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Effects of nonstructural carbohydrate level and starch:sugar ratio on microbial metabolism in continuous culture of rumen contents

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Abstract

A dual flow continuous culture system was used to examine the effects of varying sugar as a proportion of sugar plus starch (NSC) at three concentrations of NSC on nutrient digestibility, ruminal fermentation and microbial growth. Diets contained 240, 280 and 330 g NSC/kg DM. At each NSC level, diets contained 29, 63 and 95 g sugar/kg DM. Corn grain and corn silage were the major starch sources. Liquid sugar blend (LSB) was the supplemental sugar source. Negative responses with interactions were seen at the 63 g sugar/kg DM level compared to no added sugar or 95 g sugar/kg DM in microbial growth, dry matter digested, protein digested, and total carbohydrate digested. Interactions resulted mostly because the negative responses to the 63 g sugar/kg DM were with the 240 and 280 g NSC/kg DM levels, but not with the 330 g NSC/kg DM level. Sugar addition depressed fiber digestion only with the 240 g NSC/kg DM level. At 330 g NSC/kg DM, all sugar substitutions were beneficial. Microbial responses were highest on the 330 g NSC/kg DM diet with 95 g sugar/kg DM, in

Abbreviations: ADF, acid detergent fiber; ADL, acid detergent lignin; CP, crude protein; DM, dry matter; LSB, liquid sugar blend; aNDF, NDF, assayed with sodium sulfite and heat-stable amylase; NFC, non-fiber carbohydrate 1000 − (g/kg CP + NDF + ash + fat); NSC, non-structural carbohydrates (g/kg sugar + g/kg starch); NPN, non-protein nitrogen; OM, organic matter; VFA, volatile fatty acids

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which sugar made up 290 g/kg of the total NSC. Sugar additions at 95 g sugar/kg DM resulted in large increases in butyrate production. All sugar levels decreased acetate production but had little effect on propionate production.

Keywords: Sugar; Nonstructural carbohydrate; Starch; Microbial growth

1. Introduction

Sugars and starches provide the major source of carbohydrate for the growth of rumen microbes in diets of high producing dairy cows. Starches usually make up 900 g/kg of the total starch plus sugar. Hall and Herejk (2001) found that sucrose initiated *in vitro* microbial growth most rapidly followed by pectin, starch and isolated neutral detergent fiber (aNDF). With the intent of increasing the utilization of rapidly soluble protein or NPN by rumen microbes, and thus increasing microbial growth, a number of studies have been conducted in which part of the dietary starch has been replaced by sugars. A reduction in ruminal ammonia concentration has been noted in many studies in which sugars were added to the diet (Chamberlain et al., 1985; Giduck and Fontenot, 1987; Sannes et al., 2002; Lee et al., 2003). This suggests a more efficient utilization of the rapidly available nitrogen components in the diet and a concomitant increase in microbial growth and metabolism. However, Vallimont et al. (2004) found that replacing starch with sucrose at 0, 25, 50 and 75 g/kg DM in a continuous culture system resulted in no changes in ruminal ammonia concentrations and no effect on bacterial nitrogen production. McCormick et al. (2001) found that sucrose addition to the diet at 50 g/kg of the DM reduced rumen ammonia concentration but the same amount of lactose added to the diet had no effect. Substitution of starch with sugar also may affect fiber digestion. Sugars added to forage-based diets have been found to decrease fiber digestion (Huhtanen and Khalili, 1991; Heldt et al., 1999). Vallimont et al. (2004) reported, however, that low levels of sugar (25 and 50 g/kg DM) depressed, while 75 g/kg DM increased, aNDF digestion in diets containing 320 g nonstructural carbohydrates (NSC)/kg DM.

In lactation studies involving addition of sugars from molasses, whey, sucrose, dextrose or lactose, responses in dry matter intake and milk production have been inconsistent (Wing et al., 1988; Morales et al., 1989; Maiga et al., 1995). Broderick and Radloff (2004) replaced dietary high moisture corn with incremental amounts of dried molasses (0, 40, 80, and 120 g/kg DM) and found that 35 mg/kg fat-corrected milk responded in a positive quadratic manner (41.2, 42.2, 42.7, and 40.3 kg/d) and was highest when the diet contained 80 g molasses/kg DM.

One possible explanation for the inconsistent production responses to sugars is that because of the high ruminal liquid dilution rates observed shortly after eating (Dehareng and Godeau, 1989; Susmel et al., 1995; Sutoh et al., 1996), a high proportion of the sugar may leave the rumen prior to fermentation and not contribute to microbial end-product formation or microbial protein flow. Data of Henning et al. (1991, 1993) indicate sugar content can persist at high levels in rumen fluid *in vitro* and *in vivo* for several hours after eating. In these studies, the rates of sugar disappearance ranged from 0.19 to 0.69 h^{-1}. Since sugars dissolve rapidly, they could flow from the rumen with the liquid fraction, which may