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in

**Molina Alcaide E. (ed.), Ben Salem H. (ed.), Biala K. (ed.), Morand-Fehr P. (ed.).
Sustainable grazing, nutritional utilization and quality of sheep and goat products**

Zaragoza : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 67

2005
pages 213-223

Effects of grass feeding on milk, cheese and meat sensory properties

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SUMMARY – The nature of forages ingested by ruminants is one of the factors of variation of the sensory properties of milk and meat products. For dairy products, the effects on the sensory properties of cheeses (colour, texture, flavour), of the nature of forages (corn silage, grass based forages), of the conservation method (hay *vs* silage) and of the botanical composition of the grass are presented. The sensory differences observed can be due to milk constituents coming directly from animal food (carotenoids, terpenoids) and/or to milk constituents that the animal produces which are different when food varies (plasmin content of milk or fat composition). For meat colour, flavour and tenderness, the trials comparing pasture to concentrate or the type of forages given to cows are reviewed and the origin of the differences (ultimate pH, age at slaughter, carcass fatness, intra-muscular fat, skatole content, fatty acids) are discussed.

Keywords: Grass feeding, sensory properties, cheese, meat.

RESUME – *"Effets de l'ingestion d'herbe sur les propriétés sensorielles du lait, du fromage et de la viande". La nature des fourrages ingérés par les ruminants est l'un des facteurs de variation des caractéristiques sensorielles des produits laitiers et carnés. Pour les fromages, les effets de la nature des fourrages (ensilage de maïs ou fourrages à base d'herbe), du mode de conservation de l'herbe (foin vs ensilage) ainsi que de la nature botanique de l'herbe, sont présentés. Les différences sensorielles observées s'expliquent par des composants dans les fromages, directement issus des fourrages (caroténoïdes, terpènes) ou produits par l'animal, mais dont la concentration varie en fonction de l'alimentation (plasmine, composition de la matière grasse). Pour la couleur, la flaveur et la tendreté de la viande, les résultats obtenus dans les essais comparant des régimes à base d'herbe pâturée ou de concentrés ou des fourrages de nature différente sont résumés et l'origine des différences (pH ultime, âge à l'abattage, dépôts adipeux de la carcasse, gras intramusculaire, teneur de la viande en skatole, nature des acides gras) est discutée.*

Mots-clés : *Herbe, qualité sensorielle, fromage, viande.*

Introduction

The characteristics of meat and dairy products are dependent on a large number of factors linked both to the processing technology (for processed products) and to the chemical and microbiological characteristics of raw materials. The latter also depend on a number of upstream factors (genetic, physiological and dietary). Upstream factors are increasingly becoming the focus of consumers' concern, regarding in particular the animals' feeding. Their importance is enhanced in quality-identified products [Protected Designation of Origin (PDO), Protected Geographic Indications (PGI)] for which a strong link between quality and the production conditions is claimed. Among those production factors, forage-based diets are the most sensitive because they are part of the basic link between products and their original land, because grass carries a positive image that can be attractive to some, and also because it may confer special nutritional characteristics to the products.

So far, studies involving the effect of feeding on milk and meat characteristics have mainly focussed on the influence of supplementation levels and of the main diet types on milk component concentrations (protein and fat) (Coulon and Rémond, 1991) or on muscle growth (Geay *et al.,* 2001). Conversely, beside the known effect of certain plants (*Brassicaceae*, garlic, onion) on the flavour of milk and meat (Urbach, 1990) the specific effect of the type of forage, grass in particular (floristic diversity, conservation method and quality) has hardly been tackled, although a number of empirical observations concur in attributing significant effects on product sensory characteristics to this factor. The aim of this review is analysis the recent studies, which have evidenced an effect of grass on the sensory qualities of meat and cheeses. Other dimensions of quality, i.e. health and nutrition, were not investigated.

Dairy products

Among the various milk production conditions which may influence cheese characteristics the floristic composition of the forage used by animals, depending on the natural environment (soil, climate) and agricultural practices (fertilisation namely), is a recurrent argument of cheese makers. Cheese makers often note differences in the sensory characteristics of cheeses according to the forage fed the animals. These observations have been backed up by global studies aimed at analysing the sensory diversity of a given cheese and at relating that diversity to milk and cheese production conditions. Martin and Coulon (1995) in the Reblochon PDO production area, found that under certain cheese making conditions, the differences in sensory features could be associated with different types of forage (hay or pasture). Likewise, in the Comté PDO area, Monnet *et al.* (2000) evidenced a link between the botanical composition of grasslands and the cheese sensory characteristics and Bérodier (1997) showed that botanical diversity could be associated with more numerous and varied cheese flavours. At the plant scale, differences in sensory properties were also found between cheeses made with bulk milk from different groups of farms differing by their farming system (Agabriel *et al.*, 2003; Martin *et al.,* 2003). In controlled conditions of milk production and processing, experiments have been carried out to analyse the specific effect of the type of forage, its conservation method and botanical diversity.

Effects of the type of diet and grass conservation method

The effect of maize silage in the diet was tested in studies that compared cheeses obtained with milk from cows fed exclusively with maize silage or with hay- (Verdier *et al.,* 1995) or grass-silage- (Houssin *et al.,* 2000) based rations. Maize led to much whiter cheeses, because of the low carotene content, slightly firmer and globally rated lower by tasters in comparison with grass regardless of its conservation mode. Toso and Stephanon (2001) confirmed those experimental results by comparing Montasio cheeses made with milk from farms that used maize silage or not. They showed that after two months ripening, the cheeses coming from farms without maize silage were preferred to others, although those differences were less marked after 6 and 12 months of ripening. Regarding goat cheese, recent results have shown that alfalfa hay led to cheeses with much more intense flavour than maize silage (Gaborit *et al.,* 2002). In ewes, maize silage always increased the butyric spore count but had no consequences on the sensory characteristics of the cheese (Cavani *et al.,* 1991).

The silage conservation and its effect on cheese quality have been fuelling ongoing debate among the leaders of PDO cheese makers. Certain specific deficiencies can be observed with low quality silage (Urbach, 1990) especially in hard-cooked cheeses where the presence of butyric spores in silage and milk may cause serious problems (delayed swelling, unpleasant taste and odour). These problems are far less frequent with high quality silage. An experiment (Verdier-Metz *et al.,* 1998) compared grass from the same paddock, harvested on the same day, and conserved either as silage (with acid preservative) or as hay (barn drying). Conservation quality was excellent in both situations, and the nutritional supply to cows was the same. Saint-Nectaire cheeses (a French PDO semi-hard cheese made in Auvergne) were processed in an experimental plant. The cheeses made with the milk from cows fed silage were more yellow (due to the higher carotene content in silage than in hay) and tended to be bitter. The other chemical and sensory characteristics did not differ much between the two treatments. This experimental result was confirmed by observations made in farms (Agabriel *et al.,* 1999). These results show that when forage conservation is good, the conservation method has little influence on the sensory characteristics of cheese, except on colour. It is, however, possible that the effect of silage vary according to the cheese type. In a recent trial (Verdier-Metz *et al*., unpublished), grass silage induced wider sensory differences than hay on Cantal-type cheeses than on Saint-Nectaire ones.

Conversely, major differences in sensory characteristics were observed between cheeses whose milk was produced by cows fed winter diets (based on hay and grass silage) or turned to highland pasture in the spring. Saint-Nectaire cheeses made with milk from animals receiving pasture were more yellow, with a less firm texture, stronger taste and less piquant, less sour and less fruity flavour than those made with milk from winter when animals did not have pasture as food (Verdier-Metz *et al.,* 2000a). Butter characteristics (colour, flavour, spreadability) also varied widely as the cows' diet was changed (Hawke and Taylor, 1980); in particular, butter was more yellow, softer and had a grassy flavour when the cows were fed with a grass-based diet (pasture or silage) than when they were given concentrate and maize (Keen and Wilson, 1992; Houssin *et al.,* 2000). Those results confirmed the observations made by farm cheese makers when dairy cows turned to pasture. In Norway, according to early studies, it appears that the goatish flavour was less pronounced with milk produced by goats fed in sheds than when they were fed in pasture (Korvald, 1958) whereas Ronningen (1965) reported the opposite tendency.

Effect of grass botanical composition

In recent years, several trials have been conducted in Europe to describe and analyse the effect of the botanical diversity of forage fed by cattle (either in pasture or conserved) on the sensory characteristics of various types of cheese, either cooked or uncooked. Trials carried out at farmhouse cheese makers using highland pastures (Abondance: Buchin *et al.,* 1999; Beaufort: Martin *et al.,* 2001), compared the characteristics of cheeses made when the herds successively grazed on different parts of the same highland pasture where the sward botanical composition varied widely. In both experiments, sensory characteristics of cheeses varied according to the sward botanical composition. Differences concerned texture and flavour (Abondance cheese) or only flavour (Beaufort cheese). Another trial (Verdier-Metz *et al.*, 2000b) consisted in making pressed paste cheese, according to the Saint-Nectaire method, in an experimental cheese making plant with milk from cows managed under the same conditions (milking, health condition, nutritional input, housing namely) but fed cocksfoot (as hay) or natural Auvergne grassland (green silage or hay). Compared with cocksfoot cheeses, the cheeses made from natural grassland were not so melting and less bitter, with less developed rancid and mouldy odours. When natural grass was given as green silage, the cheeses were saltier and less acrid than when it was given as hay. Lastly, it has recently been demonstrated (Bugaud *et al.*, 2001) in a trial conducted in two Abondance cheese farms that in addition to inter-farms differences, wide deviations were also possible within the same farm, according to the grazing meadow characteristics. If the widest deviations were between valley and highland pastures, there was also a degree of variability within the same highland meadow. The main differences involved cheese texture that was more cohesive, elastic and deformable in valley than in mountain cheeses, and more "crumbly" in cheeses from nitrophilic and snowbound than in cheeses from damp meadows. Those results confirmed and refined those obtained by Bosset *et al.* (1999) with Gruyère-type cheeses made with either valley or highland milk. In that trial, mountain cheeses tasted stronger than valley ones and were rated as more "animal" and more "pungent".

Origin of sensory differences

A number of cheese sensory features or characteristics may be due to certain milk components, directly linked to feeding and to forage in particular. It is the case for colour, for example. Milk contains variable amounts of pigments the most common being carotene, which is present in large amounts in green forage and contributes to the yellow coloration of dairy products. Highly UV-sensitive carotene is degraded during forage wilting and conservation proportionally to the degree of light exposure (Park *et al.*, 1983). The type of feeding has a marked effect on milk carotene content, hence on the colour of butter and cheese (Waghorn and Knight, 1992; Houssin *et al.,* 2000; Coulon and Grolier, unpublished). Cheeses made with spring milk are therefore much yellow than those made with winter milk. In winter, cheeses made with grass silage are more yellow than those made with milk from hay, especially so when hay was left to wilt on the ground for a long time. Maize silage, which is carotene-poor, leads to very pale cheeses (Verdier *et al.,* 1995).

Another direct origin of the effect of forage botanical composition on the sensory characteristics of cheeses (Dumont and Adda, 1978) involves the effect of terpenes. These plant-specific molecules have identifiable smelling characteristics when concentrated. They are more profuse in certain species, dicotyledons in particular (Mariaca *et al.*, 1997; Cornu *et al.,* 2001). They rapidly pass into the milk (Viallon *et al.*, 2000) and are found in cheese in much larger quantities when the cows eat dicotyledon-rich swards, either green or conserved, which generally characterise highland swards, than when they were fed with concentrate-based diets (Moio *et al.*, 1996) or mono-specific forage

(Viallon *et al.,* 1999; Bugaud *et al.,* 2001). However, if those molecules can be useful in tracing the origins of cheeses (Fernandez *et al.,* 2003) it does not seem that any modification of their concentration in cheese would suffice to have any significant and direct effect on cheese flavour (Moio *et al.,* 1996; Verdier-Metz *et al.*, 2000b; Bugaud *et al.,* 2001).

The effect of the type of feeding on the sensory characteristics of cheeses can also be an indirect one. The texture differences noted by Bugaud *et al.* (2001), between valley and mountain cheeses, or by Buchin *et al.* (1999), between the Northern and Southern slopes, of the same highland pasture have to be related to the wide variability of milk plasmin concentration from one situation to the other. This proteolytic enzyme is known for its strong effect on the biochemical processes which occur in the course of cheese maturation, especially in cooked pressed cheeses. Its concentration increases in milk under certain feeding situations, which could be due to an increased cell permeability of the mammary tissue as a consequence of specific plant species intake (*Ranunculaceae*) only present in certain types of grassland. Milk fat composition (length of the carbon chain and degree of unsaturation) highly dependent on animal feeding conditions (Chilliard *et al.,* 2000), may also be at the origin of butter and cheese texture and/or flavour differences (Wood *et al.,* 1975; Bugaud *et al.,* 2001; Buchin *et al.,* 1999; Collomb *et al.,* 1999). Butter can thus be all the most spreadable as linoleic content is higher and palmitic acid concentration is lower (Badings *et al.,* 1976; Hawke and Taylor, 1980). Also, some fatty acids may be degraded by microbial enzymes during cheese maturation, to produce compounds that are responsible for cheese aroma (Keen and Wilson, 1992; Urbach, 1997).

Lastly, it cannot be ruled out that the type of forage modifies the microbial ecosystem or its activity in milk, as suggested by the results obtained by Buchin *et al.* (1999) or those of Bugaud *et al.* (2001), who demonstrated that sulphur compounds production by micro-organisms during maturation can be inhibited by the presence of terpenes in milk, whose the vegetal origin has been proven. In addition, the recent findings of Verdier-Metz *et al.* (2002) suggested that some diets effect could be of microbial origin: indeed, they evidenced that the marked flavour differences in Cantal cheese, depending to the diet, observed with raw milk disappear when milk is pasteurised.

Meat

Colour

Although meat colour is poorly related to its nutritional and organoleptic properties (Young *et al*., 1999) it is important because it can influence consumer acceptance. Priolo *et al*. (2001) reviewed 35 experiments in which meat colour was measured in cattle raised on pasture or on concentrates. They concluded that meat from animals grazing grass is generally darker than meat from animals fed concentrates. In the literature, however, there are few studies on the effects of grass feeding on sheep meat colour. Meat from lambs raised on pasture has been reported to be darker (higher lightness; L*) than meat from animals given concentrates (Diaz *et al*., 2002; Priolo *et al*., 2002). Hopkins *et al*. (2001) did not find differences in meat colour between lambs grazing a pasture (lucerne or clover) and lambs grazing the same pasture, but receiving supplements of roughage or oats. Carson *et al.* (2001) compared two diets with high or low forage/concentrate ratio. They did not find differences on meat lightness (L*). However, lambs finished on low forage/concentrate diet, showed higher redness (a*) and yellowness (b*) values than lambs raised on high forage/concentrate diets. Santos-Silva *et al*. (2002) compared three groups of lambs the first grazing on pasture, the second received pasture plus concentrate *ad libitum and*, the third receiving concentrate *ad libitum*. Lambs were slaughtered at 24 and 30 kg and the only significant effect of diet on *longissimus* muscle colour, was on a* value, that was higher in lambs of the third group.

Differences in colour could be due to many factors. It is well known that muscle ultimate pH and meat lightness are inversely correlated (Renerre, 1981). Animals raised on pasture have a higher incidence of high ultimate pH meat than animals on concentrates (Sheath *et al*., 2001). Animals raised on grass have wider ultimate-pH variability and lower glycolytic potential than animals given concentrates (Young *et al.,* 1997a; Vestergard *et al.,* 2000). These animals could have greater concentration of haemic pigments in the muscle, as a result of physical activity (Vestergard *et al*., 2000). Diaz *et al*. (2003) found that, with increasing slaughter weight in lambs, meat L* and b* value decreased while a* value increased. Moron-Fuenmayor and Clavero (1999) studied the effects of different feeding systems on lamb meat quality. Lambs were divided into three groups: the first group grazed pasture and *Leucaena leucocephala*; the second one received pasture and concentrate, and the third one only pasture. Lambs supplemented with *Leucaena* and concentrate had a dark red colour of muscle; the group receiving pasture only was "cherry" red. According to the authors, these differences in colour could be due to the concentration of sarcoplasmatic protein and to the reduction of myoglobin in the muscle. The physical activity, higher in grazing animals, has different effects on different muscles. Diaz *et al.* (2002) compared two production systems: pasture and sheepfold based on lambs receiving concentrate *ad libitum*. They studied the effects of the two production systems on the colour of two muscles: *longissimus dorsi* muscle and *rectus abdominis* muscle. *Longissimus dorsi* muscle showed lower lightness value that means darker meat for lambs from pasture, while no differences were found for *rectus abdominis* muscle.

Another important factor is the content of intra-muscular fat (lighter in colour than muscle) that is generally higher in animals given concentrates (Priolo *et al*., 2001).

Some pastoral species are characterized by the presence of condensed tannins (CT), polyphenolics compounds able to precipitate proteins in the rumen. Priolo *et al*. (2003, unpublished) studied the effects of CT from sulla (*Hedysarum coronarium* L.) on meat colour. Lambs were divided into three groups. The first group received sulla, the second one received sulla plus polyethylene glycol (PEG), and the third one received concentrates. The PEG is a product of synthesis that binds CT in the rumen reducing their effects. Meat from lambs receiving sulla plus PEG was darker (lower L* value) than meat from lambs receiving sulla without PEG. These results confirm those found in a preceding experiment by Priolo *et al*. (2000) in which the authors studied the effects of CT from carob pulp.

Flavour/odour

Meat obtained from animals raised on pasture has a different flavour compared with animals fed with concentrates. Bailey *et al*. (1988) reported the term "grassy" to qualify meat from cattle raised on forage diets; other descriptors include "milky", "fishy", "rancid". Similar descriptors have been used for sheep meat (Young *et al.,* 1999).

Young *et al*. (1993) report a reduction of typical sheep meat flavour and intensification in off-flavours when meat ultimate pH is high. The influence of ultimate-pH on meat flavour could be due to the presence of "odour-active compounds", such as aldehydes pH dependent (Braggins, 1996).

Many odour volatile compounds have been identified (Muir *et al*., 1998). The presence of specific volatile compounds in meat depends on the diet and animal species. For example, sheep and beef meat flavour are different.

Branched-chain fatty acids (BCFA) are considered to be responsible "for the species-related flavour" (Mottram, 1998). Sheep and goats accumulate BCFA as a result of a rich grain diet or poor in fibre (Van Soest, 1984). A high concentration of branched-chain fatty acids is often associated to a very strong sheep meat flavour (Young and Braggins, 1996). However, it is possible to find a strong flavour in meat even with a low concentration of these fatty acids because of other compounds involved, such as indoles and phenols. The effects of BCFA seem to increase by the presence of 3-methylindole (skatole) (Young *et al*., 1997b). Skatole is a product of tryptophan degradation and it is higher in animals raised on pasture. Grass diets have a high protein/non-fibrous carbohydrates ratio, therefore, in the rumen amino acids deamination by micro organism is higher than in animals raised on concentrate (Sheath *et al*., 2001). Young and Priolo (2003) found that skatole was present in pasture-raised lambs while it was at baseline level in concentrate-raised animals; mutton or lamb odour and flavour was higher in meat from pasture-raised lambs although BCFA, as expected, were higher in feedlot animals. Recently, Bella *et al*. (2003, EAAP In press) found a higher concentration of skatole in fat from lambs given fresh sulla, compared to animals receiving concentrate.

Different feeding systems influence muscle fatty acids composition. The fatty acid composition of meat can affect meat flavour (Elmore *et al*., 2000). The unsaturated linolenic acid (C18:3) is a fatty acid characteristic of forage lipids (Wood *et al*., 1999) and is notoriously not synthesized by mammals (Ha and Lindsay, 1990). Melton *et al*. (1982) found that C18:3 was highly ($P<0.001$) and positively correlated with milky-oily aroma and flavour and with sour flavour. Flavour intensity was positively correlated with C18:3 in a study made comparing British and Spanish lambs (Sañudo *et al*., 1998). Sañudo *et al*. (2000) compared British lambs, grazing a natural pasture, with Spanish lambs receiving concentrates. British lambs had higher quantities of stearic acid, linolenic acid and long chain polyunsaturated *n*-3 but, lower quantities of linoleic acid and long chain polyunsaturated *n*-6 than Spanish lambs. Odour and flavour intensity were positively correlated with the amounts of 18:0 and 18:3 and, negatively correlated with that of 18:2, both in the British and in the Spanish panel. Panellists gave higher scores, for odour and flavour intensity, to British lamb (with high levels of 18:3) and lower scores to the Spanish lambs (with high levels of 18:2). Linolenic acid oxidation products have been associated with species-related meat flavours (Marmer *et al*., 1984). Two derivates of linolenic acid, the eicosapentaenoic acid (EPA; 20:5) and docosahexaenoic acid (DHA; 22:6) play an important role in meat flavour formation during cooking (Elmore *et al.,* 2000; Enser *et al*., 1998). Meat derived from ruminants consuming grasses is, on the other hand, protected from oxidation by the presence of antioxidants in grass (Wood *et al.,* 1999). Assuming that linolenic acid has a very important role in determining meat flavour, Young and Baumeister (1999) proposed that one of the compounds responsible for pastoral odour in cattle is 4-heptenal, a product of linolenic acid oxidation reported to be a highly unpleasant odorant.

Other compounds influencing meat flavour are terpenoids. These compounds are directly transferred from pasture to animal tissue. The presence of these compounds in animal tissues is strongly depending on pasture botanical composition. Larick *et al*. (1987) found that the neophytadiene concentration in beef fat was at least 4 times higher in animals grazing on tall fescue than in those grazing brome-red clover or orchard grass-red clover. Fifty-six days on corn dramatically reduced the concentration of this compound. The neophytadiene was isolated from pasture grass (Urbach and Stark, 1975) and was positively correlated ($P>0.01$) with "grassy" flavour (Larick *et al*., 1987). Priolo *et al.* (2003) found in the fat of lambs fed grasses significantly more 2,3-octanedione, p-cymene and ß-caryophyllene than in the fat of lambs fed concentrates. The possibility to use these compounds as tracers of grass feeding is discussed, in this seminar, by Prache *et al*. (2003).

Tenderness

Sheep meat tenderness is not always influenced by feeding system (Hopkins *et al*., 1998; Hopkins *et al*., 2001; Yu *et al*., 2001; Arsenos *et al.,* 2002; Lowe *et al*., 2002). Hopkins *et al.* (1998) did not find significant differences in tenderness between groups of lambs receiving three different types of pasture. Arsenos *et al*. (2002) did not find significant differences between lambs reared under a similar nutritional management, based on concentrate and finished on irrigated pasture. Lowe et al. (2002) found Warner Brazler shear values of 2.5 kg F. According to the authors, the grasses feeding system is not "the limiting factor in producing tender meat", because, in grazing animals, there is an adequate glycogen level, in muscle, and a low stress.

However, Priolo *et al*. (2002) raised lambs on pasture or with concentrates at the same growth rates and slaughtered animals from the two production systems at the same age and weights. Stall-fed lambs gave tender meat, as assessed by a sensory panel. Meat tenderness was positively correlated with carcass fatness and carcasses from concentrate-fed lambs were fattier than carcasses from grazed lambs. Age differences at slaughter may play a role in meat tenderness because of collagen that becomes increasingly cross-linked with the covalent intermolecular bonds that makes meat tougher as the animals get older (Young and Gregory, 2001). Furthermore, collagen cross-linking increases during periods of reduced animal growth. In pasture-based extensive production systems, the seasonal variations of grasses availability could, therefore, result in reduced animal growth and, consequently, increased meat toughness (Young and Gregory, 2001).

In beef production, Ortigues-Marty *et al.* (2002) studied the relationships in beef steers between animal performances, blood nutrient profiles and *semi-tendinosus* muscle characteristics determinant for meat quality in four groups of animals receiving different diets: continuous or discontinuous growth rate with either a maize silage or grass based diet. Blood nutrient profiles and muscle characteristics varied according to diets (maize silage or grass) and animal performances (average daily gains and carcass characteristics) varied according to growth rates.

Conclusions

The various results presented here show that the characteristics of forage used by animals modify the physico-chemical and/or sensory features of cheese and meat. These effects may vary according to the processing methods (type of cheese, meat cooking method). They result from the presence in the raw material of specific molecules directly induced by feeding (carotenes, terpenes) or produced by the animal under the effect of specific diets (skatole, plasmin, fatty acids). Although their direct sensory impact is minimal (e.g., terpenes), some of these molecules can still be used as feed tracers (Prache *et al*., 2002; Fernandez *et al.,* 2003) and/or contribute to the nutritional value of the end products (Chilliard *et al.,* 2000; Daly *et al.,* 1999).

If the conservation method (silage/hay) cannot be considered as a real "terroir" factor, the floristic composition of forage, in contrast, is closely related to the natural environment and participates in that notion. Many genera, sometimes entire botanical families, are only found in highlands (e.g. Gentianaceae) and, therefore, are an essential factor of highland specificity. The existence of a link between natural environment and product characteristics may, however, be jeopardized by grassland management practices that would result in forage uniformity. In view of these results, it appears that regardless of the mechanisms that link forage and product, the maintenance of forage biodiversity (green or conserved) is crucial for cheese and meat to best reflect the typicity and diversity of their territory of origin. The current approaches in milk and meat PDO chains are entirely consistent with that.

Finally, the "terroir" effect is not restricted to the mere biological dimension of the environment; historical, social and economic dimensions, which are not within the scope of this paper and not totally unrelated to biological factors, should also be taken into account.

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