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Integration of extruded linseed into dairy sheep diets: Effects on milk composition and quality and sensorial properties of Pecorino cheese

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ABSTRACT

The objective of this work was to study the influence of including extruded linseed at different supplementation levels in dairy sheep feed on the chemical, organoleptic and nutritional quality of milk and Pecorino cheese. Three hundred and thirty multiparous Sarda ewes, three weeks before their expected date of parturition, were divided into three groups of 110 animals each. Ewes were fed one of three different concentrates: a control concentrate (CTR) without linseed and two concentrates supplemented with different levels (100 and 200 g/kg as fed; EL-10 and EL-20, respectively) of extruded linseed. The experimental concentrates were fed to the ewes during late pregnancy (400 g per head per day) and early lactation (60 days after parturition; 800 g per head per day). All animals had unlimited access to pasture and hay. Milk production was recorded, and milk samples were collected for the analysis of chemical composition and clotting properties. Cheeses were made with bulk milk from the three groups using a traditional cheese-making technique. After 60 days of ripening, the chemical composition and organoleptic properties of the cheeses were analysed using a Panel test. Milk yield and all major milk components, except milk fat yield, were both linearly ($0.01<P<0.001$) and quadratically ($0.05<P<0.001$) related to the level of linseed in the diet. Except for the urea content, which decreased at a decreasing rate (linear $P<0.001$ and quadratic $P<0.05$), milk components increased at an increased rate with increasing EL supplementation. The fatty acid composition of milk and cheese was affected by dietary linseed supplementation. Milk fat of groups receiving feed that included extruded linseed showed higher levels of monounsaturated fatty acids and lower levels of saturated fatty acids. Linseed administration linearly increased milk polyunsaturated fatty acid content ($P<0.001$). The C18:3 n-3 milk content increased by 36 and 87% ($P<0.001$) for the EL-10 and EL-20 groups, respectively. The higher content of total n-3 fatty acids in milk caused a linear decrease of the n-6/n-3 fatty acid ratio in the EL groups ($P<0.001$). Dietary treatments affected the chemical composition of cheese; the increase in the level of extruded linseed was negatively correlated with the moisture content of cheeses. Modifications to the fatty acid profiles of the cheeses were similar to those observed for milk. Sensory properties of cheese were not negatively affected by dietary treatments. Cheeses produced from groups fed diets with added linseed had higher scores for overall and ripe cheese flavour

Abbreviations: ADF, acid detergent fibre; ALA, alpha-linolenic acid; CLA, conjugated linoleic acid; CTR, control concentrate with no added extruded linseed; DHA, docosaesaenoic acid; DM, dry matter; EL, extruded linseed; EL-10, concentrate with 100 g/kg of extruded linseed; EL-20, concentrate with 200 g/kg of extruded linseed; EPA, eicosapentaenoic acid; FA, fatty acids; NDF, neutral detergent fibre; PCA, principal component analysis; PCs, principal components; PUFA, polyunsaturated fatty acids.

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and texture properties. Treated cheeses had no off-flavours and were characterised by a more marked grainy texture. The present work indicated that a concentrate containing 100 g/kg of extruded linseed can be used to increase the overall quality of Pecorino cheese without negative effects on its typical sensorial and organoleptic characteristics or on the productive performance of the animals.

1. Introduction

Linseed (*Linum usitatissimum*) is a rich source of C18:3 n-3, which makes up 180 g/kg of the total seed weight and 530 g/kg of the total fatty acids (Mustafa et al., 2003).

The benefits of linseed administration on the acidic composition of animal products are well known (Luna et al., 2008, 2005; Zhang et al., 2006a,b). Sheep and cows fed with extruded linseed (EL) show increased milk polyunsaturated fatty acids (PUFA) content, particularly n-3 fatty acids (FA), *trans*-11 C18:1 FA, and total conjugated linoleic acid (CLA) concentrations, and reduced ratios of n-6 to n-3 FA (Mele et al., 2011; Fuentes et al., 2008).

The enrichment of dairy products with n-3 FA could potentially result in niche marketing opportunities for milk and cheese producers. European Union regulations (1924/2006 CE and 116/2010 CE) claim that a food can be considered to be a source of omega-3 fatty acids if it contains at least 0.30 g of 18:3 n-3 per 100 g or at least a total of 40 mg of eicosapentaenoic acid and docosahexaenoic acid per 100 g.

Oilseed enrichment of sheep diet could lead to the development of natural and consumer-acceptable systems and the production of high quality dairy foods with enhanced healthful properties. However, the higher costs that characterise the products enriched with healthy fatty acids must also be justified by sensorial qualities that are equal or greater than those of traditional products.

Few studies have investigated the effects of linseed supplementation on the organoleptic properties of sheep cheese. Previous descriptive sensory analyses of dairy products high in polyunsaturated fatty acids did not provide definitive results. However, extensive trials on the modification of fat composition indicate that increasing the concentration of unsaturated fatty acids promotes undesirable processes of lipolysis and oxidation, leading to degradation of fat and unacceptable changes in the colour and flavour of milk and dairy products (Campbell et al., 2003).

Pecorino cheese is the most important sheep cheese in Italy. To our knowledge, there are no published studies examining the effects of dietary supplementation with EL on the sensorial properties of this milk product. The objective of the present study was to evaluate the effects of different levels of linseed supplementation in the diet on the chemical composition of milk and on the chemical and organoleptic properties of Pecorino cheese.

2. Materials and methods

2.1. Animals, experimental design, and diets

The present study was carried out in accordance with the guidelines of the Animal Welfare Committee at the University of Perugia, Italy.

The experiment was carried out using 330 Sardinian pluriparous sheep. All ewes were housed in a stable from 4.00 pm to 8.00 am and had unlimited access to pasture for the rest of the day.

Three weeks before the expected date of parturition, the ewes were randomly divided into three groups of equal size, balanced for body weight (45.1 ± 1.2 kg) and body condition score (2.29 ± 0.02; Russell et al., 1969), and fed isoenergetic and isonitrogenous concentrates. Three concentrates were formulated: a control concentrate (CTR), without EL, and two experimental concentrates which contained, respectively, 100 g/kg (EL-10) and 200 g/kg (EL-20) of ground and EL. Extrusion of linseed, ground to pass a 4 mm screen, was performed in a single screw extruder (Berga, Treviso, Italy) with a throughput of 1600 kg/h (barrel length: 3.2 m; die diameter: 7 mm; screw speed: 300 rpm; temperature at the end of the barrel: 130–138 °C; duration: 1 min). After extrusion the product was dried in a counter flow cooler for 12 min. Experimental diets were administered from three weeks before the expected date of parturition to 60 days *post partum*. Animals were fed 400 to 800 g per head per day of concentrate (during late pregnancy and early lactation, respectively), which was administered in two equal portions during milking. Alfalfa hay was provided in box feeders *ad libitum*. Concentrate represented 253 and 290 g/kg of total estimated dry matter (DM) intake during late pregnancy and early lactation, respectively.

After lamb weaning, at 40 days of age, ewes were machine-milked twice a day. From days 40 to 60, milk yield was recorded daily. Pooled morning and evening milk samples from each group were collected every two days in order to analyse the chemical composition and somatic cell count by the infrared method, using MilkoScan 4000 (Foss Electric, Hillerød, Denmark; Biggs, 1978), and to analyse clotting properties such as renneting time, curd consistency and rate of firming (Zannoni and Annibaldi, 1981; Annibaldi et al., 1977). Milk samples were also stored at −20 °C for lipid profile analysis.

A traditional cheese-making technique was used to make Pecorino cheese from bulk milk samples collected from the three groups at the end of the experimental period. Briefly, 50 L of raw milk from each batch was heated to 38 °C, and liquid calf rennet was added to curdle the milk. After the milk had clotted (after approximately 18 min), the curd was cut to the