannier et al. 2014). Furthermore, it has been shown the reduction in IMF as a result of breeding for animal growth traits is not restricted to the loin but reduces IMF throughout the carcass, including fore-quarter muscles *M. supraspinatus* and *M. infraspinatus*, and hind-quarter muscles *M. semimembranosus* and *M. semitendinosus* (Anderson et al. 2015).

The New Zealand sheep industry has been selecting for muscle growth traits for decades, primarily to improve production efficiency, but also to improve consistency of carcass size and conformation. The impacts on IMF levels in New Zealand lamb resulting from these selection pressures have not been widely investigated.

This paper aims to stimulate discussion on lamb IMF% by reporting on levels of IMF observed in the *M. longissimus lumborum* of 1,705 progeny-test lambs born in 2014 and 2015, including the relationships with carcass traits. All the lambs were raised under extensive, pasture-based production systems across New Zealand.

Materials and methods

Processing and meat samples

The lamb *M. longissimus lumborum* (LL) were sourced from various industry progeny tests described previously, including the Beef + Lamb New Zealand Genetics central progeny test (Jopson et al. 2009), Headwaters progeny test (Johnson et al. 2015a) and Perendale progeny test (Johnson et al. 2015b). All lambs were processed commercially at one of three Alliance Group Limited sites; Dannevirke, Smithfield or Lorneville in 2015 (n = 1,525) and 2016 (n = 180). Cold carcass weight (CWT) was recorded by the processing plant and estimates of carcass fatness (VSGR) and the percentage of total lean-meat yield (VSYLD) in the carcass were obtained from VIAscan® which is a two-dimensional imaging system installed within each processing plant to image the carcass before entry to the chillers (Hopkins et al. 2014).

At 24 hours *post mortem*, the carcasses were fabricated into forequarter, middle and hindquarter primal cuts. The saddle primal was recovered along with the carcass identity, and the left LL was removed with the fat-cap on. A ~2cm slice was recovered from the posterior end of each LL. The sample was trimmed of all external fat and connective tissue and placed in a small zip-lock bag. Ten bagged samples were agglomerated into one larger bag and vacuum packaged before being frozen at -20°C for subsequent freeze drying and IMF analysis.

Analysis of intramuscular fat

IMF analysis was conducted on freeze-dried LL meat powder. The weight of frozen LL samples, in their zip-lock bags complete with ID tag was electronically recorded using a calibrated three decimal-place balance, connected to a laptop computer and barcode scanner. Once 60 - 80 samples had been weighed and their barcodes read, each sample was freed from contact with the inside of the zip-lock bag and a straw was placed within the bag to allow full air circulation during the freeze-drying process. Samples were placed on a large metal tray and inserted into a Cuddon FD80 freeze dryer set to -30°C (Cuddon Freeze Dry, Blenheim, NZ). The freeze-drying program contained the three steps each with a vacuum applied: 1. -30°C for three hours, 2: -10°C for four hours and 3: 0°C for a final 72 hours. On completion, the sample was removed from the bag and weighed, and the bag and ID tag weight also recorded. Freeze-dried meat samples were removed from their bags and ground to a fine powder using a small domestic electric coffee grinder.

The conversion factor (weight of dried sample – the weight of bag and tag) / (weight of wet sample – weight of bag ID and tag) was applied to the weight of the freeze-dried meat to convert from concentration per gram of freeze-dried meat to the concentration of the wet meat. The expected range for freeze-dried values was between 0.24 and 0.28. If found to be outside this range the sample was double checked for accuracy.

IMF was analysed as the sum of triacylglyceride. A direct trans-methylation method was employed for FA analysis which combined the extraction and esterification of lipids in a single step (Knight et al. 2003). From each sample, 300 mg of freeze-dried-meat powder were placed into Kimax 15 ml tubes, 4 ml of toluene and 300 µL of internal standard (C11 TAG in toluene) were added with a volumetric pipette under fume hood. Then 4 ml of 5% methanolic sulphuric acid was added. After adding the solutions, the tubes were tightly fitted with caps and mixed thoroughly and incubated at 70°C for 2 hr. The samples were mixed every 30 minutes during the incubation time, and then left to equilibrate to room temperature for 25 minutes before 5 ml of saturated NaCl was added. Tubes were shaken vigorously and then centrifuged at 2300 rpm for 2 min to separate solvent layers. The top FAME layer was transferred into 1.5 ml GLC (Gas Liquid Chromatography, Hewlett Packard, model 6890) auto-sampler vials. The GLC was equipped with a Restex RTX 2330 column of 105 m length, 0.25 mm i.d., and 0.20 µm film thickness and a flame ionisation detector (FID). The peaks were identified and quantified by using internal standard (C11:0) and theoretical FID response factors. The equations for generating the response and conversion factors to quantify individual FA from FAME were obtained from American Oil Chemists' Society (AOCS 2004). The sum of the individual and un-reported fatty acids expressed as triglycerides represents the IMF. The conversion factor (weight of dried sample – the weight of bag and tag) / (weight of wet sample – weight of bag ID and tag) was applied to the weight of the freeze-dried meat to convert from concentration per gram of freeze-dried meat to the concentration of the wet meat (IMF%).

Data analysis

Given the unbalanced and confounded structure of the dataset it is not possible to undertake detailed analysis among groups. Therefore, data analysis is restricted to summary statistics and a meta-analysis of the IMF% and carcass data to investigate relationships between IMF%, carcass weight, VSGR and VSYLD. A step-wise regression analysis fitting CWT, VSGR and VSYLD was undertaken using the regression procedure of SAS 9.4 (SAS Institute Inc., Cary, NC, USA).

Results

The distribution of IMF% across 2014- and 2015-born lamb progeny is Gaussian (Figure 1). The number of ewe lambs processed in progeny tests (9%) is much lower than ram (42%) or wether (49%) lambs because most ewe lambs are retained for breeding purposes. The summary statistics for carcass and IMF% traits are shown in Table 1. The mean IMF for lambs across years was 2.69% (SD = 0.83). The standard industry target-weight range of lamb carcasses is 17-19 kg. The plot of CWT against VSGR shows that there is a large spread of VSGR within the target range, and that there are carcasses with LL IMF% above and below 3% in the target-weight range (Figure 2). Note that the threshold of 3% was established previously as differentiating the overall liking of lamb LL (Lambe et al. 2017). There is also evidence that IMF% is negatively correlated with VSYLD after adjusting for CWT and VSGR (Table 2).

Figure 1 Frequency distribution of intramuscular fat content in lamb *M. longissimus lumborum* from 2014- and 2015-born lambs (n = 1,705)

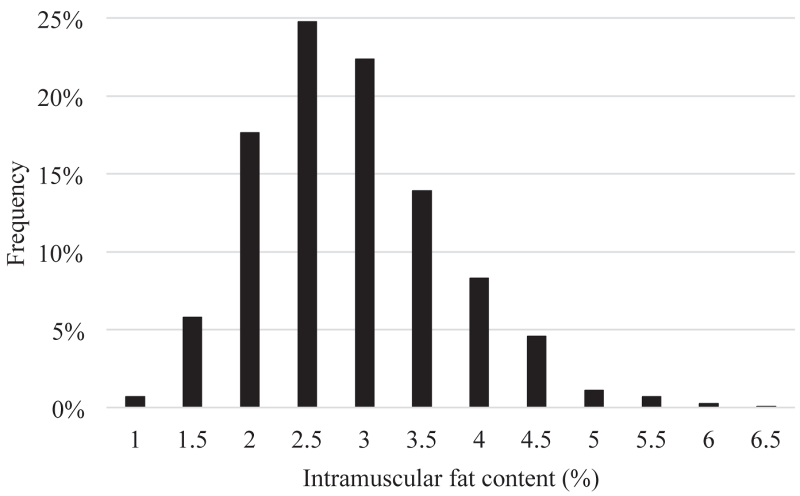

Figure 2 Scatter plot showing the positive relationship between VSGR and CWT from 2014- and 2015-born lambs (n = 1705). IMF% below 3% are shown as black points and IMF% values above 3% are shown as white points. The vertical dashed lines indicate the current industry-standard target carcass weight range (17-19 kg).

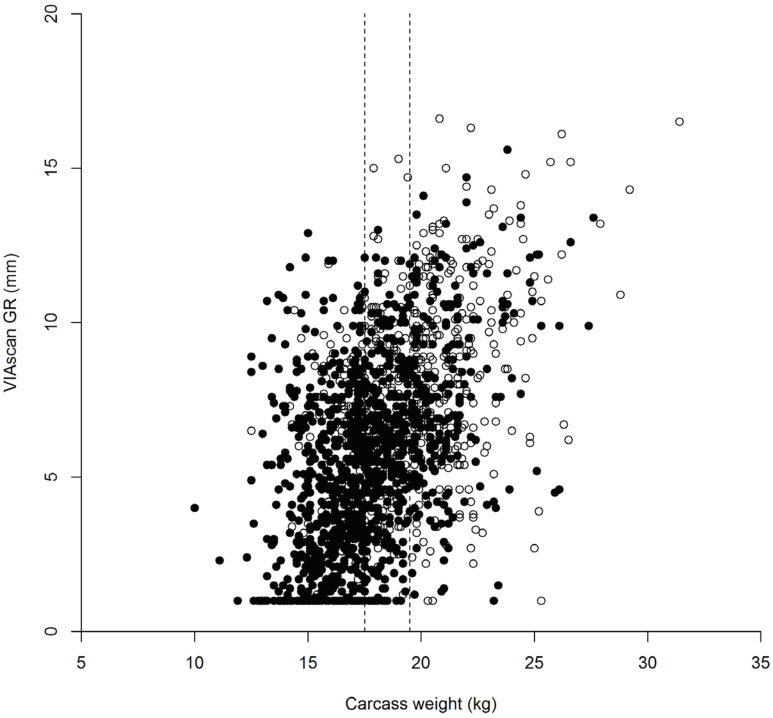

Table 1 Summary statistics for carcass traits and *M. longissimus lumborum* intramuscular fat content from 2014- and 2015-born lambs (n = 1,705).

Trait	N	Mean (SD)	Coefficient of variation	Minimum	Maximum
Intramuscular fat content (%)	1705	2.69 (0.83)	30.84%	0.91	6.42
cold carcass weight (kg)	1705	18.23 (2.64)	14.50%	10.00	31.40
VIAscan® GR (mm)	1705	6.22 (3.18)	51.15%	1.00	16.60
VIAscan® lean-meat yield (%)	1705	54.80 (2.46)	4.50%	42.18	63.25

For every unit increase in IMF%, a small (0.04%) reduction in VSYLD is observed. Conversely, IMF% is positively correlated with CWT and VSGR (Table 2).

Discussion

IMF% has an important role in ensuring that lamb eating is a positive experience and, therefore, the likelihood of a repeat purchase decision is increased. A positive association between CWT and IMF was expected (Pannier et al. 2014, Craigie et al. 2012). Every kg increase in CWT was associated with a 0.10 increase in IMF%, which is similar to the 0.07% increase in IMF per kg reported previously (Pannier et al. 2014). The negative association between IMF and selection for leanness in lambs reported in Australia (Pannier et al. 2014, Anderson et al. 2015) is also present in New Zealand. IMF% in lamb has been described as moderately to highly heritable (h^2 = 0.32 - 0.48) (Karamichou et al. 2006, Mortimer et al. 2014). It is important that the New Zealand lamb industry is aware of the importance of IMF% from a product quality perspective, the current levels observed in New Zealand lamb, and the options for balancing selection pressures for production efficiency with meat quality traits including IMF%.

The structure of the progeny tests is not ideal for comparing gender effects on carcass and IMF traits. The different progeny tests evaluate performance of different combinations of both terminal and dual-purpose sires, usually process lambs at a fixed time rather than a fixed date, and almost all ewe lambs are retained as replacement stock. Gender effects are also confounded with the different progeny tests, and therefore, differences between genders observed in this dataset for IMF% or carcass traits may not accurately reflect differences in lambs within the 17-19 kg CWT target.

It is important that the implications of improved lamb production efficiency on meat product quality are clearly understood. As the New Zealand lamb industry gradually transitions from commodity production to a more consumer-ready product trading on New Zealand's reputation for high-quality lamb, it is likely that the importance of intrinsic and extrinsic product quality parameters will increase. Although the negative association between VSYLD and IMF% appears small, further investigation

Table 2 Parameter estimates from a step-wise regression model in which carcass traits including carcass weight, VIAscan® GR (fatness) and VIAscan® lean-meat yield were provided as variables to predict *M. longissimus lumborum* IMF% in 2014- and 2015-born lambs (n = 1,705).

Step	Variable	Parameter estimate	SE	Partial R2	Model R2	P value
	Intercept	2.84	0.41			<.0001
1	Cold Carcass Weight (kg)	0.10	0.01	0.18	0.18	<.0001
2	VIAscan® GR (mm)	0.06	0.01	0.05	0.23	<.0001
3	VIAscan® Lean Meat Yield (%)	-0.04	0.01	0.01	0.24	<.0001

of the relationships among production efficiency traits and meat-quality traits, especially IMF%, is warranted.

Conclusion

IMF is fixed at the point of trucking to the meat processor, so critical control points for IMF% are all before the farm gate. Genetics and management are, therefore, the only levers to control IMF in lamb. The findings of this research give an indication of the levels of IMF% found in New Zealand lamb, and that significant variation exists in IMF%. A negative association between lean-meat yield and IMF% was identified, therefore, selection for lean-meat yield needs to be balanced with selection for IMF% to ensure New Zealand lamb retains its reputation for quality in the marketplace. How do the current IMF levels impact eating quality of New Zealand lamb, and should industry be concerned?

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