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Effect of genotype, gender and age on sheep meat quality and a case study illustrating integration of knowledge

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ABSTRACT

Subtle breed differences exist for meat quality traits and the Merino does stand out, although many comparisons are confounded by production site or lack of processing intervention. Despite this, the Merino does seem to have a propensity to produce meat with a higher pH and reduced colour stability under extended ageing. Use of the Merino in a crossbreeding system not only provides benefits from hybrid vigour, but also overcomes the meat quality constraints of pure Merinos. Genetic evaluation for lamb production has enabled impressive genetic gains, but an overemphasis on lean meat production has had to be addressed to counter adverse effects on meat quality traits like eating quality. In this regard, the development of genomic selection has provided a methodology for accurate prediction of genetic merit and applying balanced breeding objectives. The potential for negative meat quality effects has stemmed adoption of non-castration approaches, but ensuring that lamb is young when slaughtered does provide brand integrity.

1. Introduction

Meat quality includes many factors including palatability, water-holding capacity, colour, and nutritional value (Hopkins & Geesink, 2009) and it can be affected by changing the genetics and the production and processing environment. The relative importance of meat quality traits varies according to the user of the product and the type of product. For example, tenderness is more important for beef (Thompson, 2002) than sheep meat (Hopkins, Walker, Thompson, & Pethick, 2005). As improvements are made in individual traits their relative importance changes (Thompson, 2004), which impacts on their emphasis in breeding programmes. Market research indicates that meat quality traits are becoming more important to consumers (Bermingham et al., 2008; Pethick, Banks, Hales, & Ross, 2006) and this will increase the focus on methods to improve them.

Genetic change can occur through crossbreeding and selection for quantitative traits directly (using phenotypic records and pedigree), or using marker-assisted selection and genomic selection. The previous void of information on genetic variation for meat quality traits in sheep was highlighted by Safari, Fogarty, and Gilmour (2005) who reported only 2 estimates of heritability for pH and meat colour, both for Merino rams. In recent years, more information has become available for both genetic variation (Mortimer et al., 2010, 2014) and major gene effects on meat quality traits (Hopkins, Fogarty, & Mortimer, 2011) and for the use of molecular markers (Daetwyler, Swan, Werf, & Hayes, 2012; Knight et al., 2014). Marker-assisted selection has the potential to significantly increase the rate of gain from selection for meat traits (Meuwissen & Goddard, 1996). In Australia, large data sets have been generated from the Cooperative Research Centre for Sheep Industry Innovation (Sheep CRC) Information Nucleus (IN; Fogarty, Banks, van der Werf, Ball, & Gibson, 2007; van der Werf, Kinghorn, & Banks, 2010) and the Sheep Genomics (White et al., 2012) programmes. They are providing estimates of genetic parameters for a large range of traits including meat quality as well as developing molecular markers and evaluating whole genome selection using single nucleotide polymorphism technology. As highlighted by Fogarty (2009), development of strategies to combine the quantitative and molecular information into effective breeding programmes is required and this is starting to occur.

Other production factors that can impact on meat quality and which will be considered in this paper are sex (gender) and animal age. The effect of gender on traits like tenderness is not clear with no effect reported in some studies (e.g. Kemp, Mahyuddin, Ely, Fox, & Moody, 1981; Lee, 1986), whereas others have shown meat from entire male lambs (Johnson, Purchas, McEwan, & Blair, 2005) or castrates (Hopkins, Stanley, Martin, Toohey, & Gilmour, 2007) to be tougher than that from ewe lambs. The impact of animal age on meat quality traits is of particular importance as it can help to make marketing decisions, but clarifying the extent of "true" age effects is not straight forward as highlighted by Purchas (2007). This is because often older

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animals are also heavier and this can impact on cooling rates, thus pH declines and subsequently traits like tenderness and colour.

The purpose of this paper is to discuss the impact of sheep genotypes and genetics (breeds, crossbreds and genetic parameters), gender and animal age on meat quality traits of lamb meat. It is recognised that nutrition/production system of the animal also has a major impact on meat quality, particularly for traits like fatty acids (Ponnampalam et al., 2014), but this area will not be covered here. Equally processing factors have a large effect on meat quality traits like tenderness and this area has been documented previously (Hopkins, 2010). Finally the application of knowledge reviewed in this paper will be considered with reference to the lamb industry in Australia.

2. Effect of genotypes on meat quality

2.1. Impact on tenderness

Tenderness can be evaluated by objectively measuring shear force (Hopkins, Toohey, Warner, Kerr, & van de Ven, 2010) and using trained panellists (Safari, Fogarty, Ferrier, Hopkins, & Gilmour, 2001) or consumers (Hopkins, Walker, et al., 2005). The differences between genotypes may vary with the method used, as each detects subtle differences in tenderness. Some studies have shown either no differences in objectively measured tenderness between breeds and crossbreds (Dransfield, Nute, MacDougall, & Rhodes, 1979; Hopkins & Fogarty, 1998; Hopkins, Stanley, Martin, et al., 2007; Hopkins, Walker, et al., 2005) or inconsistent differences that were not explained by variation in other traits that influence tenderness, such as pH, sarcomere length, carcase weight or fat levels (Purchas, Sobrinho, Garrick, & Lowe, 2002). Different strategies have been used to minimise the impact of processing on tenderness, including conditioning (holding at temperatures above chilling for a period of time) after slaughter and ageing (Dransfield et al., 1979), electrical stimulation and ageing (Hopkins, Walker, et al., 2005) and ageing for 7 days (Hopkins & Fogarty, 1998). Such approaches are needed to estimate genetic variation because of the potential confounding due to processing factors.

No sire breed effects on taste panel assessed tenderness were reported by Dransfield et al. (1979) or Safari et al. (2001) in comparisons of Merino lambs and other breeds, including Texel × Merino or Poll Dorset × Merino (PDM). Hopkins, Walker, et al. (2005) reported minimal differences in consumer assessed tenderness between genotypes, except that the Merinos had lower sensory scores than Border Leicester × Merino (BLM) lambs for two different muscles, which may have reflected a slower rate of pH decline in the Merino lambs. More recent work by Pannier, Gardner, et al. (2014) showed by contrast that male Terminal (meat breeds) sired lambs had lower tenderness scores (~5 points on a 0–100 scale) for the loin and topside compared to the male Maternal and Merino sired lambs which had similar scores. This effect could reflect the fact that the Terminal sires used by Pannier, Gardner, et al. (2014) had estimated breeding values that indicated that these sires were on average leaner (less fat) than their breed average. It is known that this can lead to a decline in tenderness (Hopkins, Stanley, Toohey, et al., 2007), but it should also be stressed that the manifestation of effects in progeny will be influenced by processing conditions as demonstrated by Hopkins, Stanley, Toohey, et al. (2007).

Rambouillet lambs produced tougher leg steaks than Karakul and crossbred (Suffolk or Hampshire × Rambouillet) lambs (Edwards, Crenwelge, Savell, Shelton, & Smith, 1982), although the reason cannot be confirmed as other traits, such as pH, were not reported. This was also the case in a comprehensive study of lighter weight lambs, in which Merino lambs were rated more tender by trained panellists than Rasa Aragonesa and Churra breeds as slaughter weight increased (Martínez-Cerezo et al., 2005). Merino lambs had the tenderest m. *longissimus* in the work of Young, Reid, and Scales (1993), which was attributed to significantly higher pH, although this was not found by Hopkins and Fogarty (1998).

There were no effects of sire breed on sensory tenderness of lamb from 3 sire breeds (Charollais, Suffolk and Texel) sampled over 3 years (Ellis, Webster, Merrell, & Brown, 1997). Similarly, Esenbuga, Yanar, and Dayioglu (2001) found no difference in shear force or sensory assessed tenderness between 4 fat-tailed types (Awassi, Red Karaman, Tushin and Awassi × Tushin) when slaughtered at similar weights. Likewise, Hoffman, Muller, Cloete, and Schmidt (2003) reported tougher meat (shear force of the m. *semimembranosus*; SM) for only one of the 6 genotypes they studied, with the effect associated with the dam breed (Dohne Merino), although it did not affect sensory traits. In hill breeds, Carson, Moss, Dawson, and Kilpatrick (2001) reported no difference in shear force of loin meat from 6 genotypes, although the low absolute shear force values indicate that the meat had been aged for an extended period, which may have reduced any differences between the genotypes.

Inconsistent effects were reported for taste panel tenderness of roasted hind leg lamb meat from 3 Greek dairy breeds (Arsenos et al., 2002), although slaughter days were confounded with breed and few animals were evaluated. In a larger study, Navajas et al. (2008) reported a reduction in taste panel tenderness for both the loin and the SM from pure Texel compared to Scottish Blackface lambs. The authors suggested that it was due to the lower intramuscular fat (IMF) levels in the Texel, although it was not analysed and surprisingly there was no difference between breeds for muscularity, with the latter trait derived from computer tomography measures of the hindleg.

In a large study across 6 countries, lamb meat from the Icelandic breed was the most tender, whether determined by objective or subjective means, whereas the Bergamasca breed was the toughest (Berge et al., 2003; Sañudo et al., 2003). However, the data suggested that some of the effect was due to differences in sarcomere length (Berge et al., 2003), final pH and lambs raised under different production systems and slaughtered in different countries over a wide range in carcase weights (5.4–30.5 kg). In another study, genotype was confounded with feeding system and age (Fisher et al., 2000). These reports are not informative for understanding any genetic differences in tenderness between genotypes and overall no large genotype effects on tenderness are apparent. There is a need for more controlled studies, where sources of variation are controlled so the true influence of genotype is quantified.

2.2. Impact on sensory measures of eating quality

Young, Reid, et al. (1993) reported no differences in the juiciness, flavour and overall acceptability of loin meat from 6 genotypes when tested by trained panellists. A comparison of roasted legs from Romney, Border Leicester × Romney, Perendale, Corriedale and Merino animals by Kirton, Dalton, and Ackerley (1974) found that those from Merinos rated the lowest for overall preference, although they had very light carcase weights with minimal fat cover. Safari et al. (2001) reported no difference in overall acceptability, tenderness or juiciness for roasted loin meat from first cross (BLM), Merino or second cross lambs. In another study of the hindleg (m. *biceps femoris*), Merino lambs had lower juiciness, flavour liking and overall liking scores than BLM and second cross lambs, but were similar to PDM lambs (Hopkins, Walker, et al., 2005) when assessed by consumers.

Dransfield et al. (1979), Edwards et al. (1982), Crouse, Busboom, Field, and Ferrell (1981), Crouse (1983), Ellis et al. (1997) and Esenbuga et al. (2001) reported no significant differences between genotypes in eating quality. Hoffman et al. (2003) did find initial juiciness of the SM was lower from Suffolk × Merino than other genotypes, but it was of no practical significance. In other work from South Africa, Webb, Bosman, and Casey (1994) reported that roasted loin meat from South African Mutton Merino (SAMM) lambs had better flavour and overall acceptability than from Dorper lambs. This was attributed to the significantly higher fat levels in the Dorper, but it is noteworthy that the subcutaneous fat of the Dorpers also had higher levels of unsaturated fatty