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Effects of dietary protein and sunflower seed supplementation on physico-chemical characteristics of small intestinal digesta and plasma cholecystokinin concentrations in lambs

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Abstract

Two experiments in a 2 × 2 factorial design were conducted with weaned lambs to determine the effects of supplementing either high forage (Experiment 1; 140 d) or grain (Experiment 2; 70 d) diets containing either 12 or 16% protein without or with sunflower seed (SS) supplement (14% of diet dry matter [DM]) on plasma cholecystokinin (CCK) concentration, and on absolute viscosity, protein, starch and fat content, and amylase activity in digesta collected from different parts of the small intestine. There were four treatment groups in each experiment with 11 or 12 lambs (five or six wethers and six ewes) per treatment group in Experiments 1 and 4, 8-lamb (ewes only) groups in Experiment 2. Each group was fed one of four experimental diets based on corn silage, corn grain and soybean meal in Experiment 1, and on barley grain, straw and soybean meal in Experiment 2. Soybean meal was used to achieve the appropriate concentration of dietary protein in both experiments, while straw was used in Experiment 2 to achieve equal dietary fiber in all diets. Concentrations of CCK were determined in jugular plasma obtained from each lamb (4 h after feeding) 6 weeks after the initiation of the experiment. After the end of the experiments all lambs were sacrificed and the digesta sampled within 15 min of slaughter from 50 cm sections of proximal, mid jejunal and distal small intestine. In Experiment 1, dietary SS increased ($P < 0.05$) plasma CCK concentrations of ewe lambs fed the high protein diet, but reduced ($P < 0.05$) digesta viscosity to 45.2 ± 14.4 cP from 226.0 ± 70.2 cP across all intestinal sections in all lambs fed the low protein diets. In lambs fed the low protein diet with SS, digesta fat content was increased across all sections. Digesta protein content was 61.9 ± 8.22% in ewe lambs fed the high protein diet in proximal intestinal sections relative to 38.9 ± 7.08% in lambs fed the low protein diet but neither dietary protein nor supplementation with SS had any effect on the amylase activity (μM reducing sugars released g^{-1} DM min^{-1}). In Experiment 2, dietary SS decreased ($P < 0.05$) viscosity of small intestinal digesta of lambs to 3.2 ± 32.6 cP, in the distal regions of lambs fed the low protein diets relative to those receiving no SS (348 ± 79.8 cP). Small intestinal digesta protein was higher ($P < 0.05$) in lambs fed high protein diets with SS and the amylase activity as μM reducing sugars released g^{-1} DM min^{-1} was increased ($P < 0.05$) in these animals as well. Dietary SS was effective in altering

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digesta viscosity and protein content in lambs irrespective of protein content of the diet, but the activity of the amylase was substantially increased by higher dietary protein in the barley grain based diets.

Keywords: Lamb; Dietary protein; Intestinal digesta; Sunflower seed; Viscosity; Amylase activity

1. Introduction

Hydrolytic digestion in the intestinal tract by pancreatic enzymes is necessary for animals to capture the maximum benefit from the feed provided to them. Despite the observation of Remond et al. (2000) that nutrient absorption does occur across the ruminal wall, the extent of this absorption is small because the nutrients released are rapidly degraded by the microbes, thus animals have to rely on the intestine as a source of utilizable nutrients. The availability and extent of absorption of nutrients is dependent on the efficiency of enzymatic digestion in the small intestine by pancreatic enzymes. This enzyme secretion is controlled by hormones such as cholecystokinin (CCK) which is released from the intestine in response to the presence of fat or protein in intestinal digesta (Liddle, 1997). In addition, CCK augments the effectiveness of another gastrointestinal tract hormone, secretin (Meyer et al., 1971), which activates bicarbonate secretion into the intestine, causing the viscosity of intestinal contents to decrease. A decrease in viscosity appears to be critical in facilitating both digestion and absorption of the products of digestion in the small intestine (Blackburn and Johnson, 1981; Ellis et al., 1996).

Previous studies in swine and poultry have shown that the reduction in viscosity of the small intestinal contents due to inclusion of exogenous enzymes in the feed improved feed efficiency (Bedford et al., 1998; Yin et al., 2001) through positive effects on digestion and absorption of nutrients from the small intestine. Increasing dietary grain led to increased small intestinal viscosity in dairy cattle (Mir and Mir, 1998). Furthermore, Kreikemeier et al. (1991) found that infusion of starch into the duodenum did not increase portal vein concentrations of glucose, unlike the rise in portal vein concentrations with glucose infusion. These effects can be due to poor intestinal amylase activity, conditions which could hinder release of the maltose, maltase activity or glucose absorption. Similarly, Mir et al. (2000a) reported that portal vein concentrations of glucose did not increase despite an increase in small intestinal starch content in animals fed increasing proportions of dietary grain and this effect has been ascribed to the elevated viscosity in the small intestine.

Intestinal conditions and composition can affect digesta viscosity and thus comparisons of viscosity data among studies are difficult. Ellis et al. (1996) described a mathematical procedure to estimate the absolute viscosity or viscosity at zero shear, thus enabling the comparison of the biological impact of digesta viscosity. Other than those of Mir et al. (2002), there are no data comparing the effects of absolute viscosity on small intestinal digestive function in ruminants. Digesta viscosity may be critical not only in enhancing animal productivity but also to product safety. Hopwood et al. (2002) indicated that increased intestinal viscosity can stimulate proliferation of enterotoxigenic bacteria in weaner pigs. Furthermore, the determination of the impact of dietary oil in ruminants has gained interest as a mechanism to increase the deposition of altered fatty acids such as conjugated linoleic acid and the omega-3 fatty acids (Ivan et al., 2001; Mir et al., 2000b, 2003; Beaulieu et al., 2002). Although reports on the impact of dietary oil on circulating CCK concentrations in ruminants are available (Choi and Palmquist, 1996; Ingvartsen and Andersen, 2000; Benson and Reynolds, 2001), the associated effects on small intestinal digesta characteristics such as viscosity and enzyme activities have not been studied. Therefore, in the present study the impact of dietary supplementation, with sunflower seed (SS) of high forage or grain diets with 12 (low) or 16 (high) % protein (through its probable effect on the gastrointestinal hormone systems) was studied in two experiments with weaned lambs. Absolute viscosity of supernatant of intestinal contents was determined in contents collected from three locations in the small intestine of lambs. The associated effect of dietary SS and protein level in the two types of diets on digesta viscosity, and protein, starch and fat concentration and activity of a vital enzyme, amylase, in intestinal digesta was also investigated.