Genetic selection for sensory eating quality of lamb using consumer assessments

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Abstract
This paper reports genetic parameter estimates for correlations between consumer eating quality and carcase traits for Terminal sire sheep breeds. Four consumer sensory-assessment traits (tenderness, flavour, juiciness, liking) were collected on loin and topside cuts (n ~ 2700). Heritability estimates (h^2) were low to moderate for these traits ($0.12 < h^2 < 0.33$), with the topside cut having slightly more genetic variation than the loin. Genetic correlations ($\hat{r}_g$) between sensory traits were high within cuts ($\hat{r}_g > 0.94$) and across cuts ($\hat{r}_g > 0.61$). There were moderate to high correlations of sensory with the objective eating quality traits (intramuscular fat and shear force) and low to moderately negative correlations with carcase lean meat yield. These estimates can be used to revise selection indexes, and potentially develop breeding values for consumer eating quality in multi-trait models with on-farm and carcase traits.

Introduction
Australian terminal sire breeders have achieved substantial genetic gains in various traits (Swan *et al*. 2017). Balanced selection for carcase yield and eating quality was further enhanced from 2017, with new genetic tools underpinned by substantial investment in genomic reference populations. Genomically enhanced breeding values are now available for carcase yield traits, as well as the objectively measured eating quality traits of intramuscular fat and shear force. Breeding programs can now balance the antagonistic relationship between yield and eating quality using modified selection indexes. These indexes are based on breeding objectives where an economic value is defined for consumer-assessed eating quality (Swan *et al.* 2015).
Genetic correlations between consumer eating quality and selection traits (carcase yield and objective measures of eating quality) are required to develop indexes. Current eating quality indexes are based on correlations estimated from consumer eating quality trials on approximately 1,500 animals from multiple breeds. The continued collection of this information has resulted in almost double the amount of both consumer and carcase data available. This paper reports updated genetic parameter estimates between consumer eating quality and carcase traits for Terminal sire sheep breeds. These estimates can be used to revise selection indexes, and potentially develop new multi-trait breeding values for consumer eating quality.

Materials & Methods
Data were available for crossbred lambs from terminal sire breeds (mainly Poll Dorset, White Suffolk and Dorper) recorded in Australian sheep reference populations across multiple years and data sources; mainly the Sheep CRC Information Nucleus Flock 2009- and 2010-born (van der Werf *et al*. 2010), and the 2017- and 2018-born lambs from the MLA Resource Flock.

Lambs were processed at an average age of 266 ± 54 days (mean ± SD), hot carcase weight of 24.2 ± 3.9 kg and carcase fat of 4.5 ± 2.5 mm.

Carcase composition and objective eating quality traits examined were carcase eye muscle depth (mm), lean meat yield assessed from computed tomography scanning, and carcase fat (mm). The objective eating quality traits, measured in the loin, were intramuscular fat (%) and shear force 5 days of aging (N) (collected according Pearce (2009).

Consumer eating quality traits were collected by obtaining a representative subset of animals from each project. There were 335 sires represented by an average of 8 progeny per sire. Samples were collected, prepared, cooked and tasted by consumers according to the protocol described by Pannier *et al.* (2014). Briefly, five slices were collected from the topside *(Musculus semimembranosus*) and loin (*M. longissimus lumborum*) muscles from each carcase. Samples were prepared and grilled under standardised conditions during each consumer tasting session, and randomly allocated to untrained consumers according to a 6x6 Latin square design. Consumers scored each sample for tenderness, juiciness, flavour and overall liking, scored between zero and 100 (with 100 being most preferred). The scores for each animal were averaged across the 10 consumer responses for each muscle without filtering.

The above traits were analysed in a series of bivariate models ASReml (Gilmour *et al*. 2021):

$$\mathbf{y} = \boldsymbol{\mu} + \boldsymbol{contemporary\ group} + \boldsymbol{animal} + \boldsymbol{genetic\ group} + \boldsymbol{e} \qquad (1)$$

where **y** is the phenotype (average consumer eating quality scores per animal, or carcase composition and objective eating quality traits, preadjusted for the fixed effects of birth type, rearing type, age of dam and age at measurement); $\boldsymbol{\mu}$ is the mean; ***contemporary group*** is a fixed effect defined as flock, management group, year of measurement, sex, and kill group sub-classes (as well as laboratory for shear force and intramuscular fat); ***animal*** is the random additive genetic effect based on the pedigree; ***genetic group*** is the random effect to account for different base animal breeds and sub-populations within breeds (not fitted for topside traits due to lack of significance); and ***e*** is the residual random effect.

Results

On average, the loin samples scored higher for eating quality compared to the topside samples, though there was generally more variation in the topside cuts (Table 1).

Table 1. Summary statistics for eating quality traits (consumer-assessed and objectively measured) and carcase composition traits.

Trait		*n*	Mean	Min	Max	Coefficient of Variation (%)
Loin (0 to 100)	Tenderness	2,707	69.3	28.2	94.0	14.7
	Flavour	2,707	67.9	40.5	91.2	12.4
	Juiciness	2,707	64.4	28.1	93.0	15.1
	Overall liking	2,707	68.6	37.8	92.0	13.1
Topside (0 to 100)	Tenderness	2,756	46.0	5.0	83.9	25.4
	Flavour	2,756	54.2	6.0	81.7	16.4
	Juiciness	2,756	49.7	7.0	84.4	21.1
	Overall liking	2,756	51.4	6.0	84.2	19.5
Intramuscular fat (%)		16,182	4.4	1.2	11.2	25.0
Shear force (N)		16,123	32.2	10.8	110.2	37.3
Lean meat yield (%)		1,642	57.5	46.4	68.4	6.3
Carcase eye muscle depth (mm)		17,944	32.5	16.0	50.8	14.2

Genetic parameter estimates are presented in Table 2. Heritability estimates were moderate for the consumer eating quality traits (0.12 to 0.19 for the loin, 0.16 to 0.33 for the topside), with the topside generally having higher estimates. Tenderness in the topside had the highest estimate (0.33 ± 0.06), with flavour traits having the lowest estimates for both cuts. Heritability estimates were high for intramuscular fat and lean meat yield, and moderate for shear force and carcase eye muscle depth.

Table 2. Additive genetic ($\hat{\sigma}_a^2$), phenotypic ($\hat{\sigma}_p^2$), genetic group ($\hat{\sigma}_{GG}^2$) and heritability estimates ($\hat{h}^2$)(± standard error), averaged from a series of bivariate analyses of eating quality traits (consumer-assessed and objectively-measured) and carcase traits.

Trait		$\hat{\sigma}_a^2$	$\hat{\sigma}_p^2$	$\hat{\sigma}_{GG}^2$	$\hat{h}^2$
Loin (0 to 100)	Tenderness	20.92 ± 4.70	89.54 ± 2.52	13.59 ± 8.29	0.19 ± 0.05
	Flavour	7.68 ± 2.74	61.81 ± 1.73	5.90 ± 3.80	0.12 ± 0.04
	Juiciness	13.03 ± 3.90	83.48 ± 2.33	6.10 ± 4.31	0.17 ± 0.04
	Overall liking	9.92 ± 3.15	69.30 ± 1.94	7.27 ± 4.56	0.14 ± 0.04
Topside (0 to 100)	Tenderness	39.31 ± 7.04	118.19 ± 3.38	-	0.33 ± 0.06
	Flavour	11.78 ± 3.33	71.48 ± 1.98	-	0.16 ± 0.05
	Juiciness	19.58 ± 4.65	88.70 ± 2.49	-	0.22 ± 0.05
	Overall liking	21.99 ± 4.75	87.96 ± 2.48	-	0.25 ± 0.05
Intramuscular fat (%)		0.47 ± 0.02	0.87 ± 0.02	0.12 ± 0.05	0.57 ± 0.03
Shear force (N)		24.58 ± 2.07	78.97 ± 1.13	3.65 ± 2.02	0.28 ± 0.02
Lean meat yield (%)		2.83 ± 0.59	5.96 ± 0.23	6.48 ± 2.85	0.47 ± 0.09
Carcase eye muscle depth (mm)		3.43 ± 0.28	12.30 ± 0.14	1.69 ± 0.64	0.28 ± 0.02

Figure 1 presents estimates of genetic correlation ($\hat{r}_g$). The consumer eating quality traits were highly correlated with each other within cuts (ranging from 0.95 to 1; SEs ~ 0.03), as well as across cuts (0.62 to 0.80; SEs ~ 0.10). There were also moderate to strong genetic correlations between consumer eating quality traits and objective eating quality traits.

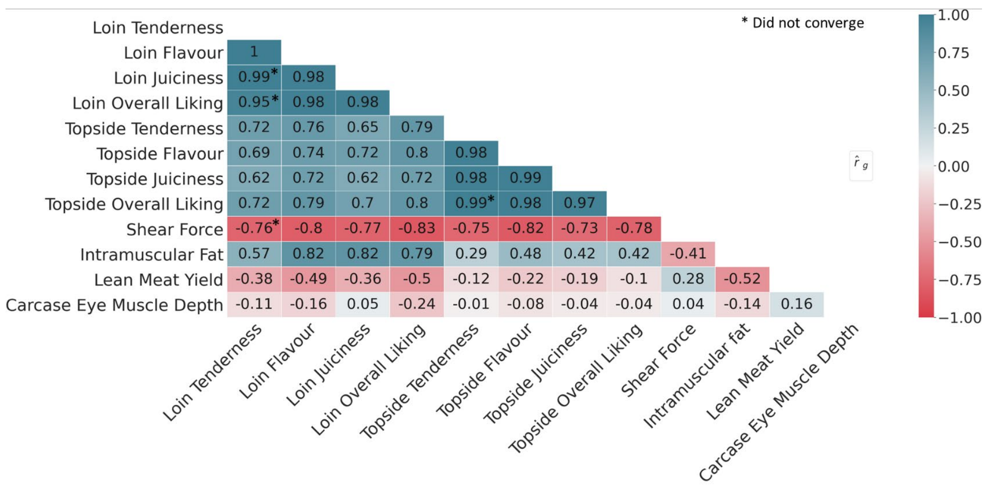

Figure 1. Genetic correlation estimates ($\hat{r}_g$) between eating quality traits (consumer-assessed and objectively-measured) and carcase composition traits (all SEs ~0.10).

Shear force had strong negative (favourable) correlations with loin and topside traits (range -0.83 to -0.73). Meanwhile, intramuscular fat (sampled from the loin) had a slightly stronger

positive relationship with the eating quality traits from the loin (0.57 to 0.82) compared to the topside (0.29 to 0.48).
The relationships between consumer eating quality traits and lean meat yield were moderately strong in the loin (-0.50 to -0.36), but weak to negligible in the topside (-0.22 to -0.10). Meanwhile, there were weak to no significant correlations of eating quality traits with carcase eye muscle depth (-0.24 to 0.05 for the loin; -0.08 to 0.01 for the topside).

Discussion
Consumer-assessed eating quality of lamb exhibited genetic variation, with the highest heritability estimated for tenderness in the topside cut, which reflects the multi-breed estimates reported in Mortimer *et al.* (2015). Although consumer eating quality traits of the different muscles may be genetically different traits, selection for better eating quality for one muscle will still result in an improvement in eating quality in another muscle.
Consumer eating quality traits were generally more highly correlated with shear force than intramuscular fat, particularly in the topside. However, both traits will be useful as selection criteria in breeding programs. With technological advances in objective carcase measurements, price signals are now emerging for intramuscular fat measured at processing. Therefore, future indexes may directly include intramuscular fat in the breeding objective as an economic trait.
The re-estimated genetic parameters between topside overall liking and lean meat yield align with the previous estimate reported in Swan *et al.* (2015). However, notably stronger genetic correlations were evident between topside overall liking and shear force (-0.78 vs. -0.31) in the current study compared to previous estimates (Swan *et al.* 2015). This study also found a negligible relationship between topside overall liking and carcase eye muscle depth (previously estimated at -0.17). Since this study used more data, there is greater confidence in the precision of estimates of genetic correlation between these traits. However, due to changes in correlations with the updated data, it will be necessary to review indexes that include eating quality, along with predictions of response to selection. Future work will explore the development of breeding values for consumer eating quality in multi-trait models with on-farm and carcase traits.

Acknowledgements
This work was partly funded by MLA Project L.GEN.1704. The authors are grateful for the staff involved in collecting this data, funded through MLA L.GEN.1814 and B.SGN.0144.

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