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Effect of corn silage harvest maturity and concentrate type on milk fatty acid composition of dairy cows

N. A. Khan,*[1] T. A. Tewoldebrhan,* R. L. G. Zom,† J. W. Cone,* and W. H. Hendriks*‡
*Animal Nutrition Group, Department of Animal Sciences, Wageningen University, PO Box 338, 6700 AH Wageningen, the Netherlands
†Wageningen UR Livestock Research, Animal Sciences Group, PO Box 65, 8200 AB Lelystad, the Netherlands
‡Faculty of Veterinary Medicine, Utrecht University, PO Box 80.163, 3508 TD Utrecht, the Netherlands

ABSTRACT

The variation in maturity at harvest during grain filling has a major effect on the carbohydrate composition (starch:NDF ratio) and fatty acid (FA) content of corn silages, and can alter the FA composition of milk fat in dairy cows. This study evaluated the effect of silage corn (cv. Atrium) harvested and ensiled at targeted DM contents of 300, 340, 380, and 420 g/kg of fresh weight and fed to dairy cows in combination with a highly degradable carbohydrate (HC) or low-degradable carbohydrate concentrate, on the nutrient intake, milk yield, and composition of milk and milk fat. Sixty-four multiparous Holstein-Friesian dairy cows in their first week of lactation were assigned to the 8 dietary treatments according to a randomized complete block design. The 8 dietary treatments consisted of a factorial combination of the 4 corn silages and the 2 concentrates. Corn silages were offered ad libitum as part of a basal forage mixture, whereas the concentrates were given at the rate of 8.5 kg of DM/cow per day during the 15-wk experimental period. Dry matter, crude protein, and energy intakes did not differ across the corn silages. However, the intake of starch increased, and those of NDF and C18:3n-3 decreased with increasing maturation. Milk yield and composition were not different across the corn silages. Yield (kg/d) of milk, protein, and lactose was higher for low-degradable carbohydrate compared with HC concentrate-fed groups. Increasing maturity of corn silages decreased the content of C18:3n-3 and total n-3 and increased the n-6:n-3 ratio in milk fat. Concentrate type significantly altered the composition of all *trans* FA, except C18:2 *trans*-9,12. Inclusion of the HC concentrate in the diets increased the contents of all C18:1 *trans* isomers, C18:2 *cis*-9,*trans*-11, and C18:2 *trans*-10,*cis*-12 conjugated linoleic acid in milk fat. Milk fat composition was strongly influenced by the stage of lactation (wk 3 to 10). The content of all even short- and medium-chain FA changed with lactation, except C8:0 and C10:0. The content of C12:0, C14:0, and C16:0 and total saturated FA increased and the content of C18:0, C18:1 *cis* total, and total *cis* monounsaturated FA decreased with lactation. Maturity of the corn silages at harvest did not affect the production performance of dairy cows, but resulted in a decreased content of C18:3n-3, total n-3, and an increased n-6:n-3 ratio in the milk fat of dairy cows.

Key words: corn silage, harvest maturity, dairy cow, milk fatty acid

INTRODUCTION

Silage corn is a major forage component in the ration of dairy cows, under most dietary regimens. The crop has a relatively stable yield, high energy content, good ensiling characteristics, and inclusion of corn silages in grass- or grass silage-based diets can increase feed intake, milk yield, and milk protein content (Phipps et al., 1995; O'Mara et al., 1998; Phipps et al., 2000). As a result, like many other European countries, the area used for silage corn production in the Netherlands has increased from 5.0×10^3 ha in 1970 to 2.4×10^4 ha in 2004 (Schroeder, 1998; Barrière et al., 2006). Due to their high consumption, forages in fresh or ensiled form are also major sources of PUFA (C18:3n-3, C18:2n-6) in dairy cow rations, and high PUFA-containing forages can be used to favorably modulate milk FA composition (Dewhurst et al., 2006; Elgersma et al., 2006).

Corn silages are high in starch and C18:2n-6 (0.52 ± 0.10 g/g of total FA), whereas grass silages are high in NDF and C18:3n-3 (0.58 ± 0.16 g/g of total FA; Khan et al., 2012). Inclusion of corn silages in grass-based rations of dairy cows increases the level of *trans* FA, mainly at the expense of their *cis* isomers and lowers the content of beneficial C18:3n-3 causing an elevated n-6:n-3 PUFA ratio in milk fat (Havemose et al., 2004; Shingfield et al., 2005; Kliem et al., 2008). Under normal rumen conditions, hydrogenation of C18:2n-6 in corn silage mainly results in an increased concentration of *cis*-9,*trans*-11 conjugated linoleic acid (**CLA**) and C18:1 *trans*-11 (Chilliard et al., 2001), which are

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[1]Corresponding author: nak126@gmail.com

considered potentially beneficial to human health. Moreover, a combination of corn silages with highly degradable carbohydrate concentrates further increases the content of *trans* FA and shifts the rumen biohydrogenation pathway toward the production of C18:1 *trans*-10 at the expense of C18:1 *trans*-11 (Piperova et al., 2000; Nielsen et al., 2006). A high level of *trans* FA, particularly with *trans-trans* double bonds, have been reported to increase the risk of coronary heart disease and diabetes (Ascherio et al., 1999; Lemaitre et al., 2002). In addition, increasing the content of n-3 PUFA and decreasing the n-6:n-3 PUFA ratio in milk fat of dairy cows fed corn silages, may be beneficial for human health (Kliem et al., 2008).

In the Netherlands, but also elsewhere in Europe (Phipps et al., 2000), silage corn is harvested at a wide range of maturation, with the whole crop DM content ranging from 250 to 450 g/kg of fresh weight (**FW**). These differences in maturity at harvest during grain filling result in considerable variation in FA content (Khan et al., 2011) and carbohydrate composition (starch:NDF ratio) of corn silages (Bal et al., 2000; Phipps et al., 2000). These changes can influence both the rumen environment and microbial hydrogenation of unsaturated FA (Shingfield et al., 2005; Nielsen et al., 2006), and as a consequence the milk FA composition of dairy cows.

The aim of this experiment was to evaluate the effect of corn silages ensiled at different maturities in combination with concentrates with a highly or low-degradable carbohydrate content on nutrient intake, milk yield, milk composition, and milk FA composition in early lactating dairy cows, to develop practical nutritional strategies to improve milk FA composition of dairy cows fed corn silages. We hypothesized that the variation in FA composition of corn silages as well as the amount and composition of carbohydrates in the different diets can affect milk FA composition of dairy cows.

MATERIALS AND METHODS

Silages

Corn silages were prepared from a single crop (cv. Atrium; Force Limagrain Nederland BV, Rilland, the Netherlands), sown on clay soil on April 20, 2009, at a density of 100,000 seeds/ha (10 plants/m^2) and row spacing of 0.75 m, at the research facility of Wageningen University and Research Center, Lelystad, the Netherlands (52°5′N and 5°5′E). The crop was fertilized with 50 t of cattle slurry/ha (containing 4 kg of N/t and 1.3 kg of P_2O_5/t), 30 kg of N/ha, and 30 kg of P_2O_5/ha as ammonium phosphate. The corn was harvested and ensiled at target DM contents of 300 (**MS30**), 340 (**MS34**), 380 (**MS38**), and 420 (**MS42**) g/kg of FW. No additives were used to improve the ensiling process. To determine the targeted harvest DM, 5 plants from 5 randomly selected spots in each cross-section of each plot were sampled twice weekly, chopped, and dried in an oven at 103°C for 24 h. The frequency was increased to daily sampling when the difference with the target DM content was less than 30 g/kg. The actual DM contents of the crop were close to the targeted DM contents (Table 1). All silages were made with the same precision chop harvester (John Deere 7750; John Deere & Co., Mannheim, Germany) using identical machine settings. The theoretical length of cut was 6 mm and roll-clearance of the kernel processor was 1 mm, to ensure that all kernels were sufficiently crushed. The corn silages were stored in bunker silos and compacted with a heavy weight tractor and a wheel loader. The silages were airtight sealed with 2 layers of 0.15-mm polyethylene plastic sheets, and covered with a 20-cm thick sand load. The total silage-clamp was covered with a protection sheet being held down with sand bags.

The grass silage was prepared from first-cut perennial ryegrass (*Lolium perenne* L.) cultivars (BG3; Barenbrug Holland BV, Oosterhout, the Netherlands), mowed on May 1, 2009 with a disc mower and conditioner. The mower-conditioner gently removed the waxy layer of leaves and stems of the grass with some additional crimping to enhance the drying process. The grass was wilted for 36 h with 20 h of sun, and tedded twice in the field. The average daytime temperature was 20.4°C and the average nighttime temperature was 7°C. The grass was ensiled in bunker silos, compacted and sealed, as described for corn silages.

Experimental Design, Animals, and Diets

Sixty-four multiparous Holstein-Friesian dairy cows were assigned to 8 dietary treatments (n = 8 cows per dietary treatment), according to a randomized complete block design with repeated measures. Cows were distributed over the 8 blocks to balance for parity, milk yield during previous lactation, BW, and DMI among blocks. The 8 dietary treatments consisted of a factorial combination of the 4 corn silages (MS30, MS34, MS38, and MS42) and 2 types of concentrate: a highly degradable carbohydrate [**HC**; low NDF, high water-soluble carbohydrates (**WSC**)] and low-degradable carbohydrate (**LC**; high NDF and low WSC) concentrate. Cows were adapted to the experimental diets and feeding regimens just after calving and data collection started the second week after calving until 17 wk after calving (March 30 to August 27, 2010).

The 4 corn silages were offered ad libitum as part of a forage mixture, which contained 61% corn silage, 28%