VISUAL MARBLE SCORE AS A PREDICTOR OF INTRAMUSCULAR FAT FOR THE GENETIC IMPROVEMENT OF EATING QUALITY IN LAMB

S.Z.Y. Guy[1,3], P. McGilchrist[2,3] and D.J. Brown[1,3]

[1]Animal Genetics & Breeding Unit*, University of New England, Armidale, NSW, 2351 Australia
[2]School of Environment and Rural Science, University of New England, Armidale, NSW, 2351
[3]Advanced Livestock Measurement Technologies Project, Meat & Livestock Australia, North Sydney, NSW, 2060 Australia

SUMMARY

Marbling refers to the small flecks of fat deposits between muscle fibres and is used as a subjective measure of intramuscular fat (IMF) – a key determinant of eating quality in red meat. In lamb, there is limited literature describing visual scoring guides and the trait correlations with other carcase traits. The objectives of this study were to establish a visual scoring system for marbling in lamb, estimate genetic parameters for the trait and estimate relationships with other eating quality and carcase traits. A 5-point visual marble score guide was constructed, which was highly correlated to the corresponding IMF of each sample ($r = 0.99$). To estimate genetic parameters, 1,120 loin samples were scored for visual marbling, with an average score of 3.01 (± 0.68, SD). On a phenotypic level, a 1 unit score increase was associated with a significant increase in IMF by 0.83 ± 0.04% ($p < 2e\text{-}^{16}$). The heritability estimate for visual marble score was 0.28 ± 0.09, and there was a high genetic correlation between visual marble score and IMF ($r_g = 0.93 \pm 0.08$). While more data are required for better genetic parameter estimates, these results indicate that visual marble score is an accurate phenotypic and genetic predictor of IMF in lamb. Therefore, there is potential for the use of visual marble scoring in lamb for the genetic improvement of eating quality in the interim period before a more rapid and accurate technology is commercially available to measure IMF.

INTRODUCTION

Marbling refers to the small flecks of fat deposits between muscle fibres. Visual marbling is used in the beef industry as a subjective measure of intramuscular fat (IMF), and is commonly accepted as a key determinant of eating quality in red meat. Measures of IMF obtained using chemical analysis of loin samples (using soxhlet extraction or near-infra red) are currently used as a selection criteria in Sheep Genetics eating quality indexes. However, this is a time-consuming and costly process.

In beef, marbling is visually scored during chiller assessment on the cut surface made between the 12th and 13th ribs. Burrow *et al.* (2001) summarised within-breed heritability estimates for a visual marbling scoring system in beef cattle, which ranged from 0.26 to 0.93. In addition to this, Reverter *et al.* (2003) report a close to unity genetic correlation between IMF and visual marble score in beef. However, no such studies exist for lamb as a cut surface is not available to grade lamb carcasses during processing, and lamb is historically not known to express the variation in visual marbling as seen in beef. Therefore, no such marble score system currently exists for lamb meat during carcase grading.

There is limited literature available on visual marble scoring in lamb. The trait, scored from 1 to 5, has reported heritability estimates ranging from 0.31 to 0.40 (Johnson *et al*. 2015a, 2015b; Brito *et al.* 2017). However, details of the visual marble scoring system used and its correlations with IMF were not provided in those studies. Therefore, the objectives of this study are to establish a visual scoring system for marbling in lamb, estimate genetic parameters for the trait and estimate relationships with other eating quality and carcase traits.

---

* A joint venture of NSW Department of Primary Industries and the University of New England

MATERIALS AND METHODS

Data. This study examined carcase data from 836 lambs slaughtered from the 2017-drop MLA Resource Flock (RF) and 284 lambs from 4 different commercial ram breeding flocks. Table 1 outlines the carcase measures collected, which included hot carcase weight (HCWT), carcase eye muscle depth (CEMD), fat measured hot at the Girth Rib (GR) site (110 mm from the midline between the 12^{th} & 13^{th} rib; GR) and fat measured cold at the C-site (45mm from the midline between the 12^{th} & 13^{th} rib; Csite). Traits that reflected eating quality analysed in this study were IMF and shear force aged at five days (SF5). All these traits were measured in accordance to the Information Nucleus Flock (INF) operations manual (Sheep CRC 2009).

Table 1. Summary of carcase traits measured on lambs from a commercial ram breeder and the 2017-drop MLA Resource Flock (n = 1,120)

Trait	Abbreviation	Mean	Standard deviation	Range	Coefficient of Variation
Hot carcase weight	HCWT	24.8	3.3	13.6 - 38.6	0.13
Eye muscle depth	CEMD	33.4	4.7	20 - 49	0.14
GR fat	GR	16.7	4.5	4 - 30	0.27
C-site fat	CSite	4.6	2.3	1 - 17	0.50
Intramuscular fat	IMF	4.8	1.1	2.6 - 9.8	0.22
Shear force at day 5	SF5	35.1	9.7	16.4 - 80.9	0.28

Visual Marble Score Guide. A loin sample for each lamb was butterflied and prepared as per protocol for assessment of retail colour. A visual marbling 5-point scale guide was constructed without knowledge of the IMF content. The aim was to produce a scale, where a score of 1 corresponded to no marbling and 5 corresponded to high marbling. Bloomed loin samples were scored for visual marbling by an experienced assessor.

Analysis. The phenotypic association between visual marble score and chemical IMF was firstly assessed by including visual marble score as a linear covariate in a linear regression model for IMF. Model selection was conducted using stepwise linear regression.

Genetic parameters for all carcase traits were then estimated with REML in ASReml (Gilmour *et al*. 2009) using a series of bivariate analyses. Fixed effects included birth type, rearing type, and the covariates of age at measure, age of dam (linear and quadratic) and HCWT. Random effects included additive genetic effect, breed-based genetic group (35 groups) and contemporary group. Contemporary group was defined as a combination of breed, flock, management group, sex, date of measurement and kill group. Genetic correlations between traits were estimated using a series of bivariate analyses.

RESULTS AND DISCUSSION

Visual marble score guide. Figure 1a is the 5-point scale visual marble score guide that was constructed. The 5 samples used for the visual marble score guide were highly correlated with their corresponding chemical IMF (r = 0.99) (Figure 1b). Using a simple linear regression model, a one unit increase in the visual marble score guide corresponded to a predicted increase in IMF by 0.94 ± 0.07% (p = 0.001, R^2 = 0.98, RMSE = 0.23). This indicates that the samples used for the subjective score guide accurately reflected the objective measure of IMF.

a)

a)

b)

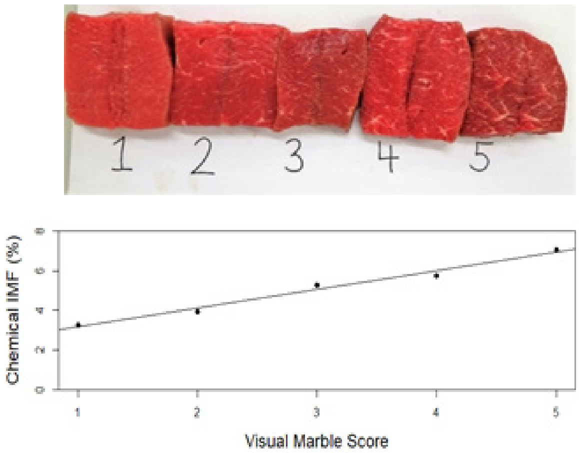

Figure 1. a) The 5-point scale visual marble score guide for lamb and b) the relationship between samples used and chemical intramuscular fat (IMF) percentage

The average visual marble score was 3.01, with a minimum of 1 and maximum of 5, and a standard deviation of 0.68. A 1 unit increase in marble score was predicted to correspond to a significant increase in IMF by 0.83 ± 0.04% (p < 2e-16). The removal of visual marble score decreased the variability explained in the model, from 42% to 18%, and an increase in RMSE from 0.81 to 0.96. Therefore, visual marble score is a significant phenotypic predictor of IMF.

Genetic analysis. The heritability estimate of visual marble score was 0.28 ± 0.09 ($\hat{\sigma}_a^2 = 0.11 \pm 0.03$, $\hat{\sigma}_p^2 = 0.38 \pm 0.02$, $\hat{\sigma}_e^2 = 0.28 \pm 0.03$). Taking into account standard errors, this aligns with estimates reported in lamb of 0.31 ± 0.03 by Brito *et al*. 2017, 0.32 ± 0.10 by Johnson *et al*. 2015b and 0.40 ± 0.06 by Johnson *et al*. 2015a. Visual marble score was very highly genetically correlated with IMF ($r_g = 0.93 \pm 0.08$). Therefore, there is potential for genetic gains in visual marbling, and selection for increased marbling is predicted to also increase IMF.

Genetic correlation estimates between visual marble score, IMF and other carcase traits are presented in Table 2. The genetic correlations for visual marble score and IMF were consistent in direction and magnitude for SF5, HCWT and GR. However, estimates did not overlap when taking into account standard errors for HCWT and CSite. More data are required to reduce standard errors and to obtain better genetic parameter estimates.

Table 2. Genetic correlation estimates (± SE) between intramuscular fat (IMF), visual marble score and other carcase traits*

	SF5	HCWT	CEMD	GR	CSite
IMF	-0.45 ± 0.07	0.77 ± 0.03	-0.19 ± 0.08	0.28 ± 0.06	0.26 ± 0.06
Visual marble score	-0.41 ± 0.22	0.96 ± 0.02	0.01 ± 0.24	0.31 ± 0.17	-0.15 ± 0.18

*SF5: shear force at day 5; HCWT: hot carcase weight; CEMD: eye muscle depth; GR: fat at girth rib; Csite: fat at C-site

Taking into account standard errors, genetic correlation estimates for IMF align with those previously reported for SF, CEMD, GR and Csite, but not for HCWT (Mortimer *et al.* 2014, 2018). Genetic correlation estimates for visual marble score reported by Brito *et al.* (2017) also align for

SF5, CEMD and GR, but not for HCWT. This may have due to the variation in HCWT, which was larger in this current study compared to the other studies.

Visual marble score is currently being used as a proxy for IMF in New Zealand sheep genetic evaluation (Johnson *et al*. 2018). However, while higher marbling in pasture-fed lambs was reported to be associated with higher IMF, marbling score did not affect eating quality in New Zealand lambs (Young *et al*. 2009), possibly due to a small range in IMF. To our knowledge, there is currently no literature available on investigations of selection for eating quality through marble score in Australian lambs.

CONCLUSIONS

While the subjective scoring of lamb loins may not be viable for grading of lamb carcases in a commercial environment, this study indicates that visual marble score is an accurate phenotypic and genetic predictor of IMF in lamb. Therefore, there is potential for the use of visual marble scoring in lamb for the genetic improvement of eating quality in the interim period before a more rapid and accurate technology is commercially available to measure IMF.

ACKNOWLEDGEMENTS

This work was conducted as part of the Advanced measurement technologies for globally competitive Australian meat (ALMTech) project, funded by the Australian Government Department of Agriculture and Water Resources as part of its Rural R&D for Profit programme, in partnership with Research and Development Corporations, Commercial Companies, State Departments and Universities. The authors would also like to thank the Sheep CRC for Sheep Industry Innovation, Meat and Livestock Australia, the Australian Meat Processor Corporation, and the contributions of research staff and industry members involved in the data collection at UNE.

REFERENCES

Brito L.F., McEwan J.C., Miller S., Bain W., Lee M., Dodds K., Newman S.-A., Pickering N., Schenkel F.S. and Clarke S. (2017). *Small Rumin. Res.* **154**:81.

Burrow H.M., Moore S.S., Johnston D.J., Barendse W. and Bindon B.M. (2001) *Aust. J. Exp. Agr.* **41**:893.

Gilmour A.R., Gogel B.J., Cullis B.R. and Thompson R. (2009) 'ASReml User Guide Release 3.0' VSN International Ltd, Hemel Hempstead, HP1 1ES, UK.

Johnson P.L., Charteris A., Tate M.L. and Dodds K.G. (2015a). *Proc. NZSAP*. **75**:111.

Johnson P.L., Young E.A., Russenklau D., Anderson T. and Dodds K.G. (2015b) *Proc. NZSAP.* **75**:106.

Johnson P.L., Agnew M.P., Shorten P.R., Reis M.M., Cullen N. and Craigie C.R. (2018). *Proc. WCGALP.* **11**: 611.

Mortimer S.I., van der Werf J.H.J., Jacob R.H., Hopkins D.L., Pannier L., Pearce K.L., Gardner G.E., Warner R.D., Geesink G.H., Hocking Edwards J.E., Ponnampalam E.N., Ball A.J., Gilmour A.R. and Pethick D.W. (2014) *Meat Sci*. **96** :1016.

Mortimer S.I., Fogarty N.M., van der Werf J.H.J., Brown D.J., Swan A.A., Jacob R.H., Geesink G.H., Hopkins D.L., Hocking Edwards J.E., Ponnampalam E.N.,Warner R.D., Pearce K.L. and Pethick D.W. (2018) *J. Anim. Sci*. **96** :3582.

Reverter A., Johnston D.J., Perry D., Goddard M.E. and Burrow H.M. (2003) *Aust. J. Agric. Res.* **54**: 119.

Sheep CRC (2009). Information Nucleus Operation Manual.

Young E.A., Bain W.E., McClean N.J., Campbell A.W. and Johnson P.L. (2009). *Proc. NZSAP.* **69**:104.