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Formation of volatile compounds in kefir made of goat and sheep milk with high polyunsaturated fatty acid content

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ABSTRACT

This article explored the formation of volatile compounds during the production of kefir from goat and sheep milks with high polyunsaturated fatty acids (PUFA) as a result of feeding animals forage supplemented with maize dried distillers grains with solubles (DDGS). The increased PUFA content of the goat and sheep milks resulted in significant changes to the fermentation process. In particular, apart from an increase in the time taken to ferment sheep milk, fermentation yielded less 2,3-butanedione. The highest quantities of this compound were assayed in kefir produced from goat milk with an increased content of PUFA. An increase of PUFA significantly elevated ethanal synthesis during lactose-alcohol fermentation of sheep milk. Neither the origin of milk (sheep or goat) nor the level of PUFA had any statistical effect on the amount of ethanal assayed during the fermentation of milk and within the finished product. The proportion of L(+)-lactic acid was higher in kefirs produced using goat milk compared with sheep milk and did not depend on the content of PUFA in milk fat. The content of PUFA had a significant effect on the aroma profile of the resulting kefirs. An increase in PUFA content resulted in the loss of whey aroma in goat milk kefirs and the animal odor in sheep milk kefirs, and a creamy aroma became more prevalent in kefirs made from sheep milk.
Key words: goat and sheep milk, fermentation, kefir, polyunsaturated fatty acids, volatile compounds

INTRODUCTION

The promotion of a healthy human nutrition model requires the search for optimal methods to produce salutogenic (i.e., supporting health) food. Modern consumers are aware of product quality and contents, and consumers increasingly look for "functional foods"—foods containing nutrients that, in addition to their traditional functions, have compounds favorable for health (Duggan et al., 2002).

Ruminant milk, especially ovine and caprine milk, is a rich source of biologically active isomers of oleic acid and conjugated linoleic acid (Bergamo et al., 2003; Haenlein, 2004; Park et al., 2007). Two CLA isomers are considered biologically active agents that have beneficial effects on human health: *cis*-9,*trans*-11, and *trans*-10,*cis*-12 C18:2.

The main source of biologically active compounds derived from fat present in the milk of ruminants is the unsaturated fatty acids. These compounds are a substrate for the biohydrogenation process as well as for de novo synthesis of fatty acids in the mammary gland (Dewhurst et al., 2001; Chilliard et al., 2007). An increased supply of these compounds in the feed ration intensifies biohydrogenation. Such intensification leads to the creation of a greater number of substrates for de novo synthesis (Kim et al., 2002).

Feed components with the potential to stimulate biohydrogenation and de novo synthesis are used in the production process of biofuels, such as oilseed meal (Anderson et al., 2006; Kleinschmit et al., 2007; Janicek et al., 2008). Distillers solubles are obtained during production of ethanol. Due to production scope, content, and nutritional qualities, distillers solubles are gaining importance in livestock animal feed. The most frequently produced are dried full solubles containing postfermentation solid and liquid fractions. These solubles are referred to as distillers dried grains with solubles (**DDGS**; Schauer et al., 2008).

Much research has been devoted to DDGS applications in cattle feed, mainly dairy cattle. However, less has been published on using DDGS in feed for small ruminants. The few publications that are available on this subject are mainly about feed for fattening sheep

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(Estrada-Angulo et al., 2008); there remains a lack of available literature on using DDGS in dairy goat feed.

The sensory properties of milk are affected by concentrations of individual volatile organic compounds (Coppa et al., 2011; Villeneuve et al., 2013). In relation to organoleptic properties, unsaturated FA could be used as precursors of lactones found in milk (Urbach, 1990). Increasing the PUFA concentration in milk fat could also increase the concentration of PUFA oxidation and degradation products. In this regard, β-oxidation at the double bonds can lead to straight-chain aldehydes and ketones, which may be converted to the corresponding alcohols under reducing conditions (Nursten, 1997). Moreover, concentrations of major FA can influence the physical properties of milk fat in relation to the individual melting point of these FA (Couvreur et al., 2006; Hurtaud et al., 2007).

In the development of dairy products such as kefir, the following play a crucial role: chemical composition of the processed milk, type and quantity of starter cultures, temperature- and time-related conditions of fermentation, and amount of chilling. Substrates of the components that form the aroma of fermented products can be proteins, fats, and especially sugars. About 100 different chemical compounds constituting the aroma of dairy products have already been isolated. Only a few of these compounds, however, are responsible for the typical and expected aroma of a particular product.

Few scientific publications have reported the profile of compounds constituting the aroma of fermented milk. The majority of the research described is related to products that have undergone a long ripening process (e.g., rennet cheeses). In long-ripening products, a long production process is needed (i.e., fermentation) as well as further ripening and a higher concentration of volatile compounds. Because of this long process, it is easier to investigate the profile of compounds in long-ripening products than in fermented milk. Most researchers involved in fermented milk studies believe the main components of fermented milk aroma are 2,3-butanodiol and ethanal and, to a lesser extent, formic acid, acetic acid, propanoic acid, propionic acid, butyric acid, and carbonylic compounds (acetone, acetoin). The flavor-aromatic desirability of fermented milk depends not only on the content of these compounds but also their relative proportions. According to the parameters of the fermentation processes, the following compounds evolve: butyric acid, isovaleric acid, capronic acid, and acetone. The enzymatic activity of pH-dependent bacteria affects the quantity of the synthesized alcohols. As the milk pH is lowered by fermentation, the enzyme activities of alcohol dehydrogenase, glutamic dehydrogenase, and α-keto-acid dehydrogenase of the lactic bacteria decrease (Helinck et al., 2004).

Bendall (2001) used gas chromatography-olfactometry to examine the effects of cows fed with feed containing 25% maize silage, 19.5% grass silage, 7.5% hay, 10% whole cottonseed, and 38% concentrate, which included maize grain, barley, soybean, fishmeal, vegetable oil, protected fat, corn gluten, molasses, minerals, and vitamins. He identified more than 71 chemical compounds associated with the aroma of the obtained milk. He also noted that aroma compounds with the highest nasal impact frequency (NIF) values can be divided into 5 chemical classes: nitrogen heterocycles, linolenic acid oxidation products, γ-lactones, phenolics, and phytol derivatives. Linolenic acid oxidation products (particularly octa-1,cis-5-dien-3-one, hept-cis-4-enal, and hex-cis-3-enal) were more important in nasal impact frequency profiles than linoleic acid oxidation products (oct-1-en-3-one and non-1-en-3-one). So far, no studies have been conducted to assess the aroma profile of sheep and goat milks containing a higher content of polyene acids. The few studies carried out to date have focused on raw and pasteurized drinking milk (Cais-Sokolińska et al., 2011). It was concluded that a higher concentration of PUFA in raw milk affects the milk aroma and that aroma changes after thermal treatment (Cais-Sokolińska et al., 2011). No studies have been done on the influence of further technological activities, including fermentation, on the profile changes of volatile compounds of small ruminant milk.

Based on these results, we hypothesized that the synthesis of aromagenic compounds can be correlated with the volume of precursors in the processed milk; that is, the availability of pyruvate resulting from citrate fermentation, whose quantity in milk depends on the way animals are fed and on the activity of the citrate permease created by lactic acid bacteria (**LAB**). As result of the enzymatic activity and thermal treatment of milk, other components of milk can be created; that is, butyric acid, hexanoic acid, caprylic acids, and ketones. They are product of the decomposition of FA and AA released from proteins during milk fermentation (Beshkova et al., 2003).

The aims of this study were (1) to define the influence of the DDGS feed additive on FA profiles, especially on the concentration of polyene FA in sheep and goat milks; (2) to assess the volume of aroma substrates and compounds stimulating the metabolic activity of LAB in processed sheep and goat milk (the milk had a higher PUFA concentration); the changes of the milk acid content and the degree of attenuation of lactose were taken into consideration in the assessment; and