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Milk volatile organic compounds and fatty acid profile in cows fed timothy as hay, pasture, or silage

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ABSTRACT

Nutrient composition and organoleptic properties of milk can be influenced by cow diets. The objective of this study was to evaluate the forage type effects on volatile organic compounds, fatty acid (FA) profile, and organoleptic properties of milk. Timothy grass was fed as hay, pasture, or silage during a period of 27 d to a group of 21 cows in a complete block design based on days in milk. Each cow also received 7.2 kg/d of a concentrate mix to meet their nutrient requirements. Forage dry matter intake averaged 13.9 kg/d and was not different among treatments. Milk yield was higher for cows fed pasture, intermediate for cows fed silage, and lowest for cows fed hay. However, milk fat content was higher for cows fed hay and silage, compared with cows fed pasture. As a result, fat-corrected milk and fat yield were not different among treatments. Increasing the supply of dietary *cis*-9,*cis*-12 18:2 (linoleic acid) and *cis*-9,*cis*-12,*cis*-15 18:3 (α-linolenic acid) when feeding pasture enhanced the concentration of these 2 essential FA in milk fat compared with feeding hay or silage. Moreover, the ratio of 16:0 (palmitic acid) to *cis*-9 18:1 (oleic acid), which is closely related to the melting properties of milk fat, was lower in milk from cows on pasture than in milk from cows fed hay or silage. Cows fed hay produced milk with higher levels of several free FA and γ-lactones, but less pentanal and 1-pentanol. More dimethyl sulfone and toluene were found in milk of cows on pasture. Cows fed silage produced milk with higher levels of acetone, 2-butanone, and α-pinene. Results from a sensory evaluation showed that panelists could not detect a difference in flavor between milk from cows fed hay compared with silage. However, a significant number of assessors perceived a difference between milk from cows fed hay compared with milk from cows fed pasture. In a sensory ranking test, the percentage of assessors ranking for the intensity of total (raw milk, fresh milk, and farm milk), sweet (empyreumatic, vanilla, caramel, and sugar), and grassy (grass, leafy vegetable, and plant) flavors was higher for milk from cows fed pasture compared with hay and silage. Using timothy hay, pasture, or silage harvested at a similar stage of development, the current study shows that the taste of milk is affected by the forage type fed to cows. More research is, however, needed to establish a link between the sensory attributes of milk and the observed changes in volatile organic compounds and FA profile.

Key words: milk volatile organic compound, milk fatty acid, solid-phase microextraction, sensory evaluation

INTRODUCTION

Sensory properties of fluid milk are affected by the concentrations of individual volatile organic compounds. Moreover, the FA profile of milk fat is reported to affect the sensory evaluation of butter. The effects of diets on concentrations of milk volatile compounds have been studied using various laboratory techniques (Bendall, 2001; Toso et al., 2002; Croissant et al., 2007; Coppa et al., 2011). Among comparisons reported on bulk milk samples, Bendall (2001) studied milk from cows fed pasture and TMR in New Zealand. A total of 66 different molecules were evaluated using the nasal impact factor procedure and among the reported profiles, 7 compounds, including 3 lactones, were found to be significantly different between milk from cows fed the 2 diets. In particular, the frequency of detection was lower for *cis*-3-methyl-γ-nonalactone and γ-dodecadienolactone, and higher for γ-hexadecalactone in milk of cows fed pasture compared with TMR. During a study conducted in Italy, Toso et al. (2002) identified 42 milk compounds using a headspace sampling technique, and a discriminant analysis indicated that aldehydes provided one of the best criteria to be used for grouping milks according to the type of forage in dairy rations (hay, corn silage, or grass silage).

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Much less data are available on organic volatile compounds when comparing the effects of different diets on an individual cow basis. In a feeding trial conducted in France, Coppa et al. (2011) evaluated the effects of feeding a hay- and concentrate-based diet with either a low- or a high-biodiversity pasture in Montbéliarde cows. A total of 74 compounds were identified and quantified in milk using the solid-phase microextraction (**SPME**) technique. Feeding the high-biodiversity pasture increased the concentrations of several monoterpenes and sesquiterpenes in milk, and this effect was explained by the presence of numerous dicotyledon species in the grazing area.

The FA profile of milk fat can also be affected by feeding in dairy cows (Palmquist et al., 1993; Dewhurst et al., 2006). In relation to organoleptic properties, unsaturated FA could be used as precursors of lactones found in milk (Urbach, 1990). Increasing PUFA concentration in milk fat could also increase the concentration of their oxidation and degradation products. In this regard, β-oxidation at the double bounds can lead to straight-chain aldehydes and ketones, which may be converted to the corresponding alcohols under reducing conditions (Nursten, 1997). Moreover, major FA concentrations can influence the physical properties of milk fat (perceived firmness and melting in mouth of butter) in relation to the individual melting point of these FA (Couvreur et al., 2006; Hurtaud et al., 2007). Based on these results, it was hypothesized that feeding cows with timothy grass harvested as hay, pasture, or silage at a similar stage of development would affect the formation of volatile organic compounds and FA profile of milk, and therefore influence its sensory properties.

MATERIALS AND METHODS

Forages, Cows, and Experimental Design

A 5.3-ha field plot of timothy (*Phleum pratense* L. cultivar AC Alliance) was used for forage production at the Centre de recherche en sciences animales de Deschambault (Deschambault, QC, Canada). In June 2009, the timothy grass was cut with a mower conditioner at the late heading stage of development. After 24 h of wilting, alternate windrows were harvested using a forage chopper, and stored as silage in a plastic bag silo. The remaining windrows were tedded, left to dry, raked, and harvested 2 d later as rectangular bales of hay. In 2010, the same plot was used as pasture during the feeding trial described below. To attenuate possible bias associated with the stage of development of timothy at harvest, pasture was planned to ensure that timothy had reached the late heading stage during the final collection period.

All procedures performed in this feeding trial were approved by the institutional animal care committee based on the current guidelines of the Canadian Council on Animal Care (1993). Twenty-one Holstein cows (209 ± 53 DIM) were first fed for ad libitum intake once per day with a TMR composed of 60.0% (DM basis) grass and legume silage, 10.0% grass hay, 9.0% rolled barley, 9.0% cracked corn, 6.7% soybean meal, 3.3% corn gluten meal, and 2.0% vitamins and minerals for a pretrial period. Cows were then divided into 7 blocks of 3 cows each according to their calving date and randomly assigned to 1 of the 3 forage types (hay and silage harvested the year before, and pasture) offered ad libitum. Regardless of the forage treatment, each cow also received and consumed 7.2 kg/d of a concentrate mix to meet NRC nutrient requirements (NRC, 2001). The mix contained 23.3% rolled barley (DM basis), 23.3% cracked corn, 46.6% soybean meal, as well as 6.7% minerals and vitamins, and was served in 2 equal meals after a.m. (0700 h) and p.m. (1700 h) milkings. Cows had free access to water at all times during the experiment.

The experimental period lasted 27 d. The first 21 d of the period were allowed for adaptation to forage treatments, and the last 6 d were for collection of samples and data. Cows fed hay and silage were housed in a tie-stall barn. Hay and silage were offered in 2 equal meals after each milking to provide 10% orts based on the intake on the previous day. Cows on the pasture treatment grazed together and were given access to a timothy plot on a full-time basis, except during the milking period when animals were brought back to the tie-stall barn. Pasture was allocated by strip grazing. The strip limits (9 × 150 m), in the form of front and rear electrified wires placed across the plot, were moved forward to allow for a fresh provision of herbage every morning after milking.

Experimental Measurements and Samplings

The BW of cows was recorded on 3 consecutive days after the morning milking at the end of the pretrial and experimental periods. The TMR (pretrial period) as well as the hay and silage refusals (experimental period) were removed and weighed each morning after milking to determine individual intake, which was then corrected for DM based on TMR, hay, and silage samples taken twice weekly and dried in a forced-air oven at 55°C for 3 d.

Pasture intake was estimated using the procedure described by Macoon et al. (2003) based on animal performance. In summary, total energy requirements were calculated by summing NE_M, NE_L, and net energy for BW change, walking, and grazing activity using