SMALL RUMINANT PRODUCTION SYSTEMS AND FACTORS AFFECTING LAMB MEAT QUALITY

C. SAÑUDO, A. SÁNCHEZ & M. ALFONSO
Department of Animal Production, University of Zaragoza, 50013 Zaragoza. Spain

ABSTRACT

The influence of sheep production systems on the environment of the Mediterranean area and the different productive systems of lamb in Spain are described. Moreover the actual knowledge (90´s decade) about factors influencing the quality of lamb meat is reviewed, highlighting the importance of productive and pre-slaughter factors on carcass quality and post-slaughter factors on meat quality. Also the significance of culinary cultural background on the acceptance of sheep meat is discussed.

INTRODUCTION

Sheep breeding is a traditional activity in the majority of the countries of the Mediterranean area and, in comparison with other species, it is much more important than in the majority of the countries of the Northern hemisphere, as regards its contribution to the final national agricultural income and with respect to the world sheep indicators.

This reality may be due to the aforementioned deeply rooted tradition, still maintained in our days, of sheep breeding in this area, which may have its origin in the proximity of the Mediterranean to the domestication nucleus of the species, dry weather conditions, irregular topography and its prevalent agricultural system (cereals). Sheep adapt perfectly to all of this and, as a "multi-product" species, it was ideal to meet the demands of the ancient civilisations of the Mediterranean basin. In adition, unlike other species, they have never had any religious impediment.

Thus, France, Greece, Italy and Spain have more than 55% of the sheep census of the 15 EU countries, producing more than 55% of the total sheep meat, they represent more than 60% of its consumption and provide almost 96% of the total ewe milk.

On the other hand, sheep meat is, in proportion, the meat which represents a greater percentage of the commercial exchanges among countries. Thus, of the total sheep meat produced in the world (almost 6,900 million tons), 24% is commercialised outside the country of production as opposed to 18% for beef, 15.5% for poultry and less than 9% for pork (Production and Trade Yearbook of the F.A.O., 1993-94). In the sheep meat market, Oceania is the continent with the greatest volume of exports with almost 70% of the total and Europe is the greatest importer, with almost 50% of the world market.

Also, in sheep production, more than in any other species, each country or region has determined a specific weight and type of carcass, depending on its own production peculiarities. Thus, the wold average sheep carcass weight is 15 kg, but there is great variation, which would vary from 6 to 9 kg in Bangladesh, Peru, or Italy, and 27 to 30 kg in Egypt, the United States or Japan.

The differences can be equally as great within one single continent, like Europe. Thus, the Mediterranean-Southern countries are the ones which generally have lower carcass weights: Portugal 8 kg, Italy 9 kg, Spain and Greece 11 kg, and the Central-Northern countries are the ones where the carcasses have a higher mean weight: Denmark 25 kg, Holland 23 kg or Ireland and Belgium with 21 kg. This, together with the lower prolificacy of southern sheep breeds (1.1-1.3 opposed to 1.5-2.0), gives rise to less productivity (kg carcass/ewe/year) in the Southern countries, (6-14 kg) than in the Northern countries (22-36 kg).

These weights ranges, with their consequent effects on quality, have managed to set the local tastes in such a way that any small modification in the carcass weight can represent important variations in the price per kg of the product. In Spain, sheep carcasses can experience a depreciation of 6 to 18% due to increases in weight of only 12% and of almost 50% depreciation with increases in weight of 36%. These reductions in the value of the carcasses are specially important in periods of low prices (Sañudo et al. 1992 a).

But, products which are so clearly appreciated in their own regions and producing countries, may not be appreciated as much in the destination markets and by potential consumers, which may clearly slow down the expansion of this species, its development and the income of its producers.

Based on the foregoing we set out, in this review, the following objectives: To establish the environmental impact of sheep breeding in the Mediterranean European Area, to describe the Spanish sheep meat production systems and highlight their pecu-

liarities within the Mediterranean countries and their differences from the countries of central-northern Europe, to review the influence of the different productive and technological factors on the final lamb product according to some findings generated in the nineties and to analyse the acceptability of sheep meat in countries with different culinary backgrounds.

SHEEP BREEDING AND IT´S ENVIRONMENTAL IMPACT IN THE MEDITERRANEAN EUROPEAN AREA. SUSTAINABLE BREEDING

Although people have always had a clear idea of what is meant by nature or the countryside, nowadays the concept of environment has replaced these. This "new" concept intends to interrelate natural processes with human activities. On the other hand, since the Stockholm Conference (1972), to the guidelines of the EU environmental policy, the concept of sustainable stock-breeding seems to preside over any territorial management project.

Thus, as specified by the European Union, for the development and application of environmental issues, actions aimed at solving environmental problems must branch out in three different directions: natural medium, where sheep breeding in general could be included, urban-rural medium, which would include certain types of intensive sheep breeding and the human medium, where only the product and its consumption could be included.

We will exclusively analyse the influence which the different sheep breeding actions (obtaining nutritional resources such as food and water, generation of waste and odours, potential source of transmission of diseases, housing, facilities and implements, and the maintenance of cultural values) exercise on the values of the medium (soil, water, atmosphere, flora, fauna, landscape and population). In Table 1 a systematic weighting of these actions is set out, which we describe below:

Table 1. Weighting of different sheep breeding actions on the values of medium

Breeding actions	Values of the medium						
	Soil	Water	Atmosphere	Flora	Fauna	Landscape	Population
Obtaining of nutrients	xxx	xx	0	xxx	x	xxx	0
Generation of waste	x	xx	x	x	0	0	x
Diseases	0	0	0	0	xx	0	xxx
Housing, facilities and implements	x	0	0	0	x	xx	x
Cultural values	0	0	0	0	0	0	xxx

0: little or no influence; x: moderate influence; xx: medium influence; xxx: great influence.
(Sanchez and Sanchez, 1995 and own preparation).

Soil. Extensive production, which is traditionally associated with sheep in the Mediterranean area, requires large grazing areas with little soil modification, unless over-grazing causes erosion. Intensive production requires intensive crops (grain, hay, etc.) which the sheep (when compared with other species) have a little need of, but which are greatly modified of the soil.

The waste from sheep is a fertilisation element in extensive stock breeding, rather than a problem and, occasionally, in intensive farming, it is a source of top quality organic fertilisers. Due to the rather dry nature of this waste in small ruminants and the lack of rainfall in the Area, it represents a smaller problem than other species. Thus, within appendix II, Com (88) 708 of the EU, where the maximum number of manure-producing animals admitted per hectare is specified, 2 milk cows, 4 fattening calves, 5 reproducing sows or 132 laying hens are included, but there is no specific mention of small ruminants.

Water. Due to the scarcity of this vital resource in extensive areas of the Mediterranean basin, all the hydraulic resources management processes represent an important impact on the natural distribution of the water. In the case of extensive stock breeding: transhumance, nomadism, etc. they mean an optimisation of those resources. But, in the case of sheep, due to their moderate drinking habits, their influence over this value is less than that of other species.

Atmosphere. The impact of sheep breeding on the atmosphere is relatively unimportant, due to the limited fermentation capacity of its relatively dry faeces, and as this type of stock does not have a particularly unpleasant odour.

Flora. The characteristic action of ruminants on the natural medium implies its modification, this modification implying a

reduction of its diversity, especially if the stock carries out selective consumption or if over-grazing exists. But, the stock also helps disperse certain seeds and at times can help enrich that vegetable medium and protect it from risks of fires if the vegetation is too dry and abundant. On the other hand, the use of the pasture is one of the clearest examples of what sustainable animal breeding should be, which sheep is specially adapted to.

Fauna. As sheep are herbivorous and not aggressive, their direct action on other species is small unless this is due to competition for the use of resources. On the other hand, they are, at times, victims of natural predators or wild dogs or food for carrion-eating species. More important is the risk of the mutual transmission of diseases and, of to a lesser extent, the alterations that some implements, especially fencing, can produce in the natural movement of wild species.

Landscape. In the case of extensive production, damage to the landscape is drastic at the beginning due to the need to create areas suitable for pasturage in detriment to scrubbage areas and woods. However, a point of equilibrium must be sought in certain areas. In general, intensive farming of sheep is moderate and adapts better than others to the rural anthropic landscape of many areas, although the visual impact is unavoidable, it is also true that contemplating a flock is a positive experience for people.

People. Sheep breeding represents a clear problem for human health in some areas. Brucellosis, hydatidosis, etc. being a good example of this. However, sheep breeding represents resources and the creation of employment for specially needy levels of the population and an inexhaustible source of traditions associated with different cultures and traditions, (Christian, Moslem or Jewish), festivities, shows such as ram fighting or the most diverse folklore and cultural activities.

It may be possible that by correctly managing these stock breeding actions, by suitably mixing and interpreting the productive factors, sustainable stock breeding could be developed. This sustainability would be interpreted in its most obvious meaning: an activity can be sustained for a very long time, without running out of the resources it needs or generating outputs that, one way or another, reduce the activity. In systems terminology, the latter would be expressed as "without generating negative feedback".

In this sustainable stock breeding, sheep have clear advantages when harnessing those renewable resources, like pasture or stubble, which would otherwise be lost, and producing solid faeces, the majority of which are eliminated in the fields. Sheep is undoubtedly an **eco-favourable species.** In terms of biological economy, sheep could be for meat as efficient as chicken. Thus, to produce one kilo of live weight in the ewe-lamb binomial, in the Mediterranean sphere, 6.860 Kc ME are required and, to produce a kilo of broiler in the hen-chicken binomial 6.989 are required (Sierra, 1996).

SHEEP MEAT PRODUCTION SYSTEMS IN THE MEDITERRANEAN AREA. THE SPANISH CASE

The conditions in the Mediterranean European countries are clearly different from those in the Centre and North of the continent. These conditions are mainly and firstly based on the rainfall, which results in a greater or lesser potential of pasture land, and as a result animals with greater or lesser productive potential.

Thus, rustic breeds adapted to difficult areas, with limited meat morphology, small or medium sized, with a long sexual activity and with good milk production generate systems devoted to the production of milk-meat, with lambs slaughtered at ultra-light weights and early ages, or systems devoted to the production of wool-meat, with animals slaughtered at light weights. The lack of resources has traditionally forced the animals and their owners to carry out clearly extensive type alternative practices such as nomadism which would be the continuous movement of men and animals, transhumance, a system where there are two clearly differentiated periods: winter, when the animals are in the valleys or low lands and summer, when the flocks make use of the resources of the mountain areas, or transterminance, a system where nearby resources are harnessed, within a radius of approximately 100 kilometres, with short stays in the different areas. Nowadays in the countries of Europe these practices are less and less frequent, campaigns being made to protect transhumance and animal tracks, and becoming part of rural tourism offers an opportunity. Semi-extensive or semi-stabled systems, using pasturage to a greater or lesser extent, are the most frequent tendencies, together with some total indoor systems.

On the other hand, large or medium-sized breeds, with good meat morphology, accompanied by abundant pastures, are used to produce meat and heavy carcasses, as occurs in the countries of Central or Northern Europe, where the animals remain in specific areas in an extensive way.

In general, at the present time, the Mediterranean European sheep production is based on five basic pillars (Torrent, 1991):

1. Its productions are obtained with its own domestic resources, without having to import raw material or technology, having a reasonable balance in the needs/resources ratio, within the extensive systems.

2. There is still a great productive potential due to the enormous possibilities of consumption in Europe, where the sheep meat market is still a loss-making one. Also, this consumption is still at a low level, having a promising future.

3. The occupation and fertilisation of abandoned and under-utilised lands, brought about by sheep development, is one of the most positive factors against erosion, desertification and in short, environmental degradation. It also helps towards the invaluable social task of settling numerous families in areas where any other profitable agricultural activity is practically impossible.

4. This species has a very good capacity to transform crude products into top quality meat, maintaining, as mentioned, the image of a natural product (Figure 1). This figure shows how some Spanish consumers associate young lamb with adjectives such as: natural, tasty or healthy, and it is one of the products which the consumer is willing to pay more for (group I), the opposite to what occurs with chicken or beef (group II) or specially pork (group III).

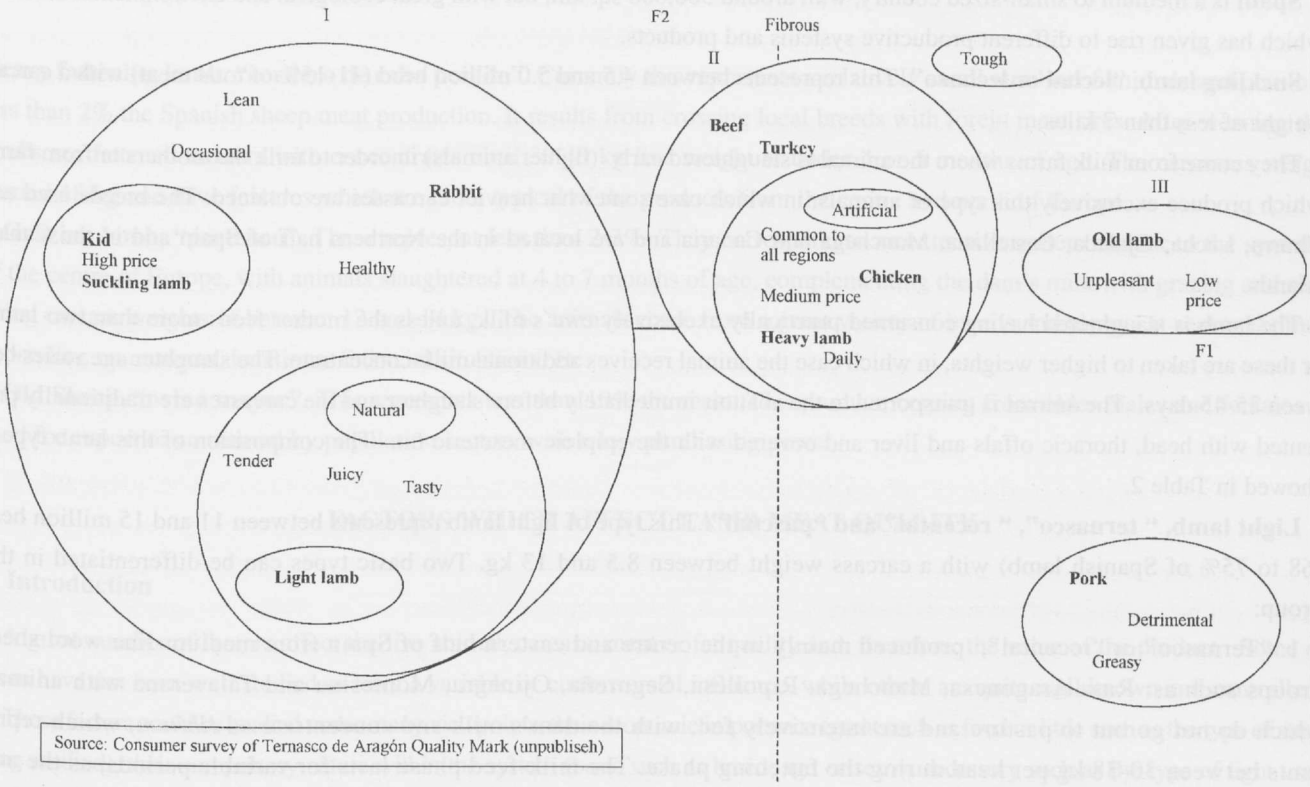

Figure 1. Placements on the Aragonese market of the different meat types

5. Within the systems which include pasturage, sheep are associated with the concept of animal welfare. So, in a survey (n = 980) carried out by us (Maria et al., unpublished), whose aim was to find out the society's idea about the degree of welfare of 11 different species of farm animals, the third place went to sheep, after the horse and milk cows. But, curiously some proposals in the EU try to penalise (animal cruelty) those farmers whose animals are below a certain level of body condition, without bearing in mind the advantages of extensive systems and the biological capacity of sheep in its recovery.

Before talking about Spanish lamb production systems, it is important to point out that in the Animal Production concept it is traditional to pose the differentiation between intensive and extensive production systems, in general associating the former with penned animals and the latter with grazing animals, but this division is an extreme simplification. So, the same

farm can be classified as extensive due to the absence of facilities or to the type of food, and as intensive, based on the labour efficiency. For example, the handling could be very rationally organised and with one annual working unit (AWU) have 800 or 1,000 heads, and this farm could even have better productive and financial indices than one of the so-called intensive ones. So, the increase in production per ewe is not always accompanied by an increase in profitability as this obeys the law of less than proportional returns (Sierra, 1996), producing, for example, a loss of profitability when going from 1.8-2 to more than 2 lambs per birth.

If we wish to be strict, we should consider the financial factors. We could say that the most intensive farms are those which are more profitable per AWU, per surface unit or per unit of capital invested, instead of talking about intensification or extensification depending on technical factors. Thus, the considerable numerical productivity (weaned lambs/ewe/year) of countries such as France, UK and Spain (1 to 1.3), opposed to the limited numerical productivity of Australia or New Zealand (0.5 to 0.8), does not mean a greater intensification of the European countries, as on introducing a proportional economic parameter (thousands of ECU's a year per AWU), the countries of the southern hemisphere, as a function of their high ewe/AWU ratio, dominate the European countries in profitability (Sierra 1996). That is: the concept of extensive or intensive is dynamic, varying in space and time, and it is subject to the search for positive economic indices as, in short, the operation of a system does not only depend on each individual factor but on the nature and efficiency of the interconnections among the factors which comprise it.

Spain is a medium to small-sized country, with around 500,000 sq. km, but with great ecological and environmental diversity which has given rise to different productive systems and products.

Suckling lamb, "lechal or lechazo". This represents between 4.5 and 5.0 million head (11-15% of total meat) with a carcass weight of less than 7 kilos.

They come from milk farms where the animal is slaughtered early (lighter animals) in order to milk the mothers or from farms which produce exclusively this type of animals, in which case somewhat heavier carcasses are obtained. The breeds used are: Churra, Lacha, Ojalada, Castellana, Manchega and Canaria and are located in the Northern half of Spain and in the Canary Islands.

The lamb is slaughtered having consumed practically exclusively ewe´s milk, unless the mother feeds more than two lambs or these are taken to higher weights, in which case the animal receives additional milk-concentrate. The slaughter age varies between 25-45 days. The animal is transported to the abattoir immediately before slaughter and the carcasses are traditionally presented with head, thoracic offals and liver and covered with the epiploic-meseteric fat. The composition of this lamb type is showed in Table 2.

Light lamb, " ternasco", " recental" and "pascual". This type of light lamb represents between 11 and 15 million head (68 to 75% of Spanish lamb) with a carcass weight between 8.5 and 13 kg. Two basic types can be differentiated in this group:

1. "Ternasco" or "recental", produced mainly in the centre and eastern half of Spain from medium-fine wool sheep groups such as: Rasa Aragonesa, Manchega, Ripollesa, Segureña, Ojinegra, Montesina and Talaverana with animals which do not go out to pasture and are intensively fed, with the dam's milk and concentrate ad *libitum,* which represents between 30-38 kg per head during the fattening phase. The milk-feed phase lasts for variable periods, as the animals can be weaned after 40 to 55 days or be milk-fed until they are slaughtered, at 70-100 days of age. "Ternasco" are the lightest (8.5-11.5 kg carcass weight) and "recental" denomination can be used for somewhat heavier animals (11-13 kg). However, there are important variations for these denominations depending on the Spanish region considered.

2. "Pascual" is a product of the Merino and other ethnic groups of the south and west of Spain. The lambs stay with their mothers in the pasture, being finished in fattening units. They are slaughtered at 4-6 months of age and 12-14 kg carcass weight. More and more often, these pasturage lambs are weaned around 40 to 50 days of age and transferred to intensive fattening units from where they are sold as "ternasco" or "recental" types.

Early fattening lamb, "cordero de cebo precoz". This product is obtained by crossing local breeds with meat breeds. The animals are subject to an intensive indoor system until they are 90-100 days of age, reaching around 13-15 kg carcass weight. This represents around of 5 to 6% the domestic meat production.

Table 2. Carcass characteristics in the most representative Spanish sheep products (males)

	Milk-lamb	Light lamb (Ternasco)	Early fattening lamb
n	10	10	10
Carcass weight (kg)	5.26	10.52	13.46
Conformation (1-5)	1.1	2.1	2.4
Fatness (1-5)	1.0	2.0	1.9
Back fat thickness (mm)	1.53	2.30	2.83
% Muscle	56.5	58.9	58.4
% Bone	26.5	21.0	19.4
% Fat	17.0	20.1	22.2

(Colomer, 1986)

Heavy fattening lamb, "cordero de cebo pesado". Currently this represents a relatively small number of animals and possibly less than 2% the Spanish sheep meat production. It results from crossing local breeds with forein meat sires. After weaning the lambs are fattened indoors with concentrates until 30-40 kg live weight at under 4 or 5 months of age. The carcasses weigh around 18 kg and have features which are more typical of the products from the centre and north of Europe.

Grazing lamb, "pastenco". These represent less than 2-3%. They correspond to an extensive system similar to the systems of the centre of Europe, with animals slaughtered at 4 to 7 months of age, complementing the dam's milk with grazing and reaching carcass weights of between 12 and 14 kg. The animals come from a great variety of breeds and always at seasonal times depending on customs, locations, financial situations, etc.

Old Sheep, "ovino mayor". This represents less than 10% the meat. This product, coming from older males and females is used for export or consumed by population sectors with a low purchasing power.

FACTORS WHICH AFFECT LAMB MEAT QUALITY

1. Introduction

A great number of factors affect the live animal, carcass, meat or fat quality and, therefore, the value of the product. Some of them have not been well studied or have a variable or controversial influence, while others are quite well known and controlled.

These factors could be studied under many viewpoints: their economic importance (great such as food or little such as the type of stunning method), their compulsory nature within the system (basic such as breed, age or sex or accessory such as the type of light used during the fattening), their possibilities of variation (bivariants or variants with reduced possibilities such as sex or the type of birth, variants with a great diversity of options such as the breed or feed type, or multi-variants such as the flock or the abattoir factors).

But perhaps the most traditional and useful system to study and understand the factors which can affect the quality of the product is the stage considered into the process.

On the other hand, when bibliographical quotations are used to prepare a publication, the logical tendency exists of including a greater relative number of the latest contributions. Perhaps this is due to the belief that this will give a more real viewpoint of the "current state or knowledge" or perhaps because the people making the quotations do not want to be considered out of date, but the fact is that in any publication, no less than 30% of the works quoted are dated exclusively in the previous decade and in some cases this figure reaches 60-70%.

Therefore, **the objective which we set out is to find out the extent to which the decade of the nineties has contributed to the knowledge of the factors affecting sheep meat quality.** To do this, we have only selected three journals: Animal Science,

Journal of Animal Science and Meat Science, as well as the abstracts of the ICOMST during this decade, except for those of the years 1991 and 1995 which we have not had access to. On very few occasions, contributions from other magazines or years are made.

In Table 3 we set out a preliminary description of the possible factors which can affect sheep meat quality. Later on we will describe these factors according to our interpretation of the information retained and our experience.

Table 3. Factors which affect the sheep meat quality

STAGE	FACTORS
Animal (Intrinsic factors)	- Species or inter-species crossing. - Breed or interbreed crossing. - Individual. - Age and milk capacity of the mother. - Dam size. - Type of birth. - Sex. - Age and weight at slaughter. - Specific genes or genetic manipulation.
Cut or muscle	- Cut. - Muscle and portion within the muscle.
Handling in life (Handling and environment)	- Exercise. - Environmental conditions (temperature, humidity, lighting, density, quality of the air, etc.). - Importance of stress agents (noise, pathology, etc.). - Type and quality of the litter.
(Diet)	- Type of milk-feeding. - Age and type of weaning. - Type of raw materials of the ration. - Physical characteristics of the ration (flour, pellet, pasture, etc.) - Chemical characteristics of the ration (energy, protein, etc.) - Water, quality and availability. - Additives.
Multi-causal factors	- Time of birth. - Flock. - Production system.
Pre-slaughter conditions	- Transport (type, and conditions). - Fasting. - Conditions of the pens in the abattoir.
Slaughtering	- Stunning method. - Type of slaughter. - Conditions for preparing the carcass (bleeding, offal removal, etc.). - Hygiene.
Post-slaughter	- Electrical stimulation. - Rigor mortis and initial chilling (type, temperature, ventilation, humidity). - Ageing, duration and conditions. - Type of preservation (modified atmospheres, vacuum, freezing). - Infusion of agents.
Marketing and consumption	- Type of cuts and jointing. - Packaging and presentation. - Cooking (temperatures, times and type). - Consumption (environment, temperature of the product, presentation, other food incorporated). - Consumption (fashion, customs).

2. Intrinsic factors

These are factors are directly related to the animal itself or its ancestors.

Species. Only a few studies have made a comparative analysis of meat quality among different species. Species should be an important quality differentiating criterion, as the meat from each species has its own characteristics. These characteristics vary a good deal more between red meat (beef, lamb, heavy pig, etc.) and white meat (young pig, calf, chicken, etc.) than within each of those groups, especially when meat is consumed cold.

It seems clear that sheep meat is more tender than beef or pork (5.37, 8.46 and 8.00 shear force respectively in New Zealand retail meat), but there is a great variability between animals, around 50% (Bickerstaffe et al, 1997).

Also, sheep meat can be considered as more desirable, juicier, tender, flavourful and fatter than goat meat (Schönfeldt et al, 1993 in agreement with several previous studies). Although lamb meat has lower W.H.C. and less sarcoplasmic protein and haem pigments, it cannot be bromatologically considered as a higher quality than goat meat (Babiker et al, 1990).

The characteristics of the meat from crosses between the species of Ovis musimon x Ovis aries should be in more detail studied.

Breed. Within the sheep species there are 264 different breeds in Europe (it is the species with the greatest variety of breeds) of which 25% are clearly in danger of extinction. In Spain (BOE of 21 November 1997) there are 41 sheep breeds of which 32 are considered to have special protection.

Breed, as a source of variation of the amount of fat and meat quality, is a complex factor, as the results will vary depending on the comparison criterion used: equal live or carcass weight, equal age, equal degree of maturity or equal percentage of adult live weight.

When making the comparison at equal carcass or live weight, the animals from precocious breeds, with a smaller adult format and therefore with lower daily growth, will be older and therefore will have more fat (Pollott et al., 1994) than the larger and later maturing breeds (Snowder et al., 1991, Field et al., 1993, Beerman et al., 1995).

If we slaughter at equal age, the precocious or smaller breeds will have lower weights and will, presumably, be fatter than the larger mature breeds (Zygoyiannis et al., 1990, Sañudo et al., 1997).

When slaughtering at equal degree of maturity the results are different. McClelland et al. (1976) studied four breeds differing widely in mature size. They found that most of the differences associated with breed or sex were eliminated when tissue weights were expressed as a proportion of carcass weight and compared at equal proportion of mature weight (Oberbauer et al., 1994, Snowder et al., 1994 a) or growth rate. Similar results have been found by Pasha and Lone (1991), Gaili (1993) or Petit and Castonguay (1994).

However, related to the fatness, with its enormous importance on meat quality (Schönfeldt et al., 1993) certain differencesbetween breeds still persist irrespective of the type of comparison made. These differences can be seen both in the amount of fat and where it is deposited. Wood et al, (1980) and Butler-Hogg et al., (1986) suggested that milk breeds have more fat, at high weights, than meat breeds. The fat-tailed breeds deposit more subcutaneous fat, in the lumbar region, than other breeds (Zygoyiannis et al., 1990, Sañudo et al., 1997). Prolific breeds tend to deposit less fat cover and more internal fat than meat breeds, having an identical amount of intramuscular fat (Fahmy et al., 1992). The rustic breeds deposit relatively more internal fat (Kempster, 1980), as do primitive breeds such as Soay (McClelland et al., 1976, Thonney et al., 1987). Exceptionally, the Texel breed (Croston *el al.*, 1987 or Ellis et al., 1997) has less fat, at any degree of maturity considered.

Furthermore, the problem of comparing breeds becomes more complex, because of the countries in question and their different selection programmes or metabolic differences between breeds (Derting, 1989), as in the case of the Welsh Mountain breed which has less fat than the Beulah breed, at the same percentage of mature live weight, especially after periods of food restriction (Iason et al., 1992) which would imply differences in the composition of the weight gain.

On the other hand, breed effects on meat quality do not seem to be very important (pH, amount of pigments, physical colour, WHC, instrumental hardness and sensorial characteristics), not being, in general, significant (Dransfield et al., 1990, Ellis et al., 1997, Hopkins et al., 1997, Rousset et al., 1997). The most significant differences lie in the WHC, colour and texture and can be justified by differences in precociousness (Fahmy et al., 1992, Sañudo el al, 1997) or in the degree of muscularity (Failla et al., 1996). Thus, the more precocious breeds and the meat breeds are more tender, although for different reasons, than breeds with intermediate characteristics. Breeds with better morphology and high level of fatness have less WHC, specially in drip losses, and juicier meat than poorer morphology or leaner breeds (Cross, 1977). Anyway, the relationship between breeds or crossbreeds in meat quality may differ when comparisons are made at more than one weight, because of variations in growth pattern and maturity (Aziz et al., 1993).

Fahmy et al. (1992) pointed out that prolific breeds had darker, tougher meat and with a more intense aroma than meat bre-

eds, but, the animals were slaughtered at a fixed live weight and the difference in precociousness, greater in prolific breeds, could partly explain the results.

In general, breed is a factor which is worth considering in product quality studies and in production and marketing systems, although it is less important than other factors such as feeding system (Notter et al., 1991, Kabbali et al., 1992 b) and in spite of the important individual intra-breed variation that exists, which can become greater than breed effect itself. It has also been suggested that the enzymatic reducing system, or the sensitivity to oxidative changes, is breed dependent (Sañudo et al., 1997), but more studies in this regard are necessary, as well as those specifically aimed at studying breed as a factor of sheep meat quality.

Individual. The individual, within the breed, is considered as one of the most important reasons for variations in quality. It is a factor with many origins, arising from differences in metabolism (Buttery et al, 1997), social level or behaviour, morphology. A particular sensitivity to stress or genetic reasons, these can be present alone or as additive factors.

Pollot et al. (1994) estimated the heritability of the amount of fat in the carcass at a value of 0.31, it being feasible then to select animals depending on their fattening capacity (Bennett et al., 1991 ab, Cameron and Bracken, 1992, Alfonso and Thompson, 1996). Animals selected for greater fat thicknes had a tendency to produce lighter-coloured meat and lower pHs, although the differences do not seem to be important (Kadim et al., 1993).

Size and morphology can also be of importance. Thus, at the same live weight, large strains had a significantly lower proportion of fat than small strains (Oberbauer et al., 1994). Kempster et al, (1981) deduced that an improved conformation is not necessarily associated with a greater amount of muscle, but, may be linked to a greater amount of fat. More recent studies have overcome this problem by making adjustments for differences in fatness, but even then the association between conformation and lean meat yield for lamb carcasses has been weak, although it has usually been positive (Pollot et al., 1994, Purchas and Wilkin, 1995).

Sire effect, as a factor which helps us statistically to evaluate this individual variability by analysing the characteristics of the descendants, does not seem to have been very important in the work of Hopkins et al. (1997) as he did not find any significant differences in pH, colour or toughness, although he did find them in WHC. More studies to discover the influence of the individual on quality and the real possibilities of genetic improvement of sheep meat need to be carried out.

Specific genes. In the nineties one gene which causes muscular hypertrophy in sheep (callipyge gene) has been studied. This gene is associated with an enhanced muscle growth, less fat and excessively tough meat (Rawlings et at., 1994, Snowder et al., 1994 b, Jackson et al., 1994, Hays et al., 1995) in at least 75% of the cases (Kerth et al., 1995), there being few differences in flavour (Busboom et al., 1994) and the meat is somewhat lighter in colour (Clare et al., 1997). The greater toughness of the callipyge lambs is due mainly to a greater activity of calpastatine (Koohmaraie et al. 1995).

Birth and rearing status. Both affect the percentage of fat, those animals coming from a single birth having more fat than twins. These differences, between lambs reared or born as singles or twins, result in differences in carcass weight.

No studies about the influence on meat quality of these factors, or: breed, age and dam milk capacity, weight of lamb at birth, alone or combined, have been carried out.

Sex. There are numerous studies that consider the sex factor. Within the review carried out five sexual types have been analysed: males (M), wethers (W), cryptorchids (C), females (F) and hormone stimulated during the embryonic phase.

In general, F is the sexual type with the greatest amount of fat, which is distributed in the carcass mainly in the front and ventral regions (Bennett et al., 1991 a), followed by W, C and M (Sainz et al., 1990, Field et al., 1990, Notter et al., 1991, Teixeira et al., 1996, or Alfonso and Thompson, 1996) but these results may vary depending on the weight range considered and the growth phase of each sex (Zygoyiannis et al., 1990). Thus, if we slaughter at a weight which is proportional to the adult live weight (much greater in males than in females) the differences would be equalled or the previous order could be modified (McClure et al., 1994). On the other hand, sex does not seem to be a factor which affects the efficiency of fat deposition related to the energy ingested (Sainz et al., 1990).

The differences between sexes in meat quality are not, in general, very important. Thus, there do not seem to be differences between M and W in the pH, WHC or colour (Field et al., 1990, Dransfield et al, 1990, Koohmaraie et al. 1996) although females could be darker than males due to their greater precociousness and fatness when comparing both sexes at equal slaughter weight (Thompson et al., 1979). With respect to texture, different authors have found M to be tougher than W (Dransfield et al, 1990, Beermann et al., 1995), because collagen accretion may be stimulated by testosterone (Miller et al., 1990). Ou et al. (1991)

did not find significant differences between M and W in toughness, also the differences found between W and F have been small (Shackelford et al., 1995, Ellis et al., 1997).

Differences between sexes are minimal with respect to juiciness (Dransfield et al., 1990) or the juiciness is greater in W than in M (Misrock et al, 1976). Flavour intensity seems to be greater in M than in F and in C than in W (Channon et al., 1997) the differences being more apparent in adult than in young animals (Rousset et al., 1997).

The use of prenatal androgenisation in ewes or compounds with estrogenic activity in M and W from birth to slaughter produce some improvements in growth and carcass characteristics but the effects on meat quality are not very noticeable or are not very clear (Nold et al., 1992 ab, Hansen et al., 1995).

Weight-age. Both factors are studied together because a greater weight represents greater age, unless the feed is manipulated. Greater ages and weights are associated with greater fatness (Field et al., 1990, Zygoyiannis et al., 1990, Vipond et al., 1993, Aziz et al., 1993, Schönfeldt et al., 1993) although sometimes the differences are not significant (Alfonso and Thompson, 1996). Differences in fatness are, within one breed or crossbreed, more noticeable at some stages of growth than at others (Andrews and Ørskov, 1970), or can vary depending on the growth rate. Thus, fat depth increased by 0.52 mm/kg carcass weight on a high nutrition plane compared with 0.13 mm/kg on a low plane (Chestnutt, 1994).

With respect to meat quality, the current situation of knowledge is not so clear. In general, it varies little with age (Jaime et al., 1992), although a certain tendency has been observed for the pH to increase with slaughter weight (Sañudo et al., 1996, Alexandrova et al., 1996) possibly due to a greater susceptibility of older animals to stress (Devine et al., 1993). A greater age associated with a lower pH has also been shown by Failla et al., (1996).

Colour variables are generally affected by carcass weight with a tendency to become darker, for the amount of pigments (Rashid and Faidhi, 1990, Field et al., 1990, Sañudo et al., 1996, Rousset et al., 1997). But colour evolution may not be linear and at certain ages the colour may become stable or change at a greater speed than expected (Alexandrova et al., 1996).

For WHC the results are more controversial and, although certain authors do not find significant modifications by age effect in WHC (Sañudo et al., 1996, Rousset et al., 1997), in other works the losses increase with age (Rashid and Faidhi, 1990, Schönfeldt et al., 1993) or decrease (Aziz et al., 1993, Failla et al., 1996). Concerning juiciness, meat from young animals should give a watery effect on first chewing but a final impression of dryness, whilst in animals of a greater weight and age, a greater sustained juiciness would be appreciated due to their greater fatness (Hernando et al., 1996). Sañudo et al. (1996) found significant differences between carcasses differing by less than 5.5 kg (8.09 vs. 13.42) but the results are not always so clear and unsignificant differences in juiciness due to age effect have also been pointed out. Thus, Solomon et al. (1980) reported that an increase in carcass weight of 16.4 kg (from 19.4 to 35.8 kg) did not result in significant differences in juiciness, flavour or tenderness, in agreement with Rousset et al. (1997).

Devine et al. (1993) suggest that the effect of age on the shear force and tenderness of lamb is relatively small, but, young animals would, in principle, be more tender as they possess a more soluble collagen (Young and Braggins, 1993). What occurs is that differences in tenderness vary depending on the time of ageing considered, as tenderising is more intense in older animals due to the increased action of the proteases (Jaime et al., 1992, Pringle et al., 1993). On the other hand, Sañudo et al. (1996) and Hernando et al (1996) suggested that shear force and tenderness are significantly affected by carcass weight. Mean shear force values are higher for median weights (approximately 10 kg) than those from heavier (13.4 kg) or smaller (8.07 kg) carcasses, which show similar values Sañudo et al. (1996). This means that in these early ages, the changes in toughness, as in other quality parameters, as juiciness, can occur much more quickly than at greater weights.

With respect to flavour intensity in lamb, the differences are not significant at early ages (Sañudo et al., 1996, Hernando et al., 1996). It is possible that sheep meat odour and flavour is exacerbated by pasture feeding and also with age, specially from 12 months of age onwards (Channon et al., 1997).

Muscle or cut. It is a well-known fact that considerable differences with respect to composition and quality exist among the muscles. In sheep there are not many muscles whose size and homogeneity are sufficient to carry out the different tests aimed at finding out the quality of the product.

Semimembranosus (SM), infraspinatus (IE), longissimus dorsi (LD), psoas (PS), gluteobiceps, gluteus, rectus femoris, vastus lateralis (VL) and semitendinosus (ST) are the muscles which have been analysed during this decade, the main one used being the LD. Abdul Wahab et al., (1990), Rashid and Faidhi (1990), Kadim et al., (1993), Nold et al., (1992 ab), Schönfeldt et al.,

(1993), Farouk and Price (1994), Badiani et al.,(1994), Rousset et al., (1997) and Garcia et al., (1997) are some of the authors who have made comparisons between muscles. Following the studies of Sañudo (1980) and Forcada (1985) together with those already mentioned, it could be said that the highest pH and greater WHC are found in the abdominal (AB) and pectoral (PC) muscles, followed by those of the thoracic and pelvic limb, LD, PS and SM. SM, VL and LD have the most intense colour and greater pigment concentration, followed by PC and IE, and the lightest meat is in the AB and ST. The greater toughness corresponds to the 3rd category muscles, those of the pelvic limb, LD and lastly for those of the thoracic limb and PS.

Within the same muscle there can be small variations in pH and important variations in toughness, thus, in the LD pH can vary by 0.05 units (Petersen, 1983) and toughness by 4.0 kg (Devine et al., 1990).

3. Extrinsic production factors and pre-slaughter factors

These are the ones imposed by man during the breeding, production and pre-slaughter periods of the animals. Basically they can be divided into factors related directly to the handling and the environment and factors related to diet.

Exercise. The amount of exercise that an animal does either due to its own mobility, stimulated movement or production system, can affect the product, although with variations due to the time the exercise lasts, its intensity and muscle considered (Mandigo et al., 1971). More exercise implies less fat, associated with greater muscle volume and greater tenderness because of greater myofibrillar protein to total collagen ratio (Aalhus et al., 1991), although in some muscles, if the exercise lasts for a long time, this is associated with greater toughness, but there is no evidence of the collagen metabolism being altered, nor of differences occurring in the final pH or in the WHC (Aalhus et al., 1991).

In any case, and although the practical use of induced exercise is doubtful for improving the quality, the search for optimum conditions for combining times, intensities, types of exercise and muscles has still not been developed.

Environmental conditions. There are a great number of aspects which could be included in the environment: temperature, relative humidity, ventilation, air quality, type and intensity of the light and sound, accessibility to nutrients, quality and type of litter, living space, etc., as well as countless variations and combinations of all of them. There are few authors, however, who have studied them. Casamassina et al., (1993 and 1994) concluded that green and red lights and 500 Lux intensity caused a growth improvement, as the animals spent more time consuming feed. These factors may not be important in isolated cases, although an effort to discover their influence on the product should be made.

Stress. Stress is a complex physiological process. A clear differentiation between what would be physical or psychological stress, as well as the possible adaptation of the individual to chronic stress or differences in individual susceptibilities or according to muscles have still to be explained. On the other hand, sheep seem to be less susceptible to stress than cattle or pigs (Warris et al., 1987) or at least have different physiological mechanisms because muscle contraction was not prerequisite of the DFD process in sheep as opposed to cattle (Apple et al., 1995) whereas increased catecholamine levels may be the predominant mechanism in sheep (Tarrant and McVeigh 1979).

We could talk about two different types of stress: one which could exist on a farm level and be more or less important depending on how long it lasts and on it existing or not at times close to the slaughter date, and another, probably more important, related to pre-slaughter conditions (handling, transport, fasting, etc.).

In general, higher levels of stress (isolation, cohibition) produce meat with a higher pH, even from the first post-slaughter hour (Apple et al., 1993 and 1995, Devine et al., 1993). It has been proven that with more stress factors the pH is higher, so some effects are cumulative. The meat from these stressed animals is darker, has greater WHC and susceptibility to spoilage by micro-organisms, tends to produce abnormal flavours (Braggings and Frost, 1997) and it is more tender (Apple et al., 1993 and 1995). Although, on the other hand, intermediate pHs of 5.8 to 6.0 would produce tougher meat than extreme pHs (Devine et al., 1993, Bickerstaffe et al., 1996).

Other stress factors such as shearing, pre-slaughter baths or transportation would have a moderate or inconsistent importance on the sensorial or instrumental meat quality, except on pH, unless the animals were placed in extreme situations and they were not given time to recover (Petersen, 1983, Summer, 1984, Bray 1989). The addition of electrolytes to the drinking water could reduce the effects of a possible stress (Apple et al., 1993).

The action of a low quality and not very appetising diet, the weaning and fasting conditions could also cause modifications in the characteristics of meat or make it more susceptible to stress (Ellis et al., 1997).

More studies on sheep should be carried out to analyse these factors in depth or to discover the actions that others, such as noise, facilities, type and quality of the litter, health state, etc., have on the product.

Time of birth and time of slaughter. Both are multi-causal effects, due to the variability of the environmental conditions. Thus, differences in the availability and quality of resources could affect carcass and meat quality. It is observed that animals born in winter are somewhat darker (Alexandrova et al., 1996) and those slaughtered in winter somewhat more tender and leaner than those slaughtered in autumn (Ellis et al., 1997).

It would be worthwhile carrying out more studies in this regard.

Others. Multi-causal effects, such as flock, should also be evaluated and studied in depth. Sañudo et al. (unpublished) detected important differences in the product quality (same lamb type) among stockbreeders. Genetic, environmental, handling and feeding variants, etc. can affect the results, but, their evaluation and quantification must be appraised and analysed in experiments designed for this purpose.

General comments about the diet effect. The effect of the diet could be considered from several viewpoints: energy level-growth rate imposed, raw materials of the ration and their physical state, nutritional handling and possible use of additives. With the exception of additives, the other aspects of the diet are quite difficult to isolate as, in short, a diet which is richer in energy is, usually, accompanied by feed with greater energetic density and presented ad libitum.

In any case, almost all the works which have been published pay more attention to the carcass (fatness) than to meat, so more works in this regard should be done.

We are going to describe the diet effect under 4 different viewpoints (weaning-milk fed, energy-growth rate, raw materials and additives) but there are still a lot more aspects to be discussed: 1.The importance of being fed by the ewe and its influence on the muscular mass and fatness of the young animals, due to a possible influence in foetal insulin status. 2. The daily synchrony of nutrient supply, which affects the rumen physiology, including the possibility that the timing of nutrient arrival at the peripheral tissues may reduce protein deposition (Buttery et al., 1997). 3. The number of meals and the timing of meals throughout the day. 4. The action of stressors and contaminating agents.

On the other hand, the physical presentation of the ration by extrusion or pelleting does not seem important (Danielson et al., 1990) but few studies have been done on this issue.

Weaning-milk fed. The effect that milk-feeding has on the amount of fat deposited is clear, as this increases (Okeudo et al., 1994, Vipond et al., 1993, Sañudo et al., 1998 b) due to the high energy content of the milk, especially when compared with water for which it substitutes (Geenty et al., 1985).

Related to the instrumental meat quality, milk feeding until slaughter produces paler meat with less pigment (Sañudo et al. 1998 b), in very young animals, but, at 5 months of age, milk feeding does not result in significantly paler meat than roughage feeding, in part because lambs are quite tolerant (more than calves) of low iron diets (Okeudo et al., 1994).

In general, an improved sensorial quality of the meat has been described in milk-fed animals (Sañudo et al., 1992 b and 1998 b), but the differences are small and are occasionally associated with greater fatness produced by the milk diet.

Chemical composition of the ration (energy, protein) and growth rate. The energy availability is clearly related to the amount of fat in the carcass, more energetic diets producing carcasses with more fat (Sainz et al., 1990, Rashid and Faidhi, 1990, Field et al., 1990, Chestnutt, 1994), the protein level being less important. Thus, Kabbali et al., (1992 b) found significant reductions in fatness when the dry matter ingested was reduced by 25%. However, with isoenergetic diets, the protein level only produces slight (and frequently insignificant) modifications in fatness (Iason and Mantecon, 1993) unless rumen undegradable nitrogen is added to the roughage diet.

The effect of the energy level of the ration on meat quality is not clear, as it is difficult to separate the level of fatness, type of diet, age or growth rate imposed. Generally, it has an unsignificant (Rashid and Faidhi, 1990) or a not very clear effect on colour and WHC (Field et al., 1990). Devine et al. (1993) and Speck et al. (1995) indicated that high energy diets produce more tender meats with less problematic pHs than low energy diets. On the other hand, certain studies indicate a possible increase in WHC with protein rich diets (Vipond et al., 1995).

The growth rate could be studied from many viewpoints: High (H), moderate (M) or low (L) growth and constant or variable growth rates like compensatory growth (CG). We could also talk about maintenance of the body weight (0 growth) or negative growth. All of these possibilities can give rise to modifications in fatness (often studied) and on meat quality (practically without reference in sheep).

In general, food restriction produces increases in the amount of lean and reductions of the amount of fat, within carcasses of equal weight (Murphy et al., 1994, Alfonso and Thompson, 1996), although much smaller than those which could be expected due to the differences in the losses in the daily gain (Bennett et al., 1991 a). Thus, food reduction increases the efficiency of lean production and reduces waste by avoiding excess fat accumulation in the carcass. This fat reduction is much more intense when the restriction is from 100% to 85% than from 85% to 70% and it is not the same in all the primal cuts (Murphy et al., 1994).

Fatness reduction varies according to the age of the animal, thus, younger animals mobilize more weight of muscle than fat from the carcass (Kabbali et al., 1992 a, Aziz et al., 1992 a,b). Likewise, the reduction of fat varies according to: 1. Weight loss rate, as sheep that lost weight rapidly or slowly contained more or less fat, respectively, than normally grown animals (Searle et al., 1972). 2. Fat depot considered, with greater effect in the intermuscular depots and little, or no effect, in internal depots. 3. Breed, thus, breeds from desert areas are adapted to move reserves at a minimum biological cost. On the other hand, when carcass weight remained constant fat weight increased (Bennett et al., 1991 a).

With respect to the CG, the effect which refed animals have on the fat is controversial. This discrepancy may be related mainly to the length and energy level of the recovery period and the severity and duration of the restriction period. In general, short refed periods would produce less fat, when compared with normally fed lambs (Iason et al., 1992, Alfonso and Thompson, 1996), but if the lambs are slaughtered a long time after the end of the initial regrowth period, they may be similar or fatter than the normally fed ones (Kabbali et al., 1992 a). Likewise, high levels in the refed periods (from 136 to 338 g of daily growth) produce considerable and positive effects on fatness, which do not occur with lesser changes (from 213 to 320 g) (Chestnutt, 1994). On the other hand, the final fat content is less with strong feed restrictions than with moderate restrictions (Kabbali et al., 1992 a). A greater effect may also exist (due to the CG) on the redistribution of fat within the carcass than on the total amount of fat (Chestnutt, 1994).

Raw material of the ration. There is a great variety of raw material of vegetable or animal origin, which can form part of the diet of the ruminants. Although the use of animal origin substances within the EU is becoming more and more limited due to possible health problems, countless vegetable products and their combinations, make this factor difficult to understand, requiring more studies, especially with respect to the possible influences on sheep meat quality.

The raw material of the ration can affect the product quality obtained with respect to: its chemical composition and energy density, digestibility, quality of taste and presence of specific substances with very specific actions.

In general, the raw material as such has not proved to be an important factor in the meat quality of ruminants, except with respect to the odour and flavour, especially in isoenergetic diets (Lough et al., 1991, Fahmy et al., 1992, Vipond et al., 1995). Thus, it is partially admitted that fish flour tends to produce off-flavours (Fahmy et al., 1992, Hopkins et al., 1995, Channon et al., 1997) and pasture produces, in general, intense odours (Rousset et al., 1997). Thus, the data of Young et al. (1997) confirm that sheepmeat odour and flavour are specifically linked to the branch chain fatty acids, and are probably exacerbated by some derived pasture compounds such as 3 methylindole and alkyl phenols.

Likewise, Vipond et al. (1995) pointed out that milk-feeding and clover grazing are two additive effects, so clover grazing with unweaned animals would be highly beneficial. More research in the sense of seeing the synergistic action or not, of different raw materials, must be carried out.

On the other hand, the amount of some specific raw material contained in the ration can be important. Thus, noticeable increases of barley (0%, 45% or 90%) can produce modifications in colour or WHC of sheep meat (Abdul Wahab et al., 1990).

Different studies have analysed the differences in quality of the product depending on whether the diet is basically comprised of forage or concentrate. In general, a more concentrated, and therefore more energetic diet produces rapid gains and fatter carcasses (Lee and Demment, 1990, Notter et al., 1991 or Petit and Costonguay, 1994, Solomon et al., 1994) as occurs with intensive or indoor systems compared to hillfarms and outdoor systems (Theriez et al., 1992, Teixeira et al., 1996). Likewise a supplement of highly energetic feed such as palm oil (Lough et al., 1990, Solomon et al., 1992), coconut meal (Willdeus and Fugle, 1991), canola seed or soy lecithin (Lough et al., 1991) produces greater fat, as does the use of protected fats, which can have some effect on lamb tenderness (Kercher et al., 1995).

Other aspect to be considered is the amount of concentrate. Thus, Fitzgerald (1986) reported that lambs fed 500 g/ day of concentrate had a higher fat score than those fed only silage, with no difference between 250 and 500 g/day of concentrate.

Although these changes may be more important in young animals than in lambs slaughtered at high maturity stages (Theriez et al., 1992, Alhadhrami et al., 1993). Likewise, the differences between forage and concentrate may become insignificant if the animals have highly appetising feed such as alfalfa (Bruns et al., 1994).

With respect to the raw material itself, not many studies analyse its influence on product quality. It seems that clover tends to produce more fat than grass due to its higher protein content, but the differences are not important (Vipond et al., 1993). Other studies have indicated alfalfa as a top quality forage to optimise the degree of fatness (Lee and Demment, 1990, McClure et al., 1994) and improve meat quality (Solomon et al., 1996).

Additives. In general, additives form a wide group of substances in terms of their action, toxicity, legal situation, knowledge of their action, especially related to possible additive or antagonistic effects. In general they have significant effects on the quality of the product. Thus:

Vitamin E has a significant effect on the colour stability, extending the shelf life of lamb meat by approximately 4 days, by supplementing with 500 IU. 1,000 IU improve meat shelf life very little,compared with 500 IU. Both vitamin E, and the use of enriched selenium, do not appear to affect the carcass composition (Kirby et al., 1996).

Anabolic steroids, such as trenbolone, oestradiol or zeranol (with oestrogen like activity) tend either to reduce the fat, especially when used together (oestradiol + trembolon) (Payne and Cope, 1991), or not to exercise any significant action (Field et al., 1993, Lough et al., 1993). The dose effect is not clear (Sulieman et al., 1992) and zeranol seems to be less active than others (Nold et al., 1992 ab). With respect to meat quality, the steroids do not seem to have a great effect (Field et al., 1993), the effects being different according to the product and sex considered, although they tend to produce tougher meat, without the collagen being affected (Lough et al., 1993, Nold et al., 1992 b).

Recombinant ovine or bovine somatotropin and growth hormone releasing factor also reduce the amount of fat, this being more effective the greater the dose, although the intensity varies according to season, housing, feed, sex and as well as differences in the source of somatotropin (McLaughlin et al., 1993, Beerman et al., 1995).

Melatonin does not seem to have any influence on the fatness in sheep, the same as chlorofibrate, a hypolipidaemic agent used in clinical medicine to lower plasma tri-glycerides (Payne and Cope, 1991), although it has potential to do so.

Antibiotics like monensin have a greater effect on protein, increasing it, than on fat, and have little action on meat quality (Gilka et al., 1989).

Immunisation with antibodies developed against ovine adipocyte plasma membranes as a means for modulating fat deposition is still in the early stage of development and could be an alternative method of fat reduction (Nassar and Hu, 1991).

In the nineties there have been numerous studies on the use of β-adrenergic agonist (Cimaterol, Clembuterol, Albuterol, etc.). In general, these substances have a clear effect on the amount of fat, reducing it, and on the meat, increasing its toughness due to the increase of the calpastatin activity (Koohmaraie and Shackelford, 1991, Pringle et al., 1993), not affecting the amount of collagen solubility . This action on the toughness can be mitigated by the infusion of $CaCl_2$ (Koohmaraie and Schackelford, 1991). They also produce a slight darkening of colour and an increase in pH (Shackelford et al., 1992). The rapidity and magnitude of the muscle hypertrophy, that results from dietary administration of β-agonists, is remarkable because it is noted that no special or fortified diet is required to accommodate the anabolic response. This effect is additive with the diet and sex effects (Sainz et al., 1990) and with the growth hormone (Link et al., 1991), but not with anabolic steroids or with the expression of the callipyge gene (Koohmaraie et al. 1996). Uterine exposure to these products does not seem to have promise as a method for improving lamb carcass cutability (Shackelford et al., 1995).

The use of metabolism regulating factors such as ∝-ketoisocaproate (they stimulate the protein synthesis and reduce catabolism) could be interesting methods to improve the composition of sheep carcasses (Flakoll et al., 1991).

4. Factors related to slaughter, post-slaughter treatments, preservation and cooking

The consumer may be more permissive when accepting changes or new techniques and technologies in post-mortem than in ante-mortem treatments. For that reason, modifying the amount of fat (trimming) and meat characteristics by post-slaughter treatments can be methods which have great practical use.

Until now, the effect that the type of stunning,bleeding, skinning or offal removal conditions, can have on the product and its preservation, have not been described. Sheridan (1990) indicated that washing the carcass can reduce its preservation losses.

Rigor mortis and ageing. A basic effect which has been described in depth, is the effect of ageing and its action on the tenderising of meat. Thus, longissimus dorsi at slaughter is intermediate in tenderness, after rigor shortening makes meat tougher and proteolysis tenderises it progressively (Sheridan, 1990, Kadin et al., 1993; Serdaroglu et al., 1993). Anyway, initial tenderness does not vary greatly in sheep and, thus, variation in initial tenderness contributes little to ultimate tenderness (Wheeler and Koohmaraie, 1994). Likewise with greater ageing time the water losses increase (Koohmaraie et al., 1990, Moore and Young, 1991, Doherty et al., 1996) changes in odour and flavour take place (Jeremiah et al., 1993 ab, Braggins and Frost, 1997), as well as an increase in the discoloration and browning with a rapid evolution of objective colour (L*, a*, b*) (Clare et al., 1997) and, of course, an immediate evolution of pH (Wheeler and Koohmaraie, 1994).

Infusion agents. Further evidence has shown that CaCl2 infusion into the carcass increases the rate of tenderisation in lamb and accelerates post-mortem ageing, producing a greater amount of general losses (Koohmaraie et al., 1990, Koohmaraie and Shackelford, 1991) probably because of an increase in moisture retained in infused samples, which may not have been fully incorporated within the muscle fibres, especially in the thoracic limb (Farouk and Price, 1994). Certain negative effects on the colour, such as lower colour score and increased of browning have been described (Koohmaraie and Shackelford, 1991, Farouk and Price, 1994) although no off-flavour problems have occurred (Clare et al., 1997). Another substance ZnCl2, a calpain inhibitor, reduced the rate of tenderisation in lamb (Buttery et al., 1997).

Post-mortem chilling. After slaughter a rapid cooling produces a toughening of the meat (coldshortening), a factor which has been well-known since the fifties and sixties. The temperature in the muscle must not drop below 10°C in 10 hours or below 10°C with the pH higher than 6 (Chrystall et al., 1980). The shortening is not the only justification for the toughening, as muscles with the same length of sarcomere can give rise to very different tenderness scores (Culler et al., 1978). This negative action of chilling could be avoided by electrical stimulation of carcasses, standing position or freezing in pre-rigor with very fast chilling (Sheridan, 1990, Brown et al., 1993). In any case it is necessary to search for a ideal temperature/time ratio to achieve a quality product (Beltran et al., 1990, Jaime et al., 1992).

Electrical stimulation. Electrical stimulation (ES), as a method to avoid these problems of rapid cooling, is being used in different countries. In general, ES produces an acceleration in the drop of pH, improvements in tenderness and meat colour and an increase in water losses, especially after freezing (Sheridan, 1990, Moore and Young, 1991, Serdaroglu et al., 1993, Kadin et al., 1993). All of this is partially due to the breakage of the muscle structure (Moore and Young, 1991). The improvement of the tenderness caused by ES is noticeable during the first days of ageing, beyond 5 to7 days the results are not so clear (McGeehin et al., 1996).

The effect of ES is greater with high voltages than with low ones (Koohmaraie et al., 1990), especially if the application of the latter is delayed after stunning (Shaw et al., 1996) and due also to the existence of a great individual variation of the response to low voltage stimulation (Simmons et al., 1997).

Knife handling of the carcasses. Hot boning (HB) and trimming can also cause considerable changes in the product quality. HB produces detrimental effects on tenderness, but an elevated temperature conditioning prior chilling for 6 hours appeared to offset these detrimental effects (Jeremiah et al., 1993 ab). Likewise, HB also affects other sensorial parameters, but not in such an important way as to affect consumer acceptance (, Simmons et al., 1997).

Carcass trimming to a final thickness of under 5 mm of subcutaneous fat, which would be a not very well accepted commercial practice in some markets and could produce tougher meat, due to the coldshortening effect (Kadim et al., 1993).

Preservation. Modified atmospheres, vacuum packaging, freezing, transformation by seasoning or drying and possible combinations of all of these cam be used for medium (25-60 days) or long-term meat preservation.

Modified atmospheres represent a newly emerging field with great possibilities. Action of CO2 has been analysed, both alone or with a mixture of oxygen or nitrogen and in comparison with air (Moore, 1990 c) or with vacuum packaging (Doherty et al., 1996, Braggins and Frost, 1997). It seems that CO_2 causes a change in odour and flavour together with an increase of pH, greater colour stability, which is not very stable in this species (Moore, 1990 c) and a reduction of water losses (Doherty et al., 1996).

The partial drying and seasoning with preservation at 30°C for 60 days produces colour losses, which could perhaps be partially avoided by vacuum packing (Zapata et al., 1990).

Likewise, the use of absorbent paper liner produces greater losses, this effect of the material in contact with meat should be considered when reporting loss data and when comparing results with those of other researchers (Moore, 1990 b).

Freezing is, undoubtedly, the most used long-term preservation method. Different variables can be considered: temperature and speed of freezing, temperatures and time of preservation and thawing characteristics.

In general, freezing produces greater water losses (Failla et al., 1996) and a greater amount of abnormal flavours and colour modifications, with a tendency to reduce L* and b*, and global meat quality, specially with not very low temperatures, greater than -15°C or with prolonged preservations (Moore, 1990 ab, Moore and Young, 1991).

Likewise, it is better to start the freezing with very low temperatures (-35°C) and then go on to temperatures of -5 or -10ºC rather than vice-versa, possibly because certain alterations, which can start at -5°C are then stopped at -35°C , and initially at -35°C these changes do not occur. Therefore, we would expect that excessively long periods of meat ageing before freezing would adversely affect the frozen storage life of lamb. Also, long preservation times affect the oxidation of fat with rancidity and cause alterations in the flavour, although if meat is handled correctly, this can be preserved in excess of two years. On the other hand, greater colour stability has been observed after long freezing times (8 months) than in a few days (Moore, 1990 a) and over meat frozen for a short time and then thawed than in meat which is simply chilled (Moore, 1990 d).

The type of packaging, during the preservation and the use of cryoprotectors could improve some of the freezing problems. Thus packaging frozen lamb chops in oxygen permeable film is preferable to packaging in film of low oxygen permeability (Moore, 1990 d). On the other hand, the injection of antifreeze glycoproteins, from Antarctic cod, reduces the thawing losses (Payne and Young, 1995) and does not introduce any significant changes in the sensorial properties of meat or slightly improves them.

Cooking. Different cooking conditions, (type, times and temperatures) produce very significant changes both in sensorial and instrumental properties of meat and in its composition. Thus, cooking produces an important loss of water, a significant loss of fat and ash and a relatively unimportant loss of protein, which is probably of low biological value (Uriyapongson et al., 1993, Badiani et al., 1994, Failla et al., 1996). Also, sensory properties of the cooked lean could be adversely affected by the removal of subcutaneous fat before cooking (Rhee et al., 1990, Ferrier and Hopkins, 1997).

Cooking a bain marie (75° - 80°C) has been described as an action which increases the toughness of meat (Failla et al., 1996). Meat cooked fresh has also been tougher than after thawing, but, the losses due to cooking were not affected (Chystall and Devine, 1991).

Processor. This would be a multicausal efect, with great variability over tenderness and possibly in other meat characteristics and its preservability (Bickerstaffe et al., 1997). This factor should be studied in the future.

5. Acceptability factors

Within the European Union, and even more so if we consider the Great Village of the World, the quantitative differences in the consumption of meat are, as already mentioned, certainly variable. However the qualitative differences are no less important. In certain Mediterranean countries such as Spain, the consumption of sheepmeat responds to a selective demand with cooking recipes which respect the taste of meat insofar as possible (roast, grilled). On the contrary, in countries of the centre and north they confer a much more modest character on lamb meat, which is mainly used for stews, where the seasoning plays an essential role.

In Spain and in many other countries, sheep meat has a strong traditional and festive component, but consumption per capita becomes progressively lower as the age of the consumer decreases and the number of inhabitants in the town increases. In these countries quality marks, geographical indications or brands are being developed in order to try to defend local products. These indications are attempting to attract young town consumers to sheep meat, because in the futur these actual young consumers will be consumers of symbols, rather than purchasers of nutrients or lovers of good meat. These quality marks, although they represent relatively low market costs, less than 0.5% in France as opposed to 20% in the poultry (Sylvander, 1994), have a high growth rate and are, undoubtedly, a point of reference and a driving force for the sheep meat sector in many areas.

Before consumption, there are some criteria which determine the acceptability and motivation for purchase; apart from preferences due to species, availability and subjective aspects-beliefs. These criteria, although they are qualitatively the same in almost all the countries: meat and fat colour, presence of exudate, particularly in pre-packed lamb, cut or chop size and particularly eye muscle area, fibre structure, apparent connective tissue and specially leanness and amount of bone (Dransfield, 1985, Kilkenny, 1990), quantitatively, they can differ a lot from one country to another or from one market to another.

It is curious how some countries such as Spain really appreciate the flavour of sheep meat, which represents 53.0% of the causes given for purchasing lamb on a home level, followed by tenderness and juiciness (13%) (Laajimi, 1991). Thus, whilst in the Spanish consumers' minds, lamb has a natural and tasty product image, in countries such as the United States (with low sheep consumptions) taste is precisely the main reason for consumers rejecting sheep meat. On the other hand, whilst in European

countries of the Mediterranean area consumers prefer pink or very pale meat, which even obtain the maximum categories in carcass classification systems, in other countries such as New Zealand, consumers select the meat on the basis of redness, with the belief that if it is red it is safe to eat, and if it is not red, it is of dubious quality (Moore and Young, 1991) and people who produce their own meat consume more lamb than those who do not (Hopkins et al., 1992).

Subsequent work has analysed the influence of these different geographical sources on meat sensorial quality. Jeremiah (1988) did not detect major differences in flavour and texture of lambs from three countries: Australia, New Zealand and Canada, except for a few differences attributable to differences in lamb age and prolonged fresh vacuum packaged storage and/or temperature abuse of some meats.

Griffin et al., (1992), evaluated sheep meat palatability in the USA using two sensory panels, one of foreign assessors from various cultural backgrounds and familiar with small ruminant meat consumption and the other from US. The foreign panel assessed the overall palatability of this type of meat with higher scores than the native assessors, who were less used to lamb consumption.

Sañudo et al., (1998 a) compared British and Spanish panels assessing meat from lambs produced in both countries, with lambs of both nationalities. The scores flavour and odour intensity, tenderness and juiciness were similar in both panels, but, the tendencies in flavour and overall acceptability were the opposite. Thus, the British panel preferred the British meat and the Spanish panel preferred the Spanish meat. So it seems that the acceptability depends upon the preferences and culinary habits of the taste panel.

WEIGHTING OF FACTORS AND PRODUCT OBTAINING (PRODUCTION AND PROCESSING) SYSTEMS

In Table 4 the influence of several of the factors, which we have analysed above, and criteria which define the product quality (dressing percentage, carcass and meat quality) are comparatively weighted.

Table 4. Summary of factors that have an influence on lamb carcass and meat quality

		Carcass quality			Meat quality				
	Dressing %	Weight	Confor-mation	Fatness	WHC Juiciness	Colour	Tenderness	Flavour	Overall
Intrinsic factors									
Breed	**	***	****	***	*	*	*	0	*
Individual and genes	**	**	****	**	0	*	***	0	**
Sex	**	***	**	***	0	*	*	*	**
Weight- Age	***	****	*	****	*	***	**	**	***
Productive and environmental factors									
Ambient- Season	*	***	0	**	0	*	*	0	*
Feeding	***	***	*	****	*	**	*	**	**
Additives	*	**	**	****	***	*	***	*	***
Pre and slaughter factors									
Fasting, stress α transpot	****	*	0	0	**	***	**	*	***
Slaughtering	**	**	0	*	*	**	*	**	*
Post-slauhter and commercialization									
Aeging	0	0	0	0	**	****	****	**	***
Electrical stimulation	0	0	0	0	**	*	***	*	**
Carcass chilling	**	*	0	0	*	*	***	*	**
Conservation	0	*	0	0	***	***	****	***	****
Consumption factors									
Cooking	0	0	0	***	****	****	****	****	****
Cultural background	0	***	**	****	*	***	*	****	****

0: no influence; *: little influence; **:moderate influence; ***:high influence; ****: fundamental.

It is posible to see that intrinsic and productive factors mainly affect carcass quality, these being the factors which the farmer and the technician on the farm can control and handle. However, pre and post-slaughter, marketing and consumption factors mainly affect meat quality, and they are factors that can only be controlled by the slaughterhouse, marketing chain and at the last moment by consumers. Different conclusions can be reached from this dilemma.

1. To obtain a quality product all the links of the production -marketing- consumption chain must be controlled.

2. Farmers must take part in the whole process, or, if this is not possible, achieve a perfect identification -traceability- of the product at the point of sale.

3. There is not much sense, when determining the quality of a product, in talking about the production system, as this would only include the intrinsic and productive factors. It would be much more logical to talk about **the product obtaining system,** which would also cover from the pre-slaughter to all the factors related with preservation and selling.

Thus, in two works carried out by us (Sañudo et al., 1992 b and Sañudo et al., not published) an analysis has been made of the sensorial quality and acceptability of 9 and 5 commercial types of light sheep (9.5 - 12.5 kg carcass) in each year respectively, which are normally sold in Spain.

The systems for obtaining the products, number of animals and number of remarks are described in Table 5. Table 6 includes the ranking found in the different sensorial characteristics analysed and the acceptability by local panels. In both cases the meat was grilled to an internal temperature of 85°C and assessed by 8 panel members in experiment 1, and up to 70°C and 11 panel members (different to the previous ones) in experiment 2.

Table 5. Descriptive caracteristics of some light lamb types commercializated in Spain

Origin or breed and code used in the table 6	Number of animals	Number of Observations	Weaning	Slaughter age (months)	Feed system	Conservation System	Aeging time (days)
First experiment							
Rasa Aragonesa[1] (RAW)	32	256	weaned	3	concentrate (C)	chilled	3
Spanish Merino (SME)	8	64	weaned	3	pasture + (C)	chilled	3
Welsh Mountain[2] (WMO)	8	64	weaned	5-6	pasture	chilled	6
New Zealand lamb (NEZ)	8	64	weaned	5-6	pasture	frozen	?[4]
Manchega[1] (MAN)	8	64	weaned	2.5	concentrate	chilled	3
Lacaune[3] (LAU)	8	64	unweaned	2-2.5	milk + (C)	chilled	3
Lacaune[3] (LAW)	8	64	weaned	2.5	concentrate	chilled	3
German Merino (GME)	8	64	weaned	3	pasture + (C)	chilled	3
Argentinian lamb (ARG)	8	64	weaned	5-7	pasture	frozen	?[4]
Second experiment							
Rasa Aragonesa[1] (RAW)	19	209	weaned	3	concentrate	chilled	3
Rasa Aragonesa[1] (RAU)	19	209	unweaned	3	milk + (C)	chilled	3
Lacaune[3] (LAW)	19	209	weaned	2.5	concentrate	chilled	3
Welsh Mountain[2] (WMO)	19	209	weaned	5-7	pasture	chilled	3
Spanish Merino (SME)	19	209	weaned	3	concentrate	chilled	3

[1] Spanish local breed, [2] British local breed, [3] French local breed, [4] tested the day after thawing

Table 6. Ranking (lowest: -, to hightest: +) of meat sensorial quality in some light lamb caracasses commercialized in Spain

	Tenderness			Juiciness			Flavour intensity			Overall acceptability	
	Exp. 1	Exp. 2		Exp. 1	Exp. 2		Exp. 1	Exp. 2		Exp. 1	Exp. 2
(-)	ARG* [a]	RAU [a]	(-)	ARG [a]	WMO [a]	(-)	LAU [a]	LAW [a]	(-)	ARG [a]	WMO [a]
	MAN [ab]	LAW [ab]		NEZ [ab]	RAW [ab]		MAN [a]	RAW [a]		NEZ [ab]	RAU [b]
	SME [ab]	RAW [b]		WMO [ab]	SME [ab]		SME [a]	SME [ab]		MAN [abc]	LAW [c]
	NEZ [b]	WMO [bc]		SME [b]	LAW [ab]		LAW [a]	RAU [b]		WMO [bcd]	RAW [c]
	RAW [b]	SME [c]		MAN [b]	RAU [b]		ARG [ab]	WMO [c]		SME [cde]	SME [c]
	LAW [b]			RAW [b]			RAW [ab]			RAW [cdc]	
	GME [bc]			LAW [bc]			GME [ab]			LAW [cdc]	
	WMO [bc]			GME [bc]			NEZ [ab]			GME [de]	
(+)	LAU [c]		(+)	LAU [c]		(+)	WMO [b]		(+)	LAU [e]	

* See table 4 for understanding abbreviations. Different superscripts in the same column means significant differences (P<0.05) (Kramer test)

From the analysis of both experiments we can conclude that the differences, apart from the genetic type, are mainly influenced by the type of feed and growth rate, slaughter age and carcass cold storage system. The younger animals, produced in intensive systems, after compensatory growth and unfrozen have the highest quality for the Spanish market. The high tenderness and high flavour intensity of British carcasses, for 3 or 6 days' ageing, stand out, as well as the high global appreciation and juiciness of the unweaned animals.

CONCLUSION

The sheep production systems in the European Mediterranean area have a series of peculiarities due, originally, to the climate and the natural medium of the area, which make lamb carcass and meat quality appreciably different to those of the North of Europe, and have formed some typical products, which are specially appreciated by the consumers who live in each particular region because they are accustomed to a particular product obtention system.

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