



## Some factors that affect ruminant meat quality: from the farm to the fork. Review

Ana Guerrero<sup>1\*</sup>, Maribel Velandia Valero<sup>2</sup>, Mari Mar Campo<sup>1</sup> and Carlos Sañudo<sup>1</sup>

<sup>1</sup>Departamento de Producción Animal y Ciencia de los Alimentos, Universidad de Zaragoza, Miguel Servet, 177, 50013, Zaragoza, Spain. <sup>2</sup>Departamento de Zootecnia, Universidade Estadual de Maringá, Maringá, Paraná, Brazil. \*Author for correspondence. E-mail: kechuana@hotmail.com

**ABSTRACT.** Nowadays consumers are highly interested in the quality of the products they eat, especially when this refers to meat. Consumption of meat from ruminant animals and its derivatives is on the increase, particularly in some countries such as Brazil, one of the main beef exporters in the world. Current analysis is a review of the different factors that affect meat quality in ruminants, with a focus on sensory analyses. Some factors throughout the entire meat chain are analyzed, or rather, from those that producers underscore to improve the quality of their products to those related with consumers' habits and beliefs. Most of the papers reviewed have been developed by researchers involved in the Meat Quality and Technology Group (University of Zaragoza and CITA of Aragon, Spain) alone or in collaboration with other local or international groups.

**Keywords:** consumers, human health, ruminants, sensory analyses.

## Alguns fatores que afetam a qualidade da carne: da fazenda ao garfo. Revisão

**RESUMO.** Cada vez mais os consumidores estão interessados na qualidade dos produtos os quais eles consomem; especialmente com referência a carne. O consumo de carne de ruminantes e de seus derivados está aumentando de forma muito rápida, especialmente em alguns países como o Brasil, que é o principal exportador de carne do mundo. Este trabalho revisa diferentes fatores que afetam a qualidade da carne de ruminantes, sobretudo sobre as análises sensoriais. Alguns fatores ao longo da cadeia da carne são analisados: aqueles que poderiam ser considerados pelos produtores relacionados ao melhoramento da qualidade dos seus produtos e aqueles relacionados aos hábitos e comportamento dos consumidores. A maior parte dos artigos científicos revisados foi desenvolvida pelo Grupo de Qualidade e Tecnologia de Carnes (Universidade de Zaragoza e CITA da região de Aragon na Espanha) isoladamente ou em colaboração com grupos locais e internacionais.

**Palavras-chave:** consumidores, saúde, ruminantes, análise sensorial.

### Introduction

Since world population is close to 7 billion (FAO, 2013), food consumption has become a concern. World population is growing by more than 200.000 people per day and it has an impact on increasing demands for food production. The economic development is normally accompanied by an increase of the average household income and subsequent improvements in food supply. Meat is one of the most important foods in the world and in some countries it is considered an essential product with very high consumption rates. In fact, meat provides valuable amounts of protein, fatty acids, vitamins, minerals and other bioactive compounds. In other countries, meat is just a complement for an already balanced diet. Recently, especially from the 1980, meat consumption has been questioned by vegetarians, animal welfare supporters,

environmental contamination supporters, to the point that a feeling that it is somewhat a dangerous product has been introduced into the

consumers' mind. Meat and meat products may be viewed as having a double mirror image with respect to its composition and nutrition (TROY; KERRY, 2010). Actually there are consumers that consider meat to be a healthy and important component in the diet (VERBEKE et al., 2010) and others are convinced that it is an agent associated with cardiovascular disease, diabetes and some types of cancer.

Family income, prices, individual preferences and beliefs, culture and traditions, as well as geographical, environmental, social and economic factors interact in a complex manner to determine dietary consumption (GRUNERT, 2006). In any case, meat, as any other food product, needs to improve its quality at three different scenarios:

1. Nutrition: increased transparency on the nutritional contents of food products may also induce changes in consumers' demand; in fact, it has already led producers to reformulate some meat products with lower fat or higher polyunsaturated fatty acid contents.

2. Sensorial: providing an acceptable product that invites more consumption and increases its demand, with a deep knowledge of consumers' cultural and cooking cultural background of each potential market.

3. Beliefs: improving the image of the product with regard to all possible and imaginable aspects: welfare, ecological, nutritive, etc., i.e. indicating factors that meat and meat products are excellent foods for the intake of bioactive compounds without changing dietary habits; for example, Omega-3 (n-3) fatty acids play a major role in human health and are involved in the development of the brain and retinal tissues and in the prevention of human illnesses, including heart diseases and some cancers (CONNOR, 2000).

From the three aspects mentioned above, the problem arises since meat varies with respect to numerous intrinsic and extrinsic factors. These include animal diet, the factor most easily manipulated and with the most profound effects on its composition, pre- and post-slaughter, technology and factors related to consumer sciences, such as Sociology, Acceptability, Economy and Marketing.

The Meat Quality and Technology Group of Research at the Zaragoza University and the Regional Research Center (Spain) have been working in the fields of Meat Quality for the last 35 years and has participated in several National and International projects with the valuable help of researchers from more than 30 countries. Many of

their works and publications are presented in this paper whose aim is to provide to the scientific community a fraction of this reality.

## Factors affecting ruminant meat quality

### Intrinsic factors

#### Species

Meat quality and characteristics differ among animal species, even within more similar or homogenous groups such as small ruminants. Sañudo et al. (2012) compared 4 goat breeds (meat, double purpose and dairy aptitude) and one lamb dairy breed. Results showed that lamb and goat products (even very young and milk-fed animals) differed in carcass characteristics and several instrumental measurements of quality. Differences were mainly species dependent.

On the other hand, differences in meat characteristics are assessed in sensory analyses. Sensorial differences between species are detected by consumers, even when meat is seasoned, as Rhee et al. (2003) showed when they compared goat and beef meat. Species-related flavors are associated with species-dependent adipose tissues. However, the acceptability of meat from different species is also linked to the population's Consumption habits. Consequently, global appreciation rates of meat from different species depend on consumers' food background Guerrero et al. (2013a).

#### Breed or crossbred

Breed is a clear source of variation in carcass morphology related to fat quantity or meat quality. In fact, it is a complex factor because results depend upon which criteria of comparison are taken into account: same weight, similar age or similar degree of maturity (live adult weight %).

The influence of breed or genetic type in the lamb varies a lot and depends on which factor is being studied or compared. Osório et al. (1995) compared 86 carcasses from 9 different breeds belonging to the same commercial group, namely 'ternasco', an intensively reared light lamb. They registered differences among the breeds, especially in morphology and tissue composition. Sañudo et al. (1997) reported effect of breed (4 types of young suckling lambs) on some instrumental measurements (meat color and cooking loss) and on some sensorial attributes (tenderness and juiciness), associating differences to precocity and inherent productive capabilities, with a focus on breed effect on sensorial analysis and consumers. Martínez-Cerezo et al. (2005a and b) developed

sensory analyses on three different Spanish lamb breeds (Merino, Rasa Aragonesa and Churra), with various slaughter weights, age and three different muscles. Results showed that sensory attributes varied according to breed, although other factors studied had a higher significance. However, research by Bianchi et al. (2006b and b) on genetic types and aging on meat tenderness showed that genetic type had no effect and that consumers did not detected differences between the two breeds analyzed (pure Corriedale and Hampshire Down x Corriedale). In fact, age and muscle type were more important factors than breed.

It may be stated that, as a rule, the effect of breed on instrumental and sensory meat quality, such as pH, color, texture and sensory characteristics, is slight. Most differences are probably justified by differences in precocity or in muscularity levels.

Albertí et al. (2008) studied several parameters related to carcass quality and characteristics of fifteen European cattle breeds and obtained significant differences between the breeds for the variables under analysis. Body size measurements and carcass traits were more useful parameters to discriminate cattle breeds, classified into specialized beef breeds, local and dairy breeds and an intermediate group. Monsón et al. (2005) compared beef from 4 breeds with different biotypes (dairy, dual purpose, meat and high muscularity) by sensory and consumer analyses. In both tests breed had a significant effect on tenderness, associated to quantity, solubility and space organization of collagen, fatness and calpain

and calpastatin activity (MONSÓN et al., 2004) according to texture analyses. Although age had relevant effects and homogenized breed differences, optimal age with regard to consumers' acceptability differed among breeds. Results for other studies may be seen in Campo et al. (1999).

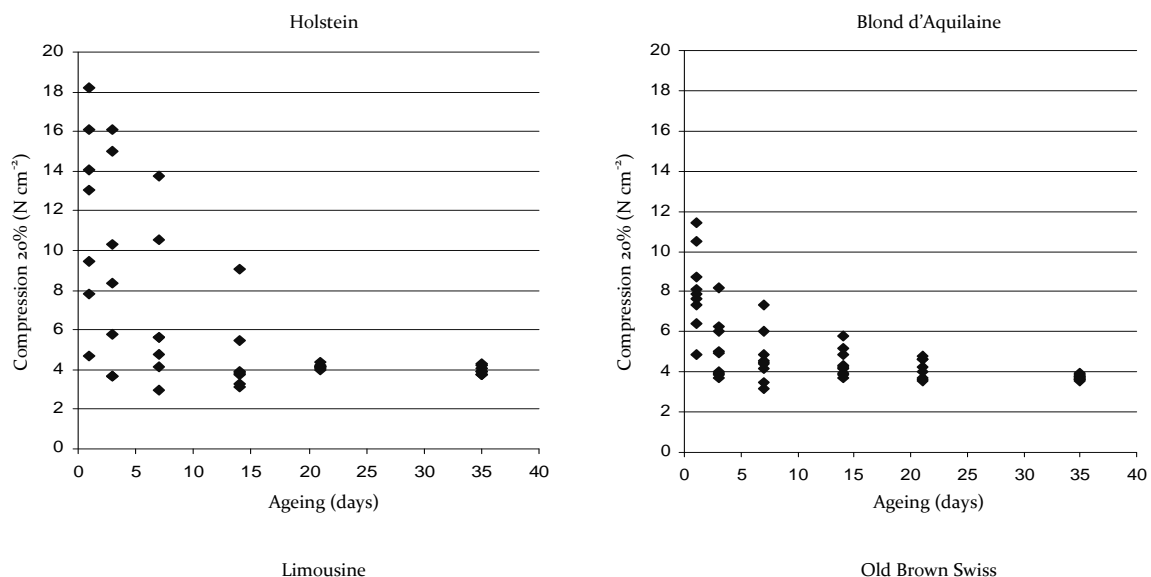
Comparing cattle purebreds and crossbred genotypes, results by Vieira et al. (2006) and Panea et al. (2011) showed high crossing effects on rustic breeds' carcass characteristics, obviously highly improved. However, other analyses (instrumental, sensorial) revealed no differences, except in color parameters such as luminosity, which in this study was considered to be lower in purebred than in crossbred.

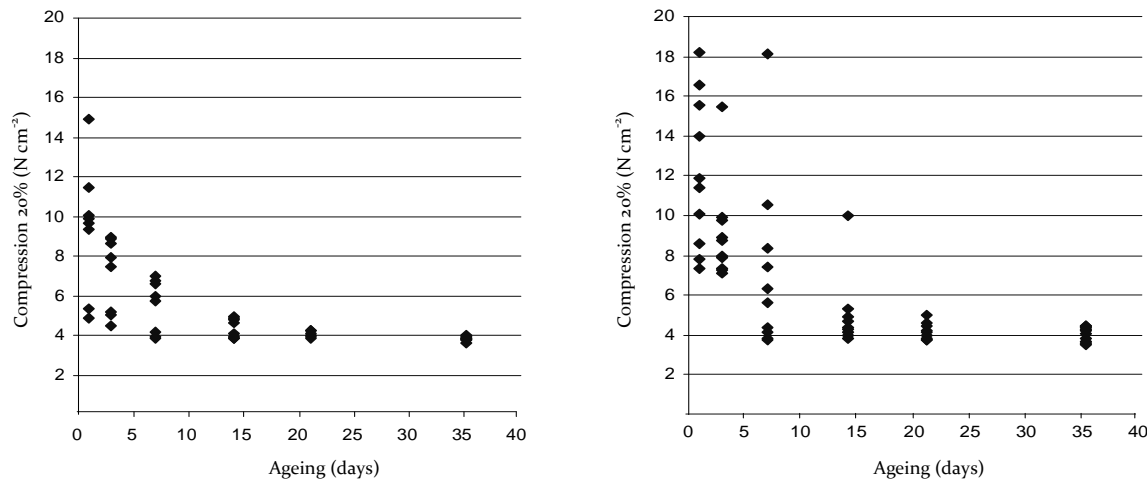
Breed is a factor that should be considered in studies on the quality of ruminant products in spite of high individual variations and although it is less important than other factors which may be more relevant than breed effect per se.

#### Individual, genetic aspect

Each specimen within a breed is one of the main causes of variation in terms of productivity and quality. However, it is a multi-causal factor, because differences in metabolism, behavior, social rank, sensibility to stress, way of birth, dam milky capacity, learning capacity or, simply genetic differences, could be presented alone or as additive factors that increase the variation.

An example of this high individual variation is reflected on texture results (compression 20%) by Monsón et al. (2004), a fact that is especially present at the first stages of ageing (Figure 1).





**Figure 1.** Stress at 20% of the maximum compression rate ( $\text{N cm}^{-2}$ ) in raw meat (*M. longissimus*) at different ageing times (1, 3, 7, 14, 21 and 35 days) in several individuals of four different cattle breeds.

(ALTARRIBA et al., 2005) used the Pirenaica breed to investigate and evaluate the possible correlated responses of selection for growth in meat and carcass traits, quantify intra-breed variations in carcass and meat quality characteristics and highlight the differences between carcasses grouped by the respective sire (PANEA et al., 2008). These studies concluded that measuring online carcasses to predict meat quality is actually a not realistic matter and, in general, a better conformation score is not related to superior meat quality. Most selection programs on extensive populations of beef cattle focus on few traits related to weight at weaning. New methodologies to estimate genetic parameters related to meat and carcass quality are also being investigated. Regarding to the Pirenaica breed, Altarriba et al. (2005) concluded that selection for weight at 210 days old produced animals with higher live and carcass weights at slaughter, wider carcasses, deeper and longer legs with a greater perimeter, and greater loin surface. However, genetic changes were not detected in dressing percentage and in physical, chemical or sensorial parameters of meat quality. Further studies should be developed to understand better the influence of genetics on meat quality variations.

### Gender

Ruminants' gender effect (male, female, castrated) is mainly related to the quantity of fat deposited, deposition site, growth rate and carcass yield. Carcass attributes are more affected by gender; likewise, females are more affected than males due to their higher precociousness, whereas steers maintain an intermediate position. Differences in carcass, fat and conformation might

also affect other meat quality parameters. In the case of beef, Panea et al. (201b) studied the effect of gender on instrumental and sensory quality and on the appraisal of meat derived from the Spanish beef breed (Avileña-Negra Ibérica). Results showed that in the two tests (sensory and consumers), meat from females was most appreciate than that from males. It was considered more tender and juicy. These results corroborated other researches and may be explained by gender differences according to physiological maturity for animals of a similar chronological age. Moreover, gender influenced other variables studied, such as pH and color. Studies on castrated bulls by Prado et al. (2013) demonstrated that castration of bulls at 20 or 150 days had no effect on consumers' acceptability.

### Age and weight at slaughter

Age and weight at slaughter are analyzed together because, taking the same genetic base, a greater weight implies a higher age, except when feed is manipulated or the animal has periods of strong alimentary restrictions.

Olleta et al. (1992) studied growth traits of 'Churra Tensina', the local Spanish sheep breed, at two slaughtering weights (light: 22.0 kg and heavy: 26.8 kg). Fat and carcass yield proportions were affected by weight, with light lambs featuring less internal fat and lower commercial and slaughter yields but more muscle and bone percentage. Further, weight affected fat contents and meat color: meat of heavy lambs was darker. On the other hand, there was no significant difference in tenderness or water holding capacity.

Sañudo et al. (1996) investigated the influence of carcass weight (CW) on instrumental and sensory traits on the sheep breed Rasa Aragonesa. Results indicated that instrumental measurements (pH, meat color and texture) were affected by CW, or rather, heavier lambs had higher pH and less tough meat which was darker too. No important effects on the meat sensory characteristics were detected.

Martínez-Cerezo et al. (2005a) analyzed sensory characteristics of three breeds with three different slaughter live weights (10-12, 20-22, 30-32 kg) and ageing. Although lamb odor and lamb flavor intensities increased with slaughter weight, meat juiciness and tenderness depended on the breed. In fact, juicier and tender meat came from Churra (dairy) breed (lightest lambs) and from Spanish Merino (heavier animals). When three muscles of the same breeds were analyzed, those from the heaviest lambs were considered the toughest and those from the 10-12 kg lambs the most tender, coupled to better flavor.

Ripoll et al. (2011) analyzed the effect of slaughter weight (light carcass weight: 7.6 kg vs. heavy carcass weight: 11.4 kg,) in milk kids. In this case, weight at slaughter had an important effect on meat quality: light kids had a higher compression on texture rates. However, with regard to sensory analyses, meat from light kids was reported tender and juicier than meat from heavy ones, with higher fibrosis and species odor.

#### **Extrinsic factors previous to slaughter**

##### **Management (stress agents)/behavior**

In groups, ruminants interact and develop relationships among themselves. Relationships are dominant-subordinate to establish a socially dominant hierarchy. In cattle, dominance-related interactions cause stress, bruises and physical injuries. Since cattle feedlot systems may be restrictive to key resources such as self-grooming substrates, shade, feeding spaces and comfortable lying places (PARTIDA et al., 2007a), competition for some of the above-mentioned resources may produce disturbances and subsequent biological costs to the animals.

Research by Partida et al. (2007a) and Miranda de La Lama et al. (2013) discussed the effect on meat quality of different cattle groups classified by social dominance index (high, medium or low). In both studies, the animals' social status had no effect on carcass or meat quality

parameters, although results from sensorial analyses differed slightly. In dairy breeds (Friesian), dominance did not affect sensorial parameters (PARTIDA et al., 2007a), although Miranda de La Lama et al. (2013) observed that in breed Gascon beef the taste panel judgment was affected by social rank with regard to tenderness and some odor and flavor scores. Animals from the medium and high ranks had the highest scores in tenderness. This fact was associated to the higher excitability of low ranked animals, which may produce a stress response with higher biological costs and, subsequently, sensorial meat quality.

Results from the above research works suggested that homogenous groups of animals in age, breed, gender, weight, body size and farm conditions were adequate and established a stable social status among the animals. Dominance effect on meat quality (instrumental and sensorial) was absent. On the other hand, under sub-optimal commercial conditions, the effect of social status within a group may be much higher, with consequences on sensorial analyses.

#### **Diet**

##### **Type of suckling (dam's milk or milk replacer)**

Panea et al. (2012) studied the two dairy breeds Malagueña and Murciano-Granadina. Half of the animals were reared on dam's milk and the other half on milk replacer. The animals were slaughtered at a light weight (4 kg). The authors found that fatness degree was higher in animals fed on a natural lactation system and that milk diet affected  $L^*$ ,  $a^*$  and hue. Kids from dairy breeds fed on dam's milk had fat with higher  $L^*$  and  $H^{\circ}$  due to a lower redness, implying lower iron availability and lower meat pigments. Moreover, Panea et al. (2011a) found a moderate effect of lactation on meat texture.

##### **Type of weaning (suckling vs. weaned)**

According to Sañudo et al. (1998b), the type of weaning affects pH, cooking losses and water-holding capacity of meat. However, it has effects on visual fatness, redness  $a^*$ , haem pigment concentration and flavor. The  $a^*$  value was higher in weaned than in suckling lambs because of its positive relation with meat haem pigments. Moreover, an improved sensorial quality of the meat flavor has been described in milk-fed, suckling, animals. However, only differences in polyunsaturated fatty acids were found when intramuscular fat composition was analyzed.

They were higher in suckling lambs, but not in total unsaturated or saturated fatty acids. Lactation until slaughter tends towards less pigmented meat with better sensory quality.

#### **Diets' ingredients (glycerin, dehydrated lucerne, barley straw, different level concentrates)**

There are numerous studies featuring diet and especially ration ingredients and meat quality. Eiras et al. (2013a and b) and Françoço et al. (2013) replaced corn by glycerin diet and found that replacement failed to affect beef color, texture, cooking loss, chemical composition and percentage of fatty acids. Moreover, sensory characteristics were not affected by glycerin (EIRAS et al., 2013b). In another work, diets containing different percentage of dehydrated lucerne in concentrates for bulls produced significant effects in succulence, but tenderness, flavor and instrumental meat quality remained unchanged (ALBERTÍ et al., 1992). Moreover, in cattle finished with forage, supplemented with different levels of concentrate, meat quality continued unaffected (ALBERTÍ et al., 1987, 1988), although animals fed on pasture for more than 120 days showed significant differences in meat color (ALBERTÍ et al., 1988).

On the other hand, Resconi et al. (2009) analyzed lambs from Uruguay, finished with different levels of pasture and concentrate amounts, and found that the inclusion of concentrates in the diet improved the meat's sensory quality and was related to the lowering of undesirable odor and flavor intensity. Lambs fed only on concentrates produced meat that had the highest fat flavor intensity and the best overall acceptability.

#### **Physical characteristics of ration**

The effects of the physical characteristic of extruded ration on the diet of animals were analyzed. Fifty-six Frisian males were reared, half of which were fed on extruded diet and the other half without. When reporting on the meat's sensorial quality, the trained panel did not find any differences between the diets for the qualities evaluated: tenderness, juiciness, odor and flavor quality or acceptability (unpublished).

#### **Chemical characteristics of diet**

The effect of protein level (13% or 15%) and quality (lys/met ratio 3.5/1 or 3/1) added to the ration and related to meat acceptability was studied by Prado et al. (2013). Beef acceptability

increased when 15% protein was incorporated rather than 13%, regardless of the lysine level added.

#### **Additives (hormones, palm oil supplements)**

In general, additives are a wide group of substances, characterized by function, toxicity, legal situation and knowledge on their activities, related to possible positive or antagonistic effects. Since they have significant effects on the product's quality, the use of some hormones may affect meat quality of bulls (MONSÓN et al., 2007). According to these authors, clenbuterol provided tougher meat, although its combination with dexamethasone may have decreased toughness by an increase in the solubilization of collagen, especially after 7 days of age.

Other additives, such as palm oil supplements, did not change negatively the sensorial characteristics of the meat of young bulls. Partida et al. (2007b) showed that diet had a significant effect on tenderness, fibrosity, and acid flavor. Consequently, diet containing hydrogenated palm oil fatty acids produced meat that had a greater intensity of acid flavor than did meat from bulls fed on the lard-tallow mix, calcium salt and partially hydrogenated palm oil fatty acids diets.

#### **Multi-causal factors: Production system**

The effect of production system in meat quality has been dealt with from different points of view since it may be considered an effect from multi-causal factors.

Research work on beef meat production system during finishing period in which animals were reared extensively and fed on different percentages of pasture or concentrate was undertaken by Campo et al. (2008), Realini et al. (2009) and Resconi et al. (2010a and b) who analyzed the meat quality of Uruguayan Hereford steers. Campo et al. (2008) found that instrumental quality of meat from extensive production systems and conventionally associated with some inferior meat quality attributes (as tenderness and color) did not clearly show changes in meat quality, even increased beef tenderness. Sensory analyses by Resconi et al. (2010b) revealed that finishing diet had a significant effect on most sensorial attributes studied, even when animals that grazed on pastures received small supplements of maize grains (0.6 % live weight). Meat from animals finished on concentrate had the lowest intensity

of beef odor and flavor and the highest intensity of strange odors coupled to the lowest tenderness. European panelists are accustomed to consume meat from animals reared mainly on concentrates and might have perceived the typical pasture odor as strange. Since animals fed on concentrate diet were finished only after a short period (41 days), the period was probably insufficient to reduce pastoral odors and their rates were presented at the same level of those from the pasture animals' diet. Researching on consumers' acceptability of this type of meat, Realini et al. (2009) showed that low levels of pasture supplementation produced beef with the highest consumer acceptability, followed by beef from pasture-fed animals. However, acceptability scores were different in each European country (France, UK, Spain and Germany) where the meat was evaluated.

However, differences between production systems are not only present when contrary systems (pasture-concentrate and intermediary values) are compared. According to Serra et al. (2008), the relationship between breed and its typical production system presents eating quality differences, mainly in beef flavor, tenderness and juiciness. The above reinforces the involvement and development of different protected geographical indications (PGI).

Differences among animals from different production systems (as extensive-pasturage vs. intensive-concentrate) may decrease sensory traits when animals are finished in same intensive conditions during a period of at least 5 months (GUERRERO et al., 2013b). In fact, the production system previous to the finishing period was not a significant factor for sensory traits.

In the case of lamb meat, when sensory analyses compared meat of lambs fed on pasture or concentrate, or on different proportions, results differed from those found in beef. Thus, preferences by type of production system differed between the two species. Results by Resconi et al. (2009) on castrated male Corriedale lambs from Uruguay showed that concentrate inclusion in lamb diet improved the meat's sensory quality. Its effect was related to a lowering intensity of undesirable odors and flavors (strange, rancid and acid) which provided a higher intensity of typical lamb aromas and produced higher tenderness. Lambs fed only on concentrates produced meat evaluated by European panelists as featuring the best overall acceptability and the

highest fat flavor intensity. Since the above fact was associated to different aroma compounds (carbonyls) that appeared in the grilled loins, Resconi et al. (2010b) demonstrated the influence of the finishing diet on the aroma of lamb meat. With regard to the European consumers' preferences for that kind of lamb meat, research work by Font I Furnols et al. (2009) showed that worldwide consumers preferred lamb fed on concentrate or on the combination of concentrate and pasture to lamb fed only on pasture. These results agree with those provided by Resconi et al. (2009). However, different segments of consumers exist in each country with different lamb meat acceptability (FONT I FURNOLS et al., 2006). It is therefore highly important to consider differences among consumers when a market study has to be carried out, since consumers from neighboring countries and consumers in different regions within the same country may nurture differences on lamb meat preferences.

Overall acceptability evaluated by consumers is a mixture of flavor and tenderness scores, as well as other sensations that consumers perceive when they taste meat lamb samples. Studies by Font I Furnols et al. (2006) show that overall acceptability was highly correlated with flavor and tenderness. These attributes are affected by fatty acid composition, a parameter which differs among production systems (SAÑUDO et al., 2000) and by the cultural background and culinary habits since the kind of meat that consumers are used to eat is generally evaluated with higher scores. As will be considered below, the meat from one's own region and country is always preferred (SAÑUDO et al., 2000).

#### **Pre-slaughter conditions**

Pre-slaughter conditions involve several facts. Transport time (especially for beef) and pre-slaughter logistic chain (which includes stays in classification centers and season of slaughter) may be considered as the most important for meat quality in ruminants.

María et al. (2003) and Villarroel et al. (2003) analyzed the effect of transport time (30 min., 3 hours or 6 hours) on beef quality. Transport time was significant for texture and some color parameters ( $a^*$ ,  $C^*$ ). In sensory analysis, transport time had a significant effect on meat tenderness and overall liking. The panel preferred meat of animals with a 3-h journey as opposed to animals with 30 min.- or 6-h journeys. In fact, meat with a

3-h journey was more tender (as also shown by mechanical compression analysis) and had a better overall liking. Changes in tenderness were explained if animals were allowed enough time to rest during the journey. However, there is no long rest period between loading and unloading in short journeys. Likewise, after a longer journey the animals were more exhausted than after a 3-h journey, which would affect tenderness and subsequently overall liking.

In the case of lambs, stays in classification centers where animals are mixed and kept for hours or days (to reach the appropriate live weight) before they arrive at the slaughterhouse is a stressful factor that affects meat quality. The season in which slaughter occurred had some significant effect on meat quality (MIRANDA-DE LA LAMA et al., 2009). Thus, slaughter during the cold season seemed to produce variations in some parameters, with lambs having significantly higher pH rates during 24 hours, or lowest values of water holding capacity and higher shear force and toughness than the meat from lambs slaughtered in the summer. In addition to handling, adverse seasonal conditions may potentially stress animals and consequently influence meat quality characteristics, detected by panel tests or consumers.

#### **Extrinsic factors related with slaughter and post slaughter**

##### **Slaughter and blood loss**

The lapse of time between stunning and blood loss is another aspect that is worth considering for a better final product quality. An excessively long period, especially if stunning has been imperfect, may cause blood spots on the meat, with subsequent low acceptability and lower quality.

##### **Freezing, storage**

Muela et al. (2012) assessed the effect of three freezing methods (air blast freezer, freezing tunnel + air blast freezer, and nitrogen chamber + air blast freezer) with three frozen storage durations (1, 3, and 6 months) on the sensory quality of lamb meat. Neither the industrial freezing method nor time of frozen storage caused enough changes in sensory quality to be detected by a panel test or rejected by consumers. There were only slight differences in tenderness and on the lack of undesirable odors and flavors caused by freezing, although lipid oxidation

increased as freezing rate decreased and/or storage duration increased (MUELA et al., 2010). Similar results, albeit unpublished, have been provided when lamb meat was kept frozen for 15 months.

Cluster analyses were also conducted to identify groups of consumers based on their preferences for the meat's overall acceptability. Besides, none of the consumers' clusters showed a significant preference for fresh to thawed meat. Differences went probably undetected because, as shown from previous studies by Muela et al. (2010) which were developed under the same previously described conditions, because neither the freezing method nor frozen storage up to 6 months influenced extensively the properties of lamb meat when quality instrumental measurements were taken.

##### **Ageing**

Research by Campo et al. (1999); Monsón et al. (2005) on beef meat ageing showed that it had a significant effect on sensory parameters when evaluated by a trained sensory panel. Most sensory attributes were affected by ageing, which made this factor of utmost importance in terms of quality. In the two works, the attributes related to tenderness and odor intensity were the most affected by ageing, whereas in Campo et al. (1999) flavor was also analyzed. All increased with ageing, especially during the period comprised between the first 3 and 7 days of ageing. Increase in odor intensity is related to meat nitrogen-containing compounds that may be formed by natural degradation during ageing and by the formation of many volatile compounds, which have been described as components of cooked meat (CAMPO et al., 1999). Generally, tenderness is higher when ageing time increases due to the enzyme activities which produce myofibrillar degradation. In fact, it is the most important factor that affects meat tenderization under normal technological procedures. Flavor intensity is caused by the development of flavor precursors due to post-mortem processes, since many peptides are formed during the post-mortem period.

Ageing-produced variations in these attributes affect consumer's acceptability, as shown by Monsón et al. (2005). Although ageing decreases the natural differences between breeds or aptitudes, the highest acceptability is different and depends on the breed under analysis (MONSÓN et al., 2005).



Results on beef are reproducible and similar to others carried out on lamb meat (MARTÍNEZ-CEREZO et al., 2005a and b), where ageing affected tenderness, juiciness, off-flavors and overall acceptability. The above research works also investigated the effect of weight at slaughter and type of muscle. Four days of ageing seems to be enough to obtain high quality in lamb meat. However, ageing for longer periods (16 days) did not seem to decrease meat quality in light (20–22 kg) and early fattening (30–32 kg) lambs but affected light lambs (10–12 kg) (MARTÍNEZ-CEREZO et al., 2005b). According to Bianchi et al. (2006a), trained panel evaluated meat with more ageing days as more tender and juicier, with an improvement in characteristics until the animals reached day 8 of ageing. From 8 to 16 days of ageing undesirables, off-odors and flavors increased, with decreasing acceptability (BIANCHI et al., 2006b). However, when different types of muscles were analyzed, ageing was even more important on the unstretchable muscles *gluteo biceps*-GB and *semimebranosus* than on *semitendinosus*-ST). ST muscle had the best ratings at a short ageing period (4 days) and GB at the long one (8–16 days) (MARTÍNEZ-CEREZO et al., 2005a).

Sensory results in lamb suggested that the effect of ageing on lamb sensory quality was at least as important as differences between muscles, which homogenized products that at the beginning were different (BIANCHI et al., 2006b).

#### Type of conservation

The extension of meat storage shelf-life is very important for meat industry and consumers. Diverse packaging techniques (vacuum, modified atmosphere or film) have been developed to maintain the product's optimum characteristics.

Studies by Medel et al. (2002) on lamb meat recommended early vacuum packed products (1–2 days post-slaughter) to maintain meat proprieties during long periods (until 29 days) without modifying negatively its textural and sensory characteristics. However, when meat was conserved in Modified Atmosphere Packaging (MAP: 60% O<sub>2</sub>; 30%CO<sub>2</sub>; 10%N<sub>2</sub>), loss of sensory qualities after 5 days of display was detected by a trained panel and consumers, especially with regard to attributes related to flavor and odor and, consequently, overall acceptability (MEDEL et al., 2003). Other attributes, such as tenderness, were not affected by MAP conservation.

On the other hand, quantitative descriptive analysis has also been used to assess beef odor and color degradation by a trained sensory panel (INSAUSTI et al., 2001), with different limits depending of the breed analyzed and a maximum of 5 – 15 days shelf-life in MAP exposition, limited by lipid oxidation and color degradation. It could be recommendable that meat packaging systems be standardized for each type of meat.

Ripoll et al. (2013) compared color evolution and degradation in several packaging methodologies. Results showed that if meat were sold during the first week post-slaughter, MAP would be the preferred packaging. However, if it were expected to be sold after more than a week (i.e. imported meat), then vacuum packaging system would be the most adequate.

#### Commercialization and consumption

##### Manner and time of cooking

Sensory appraisal of meat is conditioned by cooking method and time. When sensory analyses are developed by a trained panel or by consumers under standardized situations (laboratory or hall test), ruminants' meat is usually cooked on a grill, without any condiments, using *Longissimus dorsi* as the muscle selected for the test. However, when consumers' test are developed under home conditions, hinds or legs are usually the pieces chosen for degustation. The latter are cooked in a conventional oven with the addition of some condiments such as salt or oil. Differences in the method and time of cooking influence texture and the development of meat flavors, which are later reflected in consumers' evaluation. Score-evaluation of meat tends to be higher when meat is consumed under home conditions and conventional way of cook (oven) than under laboratorial conditions (GUERRERO et al., 2013a). This fact is associated to the habits of consumers who usually prefer the meat they are accustomed to eat and the cooking method with which they are more familiarized.

Consequently, when a trained panel from different countries evaluates the same meat, internal temperature of meat may vary and depends on the country (SAÑUDO et al., 1998a; FONT I FURNOLS et al., 2011). In fact, in some countries, as in France, it is around 65°; it is lower than in Spain (70°) or UK (80°), which are normal temperatures for local cooking conditions.

### Consumers' habits

Consumers are the last link in the food chain and their opinions on a product are highly relevant not only when assessing the potentiality of a new product but also in warranting the quality control of existing products and identifying the specific factors that influence meat quality. Several studies comparing consumers from different regions, countries and eating habits have been developed to investigate choice tendencies and to understand factors that would relate consumers' perceptions and meat quality.

Díez et al. (2006) related product descriptions (human and mechanical) with consumer preferences, trying to identify possible market segments in beef by analyzing parameters as breed, weight at slaughter and ageing. The above analysis revealed the existence of different market segments characterized by divergent sensitivities in the appreciation of this kind of meat. These segments, classified as consumer clusters with similar tastes, revealed that different segments of people preferred opposite types of meat (quantity of fat, animal's final weight and others). This result encourages the diversity of products to suit different customers' segments.

The intrinsic quality and components of beef (for instance, intramuscular fat content, fatty acid composition, flavor, juiciness or tenderness) may influence consumers' acceptability more than price and quality tags (OLIVER et al., 2006). However, tenderness and flavor in beef have been identified as the most important attributes that determine eating quality.

Related to foreign beef acceptability, research by Oliver et al. (2006) and Realini et al. (2009) identified in Europe groups of consumers with differentiated tastes and preferences bonded to different beef production systems. These clusters may be divided into three groups: "[...] consumers that prefer foreign-imported beef; consumers that prefer local beef; consumers that do not discriminate origin or ageing" (REALINI et al., 2009). These groups may constitute significant market segments that demand beef with different characteristics. It has also been demonstrated that consumers did not prefer the same type of beef within the same country. This fact suggested that individual preferences could lead to market segmentation based on taste preferences. Besides, frequency of beef consumption varied from country to country.

Bernués et al. (2012) developed a study to identify profiles of lamb meat consumers, according to their convenience orientation (defined by cooking and eating habits). Further, they characterized these profiles by socio-economic features, place of purchase and preferences, with regard to intrinsic and extrinsic quality cues of lamb. Lamb meat consumers were classified into four types: traditional, uninvolved, adventurous and careless. Moreover, residence, age and level of formal education were more relevant to segment the lamb meat market than consumers' gender or income.

Dealing also in lamb meat, research works by Sañudo et al. (1998a), Sañudo et al. (2007) and Font I Furnols et al. (2011) compared the evaluation of consumers from several European countries. As a rule, local meat was preferred without any consent on the preferred feeding system. Low prices were preferred when price was the most important attribute in purchase decisions. Differences in consumers' gender were also revealed: males were more influenced than females by the price of meat, when purchasing decision was evaluated (FONT I FURNOLS et al., 2009).

Results from Sañudo et al. (1998a) showed that the Spanish and British panels agreed when they described lamb meat attributes. This fact showed that different trained sensory panels may arrive at the same conclusion. However, when panelists were allowed to make hedonic judgments (preference tests), each panel preferred lamb from their respective country, a fact that emphasized the link between cultural background, culinary habits, food acceptability and preferences previously described. Similar results were shown when families from six European countries tested different local types of lambs produced in the same six countries (SAÑUDO et al., 2007). Results suggested a link between the assessments of a given lamb type and the consumers' culinary background, with clear associations between country and lamb type preferences. It was possible to separate, regardless of country, different groups of families with similar preferences. They were classified according to their region in Europe (Mediterranean origin, Nordic origin and others). It became clear that there were two categories of consumers of lamb meat within the European market, or rather, those who prefer 'milk or concentrate taste' and those who prefer 'grass taste'. The effect of the household where meat was tasted was highly relevant: there was more agreement among individuals within a

household than among households within a country (DRANSFIELD, 2008).

### Conclusion

All the agents within the meat chain should be involved so that a quality ruminant meat product in terms of durability and acceptability could be obtained. Producers' and consumers' information and formation should be available to understand the product's characteristics and how they could be enhanced.

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