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Modifying milk and meat fat quality through feed changes

T. Manso*, B. Gallardo, C. Guerra-Rivas

Área de Producción Animal, Dpto. Ciencias Agroforestales, E.T.S. Ingenierías Agrarias, Universidad de Valladolid, Avda Madrid s/n. 34004 Palencia, Spain

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ABSTRACT

Feeding is the major factor affecting the quality of sheep products (milk and meat). The feeding strategies useful for increasing the levels of healthy fatty acids (FA), such as conjugated linoleic acid and omega-3 FA, in milk and meat in the human diet are reported. The addition of supplements rich in oils and the level and quality of forage seem to be valuable tools for influencing the fatty acid composition of milk and lamb meat. The use of alternative feed resources such as grape pomace, rich in phenolic compounds, in sheep and lamb diets and their effects on meat FA composition and oxidative stability are also discussed.

1. Introduction

Sheep products (milk and meat) are considered to be high-quality foods because of their high nutritive value and their organoleptic characteristics. However, although they are traditional products strongly established in society, consumption of them has sometimes been questioned, partly because of the negative image that the consumer has of the quantity and composition of the fat that they contain. Fat in sheep milk and meat has a high content of saturated fatty acids and low content of polyunsaturated fatty acids and has been related to the incidence of cardiovascular diseases.

However, this negative idea of ruminant fat has been changing in recent years because it has been found that some saturated fatty acids are atherogenic only if they are ingested in excessive quantities and that it contains some unsaturated fatty acids that are potentially beneficial for human health (Parodi, 2009). The ruminant fatty acids that have bioactive properties include unsaturated fatty acids such as vaccenic acid (VA), conjugated linoleic acid (CLA), particularly its most abundant isomer, known as rumenic acid (RA, *cis*-9 *trans* 11CLA), and the omega-3 fatty acids (n-3 PUFAs), so there is great interest in increasing their levels in milk and meat (Lock and Bauman, 2004; Raes et al., 2004).

Numerous biological, antic-carcinogenic, anti-obesity and immune system enhancing properties, among others, have been attributed to CLA, particularly to *cis*-9 *trans*-11CLA. The omega-3 fatty acids, which include α-linolenic acid (ALA, C18:3 n3), 22:6 n-3 (DHA) and 20:5 n-3 (EPA), have been related mainly to reductions in the risk of cardiovascular diseases, type-2 diabetes, cancer and neurological alterations (Lock and Bauman, 2004).

Feeding is the major factor affecting the quality of sheep products. Consequently, nutritive strategies have been used most to modify the composition of fat and adapt it to consumer demands. The incorporation of fat in rations and the possibilities offered by microbial biohydrogenation in the rumen have been indicated as effective methods for increasing levels of functional fatty acids in milk and meat. These feeding changes must be made carefully because they sometimes lead to increases in *trans*-10 fatty acids associated with negative effects for human health (Shingfield et al., 2008).

An increase in the degree of unsaturation of fat also makes it more susceptible to oxidation and therefore shortens its shelf life. One of the strategies most commonly employed to prevent lipid oxidation of meat is the use of antioxidants in rations.

Vitamin E has been widely used in animal nutrition in order to preserve meat, but it have been questioned because of their synthetic origin and its limited bioefficiency when n-3 PUFA intake is too high. The increasingly demanding consumer preference for natural products and health benefits has intensified the search for alternative methods to retard lipid oxidation of meat. Supplementation of the diet with phenolic substances has been suggested as a feeding strategy to increase the functional characteristics of meat and milk of small ruminants, and also to improve the oxidative stability and colour of meat during storage (Nieto et al., 2010; Vasta and Luciano, 2011).

* Corresponding author.
E-mail addresses: tmanso@agro.uva.es, tmansoal@gmail.com (T. Manso).

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Grape pomace is a winemaking by-product that has a high content of phenolic compounds with a high antioxidant capacity that can act on the quality of the products obtained (Makris et al., 2007; Spanghero et al., 2009). Therefore the use of this by-product is being studied as an interesting low-cost feed alternative to decrease the unhealthy fatty acids and to increase the functional fatty acids of fat and the oxidative stability of meat.

With these points in mind, in this paper we present some of the nutritional strategies based on the use of fat and aimed at increasing the level of fatty acids with bioactive effects in sheep milk and meat. Some of the results of our research group concerning the use of grape pomace in sheep rations as a possible strategy to improve meat and milk fatty acid profile and as an alternative to other antioxidants of synthetic origin that favour the oxidative stability of animal products are also presented.

2. Metabolism of lipids in the rumen

Fat in milk and meat differs considerably from the fat consumed by ruminants because the fatty acids that leave the rumen are different from those that are present in the diet. This is a consequence of the processes of digestion and metabolism of fat that take place in the rumen, in the mammary gland and other tissues.

Metabolism of fat in the rumen includes its hydrolysis and subsequent biohydrogenation. As the major polyunsaturated fatty acids present in food consumed by ruminants are linoleic acid (*cis*-9 *cis*-12C18:2) and α-linolenic acid (ALA, *cis*-9 *cis*-12 *cis*-15C18:3 n-3), their biohidrogenation routes are the most studied and their intermediate products the best identified.

As shown in Fig. 1, during the process of biohydrogenation of linoleic acid to stearic acid in the rumen various intermediate fatty acids are generated, such as conjugated linoleic acid (CLA), whose major isomer is rumenic acid (RA, *cis*-9 *trans*-11CLA), and vaccenic acid (VA, *trans*-11C18:1) (Shingfield et al., 2010). Biohydrogenation of α-linolenic acid also involves the formation of VA; however, although the conversion of VA to stearic acid is identical to linoleic acid biohydrogenation, what it generates is not RA but different intermediates. RA and VA have been associated with beneficial effects on the health, and therefore there is great interest in increasing their levels in milk.

One of the most commonly employed strategies for increasing the levels of VA and RA in meat and milk has been to increase their levels in the rumen by the use of fats rich in linoleic acid and α-linolenic acid, such as vegetable oils and fats.

However, rations low in fibre and with an excess of rapidly fermentable starch, as in the case of the concentrates and rations used in intensive systems, or with a small particle size, reduce ruminal pH and have a negative effect on cellulolytic bacteria, which are mainly responsible for the efficiency of biohydrogenation of linoleic acid and/or produce alternative routes (see Fig. 1) with increases in other trans fatty acids such as *trans*-10 *cis*-12C18:2 and *trans*-10C18:1. These fatty acids have been associated with a greater risk of suffering coronary diseases and sometimes with negative effects on the productive yield of dairy animals associated with milk fat depression syndrome, and therefore any feeding strategy should avoid the formation of these *trans*-10 fatty acids.

The ruminal metabolism of other omega-3 fatty acids that are less frequent in ruminant diets, such as 20:5 n-3 (EPA) and 22:6 n-3 (DHA), is less well known. Some authors (Abughazaleh and Jenkins, 2004) have indicated that EPA and DHA are totally biohydrogenated in the rumen, and, although the mechanisms responsible and the intermediate products of their biohydrogenation are not known, this might explain the low transfer of EPA and DHA from dietary origin to milk and meat. Moreover, it has been verified that, as with linoleic acid, these long-chain fatty acids contribute to the accumulation of VA in the rumen owing to the inhibition that they produce in the reduction of *trans*-11C18:1 to C18:0. Therefore the incorporation of very long chain fatty acids in rations has also been proposed as a strategy to increase the levels of RA in milk from VA (Lock and Bauman, 2004).

However, the composition of the lipids in milk and meat does not depend solely on the fatty acids absorbed in the intestine, and there are descriptions of transformations of these fatty acids in the mammary gland and in tissues as a result of a complex enzymatic system of desaturases and elongases. Mammary cells and muscle tissue cells have a powerful Δ^9-desaturase activity. In fact, it has been estimated that 64 and 97% of the *cis*-9 *trans*-11CLA in milk comes from endogenous synthesis from vaccenic acid in the mammary gland (Bauman et al., 2003). Therefore an increase in Δ^9-desaturase activity in tissues has also been proposed as a strategy to increase the levels of RA in milk from VA (Lock and Bauman, 2004).

In view of the foregoing, various alternatives for feeding sheep have been proposed in order to modify the fatty acid profile of milk and meat in accordance with current trends.

3. Feeding strategies to modify the fatty acid profile of sheep milk

Of the feeding strategies employed, supplementation with fat and the consumption of a high-quality forage ration that favours a ruminal environment suitable for ruminal biohydrogenation are the alternatives that have been most studied and that have produced the most favourable results to increase the levels of fatty acids with beneficial effects on human health (RA, VA and n-3 PUFAs) in milk. Moreover, cheese and dairy products reflect the fatty acid profile of the milk used to make them, so any strategy for improving milk quality is applicable to the dairy products that are obtained (Nudda et al., 2005; Bodas et al., 2010).

3.1. Supplementation with fat

The effect of fat on the fatty acid profile of milk depends on its composition and on the form in which it is incorporated in rations. Fat can be added in the form of oils (bare oils), whole seeds and/or plants and processed seeds and also fat could be protected from ruminal biohydrogenation, calcium soap being the form of protection most commonly used.

Fig. 2 shows the effects of various commercially available fat sources tested by our research group on the levels of rumenic acid, omega-3 fatty acids (n-3 PUFAs) and very long chain omega-3 fatty acids (n-3 VLCFAs) in milk.

Free oils are the most accessible sources of fat for the microorganisms responsible for biohydrogenation in the rumen, and they can increase the contents of rumenic acid, vaccenic acid and polyunsaturated fatty acids in milk. In a study conducted by Bodas et al. (2010) on dairy sheep, the results of which are presented in Fig. 2, which compared the effect of rations that differed only in the type of oil incorporated (palm, olive, soy or linseed), it was found that, with an oil intake of 70 g per day, the oil with the highest linoleic acid content (soybean oil) was the one that was most effective in increasing the levels of RA, and linseed oil, which is high in α-linolenic acid (ALA, C18:3 n-3), not only increased the levels of ALA but also generated considerable increases in RA in the milk, although not as great as those produced by soybean oil. In the case of soybean oil, RA is the result of processes of biohydrogenation of linoleic acid in the rumen and is also generated by desaturation of VA in the mammary gland, whereas in the case of α-linolenic acid, which is predominant in linseed oil, RA is only generated in the mammary gland, from VA, as Fig. 1 shows.