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Effects of vitreousness and particle size of maize grain on ruminal and intestinal *in sacco* degradation of dry matter, starch and nitrogen

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Abstract

We assessed the effects of vitreousness and particle size of maize grain on ruminal and intestinal *in sacco* degradation of dry matter, starch and nitrogen. Six maize grain (*Zea mays*) genotypes characterized by differing vitreousness (proportion of vitreous in total endosperm) were ground (3-mm screen; Gr, ground particles, mean particle size (MPS): 526 μm) and cracked with a roller mill using two gap width settings (CS, cracked small particles, MPS: 1360 μm; CL, cracked large particles, MPS: 2380 μm). The ruminal and intestinal *in sacco* degradation of dry matter, starch and nitrogen was measured on three dry Holstein cows, fitted with rumen, proximal duodenum and terminal ileum cannulas, fed maize silage *ad libitum* twice daily. The ruminal starch degradability and intestinal digestibility differed among genotypes ($P<0.001$) and decreased as particle size increased ($P<0.001$). For the same particle size, starch ruminal degradability decreased ($P<0.05$) and intestinal digestibility decreased ($P<0.002$) with vitreousness. Particle size and vitreousness of maize grain are efficient factors for manipulating the amount of starch escaping rumen degradation, but may be limiting for the amount of starch digested in the small intestine.

Keywords: Mobile bag technique; Small intestine digestibility; Particle size; Vitreousness; Maize starch

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1. Introduction

The milk and meat produced by ruminants are strongly dependent on the digestive use of ration constituents. A large part of the ration is made up of concentrates, grains or grain by-products rich in starch and protein. Starch is an important source of energy and its degradation in the rumen fuels microorganisms for the synthesis of microbial proteins and volatile fatty acids (VFA). The starch that escapes digestion in the rumen enters the small intestine where it is broken down by pancreatic alpha-amylase and disaccharidase action, producing glucose. The control of the site and extent of starch digestion limits the risk of ruminal acidosis (Sauvant, 1997). Also, different sites of starch digestion generate different nutrients (volatile fatty acids or glucose), which are used with different efficiencies for energy production.

The proportion of the starch that escapes degradation in the rumen ranges from 50 to 650 g/kg of starch intake (Huntington, 1997; Crocker et al., 1998). This variation depends partly on intake level and on the nature of the cereal. For the same cereal, technological treatments (grinding, cracking, steam flaking, pelleting, extrusion and expander processing) have a significant effect on ruminal starch degradability, resulting in considerable amounts of starch escaping the rumen and entering the small intestine (Svihus et al., 2005; Huntington et al., 2006). The physical characteristics of the cereal can also affect digestion rates. Vitreousness is a variable used to define the hardness of a cereal grain. It is characterized by structural and chemical features that cause the protein distribution (zeins/glutelins) in the endosperm to affect the ruminal starch degradation by hindering the access of microorganisms to starch granules (Philippeau et al., 2000). Vitreousness has been shown to adversely affect microbial colonization of grain (McAllister et al., 1990) and starch ruminal digestion in steers (Philippeau et al., 1999b) and dairy cows (Rémond et al., 2004).

Digestion of starch entering the duodenum occurs mainly in the small intestine and is estimated to range from 380 to 880 g/kg (Owens et al., 1986). The amount of pancreatic amylase secreted in the duodenum increases with increasing grain intake (Harmon, 1992). The intestinal starch digestibility still can be limited by factors as unfavorable chemical conditions in the small intestine or the presence of pancreatic amylase inhibitors, starch inaccessibility to enzymes linked to insolubility, or particle size decreasing the surface area for starch digestion (Owens et al., 1986). Whereas the effects of intrinsic features of feeds on ruminal starch degradation have been widely investigated and quantified (Offner et al., 2003), their effects on intestinal digestion remains still unclear.

Our present objective was to evaluate intrinsic features of feeds known to affect starch digestion in the rumen and that could influence the accessibility of starch by endogenous enzymes in post-ruminal digestion. We set out to assess: (i) the effects of maize genotypes (vitreousness) and physical processing (particle size) of grain on ruminal and intestinal starch degradation, and (ii) the relationships between ruminal and intestinal starch degradation. Because the protein distribution in maize grain endosperm is known to affect accessibility of starch granules and their subsequent degradation, nitrogen degradation was also measured simultaneously.