REVIEW

Influence of breed and feeding on the main quality characteristics of sheep carcass and meat: A review

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This paper reviews two factors (breed and feed) affecting the carcass and meat quality of sheep. The quality of livestock products has acquired greater importance from the distinct perspectives of the different participants in the agricultural food chain. Consumers, producers and the industry give different levels of importance to the parameters of meat and carcass quality. Nevertheless, all the participants in the meat production chain must ensure quality to improve their competitiveness. The quality of the carcass and meat can be influenced by different factors such as breed and type of feed. The breed can influence weight, yields, and the conformation of the carcass, among other variables, as well as the pH level and the fatty acid composition of the meat, whereas the feed mainly affects carcass conformation and several physicochemical and organoleptic parameters of meat quality such as proximal composition, the fatty acid profile, tenderness and color. Consequently, the effects of breed and feed type should be considered to obtain a quality product that satisfies consumer demand.

Key words: Breed, carcass, Chilote, fatty acids, grasslands, lamb, meat quality.

INTRODUCTION

The globalization of markets has resulted in greater economic integration, but at the same time has imposed the need to meet quality requirements to satisfy consumer demands. The meat industry and sheep producers must comply with certain quality standards to meet consumer demands and remain competitive in the global market. In this context, it is necessary to know the different factors that can affect the main characteristics of meat and carcass quality. Investigations have determined that age, sex (Horcada et al., 1998; Vergara et al., 1999; Barone et al., 2007), breed (Crouse et al., 1981; Hopkins and Fogarty, 1998; Kremer et al., 2004), and also the type of feed (Hopkins et al., 1995; Jacques et al., 2011) can affect the characteristics of carcass (weight, conformation, fat content, among others) and meat (pH, texture, instrumental color, and nutritional composition).

Considering the above, the objective of this work was to review the most recent works on the effect of breed and feed (concentrates, grasslands or others) on the quality of the carcass and meat.

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Situation of the ovine production sector

According to the last national agricultural survey in Chile in 2007, there were over 3,938,059 sheep in the country (INE, 2012b). The INE reports that between the regions of Libertador General Bernardo O’Higgins (34°10’ S, 70°43’ W) and Magallanes (53°9’ S, 70°55’ W) there are around 3.5 million sheep, representing 95% of national production. In the period from January to July 2012 some 536 406 sheep were slaughtered, 14.6% fewer than during the same period in 2011 (INE, 2012b). Per capita consumption in 2012 was also lower, estimated at 0.3 kg (INE, 2012b), which is mainly associated with the variable and seasonal consumption of ovine meat (Hervé, 2013). As well, the volume of exports in the first quarter of 2012 was 29.9% lower than during the same period a year earlier (INE, 2012b). This translates into a 35.9% decrease in the values of exports from the previous year, for a total value of only US$22.1 million (INE, 2012b). Nevertheless, it is estimated that real market prices globally for ovine meat and the prices paid to producers will remain the same in the coming years, although much lower than the prices in 2011 (INE, 2012a). Decreased internal consumption and exports together can be an incentive to increasing ovine herds throughout the country to meet external demand for ovine meat. Likewise, ovine production presents a higher degree of utility per hectare than other types of livestock activities in southern Chile, such as dairy farming and cattle feedlots (Vidal, 2012).

Quality does not mean the same thing to the different actors in the meat production chain. While producers and the industry are guided by more objective parameters,
such the characteristics of the ovine carcass (Becker, 2000), consumers consider more subjective factors like the meat/fat ratio, color, tenderness and flavor (Rodrigues et al., 2006; Sepúlveda et al., 2011). This is why the quality of carcass and meat represent complex characteristics that can be difficult to evaluate (Rodrigues et al., 2006). However, if the different parameters are considered in the productive system it is possible to supply a quality product that meets the needs of both the industry and consumers and for which consumers are prepared to pay a higher price (Warner et al., 2010; Font i Furnols et al., 2011), consequently resulting in more profits for participants in the meat production chain.

Quality of the ovine carcass

The ovine carcass is defined as a “primary unit of meat resulting from the slaughter, bleeding out, skinning, gutting, and removal of the head, genitals, organs and extremities at the level of the metacarpal joint and tarsal metatarsal” according to Chilean government standards (INN, 2002).

The main criteria used to assess carcass quality are warm and cold carcass weights, because these affect other important parameters such as fat content, carcass conformation and the weight of different cuts (Díaz, 2001; Carter and Gallo, 2008; Lambe et al., 2009). Fat content is important given its impact on the price of the carcass (Díaz et al., 2002). Some of the measurements for this criterion are the thickness of the dorsal fat, the weight of renal pelvic fat, and the visual assessment of the fat content of the carcass (Díaz et al., 2002; Carrasco et al., 2009). Another variable used as a general indicator of the quality of the carcass is its conformation (Díaz, 2001), which involves a visual assessment and objective measurements such as the width and depth of the thorax, length of legs, width of the rump or the area of the rib eye, among others (Díaz, 2001).

The aforementioned factors affect to different degrees the quality of the carcass and consequently the price paid to producers. All of these factors have been studied to determine if they can be influenced by sex (Thatcher et al., 1991), breed (Kremer et al., 2004), genotype (Santos-Silva et al., 2002), age (Leymaster and Jenkins, 1993), weight at slaughter (Pérez et al., 2007), type of feed (Díaz et al., 2002), and productive year (Thatcher et al., 1991). Breed (Kremer et al., 2004), genotype (Santos-Silva et al., 2002), age (Leymaster and Jenkins, 1993), weight at slaughter (Pérez et al., 2007), type of feed (Díaz et al., 2002), and productive year (Thatcher et al., 1991). Breed (Kremer et al., 2004), genotype (Santos-Silva et al., 2002), age (Leymaster and Jenkins, 1993), weight at slaughter (Pérez et al., 2007), type of feed (Díaz et al., 2002), and productive year (Thatcher et al., 1991). Breed (Kremer et al., 2004), genotype (Santos-Silva et al., 2002), age (Leymaster and Jenkins, 1993), weight at slaughter (Pérez et al., 2007), type of feed (Díaz et al., 2002), and productive year (Thatcher et al., 1991). Breed (Kremer et al., 2004), genotype (Santos-Silva et al., 2002), age (Leymaster and Jenkins, 1993), weight at slaughter (Pérez et al., 2007), type of feed (Díaz et al., 2002), and productive year (Thatcher et al., 1991). Breed (Kremer et al., 2004), genotype (Santos-Silva et al., 2002), age (Leymaster and Jenkins, 1993), weight at slaughter (Pérez et al., 2007), type of feed (Díaz et al., 2002), and productive year (Thatcher et al., 1991). Breed (Kremer et al., 2004), genotype (Santos-Silva et al., 2002), age (Leymaster and Jenkins, 1993), weight at slaughter (Pérez et al., 2007), type of feed (Díaz et al., 2002), and productive year (Thatcher et al., 1991). Breed (Kremer et al., 2004), genotype (Santos-Silva et al., 2002), age (Leymaster and Jenkins, 1993), weight at slaughter (Pérez et al., 2007), type of feed (Díaz et al., 2002), and productive year (Thatcher et al., 1991). Breed (Kremer et al., 2004), genotype (Santos-Silva et al., 2002), age (Leymaster and Jenkins, 1993), weight at slaughter (Pérez et al., 2007), type of feed (Díaz et al., 2002), and productive year (Thatcher et al., 1991). Breed (Kremer et al., 2004), genotype (Santos-Silva et al., 2002), age (Leymaster and Jenkins, 1993), weight at slaughter (Pérez et al., 2007), type of feed (Díaz et al., 2002), and productive year (Thatcher et al., 1991). Breed (Kremer et al., 2004), genotype (Santos-Silva et al., 2002), age (Leymaster and Jenkins, 1993), weight at slaughter (Pérez et al., 2007), type of feed (Díaz et al., 2002), and productive year (Thatcher et al., 1991). Breed (Kremer et al., 2004), genotype (Santos-Silva et al., 2002), age (Leymaster and Jenkins, 1993), weight at slaughter (Pérez et al., 2007), type of feed (Díaz et al., 2002), and productive year (Thatcher et al., 1991). Breed (Kremer et al., 2004), genotype (Santos-Silva et al., 2002), age (Leymaster and Jenkins, 1993), weight at slaughter (Pérez et al., 2007), type of feed (Díaz et al., 2002), and productive year (Thatcher et al., 1991). Breed (Kremer et al., 2004), genotype (Santos-Silva et al., 2002), age (Leymaster and Jenkins, 1993), weight at slaughter (Pérez et al., 2007), type of feed (Díaz et al., 2002), and productive year (Thatcher et al., 1991). Breed (Kremer et al., 2004), genotype (Santos-Silva et al., 2002), age (Leymaster and Jenkins, 1993), weight at slaughter (Pérez et al., 2007), type of feed (Díaz et al., 2002), and productive year (Thatcher et al., 1991).

Table 1: Some works that have compared the main variables used to determine ovine carcass quality.

<table>
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<th>Breed</th>
<th>Feed</th>
<th>Grasslands</th>
<th>Natural grasslands</th>
<th>Marginal grasslands and concentrates</th>
<th>Rainfed grasslands and concentrates</th>
<th>Tropical pasture and concentrate</th>
<th>Concentrates</th>
<th>Mother’s milk</th>
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more specialized animals in response to market demands while increasing the profitability of the productive system (Crouse et al., 1981). Santos-Silva et al. (2002) compared ‘Merino Branco’ lambs to those from crossbreeding ‘San Merino’ and ‘Île de France’. The lambs obtained from the crossing had better carcass yields and muscle/bone ratios, but the authors considered these differences of limited importance given that these factors do not greatly influence the commercial value of the carcass. In contrast, Rodrigues et al. (2006) found differences in the carcasses of ‘Churra Galega Bragancana’ and ‘Suffolk Down’ lambs in terms of yield and proportion of cuts obtained from the carcass, with a higher proportion of relevant cuts (leg, shoulder, and breast) obtained from the ‘Suffolk Down’ lambs.

There were also differences in carcass composition and fat content, with ‘Suffolk Down’ lambs presenting better results. Pérez et al. (2007) did not find differences between carcasses of ‘Suffolk Down’ and ‘Merino Precoz Alemán’ lambs. Miguélez et al. (2006) compared three breeds (‘Churra’, ‘Castellana’ and ‘Ojalada’) belonging to Protected Geographical Indications under the European Union and found differences in some parameters (cold carcass weight, tissue and others). Barone et al. (2007) compared ‘Gentile di Puglia’, a breed raised for wool and meat, ‘Île de France’ and their cross, and found differences in characteristics of the carcasses of the two pure breeds, which were more pronounced when compared to those of the crossbred lambs. Santos-Silva and Váz (2001) found significant differences between the carcasses of the breeds ‘Serra da Estrela’ and ‘Merino Branco’ in all the analyzed variables except carcass yield. The varying results reflect differences in development among breeds, for example muscle distribution owing to specialization in animal production (Santos-Silva et al., 2002; Rodrigues et al., 2006; Mustafa et al., 2008). A recent study comparing ‘Suffolk’ and ‘Chilote’ lambs under the productive conditions of Chiloe Island found that the rump of ‘Chilote’ lamb was thinner, whereas horns and hooves accounted for a higher proportion of its weight (Ramírez-Retamal et al., 2013).

There are different types of productive systems that establish feeding according to their resources, taking into account that feeding is one of the major costs in animal production. Feeding systems for lambs can be based on grazing or concentrates (Ponnampalam et al., 2010). There are also mixed systems that combine the two (Jacques et al., 2011) and systems based on mother’s milk or milk substitutes (Pérez et al., 2002). The feeding system can affect the composition of the carcass (Lewis et al., 2002) and the degree of fattening. Animals fed by grazing present low levels of fat, which increases their acceptability to consumers (Sañudo et al., 2000b). Likewise, the fat of grass-fed animals tends to be yellow (Priolo et al., 2002). The carcasses of grass-fed lambs weigh less than those of lambs fed on concentrates that are slaughtered at the same age (Priolo et al., 2002), thus animals fed mainly on concentrates require less time to be prepared for slaughtering (Mustafa et al., 2008).

Despite the importance that breed and feed type have individually in determining the quality of the carcass, it is possible that the interaction between two or more factors also affects quality and characteristics of lamb carcasses (Díaz et al., 2002; Mustafa et al., 2008).

Research on carcass quality is generally conducted under optimal productive conditions and there has been relatively little research conducted under less favorable conditions (Fraser et al., 1996; Prache et al., 2011), because of which it is necessary to consider systems in which productive conditions are more restricted, such as grazing in areas with naturalized or natural grasslands. Ramírez-Retamal et al. (2013) compared the main characteristics of the carcasses of Chilote lambs fed on naturalized pasture or natural range and did not find differences resulting from the grassland types used by small-scale producers in Chiloe Island, Chile.

### Quality of ovine meat

A series of biochemical processes and changes at the cellular level must occur to change muscle into flesh (Pearce et al., 2011). An important stage in this process is rigor mortis, together with alterations at the myofibril level of the muscles (Pearce et al., 2011). As well, ATP and glycogen levels should decrease, this in turn causing a decrease in muscular pH from 7.0 to less than 6.0 (Kooomharaie et al., 1991; Ouali et al., 2006; Pearce et al., 2011).

There are several parameters to establish the quality of the meat. One of the main indicators is the pH of the meat (Weglarz, 2010), given that abnormal pH values can alter the quality of meat, especially in terms of color and tenderness (Priolo et al., 2001; Mounier et al., 2006). Levels of 5.8 or less 24 h after slaughter are recommended to avoid problems in meat quality (Tejeda et al., 2008). Table 2 presents some works that compared the main characteristics used to determine the quality of ovine meat.

The color of meat is an important factor influencing consumer-purchasing decisions (Moore et al., 2003). Color is influenced by the chemical status of myoglobin in the meat. Freshly cut meat has higher concentrations of desoxymyoglobin molecules, which give the meat a reddish purple color. However, after exposure to oxygen, desoxymyoglobin is transformed to oxymyoglobin, resulting in a desirable bright red color. Finally, with more exposure the meat turns brown owing to the transformation of oxymyoglobin to metamyoglobin due to oxidization (Moore et al., 2003). Meat color can be evaluated instrumentally or by a sensory panel. The instrumental approach is based mainly on the CIE system, which was developed by the Commission Internationale de l’Eclairage of France, and is the universally accepted...
Hoffman et al., 2003

Komprda et al., 2012

Kuchtík et al., 2012

Teixeira et al., 2005

Altamurana, Trimeticcio, 2013

Gonzalez Febrero, Lopez-Martinez, et al., 2012

Carpenter et al., 2009

Ekiz et al., 2009

Blanco et al., 2014

Aguayo-Ulloa et al., 2014

Marino et al., 2008

Cañeque et al., 2004

Miguélez et al., 2008

Blanco et al., 2014

Kivircik, Chios, Imroz Merino, Churra, Castellana and Ojaleda Manchego

Marmet. Simmental and Ile de France

Blanco et al., 2014

Santos-Silva et al., 2002

Ramírez-Retamal, 2013

Santos-Silva et al., 2002

Ramírez-Retamal, 2013

Gallo, 2013

Mamani-Linares and Natural grasslands

Mamani-Linares and Natural grasslands

Longissimus dorsi muscle.

The influence of intramuscular fat (IMF) on tenderness and juiciness varies depending on the study and the species studied (Wood et al., 2008). With sheep, meat with more marbling or IMF is more valued by sensory panels (Fisher et al., 2000; Wood et al., 2008). Similarly, meat with a higher IMF level has a lower shear force value, which nevertheless does not directly relate the IMF level to the degree of tenderness (Sañudo et al., 2000a). The fatty acid composition of the meat is important given its implications for human health (Givens, 2005) in relation to heart disease and cancer (Wood et al., 2003). Likewise, the fatty acid composition affects characteristics of the meat like juiciness, flavor, shelf life, and firmness of the meat (Wood et al., 2003). Polynsaturated and saturated fatty acids and the ratio between them and the n-6:n-3 ratio have important implications for human health. Both ratios are considered indicators of risk factors for certain cancers and coronary heart diseases (Wood et al., 2003; De Smet et al., 2004; Givens, 2005). A value of 0.4 or higher is recommended for the polyunsatuated:saturated fatty acids ratio, whereas a value of 4.0 or less for a diet is recommended for the n-6:n-3 ratio (British Department of Health, 1994). Likewise, there is great interest in the qualities of polynsaturated fats termed conjugated linoleic acids (CLAs). The abbreviation CLA is a collective term used for all positional and geometric isomers of linoleic acid with conjugated double bonds. Among them, two isomers are predominant: a) CLA cis-9, trans-11 (rumenic acid), and b) CLA trans-10, cis-12, occurring in ruminant meat and dairy products (Schmid et al., 2006) in proportions of about 75-90% and 10-25% of total CLA, respectively. The major reported

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benefits of CLAs are their anticarcinogenic, anti-diabetic, anti-adipogenic effects and their positive effects on the immune system (Williams, 2000; Webb and O’Neill, 2008; Scerra et al., 2011).

CLAs are formed by the partial biohydrogenation of conjugated fatty acids, mainly in the rumen, because of which they are found in major concentrations in the meat of ruminant animals such as sheep (Williams, 2000; Schmid et al., 2006). The major factors affecting biohydrogenation are ruminal pH, the forage:concentrate ratio, and the type and level of fatty acid intake. For instance, low ruminal pH has a significant protective effect on linoleic and linoleic acids. For more information see the reviews of Schmiedly et al. (2008) and Glasser et al. (2008).

Vasta and Luciano (2011) suggest increasing CLA cis-9, trans-11 content in meat and milk products as a strategy to enhance C18:1 trans-11 uptake in the duodenum. This is because CLA cis-9, trans-11 is also synthesized by endogenous conversion of C18:1 trans-11 (trans-vaccenic acid) by the enzyme Δ-9-desaturase in adipose tissue and the mammary gland (Griinari and Bauman, 1999). CLA cis-9, trans-11 synthesis increased linearly with an increase in the C18:1 trans-11 content of the diets of human subjects (Salminen et al., 1998; Turpeinen et al., 2002). The rate of C18:1 trans-11 conversion to CLA cis-9, trans-11 ranges from 5 to 12% in rodents to 19 to 30% in humans (Turpeinen et al., 2002).

One of the main sources of minerals in western diets is meat, especially lamb (Reykdal et al., 2011; Polidori et al., 2011), notably providing Fe, Zn, P, K, Mg, and Se (Sheridan et al., 2003; Osorio et al., 2007; Ramírez-Retamal, 2013). These minerals are essential for different biological processes (free radicals and oxygen transport, among others) and their deficiency can cause problems for the organism (Cabrera et al., 2010). As well, different minerals can be associated with the quality of meat given their influence on characteristics like color, tenderness, and oxidation (Osorio et al., 2007). However, there is very little reference information in the case of minerals independent of the factors analyzed. The main minerals found were Fe and Zn. This concurs with the importance assigned to these in the literature for the greater contribution of minerals to the human diet (Hoffman et al., 2003) and the importance of lamb meat as a source of Fe and Zn compared to plant sources (Williamson et al., 2005).

The quality of sheep meat, like that of the carcass, can be affected by different factors, among them the breed. A study by Hoffman et al. (2003) of several breeds and crossings found differences among breeds in pH values and fatty acid composition of the meat, especially monounsaturated fatty acids, which coincided with the results of Santos-Silva et al. (2002) and Marino et al. (2008). There are also differences in the concentrations of Fe, K, and Mg, among other minerals. However, while associated with breed, these differences may also be influenced by factors like the place of origin of the animal. Another study (Teixeira et al., 2005) found no differences in pH values and the fatty acid profiles of the meat of two similar breeds. Nevertheless, they found differences in the b* coordinate of meat color. Despite the importance that breed can have on meat quality, some authors attach more importance to other factors, such as the age of the animal and the type of feed. According to these authors, breed plays only a secondary role (Navajas et al., 2008). Latorre et al. (2011) compared four breeds of sheep (‘Polled Dorset’, ‘White Suffolk’, ‘Meat Merino’ and ‘Corriedale’) in the far south of Chile and found no differences in protein content, but did find differences in vitamin E concentrations (antioxidant), which was highest in ‘Corriedale’ (0.26 mg) (Latorre et al., 2011).

The various types of productive systems are focused on meeting consumer demand for quality meat, which can have different characteristics depending on the feed used. This factor, in association with others like cultural aspects and consumer habits, determines consumer preferences. There is more acceptance among European consumers of meat from animals fed on concentrates or mixed systems (forage and concentrates) (Font i Furnols et al., 2009). The pH level of the meat is not affected by the type of feed (Priolo et al., 2002; Velasco et al., 2004; Lanza et al., 2006). The color and luminosity of the meat, on the other hand, are affected by the feed type. The meat of grass-fed animals is darker than that of animals fed on concentrates (Alcalde and Negueruela, 2001; Priolo et al., 2001). Tenderness can also be influenced by feed, the meat of animals fed on concentrates being more tender due to the level of fat associated with this type of feed (Priolo et al., 2002), although results obtained by Sañudo et al. (2003) indicated that meat of grazing animals was more tender. Likewise, there are differences among grassland types (Lind et al., 2009).

The fatty acid profile is mainly affected by the type of feed. Independent of feed type, the P:S ratio reported for sheep meat is around 0.1-0.26 (Enser et al., 1998; Wood et al., 2003; Wood et al., 2008; Ponnampalam et al., 2010; Scerra et al., 2011). Grass-fed lambs tend to have higher concentrations of CLA cis-9, trans-11 and C18:1 trans-11. Grass-fed animals also tend to have a n-6:n-3 fatty acid ratio four points lower than that of lambs produced under other systems (Enser et al., 1996; 1998; Webb and O’Neill, 2008). Differences in fatty acid profiles are also reported in lambs feeding with different type of pastures (Whittington et al., 2006; Lind et al., 2009; Ramírez-Retamal, 2013). Owing to these differences, the meat of grass-fed animals is recognized as healthier. In addition, pasture-based feeding has acquired importance because consumers view resulting meat products as more natural, less contaminated and reflecting more respect for animal welfare (Hersleth et al., 2012; Vasta et al., 2012). However, some authors argue that grass-feeding has negative effects
on productive parameters like growth rates and yield, owing to the longer period of time required to prepare animals for slaughter (Aurousseau et al., 2007; Webb and O’Neill, 2008; Scerra et al., 2011).

Despite the importance of determining meat quality for the food chain, there have been few studies on animals raised in marginal areas (Lourenço et al., 2007; Lind et al., 2009; Gallardo et al., 2011; Ramírez-Retamal, 2013), because of which there is a need to determine the effects of this on meat production. In this sense, the use of autochthonous breeds or breeds native to the area represents an opportunity to develop sustainable productive systems, but it is necessary to carry out more studies to determine if these breeds meet the quality parameters for ovine meat.

Finally, there is increasing interest in secondary compounds in some plants as potential tools to improve lamb quality. This is the case of phenolic compounds, such as condensed tannins, and of saponins and essential oils rich in terpenes (Vasta and Luciano, 2011; Jerónimo et al., 2012). The scarce information available suggests that it is possible to increase the content of CLA with the use of autochthonous breeds or breeds native to the area. However, it is important to carry out more studies to establish if these breeds meet the quality parameters for ovine meat.

CONCLUSIONS

Different factors should be considered in developing an optimal ovine production system to meet the demands of industry and final consumers with a quality product. Breed is an important factor in carcass quality, but of less importance for meat quality. In contrast, feed type does have a major effect on meat quality, but less effect on carcass quality, affecting mainly conformation and fat content.

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