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Animal factors affecting the meat quality of Australian lamb meat☆

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ABSTRACT

This paper integrates the key industry findings from the twelve preceding papers in this special edition of Meat science. In so doing, various animal factors important for the quality of Australian lamb meat are highlighted for sensory, visual appeal and human health attributes. Intramuscular fat concentration (IMF) was found to be a key element of eating quality that interacts both positively and negatively with a range of other factors. Shear force, IMF, colour stability and docosahexaenoic acid (DHA) will likely respond to genetic selection whilst other omega-3 fatty acids require nutritional intervention. Australian lamb meat can generally be regarded as a good source of the minerals iron and zinc; and a source of omega 3 fatty acids when finished on green pasture. Breeding priorities for meat quality will likely depend on breed type with improvement of meat colour stability more important for the wool focused Merino breed and improvement of sensory quality for the terminal sire breeds.

1. Introduction

Sheep meat is a niche product that accounts for only about 3% of the meat market worldwide. As well as having to satisfy very specific market requirements, the sheep meat industry has to keep pace with productivity gains made elsewhere in the agricultural sector. The land allocated to sheep production in Australia has reduced at the rate of 4% and ewe numbers by 10% per annum since about 1990 (Barson, Mewett, & Paplinska, 2011). Despite this, prime lamb productivity has been maintained due to changes made to flock structure and increases in the yield of meat per lamb from increases in carcase weight and leanness (Pethick, Banks, Hales, & Ross, 2006). The weight of the average Australian lamb carcass increased from 17.5 kg to approximately 21 kg between early 1990 and 2006 (CIE, 2008). Lamb meat exports increased during this period, by an average rate of 14% per year to the U.S.A. for example (CIE, 2008). The lamb meat industry is now worth in excess of $3.5 billon (AUS) to the Australian economy, up from $1.5 billion (AUS) in 1999 (CIE, 2008).

Linked to this, meat consumer's value quality and nutritional attributes, but also seek value for money (Pethick, Ball, Banks, & Hocquette, 2011). In this context, there is little doubt that the Australian lamb meat industry needs to continue to research, develop and adopt appropriate technology to achieve gains for productivity, quality and nutritional value simultaneously. To this end the papers in this special edition collectively report a successful outcome for one major component of a very large and ambitious research programme conducted by the Cooperative Research Centre for Sheep Innovation (Sheep CRC). In so doing this builds on a previous Australian work which began circa 1999 and largely satisfies the goals of the program that were to:

- Build a large phenotypic database of carcase and eating quality traits,
- Use the database to develop breeding values for lean meat yield and objective measures of eating quality and meat quality,
- Understand the genetic and non genetic factors affecting the carcase, eating quality and meat science traits,
- Quantify the associations between biochemical measures of muscle aerobicity and the eating quality and meat science traits, and
- Quantify the relationships between sensory and objective measures of eating quality.

Following the introductory paper by Pethick et al. (2014), this special edition consists of twelve papers that are linked by a common data set, created from the information nucleus flock (INF) (van der Werf, Kinghorn, & Banks, 2010). The theme of these papers is predominantly the description of animal traits that could be used to improve the eating/meat quality and or nutritional value of Australian lamb meat. Lean meat yield traits were also measured, but will be reported in other publications. An implicit and very important finding is that animal factors were found to have a significant and large effect on meat quality, once processing conditions had been optimised with a standard slaughter protocol between sites. This general finding provides a clear role for the production sector of the lamb meat industry to be an active participant, in endeavours to improve market acceptance of Australian lamb

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meat by improving its meat and eating quality. An example of this is the effect of intramuscular fat concentration (IMF) on tenderness that was influenced by animal more so than processing factors. Whilst processing factors such as the rate of pH decline are clearly important, maximising tenderness will require attention to IMF and this depends to a large extent on a lamb's genotype (heritability of 0.48, Mortimer et al., 2014) as well as carcase weight and fatness. Processing factors obviously influence the myofibrillar components of shear force, but have no effect on the IMF component. Supply chains will in the future need to consider animal breeding objectives therefore, as a vital component of their overall strategy for improving eating quality. This confirms the value of genomic information and resource flocks (Banks & van der Werf, 2009), since many of the important traits like IMF cannot be directly measured in sires, thus a reliance on genomic breeding values coupled with continual verification.

2. Genetic tools

A major goal of the INF was to provide genetic tools, particularly Australian Sheep Breeding Values (ASBVs), for eating quality and carcase lean meat yield traits. So a key output has been to discriminate traits that can be manipulated genetically from those for which non genetic management strategies will be more important. Two of the twelve papers might be considered as methodology development that better specify traits for different research and industry applications, both genetic and non genetic. This includes the paper by van de Ven, Pearce, and Hopkins (2014) on the modelling of pH decline and the paper by Jacob, D'Antuono, and Gilmour (2014) on colour stability. The modelling of pH decline post slaughter represents an enhanced method to predict the temperature of the lamb loin at pH 6 which is assessed in the Meat Standards Australia (MSA) grading system for lamb carcases. A more accurate prediction of pH and temperature conditions post mortem will be important for processing systems to be more tightly managed so as to optimise tenderness (Hwang, Devine, & Hopkins, 2003; Pearce, Hopkins, Toohey, Pethick, & Richards, 2006). Colour stability can be influenced by a range of processing factors as discussed by Jacob and Thomson (2012). The rate of colour change varies with time during the retail display period and this varies between animals (Jacob, Mortimer, Hopkins, Warner, & D'Antuono, 2011; Khliji, van de Ven, Lamb, Lanza, & Hopkins, 2010). To overcome this Jacob et al. (2014) described a method using splines to predict the time required for the colour to reach a benchmark value for redness (R630/R580). This is an alternative to measuring colour at one time point at the end of a simulated retail display (Calnan, Jacob, Pethick, & Gardner, 2014). Whist this has improved our understanding of colour stability; more work is required to develop a simple and practical method to predict meat colour stability. Ideally, this could be done early in the post mortem period without a need to expose meat to a simulated display period and potentially then integrated into breeding programmes.

The paper by Mortimer et al. (2014) provides clear evidence that many of the meat quality traits are highly correlated with other traits and have moderate to high heritability's. Pannier, Gardner et al. (2014a) showed there were significant effects of sire type and sire (within sire type) on sensory scores for lamb loin. Further the genetic correlation between shear force after 5 days ageing (SF5) and IMF levels was found to be −0.65 (Table 1) suggesting that selection for one will cause a change in the other. This will underpin the future use of both shear force and IMF as indirect predictors of the eating quality; allowing sires to be ranked for the likely eating quality of meat from their progeny with Australian Sheep Breeding Values (ASBVs). The cost of measuring sensory parameters means such indirect predictors must be used.

2.1. Single nucleotide polymorphism (SNP) associations

Novel associations between SNPs and phenotypes for shear force and omega 3 fatty acid concentrations were shown by Knight et al. (2014). These specific SNPs have been added to genomic association studies to strengthen the accuracy of genomically enhanced breeding values, especially for shear force (Daetwyler, Swan, van der Werf, & Hayes, 2012). Furthermore, breeding values can now be efficiently estimated for the hard to measure slaughter traits using the data generated in the INF.

2.2. Eating quality traits that are heritable

Intramuscular fat, SF5 and retail colour (hue, lightness, redness - measured after 3 days of simulated retail display) all had heritability estimates > 0.25. The pH of the loin 24 hour post slaughter (pH24LL, an estimate of ultimate pH) had a very low heritability at 0.07 and DHA had the highest heritability (0.22) of all the long chain fatty acids measured. The composition of the fatty acids in meat is very sensitive to diet (Ponnampalam et al. (2014)) and therefore manipulation through genetic selection would appear unattractive. A potential exception might be for the DHA content of muscle which is insensitive to diet, unlike the other omega 3 long chain fatty acids (Scollan et al., 2005). IMF, SF5, and retail colour stability and perhaps DHA could all be considered either directly or indirectly in sire breeding programmes. This in turn justifies the inclusion in future resource flock protocols for ongoing verification of genomic breeding values of these traits.

2.3. Genetic correlations between parameters

The scale of the INF program and the extensive list of traits have resulted in genetic correlations between traits with high precision (i.e. low standard errors). Some of the most important correlations are outlined in Table 1.

The genetic correlation between iron and myoglobin concentrations was extremely high suggesting these parameters effectively describe the same genetic trait in lambs. Iron concentration is important from a nutritive value point of view (FSANZ, 2012) and myoglobin concentration clearly affects the colour of meat.

The strength of the correlation between IMF and SF5 supports similar studies in beef cattle (Reverter et al., 2003) and further underpins the

Table 1
Examples of traits found to be closely correlated from (Mortimer et al., 2014) pH24LL = the pH of the loin 24 hour post mortem, ICDH = isocitrate dehydrogenase activity. Retail colour parameters were measured after a 3 day simulated retail display period commenced 5 days after slaughter.

Trait 1	Trait 2	Genetic correlation	Phenotypic correlation
Myoglobin	Iron	0.97	0.35
Retail hue	Retail redness (R630/R580)	−0.90	−0.52
Retail chroma	Retail redness (R630/R580)	0.80	0.83
Myoglobin	Fresh L value	−0.81	−0.21
pH24LL	Retail hue	0.62	0.21
IMF	SF5	0.65	0.30
Linoleic acid	IMF	0.63	0.34
HCWT	pH24LL	−0.32	−0.12
ICDH	SF5	−0.27	−0.12
Arachidonic acid	IMF	−0.22	−0.05