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Effects of dairy system, herd within dairy system, and individual cow characteristics on the volatile organic compound profile of ripened model cheeses

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ABSTRACT

The objective of this work was to study the effect of dairy system, herd within dairy system, and characteristics of individual cows (parity, days in milk, and daily milk yield) on the volatile organic compound profile of model cheeses produced under controlled conditions from the milk of individual cows of the Brown Swiss breed. One hundred fifty model cheeses were selected from 1,272 produced for a wider study of the phenotypic and genetic variability of Brown Swiss cows. In our study, we selected 30 herds representing 5 different dairy systems. The cows sampled presented different milk yields (12.3–43.2 kg/d), stages of lactation (10–412 d in milk), and parity (1–7). In total, 55 volatile compounds were detected by solid-phase microextraction and gas chromatography-mass spectrometry, including 14 alcohols, 13 esters, 11 free fatty acids, 8 ketones, 4 aldehydes, 3 lactones, 1 terpene, and 1 pyrazine. The most important sources of variation in the volatile organic profiles of model cheeses were dairy system (18 compounds) and days in milk (10 compounds), followed by parity (3 compounds) and milk yield (5 compounds). The model cheeses produced from the milk of tied cows reared on traditional farms had lower quantities of 3-methyl-butan-1-ol, 6-pentyloxan-2-one, 2-phenylethanol, and dihydrofuran-2(3H)-one compared with those reared in freestalls on modern farms. Of these, milk from farms using total mixed rations had higher contents of alcohols (hexan-1-ol, octan-1-ol) and esters (ethyl butanoate, ethyl pentanoate, ethyl hexanoate, and ethyl octanoate) and lower contents of acetic acid compared with those using separate feeds. Moreover, dairy systems that added silage to the total mixed ration produced cheeses with lower levels of volatile organic compounds, in particular alcohols (butan-1-ol, pentan-1-ol, heptan-1-ol), compared with those that did not. The amounts of butan-2-ol, butanoic acid, ethyl-2-methylpropanoate, ethyl-3-methylbutanoate, and 6-propyloxan-2-one increased linearly during lactation, whereas octan-1-ol, 3-methyl-3-buten-1-ol, 2-butoxyethanol, 6-pentyloxan-2-one, and 2,6-dimethylpyrazine showed a more complex pattern during lactation. The effect of the number of lactations (parity) was significant for octan-1-ol, butanoic acid, and heptanoic acid. Finally, concentrations of octan-1-ol, 2-phenylethanol, pentanoic acid, and heptanoic acid increased with increasing daily milk yield, whereas dihydrofuran-2(3H)-one decreased. In conclusion, the volatile organic compound profile of model cheeses from the milk of individual cows was affected by dairy farming system and stage of lactation and, to lesser extent, by parity and daily milk yield.

Key words: cheese quality, lactation stage, milk yield, solid-phase microextraction/gas chromatography-mass spectrometry (SPME/GC-MS), aroma

INTRODUCTION

Dairy products are deemed acceptable by consumers mainly on the basis of their sensory qualities, with flavor playing a major role (Liggett et al., 2008; Liaw et al., 2010; Bittante et al., 2011b). Cheese flavor is determined by volatile and nonvolatile compounds generated from milk fat, protein, and lactose during the ripening process (Marilley and Casey, 2004; Drake et al., 2010; Le Quéré, 2011). Discovery of the origins of these molecules can provide information on both the raw materials and the processes used to produce the cheeses (Izco and Torre, 2000). Volatile organic compounds (**VOC**) in particular are of utmost importance in uncovering the relationships between production chain and consumer acceptability ratings (Fox et al., 2004). Perceived odors or flavors are the result of a

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mixture of odorants, and individual components may lose their specific identity when combined with others to produce a new mixture-specific aroma (Le Berre et al., 2008). Therefore, although identification of the quality attributes of individual volatile compounds may be related to the flavor of the product, the interactions between several compounds must also be taken into account (Aprea et al., 2012).

The sensory properties of cheese are affected by several genetic, environmental, and technological factors (Bittante et al., 2011b), and consumers are increasingly concerned, in particular, by those relating to the feeding, breeding, and health of animals. The chemical composition of milk, and consequently of cheese, is affected by several factors, such as dairy cow management, season, genetics, diet, parity, and stage of lactation (Coulon et al., 2004; Coppa et al., 2011). It is essential to quantify the relative importance of the different factors influencing cheese production, in particular those relating to milk production conditions, to be able to better predict and manage cheese quality (Bittante at al., 2011a). Although the effects of farming methods and diet on milk and cheese composition have been studied (Romanzin et al., 2013; Bovolenta et al., 2014), few studies have examined the relationships between variations in VOC of cheese and variations among individual animals. Understanding the possible effects of environmental, management, and individual cow factors on the characteristics of milk that could in turn affect the quality of cheese is essential (Barbano and Lynch, 2006), especially where Protected Designation of Origin (**PDO**) cheeses produced according to traditional techniques are concerned. Interesting and fundamental insights as well as practical indications can be gained by an approach that accounts for the entire production chain; that is, by studying the relationships between the characteristics of milk produced on different farms and from individual animals and the sensory characteristics of ripened cheese, in particular the VOC profile.

The development of model cheese-making procedures suitable for application to large numbers of individual samples (Cipolat-Gotet et al., 2013) offers a new tool for research in this field. Model cheeses appear suitable for studying the effects of herd-test date, lactation stage, parity, and milk yield of cows on percentage cheese yields (fresh curd, curd solids, and water retained in the curd as fractions of milk processed), daily cheese yields (expressed per cow per day of lactation), and nutrient recovery or whey loss (weight of protein, fat, total solids, or energy retained in the curd as a percentage of the same nutrient in the processed milk). These data could also be used for genetic analysis, because all cheese yield and recovery traits are characterized by heritability coefficients equal to or greater than those of milk yield and composition (Bittante et al., 2013). Individual model cheesemaking is not feasible at the population level, but infrared (Fourier-transform infrared, **FTIR**) calibrations have been shown to be a feasible means to predict cheese yield traits from unprocessed milk samples collected for milk recording (Ferragina et al., 2013). This is because the predicted new phenotypes are characterized by heritability coefficients similar to those of the corresponding measured traits and the genetic correlations between the 2 are high (Bittante et al., 2014). The FTIR predictions can be used on dairy cows of different breeds at the population level (Cecchinato et al., 2015).

If model cheesemaking technology has allowed new insights to be gained, it is important to assess the feasibility of using it to improve our knowledge of the factors affecting cheese quality, especially flavor. Volatile organic compounds are generally analyzed by GC-MS, and solid-phase microextraction (**SPME**) is used to collect and concentrate the compounds present in the headspace from matrices in both solid and liquid states. This method is simple and rapid, uses a sample preparation method free from organic solvents, and has good resolution, high sensitivity, and low cost, which is why SPME is now commonly used in food analysis as well as in cheese volatile compound analysis (Tunick et al., 2013; Padilla et al., 2014).

A large research project has been set up with the aim of studying relationships between individual cow characteristics and herd environment and management. The present study is intended to contribute to our understanding of the factors affecting cheese volatile compounds potentially contributing to cheese flavor by investigating the effects of the dairy system, herds within the dairy system, and the characteristics of individual cows (DIM, parity, milk yield) on the VOC profiles of individual model cheeses.

MATERIALS AND METHODS

Animals and Milk Sampling

This study is part of the "Cowplus Project," supported by the Province of Trento, the objectives of which were to investigate the relationships between dairy cows and cheese quality traits and to assess the potential for genetic improvement of the dairy cattle population. The sampling procedure used in the project has been described in detail by Cipolat-Gotet et al. (2012) and Cecchinato et al. (2013), and the production environment is described in Sturaro et al. (2013). Individual milk samples were obtained from 1,272 Brown Swiss cows from 85 herds located in Trento province,