J. Dairy Sci. 101:1–11
https://doi.org/10.3168/jds.2017-12972

Characterization of linoleic acid (C18:2) concentration in commercial corn silage and grain hybrids

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ABSTRACT

Corn silage and high-moisture corn grain are commonly recognized as risk factors for biohydrogenation-induced milk fat depression and may be due to the high concentration of linoleic acid (C18:2) in corn. Corn silage and corn grain have a low concentration of fatty acids (FA), but due to their high inclusion rate in diets they contribute substantially to unsaturated FA intake. The first objective of this study was to characterize the contribution of individual plant parts to total FA in whole-plant chopped corn. The second objective was to characterize the variation in FA profile in commercial silage and grain hybrids and evaluate the relationship between FA profile and other nutrients. To determine the location of FA in the corn plant, 4 stalks from 4 different commercial hybrids were separated into stalk, husk and shank, leaves, cob, and kernels. On a dry matter basis, 80.5% of total FA were in the kernels, 11.8% in the leaves, 5.1% in the stalk, 1.7% in the cob, and 1.0% in the husk and shank. More than 96% of the oleic acid (C18:1) and 92.5% of the C18:2 was in the kernels, whereas 71.0% of the linolenic acid (C18:3) was in the leaves. Next, the FA composition of fresh whole-plant chopped corn from 124 silage hybrids and grain from 72 grain hybrids was determined over 2 yr from test plots in Pennsylvania. Last, to extend the characterization, FA composition of whole-plant corn silage from 45 hybrids grown in test plots in South Dakota were characterized. In the fresh whole-plant chopped corn from PA test plots, C18:2 as a percentage of total FA averaged from 48.7% in 2013 (percentiles: 10th = 45.2, 90th = 52.2) and 48.0% in 2014 (percentiles: 10th = 44.1, 90th = 49.4). Concentration of C18:2 in corn grain averaged 57.5% in the 2013 (percentiles: 10th = 53.4, 90th = 60.8) and 56.1% in 2014 (percentiles: 10th = 53.5, 90th = 59.4). In the corn silage from South Dakota, the concentration of C18:2 as percentage of total FA averaged 45.4% (percentiles: 10th = 39.4, 90th = 50.2) and C18:2 concentration as a percent of dry matter averaged 1.1% (percentiles: 10th = 0.76, 90th = 1.41). An increase in the concentration of C18:2 was associated with a decrease in C18:3 in fresh whole-plant chopped corn and with a decrease in C18:1 in corn grain. Total FA and C18:2 (as a percentage of dry matter) were positively correlated with starch and negatively correlated with neutral detergent fiber in both fresh whole-plant chopped corn and corn silage samples, whereas no correlation with these traits was observed for C18:2 as a percentage of total FA. In conclusion, FA concentration and profile of corn silage reflects to a great extent the FA composition of kernels and the proportion of grain in the silage. The variation in C18:2 across hybrids provides the opportunity to develop selection programs to decrease C18:2 in corn silage and grain. Selection based on C18:2 concentration as a percent of total FA is preferred as this trait did not correlate with other nutritional properties.
Key words: corn, milk fat depression, unsaturated fatty acids, corn silage

INTRODUCTION

Corn (*Zea mays* L.) whole-plant silage and grain make up the majority of contemporary lactating cow diets in the United States (Klopfenstein et al., 2013). Corn silage and high-moisture corn grain are commonly recognized as risk factors for biohydrogenation (**BH**)-induced milk fat depression (**MFD**), and many nutritionists cite higher rates of starch digestion, low effective fiber, or fiber digestion kinetics as the culprit.

Received April 1, 2017.
Accepted August 4, 2017.
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However, the increased risk may also be due to the amount or availability of UFA.

Biohydrogenation-induced MFD occurs when specific intermediates of bacterial fatty acid (**FA**) metabolism escape the rumen and inhibit milk fat synthesis in the mammary gland (Bauman and Griinari, 2003). Much of the attention has been directed at linoleic acid (C18:2) BH because it is believed to be the parent compound for most of the bioactive *trans* FA that decreased milk fat (Jenkins, 2011). Indeed, diets rich in C18:2 increase the risk for BH-induced MFD (He and Armentano, 2011; He et al., 2012). Substitution of other FA for C18:2 may decrease risk; for example, milk fat was increased from 2.42 to 2.92% when cows were fed high C18:1 compared with high C18:2 sunflower seeds (Casper et al., 1988). Furthermore, addition of rumen-available supplements rich in C18:2 (e.g., soybean oil) to lactating cow diets is a well-established model to produce BH-induced MFD (Rico and Harvatine, 2013; Rico et al., 2015). Reducing rumen-available UFA, and especially C18:2, is commonly recommended to control the risk of BH-induced MFD (Jenkins, 2011).

The predominant long-chain FA in corn silage and grain is commonly reported to be C18:2. These feeds have a low concentration of FA, but because of their high inclusion rate in lactating cow diets they contribute substantially to total UFA intake. Therefore, the increased risk of BH-induced MFD when feeding corn-derived feeds may be associated with their contribution to C18:2 intake.

Studies conducted over the past 3 decades have reported a considerable genetic diversity in corn FA concentration and profile (Widstrom and Jellum, 1975; Pamin et al., 1986). A literature search recovered a limited number of papers reporting FA profile of corn hybrids, but provided support for a reasonable range of C18:2 concentration (Table 1). Although these studies provide insights into variation in grain of various corn strains, a limited view of the variation in C18:2 concentration in whole-plant corn silage and grain of modern commercially available hybrids is available. Additionally, previous characterizations have reported that the majority of the FA in corn grain is in the germ, but we are not aware of a characterization of the contributions of FA to the whole plant. Our first objective was to characterize the contribution of individual plant parts to total FA in whole-plant corn silage. The second objective was to characterize the variation in FA profile in commercial corn silage and grain hybrids and evaluate the relationship between FA profile and other nutrients. Our hypothesis was that variation exists between hybrids that would allow for selection of hybrids with lower C18:2 concentration that would be expected to have a decreased risk of BH-induced MFD. During the course of the investigation, the effect of drying method (freeze drier and forced-air oven) on sample FA profile was assessed to allow comparison to the literature and between data sets and assist with commercial application in forage testing laboratories.

MATERIALS AND METHODS

Sample Sets

The initial characterization used samples from corn hybrid test plot from Pennsylvania (**PA**) using fresh whole-plant chopped corn from silage hybrids and grain from grain hybrids in 2013. Similar samples were collected from PA test plots in 2014 to replicate the findings. Lastly, through collaborations, corn silage samples from South Dakota test plots were analyzed to extend the characterization to other hybrids in a second region.

Samples from Pennsylvania were part of the Corn Silage Research Project, which is a research program conducted in a collaborative effort between the Professional Dairy Managers of Pennsylvania, Penn State University, and seed companies (www.pdmp.org/corn-silage-research-project). Pennsylvania samples came from research plots located in Blair and Centre County, PA, and were collected in 2013 and 2014 (Plant parts data set was collected in 2013 only, Table 2). In the fresh whole-plant chopped corn data set collected in 2013, 35 out of the 67 samples were cultivated in Lancaster County, PA, in a commercial test plot (Croplan, WinField Solutions LLC, Shoreview, MN). Samples from South Dakota were part of the Corn Silage Variety Trials and Crop Performance Testing project, which is a research program coordinated by the Department of Dairy Science and Extension, South Dakota State University. These hybrids were cultivated at the South Dakota State University Volga Research Farm, Brookings County, South Dakota (corn silage data set in Table 2).

Sample Collection and Processing

For determination of the FA concentration of individual plant parts, stalks were manually harvested from 4 different hybrids in quadruplicates (4 stalks/hybrid) at approximately 30% DM. Test plots were 5.5 m long, 4 rows wide, row spacing of 76 cm, and seeded at density of 84,000 plants per hectare. The 4 stalks for each hybrid were randomly harvested from the central region of the 2 middle rows of one test plot. Each corn plant was individually separated into stalk, husk and shank, leaves, cob, and kernels. These samples were dried in a forced-air oven at 55°C for 48 h to determine DM content, ground to 1 mm with a Wiley Mill (Arthur H.