The contribution of mountain pastures to the link to terroir in dairy and meat products

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Abstract. The existence in mountain areas of specific traditions and know-how for the agricultural production and food processing constitute an opportunity to develop differentiated mountain terroir products able to add value to the farmers. The aim of this text was to review the definition of terroir in the case of animal products and to identify the contribution of mountain pastures and associated farming practices. The terroir refers to a system of interactions between biophysical and human factors that were built during the history, that are specific from a geographical limited area and confer typicity to the products. This typicity results partly from the use of mountain pastures that influence the characteristics of milk and cheeses and carcass and meat. The secondary metabolites of the dicotyledonous plants found in mountain pastures like terpenoids or phenolic compounds are directly transferred to animal products or modify animal digestion and therefore influence indirectly fatty acid composition of animal product. The role of these molecules (and microbes in the case of raw milk cheeses) on meat and cheese sensory properties are often reported, and, even if not fully understood, they obviously contribute to the link to terroir. The way the mountain pastures are managed and the characteristics of the animals used (breed, physiological status) also influence the grazing selection and phenology of grazed herbage. Understanding the interconnections between these aspects refers back to the measures to be taken so that the animal products reflect the uniqueness and diversity of the terroir where they originate.

Keywords. Mountain Pasture – Terroir – Milk – Cheese – Carcass – Meat.

La contribution des pâturages de montagne au lien au terroir des produits laitiers et carnés

Résumé. *L'existence dans les zones de montagne de traditions et de savoir-faire dans le domaine de la production et de la transformation des produits animaux constitue un atout pour le développement de produits de terroir capables d'assurer une plus-value intéressante pour les éleveurs. Le but de ce texte était de préciser la définition du terroir dans le cas des produits d'origine animale et d'identifier la contribution des pâturages de montagne et les pratiques agricoles associées. Le terroir se réfère à un système d'interactions entre les facteurs biophysiques et humains qui ont été construits au cours de l'histoire, qui sont spécifiques d'une zone géographique limitée et qui confèrent une typicité aux produits. Cette typicité résulte pour partie de l'utilisation des pâturages de montagne qui influencent les caractéristiques du lait et des fromages et de la carcasse et de la viande. Les métabolites secondaires des plantes dicotylédones très diverses trouvés dans les pâturages de montagne comme les terpènes ou des composés phénoliques sont directement transférés aux produits d'origine animale ou sont susceptibles de modifier la composition des acides gras des produits en raison de leur action sur le fonctionnement du rumen. Le rôle de ces molécules (et des microbes dans le cas des fromages au lait cru) sur les propriétés sensorielles de la viande et du fromage est souvent mentionné. Le mode de gestion des pâturages de montagne et les caractéristiques des animaux utilisés (race, état physiologique) influencent également les caractéristiques du couvert végétal (phénologie) et les choix alimentaires des animaux au pâturage. Comprendre les interconnexions entre les produits et les caractéristiques des couverts végétaux renvoie aux mesures à prendre pour que les produits d'origine animale reflètent au mieux le caractère unique et la diversité du terroir dont ils sont issus.*

Mots-clés. *Pâturages de montagne – Terroir – Lait – Fromage – Carcasse – Viande.*

I – Introduction

In the EU, about 14% of the agricultural area (27 million ha) and 18% of the farms (2.4 millions) are located in mountain areas. This area hosts 12.5, 20.4 and 46.8 % of the EU cattle, sheep and goats respectively. Mountain cattle accounts for 10.4 and 13.3% of the total cattle milk and meat production and this share is higher for small ruminants that produce 32.0 of the total goat and ewe milk and 23.4% of the sheep meat (Santini *et al.*, 2013).

These data underline the quantitative importance of mountains outputs for the ruminant livestock sector that is also involved in maintaining the landscape and the rural social network. It is therefore one of the guarantors of the attractiveness of these territories and the development of other economic activities like tourism. Nevertheless, mountain farming faces several limitations related to the existence of permanent structural limitations that results in significant lower labour and land productivity (Martin *et al.*, 2014) and in higher production costs. Poor accessibility of mountain farms also affects the food industry due to increased collection and transport costs. In order to preserve the mountain ruminant sector, specific public policies dedicated to compensate partly the limitations of mountain agriculture were initiated for long in many European countries through specific measures of the national and Common Agricultural Policy. Currently, in most mountain areas, these subsidies contribute to a large part of farmer's income. They are essential for the economic viability of mountain farms and are justified by the multiple ecosystem services provided by mountain farming.

Nevertheless, the long term viability and attractiveness of mountain ruminant farming mainly relies on higher farm gate prices for productions. The gap between mountain and lowland prices is in general positive in the milk and meat sector but very different patterns according to the sectors and regions still exist. The success stories of some mountains areas rely on the dynamism of local stakeholders who proposed very specific and differentiated food products (Martin *et al.*, 2014) that add value for the entire food chain. The existence in mountain areas of specific traditions and know-how for the agricultural production and food processing is indeed an opportunity. The valorisation of the synergies between agricultural products issued from local history and culture, tourism, handcraft and gastronomy constitute a "basket of goods" (Mollard and Pecqueur, 2007) able to develop a long term added value for products issued from a specific terroir. The emblematic success stories of the Beaufort, Comté and Laguiole mountain areas in France or the Aosta Valley in Italy rely on the differentiation of a terroir product correctly identified and protected by a Geographical Indications These models seem replicable in other mountain areas where farm density remains important (Dervillé and Allaire, 2014).

The aim of this text is to identify which are the farmer's practices important to consider within the mountain production systems of milk and meat products for the production of differentiated terroir products. We will first define the terroir notion then, for milk and meat products propose a literature review on the contribution of mountain pastures and associated farming practices to the link to terroir.

II – The link to terroir

1. The definition of terroir

Historically, terroir refers to an area, usually rather small, whose soil and microclimate impart distinctive qualities to food products. The word terroir was first associated with the production of wine. It is related to a doctrine that defines quality by reference to the geographical origin. It refers both to climatic and soil characteristics of the place and to the know-how of the men who exploit it. The most complete and operational definition of terroir arises from the deliberations of a French working group who define the terroir as follows (Casabianca *et al.*, 2006):

"a terroir is a geographical limited area where a human community generates and accumulates along its history a set of cultural distinctive features, knowledges and practices based on a system of interactions between biophysical and human factors. The combination of techniques involved in production reveals originality, confers typicity and leads to a reputation for goods originating from this geographical area, and therefore for its inhabitants".

This definition refers to the close connections between environmental and human factors; human practices modify environment and *vice versa*. Terroir is considered as a construct; the historical dimension is important but terroirs are also living and innovative spaces that cannot be reduced only to tradition.

2. The application to the case of ruminant livestock products

In the case of cheeses, Grappin and Coulon (1996) define the terroir as "*a geographic area characterized by environmental conditions and types of animals, that when exploited by humans, lead to specific products*". In the case of ruminant livestock products, *terroir* is therefore an inseparable package of (i) the physical environment including geology, geography, soil and climate, (ii) animals with the dominant breed and its genetic characteristics, and (iii) the man who can affect the physical environment and animals through cultural and husbandry practices and whose role is essential in the process of the raw material (muscle and milk). Dorioz *et al.* (2000) added a fourth element in this system; the fodders (or more generally the feedstuffs) produced on the terroir, with their botanical composition depending on both physical environment and farmers' practices and the way they are included in the animal diet (phenology, grazed or preserved…). The characteristics of animal products are therefore the result of a long process from the physical environment to the product that implies in the case of cheeses two main complex fermenters; the rumen and the cheese. In comparison to wine, the complexity of the interactions in the development of the characteristics of the products is increased, especially because of the mobility of the animals and to the complexity of the vegetation used as fodder.

The influence of the terroir on the product characteristics may result from the specific influence of one of the basic components of the terroir. In this case, we can consider the direct flux of microorganisms or molecules from one of these components to the meat and cheese. We can also consider a succession of metabolic and chemical processes starting from one of the component and that finally influence the product characteristics. More systemic approaches taking into account the biological or physical interactions between the basic components of the terroir and including the farmer's practices and the process are also necessary to explicit the link to terroir. These approaches are particularly complex, uneasy to study in experimental conditions and generally do not allow to understand all the biological mechanisms underlying. They are nevertheless necessary considering that the link to terroir cannot be restricted to a simple flux of microorganisms or molecules. The link to terroir also relies on a very important historical and cultural aspect that will not be considered in this text.

We will focus on the possible contribution of mountain pastures and associated management practices on dairy and meat product characteristics. The permanent grasslands found in mountain areas, are indeed not transferable because their characteristics and botanical composition depend on the soil and climate and associated management. They can therefore be considered as an important component of the terroir in the case of mountain products.

III – Dairy products

Empirical knowledge related to the influence of specific vegetal communities found in mountain grasslands on cheese sensory properties are known. It was developed by farmhouse cheesemakers, especially in mountain conditions where vegetation gradients and contrasting plant mosaics are met even within the same pasture according to variable micro-climates, soil and agricultural practices.

1. Biochemical link

Based on the empirical knowledge of the farmers, the study of the effect of the botanical composition of forages on milk and cheese characteristic have been the first to be studied for the characterization of the terroir. Primarily, differences on sensory properties of cheese derived from animal grazing different vegetation or fed conserved forages with different botanical composition were investigated (Buchin *et al.*, 1999). These differences being found relevant, the further studies focused on the direct transfer of plant compounds, supposed to be responsible of the variation of the odours and aromas in cheese according to the forages fed to the animals. Plant secondary metabolites, such as terpenoids were known to vary widely according to the botanical species composing grasslands (Mariaca *et al.*, 1997). In particular, grasses are poor in terpenoids whereas these compounds are abundant and widely variable in forbs. Their direct transfer from herbage to milk was demonstrated (Viallon *et al.*, 2000), and several studies highlighted differences in milk terpenoids composition according to the botanical composition of pasture or hay (De Noni and Battelli, 2008). Relations between terpenoids and specific sensory traits (Buchin *et al.*, 1999; Bendall, 2001), such as stable, overripe fruit, manure, orange, fruity and green notes have been suggested. However, non-terpenoids compounds, such as indoles (skatole in particular), lactones, aldehydes, ketones, alcohols or esters resulted to determine much more milk and cheese sensory profile than terpenoids (Buchin *et al.*, 1999; Bendall, 2001). Furthermore, Tornambé *et al.* (2008) showed that the concentration of essential oils, rich in terpenoids, in milk to reach the threshold for sensory perception are ten folds higher than those achievable in milk by grazing animals, even on highly biodiversified pastures. The high variability of terpenes and the low repeatability of their analysis, moved the research of the origin of the sensory differences on other milk constituents. Among these, polyphenols are other plant metabolites that can be transferred to milk (Besle *et al.*, 2010). Herbage polyphenols composition varies largely according to pasture botanical composition (Reynaud *et al.*, 2010). However, the majority of phenolic compounds in milk and herbage are still unidentified and their direct effect on the sensory properties of dairy products have still to be demonstrated. Even though, plant secondary metabolites can have significant indirect effect on milk and cheese composition, as they can interact with rumen microflora, by partially inhibiting the biohydrogenation of dietary fatty acids in the rumen (Leiber *et al.*, 2005). Indeed, differences in milk fatty acid composition according to pasture botanical composition were shown by several authors on both fresh herbage (Falchero *et al.*, 2010) and conserved forages (Ferlay *et al.*, 2006). Collomb *et al.* (2002) correlated milk FA composition to the presence in grasslands of some botanical families or species. The main differences seemed to concern C18:3n-3, total PUFA, and the FA intermediate product of its hydrogenation in rumen, such as C18:1t11, CLAc9t11; C18:2t11c15 and other trans or cis isomers of C18:1 and C18:2 (Leiber *et al.*, 2005; Iussig *et al.*, 2015). As examples, an increase of about 0.20 g/100 g FA of CLAc9t11 and C18:3n-3 was shown on a grass-dominated pasture rich in forbs compared to one poor (Povolo *et al.*, 2013; Coppa *et al.*, 2015). Milk FA composition can affect cheese sensory properties (Martin *et al.*, 2005). High concentration of PUFA in milk resulted a lower fat melting point, with consequent less firm, softer and more melting texture of cheese (Coppa *et al.*, 2011a). The PUFA oxidation can also generate large amount of odour active compounds during ripening, with significant effect on cheese odour and aromas (Coppa *et al.*, 2011b). Cheese appearance can be affected by milk FA composition (Coppa *et al.*, 2011a) possibly because PUFA rich fat may oil-off during pressing and therefore interact with the development of moulds and yeasts.

Some recent researches have highlighted that other factors, related to pasture characteristics can have important effect on milk composition and cheese characteristics. Among these factors, the herbage phenological stage seems to have a great impact on milk carotenoids content (Calderon *et al.*, 2006). Carotenoids, are plant essential pigments derived from the chlorophyll, and can be transferred from diet to cow milk, especially the β-carotene. The herbage β-carotene content decreases with herbage maturation (Calderon *et al.*, 2006), resulting in lower concentration in milk from cows grazing mature herbage instead of herbage at the vegetative stage. Carotenoids are thus responsible for the yellow colour of milk issued from cows fed fresh herbage (Martin *et al.*, 2005) and the yellowness of cheese was shown to decrease of about the 20% when cows' grazed herbage at a late compared to an early phenology (Coppa *et al.*, 2011a). However, the transfer of β-carotene form diet to milk is a specificity of cows, as it is negligible in small ruminants (Martin *et al.*, 2005). The effect of phenological stage was shown to be important also on milk fatty acid composition. A decrease in total lipid, and in C18:3n-3 herbage content with herbage maturation results in a decrease in milk C18:1t11 and CLAc9t11 concentration comparable to those achievable by reducing of 30% the fresh herbage proportion in cow diet in on farm conditions (Coppa *et al.*, 2015). These differences are therefore greater than those observed among pastures with different botanical composition (Coppa *et al.,* 2015).

Furthermore, animal grazing selection at pasture could interact with the botanical composition (Iussig *et al.*, 2015) and change during the season according to herbage phenology development (Farruggia *et al.*, 2014). On continuous grazing on biodiversified and heterogeneous pastures, cows often overgraze the preferred vegetation type, dominated by grasses, and the selection of dicotyledonous species increases only in the late season, when the regrowth of grasses is not sufficient to cover cow herbage requirements (Farrugia *et al.*, 2014). This pattern may have important effect on milk fatty acid composition, cheese yellowness and sensory profile (Coppa *et al.*, 2011a; Farrugia *et al.*, 2014). The grazing selection depends also on the grazing management adopted, decreasing with the increase of stoking density. Thus, in the rotational grazing systems, shorter is the duration of paddock utilisation, lower is the selection by cows (Coppa *et al.,* 2015). A lower selection among species results in grazing by layers, with a consequent significant change in the nutritive quality of ingested herbage from the upper leafy layers to the lower layers, rich in stems (Coppa *et al.,* 2015). The result is a wide variation in milk FA concentration during the few days occurring form the beginning to the end of paddock utilisation (-1.71 and -0.41 g/100 g FA for C18:1t11 and CLAc9t11, respectively), with range of variation comparable or even larger than those observed for the effects of herbage phenology, or botanical composition (Coppa *et al.*, 2015).

2. Microbial link

The raw milk microbiota, that prints the milk production system, is another important aspect to be considered in order to explicit the link to terroir is the case of raw milk cheeses. Furthermore, its role on the cheese sensory properties (especially the flavour) was demonstrated for long, even when starters are used to fasten acidification of fresh cheeses (Montel *et al.*, 2014) and some observations suggest that the effects of animal feeding on cheese sensory properties are partly eclipsed when milk is pasteurized. Knowledge about the raw milk microbiota is increasing rapidly thanks to the application of rRNA-based culture-independent high-throughput amplicon sequencing (Montel *et al.*, 2014). For example, the ITS-PCR fingerprinting of raw milks from Alpine pasture were distinguished from lowlands by higher diverse bacterial communities (Bonizzi *et al.,* 2009). Composition of milk microbiota results of a combination of human factors (milking practices, breeding practices), animal physiology, animal health, animal feeding, and environmental factors (air, faeces, milking equipment) (Vacheyrou *et al.*, 2011; Monsallier *et al.*, 2012). Defining the contribution of each factor is not an easy task. In particular, the effect of feeding is difficult to disassociate from that of animal housing (inside -outside) or cleanliness.

Some reservoirs of milk microbial diversity have been identified but we are still lacking of information about microbial transfers from reservoirs to farm milk. The theoretical microbial transfer pathway can be schematised as indicated in Fig. 1 and teats are the essential vectors of microorganisms from animal environment to raw milk.

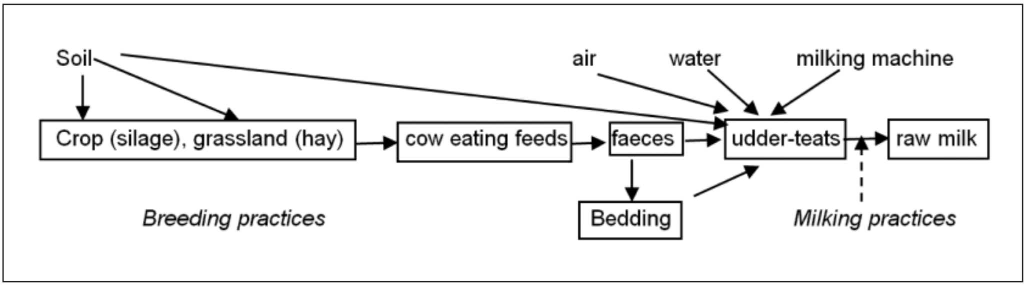

Fig. 1. Theoretical microbial transfer pathway from reservoirs to farm milk.

Different researches underline that animal feeding (grassland, silage and hay) may be an indirect source of micro-organisms for milk. For example, grassland of Normandy contains high levels of Gram negative bacteria (*Pseudomonas, Enterobacteriaceae*) coryneform bacteria and yeasts, but low levels of *Lactococcus lactis* ssp *lactis* (Denis *et al*., 2004). Lactobacilli were found in alfalfa and grass (Chunjian *et al.*, 1992) and at high level in milk from animal grazing or green-fed in the barn (Elmoslemany *et al.*,2010). Fungal genera such as *Eurotium* sp., *Aspergillus* sp., and Gram positive (*Curtobacterium* sp., *Bacillus* and *Paenibacillus* sp.) and Gram negative rods (*Pantoea* and *Pseudomonas* sp.) have been found in hay (Vacheyrou *et al.*, 2011). Milks from animals grazing had lower microbial population and level of *Streptococcus agalactiae* (possible cause of mastitis) than those from animal confined and fed with concentrates and preserved fodders (Goldberg *et al.*, 1992). The transition to the grass could enrich milk with coagulase negative *Staphylococcus* (Hagi *et al.*, 2010). Levels of microbial groups (total bacteria, Gram negative bacteria, yeasts, moulds, lactic acid bacteria, ripening bacteria) of the surface teats of dairy cows at pasture were shown 10 to 1000 times lower than those of dairy cows confined in the barn (Verdier-Metz *et al.*, 2012). But the number of microbial species was higher on teats of cows on a pasture with high floristic diversity than those of cow confined (72 at pasture *versus* 43 indoor) (Verdier-Metz *et al.*, 2012).

These recent researches underline the role of the milk microbiota in order to explicit the link to terroir. They also stress the importance of maintaining the possible microbial transfers from farm reservoirs to milk and therefore to avoid milking or cheesemaking practices (like pasteurisation, for example) able to disrupt this link.

IV – The case of meat products

In comparison to dairy products, explicating the links between animal husbandry and meat characteristics is even more complex due to the fact that, unlike milk whose characteristics vary in the short term according to the diet, carcass and meat characteristics are shaped during the entire life of the animals. Nevertheless, many researches show that the current tendency for changing indoors to grass production systems, affects meat characteristics. One of the most affected traits is the colour, the most important attribute taken into account by consumers in their purchase decision. The magnitude of their influence on carcass and meat quality remains unclear, especially in young animals fed on their dams' milk until slaughter.

1. Lamb's performance, carcass and meat quality in mountain areas

The production of lambs in Mediterranean areas is based on young lambs slaughtered as suckling lambs (10-12 kg live-weight, LW) or as light lambs (22-24 kg LW, younger than 90 days) to produce light carcasses. Suckling lambs are fed only their dams' milk, whereas light lambs after weaning at 45-50 days are fattened indoors with concentrates. In these systems, ewes are stalled around parturition and fed indoors hay or straw with concentrates during the lactation period. Meat of light lambs from these production systems is very homogeneous, its colour is pale pink and it has white fat. Alternatively in Mediterranean mountain pastures, light lambs can be raised by their dams during the spring season (Joy *et al.*, 2012b) or on alfalfa pastures between late spring and early autumn (Ripoll *et al.*, 2014a) with minimum or even no detrimental effects on lamb performance and carcass quality. The effect of these feeding managements (grazing mountain pasture *vs*. indoors concentrate feeding) on fat colour in light lambs is minor as the subjective scores were similar (Carrasco *et al.*, 2009). However, subcutaneous fat of lambs from grazing systems had greater yellowness (b*), associated with the presence of carotenoids, flavonoids and a-tocopherol in their diet (Prache and Theriez, 1999), than those from concentrate-based diets. Similarly, fat from suckling lambs whose dams grazed had greater yellowness and redness than that from lambs whose dams were fed hay (Joy *et al.*, 2012b). This might be due to the small grass intake by the lamb (Álvarez-Rodríguez *et al.*, 2007) in addition to the intake of milk carotenoids (Prache *et al.*, 2005). Grass-fed lambs may provide meat with a low degree of fatness and red meat colour (Priolo *et al.*, 2002).

Grass feeding of dams is effective improving the meat quality of lambs raised exclusively on maternal milk (Valvo *et al.*, 2005), due to the healthiness of milk from grazing sheep (Atti *et al.*, 2006). Lamb intake of milk from grass-fed ewes led to a higher proportion of linolenic acid in intramuscular fat. The feeding strategy around parturition and lactation affects the milk FA profile (Joy *et al.*, 2012a). The most affected by grazing are CLA, C18:1t11 and PUFA, n-6/n-3 ratio, with a positive effect for human health. Pre-partum grazing, regardless of post-partum feeding, can modify the FA composition, increasing the CLA content in meat. The extent of the increase of CLA, C18:1t11 and PUFA n-3 of grass-based diets in comparison to grain-based diets depends on the maturity, variety and preservation of the forage (Dewhurst *et al.*, 2006). Green grass is a source of n-3 PUFA, haymaking processes lead to a loss of FA precursors of CLA, while modest losses are recorded in wilting prior ensiling (Dewhurst *et al.*, 2006).

2. Cattle performance and meat quality in mountain fattening systems

Suckler cattle farms located in Mediterranean mountain areas traditionally produce weaned calves, which are fattened under intensive conditions in feedlot farms in the plains. Despite this general trend, some mountain farms have undertaken on-farm fattening activities, either individually or in a cooperative way (García-Martínez *et al.*, 2009), as a strategy to retain a higher share of the added value of the product sold into the market. This is also common in other mountain areas in Central Europe. Since a high growing rate is expected in fattening animals, weanlings are fattened on valley meadows, while the less productive pastures are used more efficiently by other types of cattle. In these production systems, the growth rates on pasture of entire males sold as yearlings (12 months) or young steers (18 months) depend on the pasture quality and quantity available and the amount and type (barley, maize or concentrates) of supplement offered to young bulls and steers, but gains over 1 kg/day are always achieved (Blanco *et al.*, 2014). Several studies that compared concentrate-, hay- and grass-fed cattle had different end-weight, and found that dressing percentage and meat quality differed among diets (Serrano *et al.*, 2007). However, carcass weight influences carcass and meat quality and effects can be confounded. In cattle slaughtered at the same body weight, grazing generally reduces subcutaneous fat cover, dressing percentage and fat deposition in veal calves (Ripoll *et al.*, 2013) and young bulls (Blanco *et al.*, 2011). Dressing percentage did not differ after a 2-month finishing period on concentrates in young bulls (Blanco *et al.*, 2011) but decreased after a 2-3 month finishing period on a total mixed ration in 18-month old steers. Nevertheless, finishing on concentrates or on a total mixed ration increased the deposition of fat in the carcass (Blanco *et al.*, 2014, Ripoll *et al.*, 2014b). Fat colour was greatly affected by the grass-feeding, yellowness and the estimator of carotenoids being the most affected parameters (Blanco *et* *al.*, 2010) due to a high deposition of carotenoids in fat. Therefore, fat colour can be used to trace and guarantee forage feeding. A finishing period of 2 months on a total mixed ration did not affect fat colour (Ripoll *et al.*, 2014b) but 2 months on concentrates affected yellowness and the estimator of carotenoids of subcutaneous fat (Blanco *et al.*, 2011) .

Meat colour and toughness were affected to a lower extent by grazing (Blanco *et al.*, 2010) when carcasses had an appropriate fat cover. In fact, grazing had a negative impact in meat colour of veal calves (Ripoll *et al.*, 2013), probably due to the scarce subcutaneous fat cover. A 2 month finishing period on concentrates after grazing had no effect in the colour and toughness meat from young bulls (Blanco *et al.*, 2010) but a 2 month finishing period on a total mixed ration improved toughness in meat aged for 9 days but not in meat aged for longer periods (Ripoll *et al.*, 2014b). Regarding the chemical composition, grazing had a major effect on the fatty acid profile at a similar deposition of intramuscular fat. Grazing improved the fatty acid profile in veal calves (Ripoll *et al.*, 2013) and young bulls (Blanco *et al.*, 2010), increasing n-3 PUFA content. The difference between grazing and finished cattle depended on the type of feed offered during the finishing period, if concentrates were offered total PUFA decreased and n-6:n-3 ratio increase (Blanco *et al.*, 2010); if a total mixed ration was offered the fatty acid profile was not affected (Ripoll *et al.*, 2014b).

V – Conclusions

The terroir basically refers to a system of interactions between biophysical and human factors that were built during the history and that are specific from a geographical limited area. The typicity of animal products originating from a terroir results from specific traditions and know-how for animal production and processing. In addition to the historical and cultural aspects of the link to terroir, the results presented here underline the primary contribution of the mountain pastures animal products typicity. The specific botanical composition and biodiversity of mountain pastures is governed by geo-climatic conditions and agronomic practices (fertilization, stoking density, grazing management) and has a direct influence on meat and cheese composition. Both direct and indirect fluxes of molecules from mountain grasslands to meat and cheese are now well documented. It most cases, the secondary metabolites of the very diverse dicotyledonous plants found in mountain pastures are involved. These molecules allow in some cases to authenticate through analytical techniques, the mountain and/or pasture origin of meat and dairy products. The role of these molecules (and microbes in the case of raw milk cheeses) on meat and cheese sensory properties are often reported, and even if not fully understood they obviously contribute to the link to terroir. The way the mountain pastures are managed and the characteristics of the animals used (breed, physiological status) also influence the grazing selection and herbage phenology. The interconnections of these aspects can be considered as an adaptation of a farming system itself (considered under agro-environmental, human and animal components) to a specific geographical context that make unique a terroir and its animal products. Understanding this system of interactions refers back to the measures to be taken so that the animal products reflect the uniqueness and diversity of the terroir where they originate.

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