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Feeding strategies to obtain high quality milk in intensive dairy sheep production systems

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Abstract. Castile and Leon is the main producing region of ovine milk in Spain, with more than 60% of national milk production and more than 40% of sheep census. Current systems of dairy sheep production in this area are characterized by an important increase in milk yield (55%) in the last decade and a lower number of farms. These changes result from enlarged flock size, use of specialized breeds, intensification, and a high individual production (over 300 L/ewe on average), which rely on feeding systems including no grazing and low forage: concentrate ratios. Under this situation, the nutritional value of the milk fat, in terms of impact on consumers' health, can be detrimentally affected. It is known that moving away from pasture-based diets increases undesirable saturated and decreases potentially health-promoting (e.g., 18:3n-3, CLA, or *trans*-11 18:1) fatty acid (FA) levels. On the other hand, it provides an incomparable scenario to develop nutritional strategies to enhance milk quality. Dairy ewe diet supplementation with vegetable or marine lipids enables modulation of milk FA composition towards a healthier profile. However, the latter strategy causes milk fat depression, which prevents its application under practical farm conditions. Other compounds, such as tannins, may also modulate milk FA composition. From a research point of view, it is expected that new disciplines (e.g., nutrigenomics), may provide new insights into the mechanisms underlying the nutritional regulation of mammary lipogenesis and enable to modify, naturally and effectively, ovine milk fat without impairing animal performance.

Keywords. Ewe – Fatty acid – Lipid supplement – Nutrition – Production system.

Stratégies alimentaires pour l'obtention du lait de haute qualité dans des systèmes d'élevage intensifs chez les ovins laitiers

Résumé. *Castille-et-León est la principale région productrice de lait ovin en Espagne, avec 60% de la production nationale de lait et 40% du cheptel ovin. Les systèmes actuels de production de lait de brebis dans cette zone sont caractérisés par une augmentation importante de la production laitière (55%) dans la dernière décennie malgré une réduction du nombre d'exploitations. Ces changements sont le résultat d'une augmentation de la taille des troupeaux, de l'utilisation des races spécialisées, de l'intensification et d'une production individuelle élevée (plus de 300 L/brebis en moyenne), de modifications qui reposent dès lors sur des systèmes d'alimentation qui comprennent zéro-pâturage et de faibles rapports fourrage : concentré. Dans ces circonstances, la qualité nutritionnelle des matières grasses du lait, en termes d'impact sur la santé du consommateur, peut être négativement affectée. Il est connu que l'abandon de l'alimentation au pâturage entraine un accroissement de la teneur en acides gras (AG) saturés délétères et une diminution des autres potentiellement bénéfiques pour la santé (par exemple, 18:3n-3, CLA, ou* trans*-11 18:1). En revanche, cette situation fournit un scénario incomparable pour développer des stratégies alimentaires en vue d'améliorer la qualité du lait. La supplémentation du régime des brebis laitières en lipides végétaux ou marins permet de moduler la composition en AG vers un profil plus favorable à la santé. Toutefois, cette dernière stratégie provoque une chute de la teneur en matières grasses du lait, empêchant son application dans les conditions d'élevage actuelles. D'autres composés, comme les tanins, peuvent aussi moduler la composition en AG du lait. Du point de vue de la recherche, il est attendu que de nouvelles disciplines (par exemple, la nutrigénomique) pourraient ouvrir de nouvelles perspectives sur les mécanismes sous-tendant la régulation nutritionnelle de la lipogenèse mammaire et permettre de modifier, de manière naturelle et efficace, la composition des matières grasses laitières chez les brebis sans altérer leurs performances zootechniques.*

Mots-clés. *Brebis – Acide gras – Supplément lipidique – Nutrition – Système de production.*

I – Introduction

This work reviews first of all the main changes occurred in dairy sheep production systems in the Spanish Autonomous Community of Castile and Leon in the last decades. These are characterized by a remarkable increase in milk yield that relies on the use of specialized breeds and feeding systems including no grazing and low forage:concentrate ratios.

Under this current situation, the nutritional value of the milk fat, in terms of impact on consumers' health, can be detrimentally affected. On the other hand, it provides an incomparable scenario to develop nutritional strategies to enhance milk quality. This will constitute the basis for the second part of the paper.

II – Current dairy sheep production systems in north-central Spain

The Community of Castile and Leon, located in north-central Spain, is a traditionally ovine milk producing region with a great demand for its high quality sheep cheeses, which are highly valued in the market. The region leads the ewe milk yield, concentrating currently 66.6% of the total production in Spain (385.3 million liters) through the milking of 1.2 million breeding ewes from 2,585 farms, which represents 46.7% of national dairy sheep census (MAGRAMA, 2014a,b).

Dairy sheep production systems have been submitted to significant changes in recent years, with the abandonment of many farms and decreased censuses. In this respect, 684,000 breeding ewes have disappeared in Castile and Leon since 2000, which represents a relative decline of 36.2% (JCYL, 2015), while the reduction in the whole country was of 28.1% (corresponding to 1 million milking ewes). Returning to the region, this decline was 2.4%/year from 2000 to 2010 and accelerated then to 5.2%/year from 2010 to 2013. These changes have been accompanied by the disappearance of 58.2% of dairy sheep farms in the region over the same period (2000-2013).

With the aim of being more profitable and competitive in today's market, farms have adapted using all available technologies (genetics, feeding, handling, health, etc.) in order to increase individual ewe's production. Thus, despite the important decrease in the census, the sheep milk production in Castile and Leon has increased by 82.1% in the period 2000-2013, with modest annual increases from 2000 to 2005 (3.7%/year), greater from 2005 to 2010 (10.8%/year) and stable values in recent years. To have a reference for comparison, the increase in Spain in this period (2000-2013) averaged 47.6%.

The analysis of the main annual individual milk production (L/ewe), estimated from the production and milking census, also shows an increase in recent years. Thus, in Castile and Leon, data have evolved from 111.9 in 2000 to 319.1 L/milking ewe in 2013, representing an annual average increase of 15.9 L/milking ewe in the period 2000 to 2013. In Spain, annual individual productions were close to those of Castile and Leon in 2000 (109.1 L/milking ewe), but still differed significantly in 2013 (223.9 L/milking ewe).

This higher level of production is particularly evident in an study conducted in 2014 on 158 dairy Assaf flocks from Castile and Leon (67,364 lactations; unpublished data) where average data shows 2.1 L/milking ewe and day, 201.5 days of lactation length and 420.2 L of milk production/lactation (337 L/150 day standardized lactation).

Changes in the breed basis of farms, mainly the introduction of the Assaf breed, have been at the core of the increase in the individual milk production in this region. Traditional dairy sheep production in Castile and Leon was based on local breeds (Churra and Castellana) under grazing systems; however, during the 70's, it began a massive cross absorption of indigenous ewes with rams of foreign breeds (Awassi and Assaf initially, and Lacaune more recently), changing completely the regional racial map. Thus, about 62% of the total milk production came from Assaf, Awassi and Lacaune breeds in 2000 (de la Fuente *et al.*, 2006) while it is around 90% nowadays.

Introduction of improved foreign breeds has increased the production level but has also been associated with loss of rusticity and intensification of production systems (Rancourt *et al.*, 2006), with a progressive rise in the number of flocks with permanently housed animals and indoor feeding (Mantecón *et al.*, 2009). Currently, 60-70% of farms use zero-grazing systems throughout the year, which means a great reliance on food purchased outside the farm and represents up to 70% of the total annual farm costs. System intensification involves reproductive management and reduction of lambing intervals (a single annual lambing in the past *vs* 1.2-1.3 lambing/year nowadays). In the study carried out by Mantecón *et al.* (2009), more than half of the surveyed farms possess both non-irrigated and irrigated surfaces. At that moment, the proportion of no-land farms was less than 10% while it was higher than 20% in 2014. The difficulty to improve grazing systems lies mainly on labour power limitations and its hour cost, as well as on the impossibility to use fences due very often to communal properties or high land fragmentation.

Table 1. Evolution of average sheep milk production, number of milking ewes, and annual individual milk production in Spain and Castile and Leon in 2000, 2005, 2010 and 2013

	Sheep milk production (x1,000,000 L)		Milking ewes (x1000)		Annual individual production (L/dairy ewe)	
	Spain	Castile and Leon	Spain	Castile and Leon	Spain	Castile and Leon
2000	392.0	211.6	3593	1891	109.1	111.9
2005	407.8	250.9	2850	1284	143.1	195.5
2010	565.9	386.1	3142	1431	180.1	269.9
2013	578.6	385.3	2583	1207	223.9	319.1

MAGRAMA (2014a,b).

The intensification of dairy sheep production systems has been accompanied by increasing flock size and the investment of farms to be competitive (Riveiro *et al.*, 2013). In this sense, the average milking sheep flock size in the Castile and Leon region has varied from 306 ewes/farm at the beginning of the 21st century to 467 ewes today (MAGRAMA, 2014b).

According to Riveiro *et al.* (2013), the intensive dairy sheep farming sector in Castile and Leon concentrates 60% of the ewes in typological groups composed of medium-size farms under three possible production systems: systems without land, systems associated to the production of forage and cereals (which are the most representative systems), and diversified systems that mostly sell surplus farm products. The restructuring process undergone by this sector has involved the disappearance of the smallest farms and increases in investment (in buildings, machinery and facilities) associated to the intensification and resizing (larger flock size) of many farms without increasing their land. Furthermore, even in good economic conditions, about 25% Assaf breed farms would be in danger of disappearing due to the lack of owner replacement. However, the young age of some owners or the high expectations for generational replacement detected in medium-sized farms, combined with a higher level of dynamism of investment, would point to good expectations for continuity of these dairy sheep family farming (Riveiro *et al.*, 2013).

In the present context, the profitability of dairy sheep farms relies on an increase in individual production for which animal feeding has been adapted to achieve the maximum amount of nutrients through the use of high-concentrate diets, reaching forage:concentrate ratios of down to 20:80. Dependence on external food supply makes the search for alternatives in ewe feeding a priority to develop dairy sheep production in Castile and Leon. This may also be linked to the potential to improve the quality of the ovine milk through nutritional strategies. It is probably worth noting that 98.9% of the sheep milk produced in the region goes to the dairy industry for cheese manufacturing, highlighting the relevance of the quality and technological characteristics of this final product.

III – Nutritional regulation of milk fat composition

Changes in eating habits in so-called developed countries go hand in hand with a higher incidence of chronic cardiovascular, metabolic and degenerative diseases (WHO, 2003). It is therefore a matter of urgency to improve these habits, so that diet becomes a basic pillar of prevention instead of a risk factor, and stimulate the production of foods with potentially beneficial effects on consumer's health. A major part of the interest in this type of foods lies in dairy products. Given that the concentration of a number of health-promoting bioactive lipids in milk can be improved by changes in livestock feeding, special attention has been paid in recent years to research in the area of ruminant nutrition (Chilliard *et al.*, 2007; Shingfield *et al.*, 2010).

Fatty acids (FA) such as conjugated linoleic acids (CLA), particularly the *cis*-9,*trans*-11 isomer (rumenic acid, RA), its precursor *trans*-11 18:1 (vaccenic acid, VA), oleic acid, 18:3*n*-3 (alpha-linoleic acid, ALA), butyrate or branched-chain FA may have the potential to improve long-term human health, whereas medium-chain saturated FA (12:0, 14:0 and 16:0) increase the cardiovascular disease risk when consumed in excess (Lock and Bauman, 2004; Shingfield *et al.*, 2008). It is well known that ruminant milk FA profile is related not only to intrinsic (e.g., species or breed) but also, and mainly, to extrinsic (nutrition) factors (Shingfield *et al.*, 2008; Tsiplakou *et al.*, 2008). Therefore, nutritional strategies improving milk concentrations of the former and decreasing those of the latter could make dairy products more attractive for health-conscious consumers and provide worthwhile support for breeders. However, to be used under practical farming conditions, improvements in FA composition should be proven sustainable and cost-effective and cause no negative side effects on animal performance. Unfortunately, this has not always been the case and some feeding strategies detrimentally affect dairy performance, in particular milk fat content (Bauman and Griinari, 2001; Capper *et al.*, 2007; Bichi *et al.*, 2013a), which is referred to as milk fat depression (MFD). This side effect represents a major concern for ruminant nutritionists, and constitutes a key aspect of their research.

Before going on with the nutritional regulation of milk lipids, it is important to recall that the high milk content in short- and medium-chain FA arises mostly from *de novo* synthesis in the mammary tissue. Long-chain FA (≥18 C) are uptaken from the circulating plasma lipids, while FA with 16 C derive from both sources (Moore and Christie, 1981). In addition, the lipid metabolism in the rumen is a key point in ruminant milk FA composition because, to reduce the toxic effect of dietary unsaturated FA on microbial growth, some ruminal bacteria have developed the ability to biohydrogenate them to saturated FA (Jenkins *et al.*, 2008). Incomplete biohydrogenation (BH) of those FA leads to a bewildering number of intermediate metabolites with various degrees of unsaturation and positional isomerization (Jenkins *et al.*, 2008; Toral *et al.*, 2012) that will escape the rumen and will be subsequently incorporated into milk lipids (Shingfield *et al.*, 2008).

1. Effect of basal diet composition

Forages contain relatively low amounts of lipids but are often the principal source of FA in ruminant diets (Cabiddu *et al.*, 2005; Dewhurst *et al.*, 2006). Pasture is a rich source of ALA and, compared to conserved forages and total mixed rations, results in increased levels of milk ALA, RA and VA, and decreased of 10:0 to 16:0 FA (Tsiplakou *et al.*, 2008; Gómez-Cortés *et al.*, 2009). Higher pasture quality in spring, when compared to summer, has a positive influence on milk FA composition, the physiological stage of forages being therefore of significance when making hay or silage (Cabiddu *et al.*, 2005; Dewhurst *et al.*, 2006).

Concerning the forage:concentrate ratio, its effects on milk FA profile can be mediated by changes in ruminal fermentation that will affect microbial lipid metabolism and consequently the FA profile of ruminant-derived products. Thus, feeding high concentrate diets has been shown to reduce the extent of ruminal BH and increase the concentration of desirable VA and RA in cow and ewe milk

(Gómez-Cortés *et al.*, 2011). However, they have been related in cows to a shift toward rumen and milk *trans*-10 18:1 (a FA that might exert negative effects on both animal performance and consumers' health; Bauman and Griinari, 2001; Shingfield *et al.*, 2008) at the expense of *trans*-11 18:1. Nevertheless, this shift, which has also been associated with MFD conditions, is of small magnitude in dairy sheep (Gómez-Cortés *et al.*, 2009, 2011).

Another negative effect commonly observed in cows fed low forage:concentrate diets is that they lead to decreases in milk fat content. Yet, in high production dairy ewes, this has been largely attributed to their positive effect on total milk yield (i.e., to a dilution effect; Pulina *et al.*, 2006; Gómez-Cortés *et al.*, 2011).

Overall, these observations highlight the need for an integrated vision of the whole issue before establishing recommendations for modulating milk FA composition.

2. Effect of diet supplementation with plant lipids

For decades, dietary lipid supplementation has been used to meet the energy requirements in unfavourable areas and in high productive lactating ruminants (Gargouri *et al.*, 2006). However, nowadays, emphasis is laid on its effect on milk FA profile.

For example, when the goal is to enhance the CLA content of milk fat, diet supplementation with vegetable grain oils and oilseeds rich in linoleic acid (e.g., sunflower or soybean) or ALA (e.g., linseed or rapeseed), which provide the substrates for the production of VA or RA in the rumen, has proved very effective (Toral *et al.*, 2010; Manso *et al.*, 2011; Nudda *et al.*, 2015). Furthermore, this supplementation decreases milk saturated FA, in particular 12:0, 14:0 and 16:0 (Mele *et al.*, 2006; Hervás *et al.*, 2008; Bodas *et al.*, 2010). These changes in milk FA profile remain broadly stable during cheese manufacturing processes and do not negatively affect its sensorial and organoleptic characteristics (e.g., Bodas *et al.*, 2010; Mughetti *et al.*, 2012).

Nonetheless, despite the positive effects of feeding vegetable lipids on milk FA profile, in some cases, quite high concentrations of *trans*-10 18:1 are observed (Hervás *et al.*, 2008; Gómez-Cortés *et al.*, 2011). However, despite the rise, relatively high levels of this 18:1 isomer can still be accompanied by notable increases in VA and RA in ovine milk, in contrast to observations in cows (Chilliard *et al.*, 2007; Hervás *et al.*, 2008; Gómez-Cortés *et al.*, 2011).

Another potential side effect of plant lipid supplementation is a decrease in milk protein content, which is of paramount importance in sheep and goats because their milk is meanly processed into cheese (Caja and Bocquier, 2000; Bodas *et al.*, 2010). However, the extent of this reduction is relatively minor (in general, <7%) and often derives from increased milk production, with milk protein yield being rarely affected (Mele *et al.*, 2006; Toral *et al.*, 2010; Nudda *et al.*, 2015).

Remarkably, the addition of plant lipids to dairy ewe diets, even at relatively high doses, does not cause MFD in this species (Pulina *et al.*, 2006; Gómez-Cortés *et al.*, 2011), in marked contrast with the situation in dairy cows (Shingfield *et al.*, 2010).

3. Effect of diet supplementation with marine lipids

Ruminant dairy products are poor sources of long-chain *n*-3 polyunsaturated FA, such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), in the human diet (Lock and Bauman, 2004). For this reason, a number of studies attempted to enrich their content in milk fat through the supplementation with fish oil and marine algae (Reynolds *et al.*, 2006; Chilliard *et al.*, 2007; Toral *et al.*, 2010), about which it is probably worth mentioning that leads to dairy products with satisfactory flavour (Jones *et al.*, 2005). Marine lipids are rich in EPA and DHA but their transfer efficiency from diet into milk is hindered by their extensive BH in the rumen and preferential incorporation into plasma lipid fractions poorly used by the mammary gland (Lock and Bauman, 2004). Thus, the reasons for the relatively higher transfer rates observed in sheep (4-18%; Reynolds *et al.*, 2006; Bichi *et al.*, 2013a; Tsiplakou and Zervas, 2013) than in cows (2-5%; Chilliard *et al.*, 2007) would merit further investigation.

Interestingly, research on the inclusion of marine lipids in the diet has more often been directed toward their use as modulators of rumen lipid metabolism, with the aim of improving CLA content in meat and milk, as a result of their inhibitory effect on the final BH step (Huws *et al.*, 2011; Toral *et al.*, 2012). In this regard, studies in dairy sheep have shown that complementary supplementation with marine lipids and linoleic-rich oils (as a substrate for VA formation in the rumen) can further increase the content of RA in milk fat (Reynolds *et al.*, 2006; Toral *et al.*, 2010; Bichi *et al.*, 2013a). However, inhibition of the last step of BH is often accompanied by alterations in other metabolic pathways, in particular by increased *trans*-10 18:1 formation (Shingfield and Griinari, 2007; Toral *et al.*, 2012), which might be associated to negative side effects on animal performance. Thus, conversely to what happens when plant oils are included in the diet, addition of marine lipids is usually linked to MFD in dairy ewes (e.g., Capper *et al.*, 2007; Bichi *et al.*, 2013a). However, our knowledge of the mechanisms involved in the low-milk fat syndrome due to this type of supplements is still very scarce, especially in the ovine.

Several theories explaining the origin of MFD have been proposed and subsequently found inadequate or incomplete (Bauman and Griinari, 2001; Shingfield and Griinari, 2007). The BH theory suggested by Bauman and Griinari (2001) appears to be the most robust and establishes that MFD relates to an inhibition of mammary lipogenesis by specific BH intermediates that are produced under certain feeding conditions that alter rumen function. *Trans*-10,*cis*-12 CLA was the first BH intermediate shown unequivocally to exert anti-lipogenic effects but some studies have reported that other C18 FA, such as *cis*-10,*trans*-12 and *trans*-9,*cis*-11 CLA isomers, and probably *trans*-10 18:1, might also inhibit milk fat synthesis (Shingfield *et al.*, 2010). However, studies on the addition of marine lipids provided evidence that MFD can also occur in the absence of or after minor increases in milk *trans*-10,*cis*-12 CLA content (Shingfield and Griinari, 2007; Toral *et al.*, 2010; Bichi *et al.*, 2013a), which suggested that other BH intermediates or mechanisms may be involved.

In consequence, Shingfield and Griinari (2007) proposed an extension of the BH theory based on changes in the availability of preformed long-chain FA. Thus, a shortage of 18:0 for *cis*-9 18:1 synthesis in the mammary gland, together with an increase in *trans* FA originating in the rumen (with higher melting points than their equivalent *cis*-isomers), would have a negative impact on the maintenance of milk fat fluidity and, consequently, on the rate of milk fat secretion, causing MFD (Chilliard *et al.*, 2007; Shingfield and Griinari, 2007). However, recent findings from dedicated experiments conducted by our team to test this hypothesis in dairy ewes does not seem to point to the decrease in 18:0 availability as a major component of this type of MFD. Therefore, it remains possible that specific intermediates formed in the BH of long-chain *n*-3 polyunsaturated FA may also contribute to MFD in animals receiving marine lipids (Shingfield and Griinari, 2007), which merits further investigation. In line with this, reporting detailed descriptions of FA profiles, including minor metabolites, is highly recommended because it may provide valuable information for identifying new candidate inhibitors.

4. Effect of diet supplementation with tannins

The ability of tannins to interfere with ruminal BH and modulate the FA profile of ruminant-derived products is highly controversial (Vasta *et al.*, 2009; Toral *et al.*, 2013; Buccioni *et al.*, 2015). Some *in vitro* studies have shown that tannins can increase the rumen accumulation of RA and VA by impairing microbial BH in general and the conversion of 18:1 to 18:0 in particular (Vasta *et al.*, 2009; Minieri *et al.*, 2014; Carreño *et al.*, 2015). However, this has rarely been validated *in vivo* (Toral *et al.*, 2011, 2013; Buccioni *et al.*, 2015) and most results suggest that, due to the high dose required in many cases, their efficacy would be rather limited under practical farm conditions, especially over the long-term.

On the other hand, given the great diversity in the structural features and reactivity of different tannins, the controversy is probably related to the type of tannin and the dosage (Toral *et al.*, 2013; Buccioni *et al.*, 2015; Carreño *et al.*, 2015), which encourages further research to investigate the potential use of these phenolic compounds to favourably modify ruminal BH and milk fat composition.

5. New approaches to study the nutritional regulation of lipid metabolism

This little section intents to highlight two areas for future investigation to provide an insight into causes explaining variations in ovine milk fat yield and composition.

Rumen microbiota: As the effect of nutrition on the milk lipid profile is brought about by changes in rumen microbiota, it is of the utmost importance to determine which populations are specifically involved (Jenkins *et al.*, 2008). In this regard, modern molecular biology techniques, such as pyrosequencing, have revealed that first explanations of BH are rather inconsistent (Huws *et al.*, 2011; Castro-Carrera *et al.*, 2014) and strains potentially involved in *in vitro* ruminal BH have no major role in the *in vivo* process. It seems most likely that other as yet uncultured bacteria play a relevant role in the ruminal metabolism of FA (Huws *et al.*, 2011; Toral *et al.*, 2012; Castro-Carrera *et al.*, 2014), which makes further in-depth research necessary.

Nutrigenomics: Nutrigenomics is a promising and recent discipline that studies the impact of nutrition on physiological processes by altering gene expression (Bauman *et al.*, 2011) and offers the potential to improve our knowledge of the interaction between nutrients and milk fat yield and composition. In our case, there is increasing evidence that several FA modify the expression of genes involved in mammary lipogenesis pathways. Thus, for instance, the antilipogenic effect of *trans*-10,*cis*-12 CLA seems to be mediated by the repression of genes related to *de novo* FA synthesis (e.g., *ACACA* and *FASN*) and FA uptake (e.g., *LPL*) in the mammary tissue (Bauman *et al.*, 2011). Furthermore, the coordinated decrease in the mRNA abundance of some key genes (e.g., *ACACA*, *LPL*, *GPAT*, *AGPAT* or *SCD1*) during MFD suggests the involvement of transcription factors that would up- or down-regulate genes taking part in the same metabolic pathway (e.g., *SREBF1, PPARG* or *INSIG1*; Bernard *et al.*, 2008; Bauman *et al.*, 2011).

However, most studies on the nutritional regulation of molecular mechanisms underlying milk fat secretion have been conducted *in vitro* or using rodent models, and additional research *in vivo* would be strictly necessary to unravel their role in mammary lipogenesis in ruminants (Bernard *et al.*, 2008; Bichi *et al.*, 2013b). Furthermore, although they were initially based on candidate gene approaches, which only focus on a few genes, the development of transcriptomic tools enables now the detection of changes in the expression of thousands of genes (Wickramasinghe *et al.*, 2014). This will probably provide a more comprehensive insight into the role of specific metabolites on milk fat synthesis in ruminant species (Shingfield *et al.*, 2010; Bauman *et al.*, 2011).

IV – Dairy sheep production systems and milk fat composition

In closing, the economic importance of ovine milk production in Spain and particularly in the region of Castile and Leon, together with changes caused by moving away from pasture-based diets to systems including no grazing and low forage:concentrate ratios, open many opportunities for the development of feeding strategies to further improve the nutritional quality of sheep milk, and particularly milk fat. Modulation of the milk FA composition towards a profile that it is more attractive to health-conscious consumers may provide worthwhile support to dairy sheep breeders in rural areas.

Diet supplementation with plant oils has proven very effective to this aim. However, supplementation with marine lipids causes MFD, a side effect precluding their implementation under farm conditions, and obliges ruminant nutritionists to further investigate the whole process. Eventually, it is expected that this will lead to establishing the framework necessary to be able to modify the plasticity of ovine milk fat without impairing animal performance.

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