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Effects of breed, feeding system, and lactation stage on milk fat characteristics and spontaneous lipolysis in dairy cows

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ABSTRACT

Spontaneous lipolysis (SL) is an enzymatic reaction which leads to a release of free fatty acids that can modify technological and sensory properties of milk and milk products. However, few studies have been done to assess the effect of feeding systems (FS) and breed on SL. Most of them were conducted in the 1980s and are not fully representative of cattle today. No previous study investigated the effect of cow breed at the whole-lactation scale. Thus, a trial was carried out to study the effects of 2 FS (high- and low-input FS) with 2 breeds [Holstein (HO) and Normande (NO)] during 1 entire lactation. Sixty-three cows were followed throughout 1 lactation. Cows were divided into 4 groups according to their breed and their FS. The high FS (HFS) consisted of a high-energy diet (in winter, corn silage with 30% concentrate; otherwise, pasture with 4 kg/d of concentrate) and the low FS (LFS) consisted of a low-energy diet (in winter, conserved grass with no concentrate; otherwise, pasture with no concentrate). The cows calved between January and March. Individual milk samples were collected every month from both morning and evening milkings for fat, protein, milk fat globule size, major fatty acids and proteins profiles, and SL determinations. Data were analyzed using the mixed procedure of SAS. The SL was higher in evening milks compared with morning milks. In early lactation, in evening milks, SL was higher in LFS than in HFS. No difference was shown according to the FS in mid and late lactation. Pasture was associated with low SL rate in mid lactation. The NO cows were less susceptible to SL during the entire lactation than HO cows. Finally, early and late lactation periods were identified as being more susceptible to SL, but this depended on breed and FS. During early lactation, HO cows and LFS were associated with higher levels of SL, particularly in evening milks, and, during late lactation, HO cows were associated with higher levels of SL. No intertreatment or intercow correlations (coefficient of determination <0.16) were found between SL, milk fat and protein contents, milk production, milk fat globule size, proportion of fatty acids and proteins, body condition, and weight during the entire lactation. Effects of breed, FS, and lactation stage were clearly identified and quantified. Causal mechanisms might involve energy balance and circadian secretion of milk fat globule components.
Key words: free fatty acids, herd management, milk quality

INTRODUCTION

Nutritional factors and breed affect spontaneous lipolysis (**SL**) and thus modify technological and sensory properties of milk and milk products (Cartier and Chilliard, 1990; Deeth, 2006; Ferlay et al., 2006). Indeed, short-chain fatty acids released by the lipoprotein lipase cause development of rancid flavors, which is undesirable for consumers (Scanlan et al., 1965; Chilliard et al., 2003), and partial glycerides impair foaming and creaming abilities (Deeth, 2006). Several studies have pointed out that SL depends on lactation stage, breed, and feeding systems (**FS**), among other factors (Cartier and Chilliard, 1990). Conserved and fresh grass was found to induce less SL than a corn silage-based diet when energy and protein needs were met (Ferlay et al., 2006). On the contrary, low-energy diets were found to be associated with higher levels of SL, particularly in late lactation (Chazal et al., 1987; Cartier and Chilliard, 1990; Thomson et al., 2005). Several studies have shown a link between breed and SL (Chilliard, 1982; Chazal and Chilliard, 1987a; Bachman et al., 1988; Ferlay et al., 2006), and although Normande (**NO**) is the third ranking dairy cow breed in France and is present all over the world, no study has been done to quantify SL of NO cow milk throughout lactation. Few studies have been done to assess the effect of the interactions

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between FS and breed on SL; although interactions between breed [Holstein (**HO**) and NO] and diet on milk traits have been shown in various previous trials (Kolver et al., 2002; Delaby et al., 2009; Chilliard et al., 2014), none of those studies investigated the entire lactation.

Most of the studies dealing with SL in relation to dairy farming systems were conducted in the 1980s with cows having a lower potential for milk production. Genetic selection and feeding strategies have co-evolved for several decades, and genetic potential of dairy herds increased and FS changed to satisfy the energy requirements of high-genetic merit cows. The proportion of corn silage and energy concentrate increased in dairy cow diets (Pflimlin et al., 2009); however, there is a wide range of farm practices between intensive systems maximizing HO cows' performances and more extensive systems prioritizing local resources and other breeds (Dillon et al., 2005; Raison et al., 2008; Le Gall et al., 2009; Peyraud and Delagarde, 2013), and the effects of these systems on SL remain unknown.

The aim of our trial was to assess the effect of 2 breeds, NO and HO, and of 2 FS, a high FS (corn silage in winter and grazing plus concentrate in spring and summer) and a low FS (conserved grass in winter and grazing with no concentrate in spring and summer), on milk SL. Effects were tracked over the entire lactation to evaluate correlations between SL, milk composition, and milk fat characteristics intertreatment, intercow, during the entire lactation, and among lactation periods (early, mid, and late lactation).

MATERIALS AND METHODS

Experimental Design

Two breeds, HO and NO, and 2 FS, a high FS (**HFS**) with high-energy diets and a low FS (**LFS**) with low-energy diets, were used in this trial. These 2 systems corresponded to 2 different winter diets and 2 different pasture managements. Sixty-three cows were divided into 4 groups according to their FS and their breed: the HFS was composed of 15 HO cows (8 multiparous and 7 primiparous) and 17 NO cows (11 multiparous and 6 primiparous) and the LFS was composed of 14 HO cows (8 multiparous and 6 primiparous) and 17 NO cows (14 multiparous and 4 primiparous). The other criteria for batching multiparous cows were, in order: parity, milk production, fat content, protein content, weight, BCS, and SCS. Primiparous cows were introduced in each group with the same criteria, except for the rank of lactation and milk fat and protein contents, SCC, and the number of animals in each group, to keep the same number of cows in each group. Calving was compacted from January to March 2014 and cows were monitored thorough their lactation until January 2015. Cows were milked every day at 0730 and 1730 h. When kept indoors, cows had an average area of 10 m^2 per cow.

Description of FS and Diets

HFS. From January 1 to April 3, 2014, cows received a highly digestible diet ad libitum composed of corn silage (55% of DM of the diet), dried alfalfa (16% of DM of the diet), rapeseed meal (4% of DM of the diet), and energy concentrate (25% of DM of the diet). Concentrate was composed, on a DM basis, of 45% soybean meal, 12% wheat, 12% corn, 12% barley 11% beets pulp, 4% molasses, and 4% minerals. From April 3 to 15, cows were in dietary transition to turn out to pasture. From April 15 to November 17, cows were grazing white clover (15–20%) and perennial ryegrass (80–85%) pastures, received 4 kg/d of concentrates, and were given between 3 and 8 kg of DM/d of corn silage when grass growth was not sufficient to cover the cows' needs. The mean surface allocated per cow was 0.22 ha of pasture from April 15 to July 10, and 0.33 ha of pasture from July 10 to November 17. Cows were managed on a simplified rotational grazing system (Hoden et al., 1991; Delaby and Peyraud, 2003) based on 3 to 4 plots in spring and extended to 5 plots in autumn. From November 17 to December 31, 2014, cows received 5 kg of DM/d of corn silage, 4 kg/d of concentrate, and grass silage ad libitum. Diets were formulated to meet cows' requirements (Institut National de la Recherche Agronomique, 2007). Nutritive values of forages, concentrates, and winter diets are presented in Tables 1 and 2.

LFS. From January 1 to April 3, 2014, cows received grass silage (50% of DM of the diet), haylage (48% of DM of the diet), and minerals (2% of DM of the diet) ad libitum. From April 3 to April 15, cows were in dietary transition to turn out to pasture. From April 15 to November 17, cows were grazing white clover (15–20%) and perennial raygrass (80–85%) pastures. The total area allocated per cow was 0.22 ha of pasture from April 15 to July 10, and 0.55 ha of pasture from July 10 to November 17. Cows received grass silage when grass growth was not sufficient. Grazing management was the same as in the HFS treatment. From November 17 to December 31, 2014, cows received grass silage ad libitum. Cows did not receive any concentrate during their entire lactation. Diets were formulated to meet 80% of the energy of cows' diet in HFS (Institut National de la Recherche Agronomique, 2007). Nutritive values of forages, concentrates, and winter diets are presented in Tables 1 and 2.