THE EFFECTS OF FORMALDEHYDE ON THE IN VITRO DIGESTION OF BARLEY STARCH

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Introduction

The microbial conversion of feed grains to volatile fatty acids and to microbial biomass is the pivotal process in the digestion of these feedstuffs. At least 90 % of the starch in barley is fermented in the rumen (Waldo, 1973). The rapid digestion of barley often causes digestive disturbances such as acidosis, rumenitis and liver abscess (Orskov, 1986). Economic losses due to these disturbances would be reduced if the rate of microbial starch digestion could be controlled.

The rate of microbial digestion of feed grains depends on the accessibility of the endosperm to rumen microorganisms. The endosperm cells contain starch granules embedded in a protein matrix. Therefore, a reduction in the microbial digestion of the protein matrix may indirectly reduce the rate of starch digestion. Formaldehyde has been used extensively to increase the resistance of dietary protein to microbial digestion (Barry, 1976). The purpose of this experiment was to determine if formaldehyde treatment of barley alters the rate of microbial starch digestion.

Materials and Methods

Barley grain was ground and sieved to obtain a particle size between 2 and 3 mm. One-half gram samples of formaldehyde-treated (5 g.kg^{-1}) barley (FB) or untreated barley (B) were placed in 30 mL vials. Rumen fluid, from a steer fed 80 % barley, was diluted 1:1 with an anaerobic salt solution and 20 mL of the mixture was added anaerobically to each vial. Triplicate vials were analyzed for starch and ammonia content after 4, 8, 12, 24, 36 and 48 h of anaerobic incubation. In addition, scanning electron microscopy (SEM) was used to examine microbial colonization and digestive patterns in both FB and B.

Results

Formaldehyde treatment of barley reduced ($P < 0.05$) microbial starch digestion between 4 and 24 h of incubation (Fig. 1a). After 24 h of incubation there was no difference in the extent of starch digestion between FB and B.

The release of NH_3 from FB was less ($P < 0.01$) than from B throughout the incubation period (Fig. 1b). The reduced NH_3 concentration suggests that treatment with formaldehyde effectively

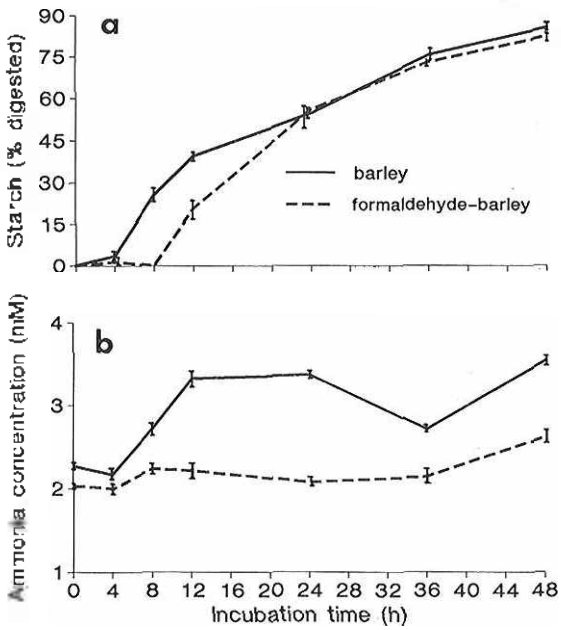

Figure 1. (a) Percent of starch digested in untreated and formaldehyde-treatec barley. (b) NH_3 concentration in media containing untreated for formaldehyde-treated barley. Vertical bars represent ± SE.

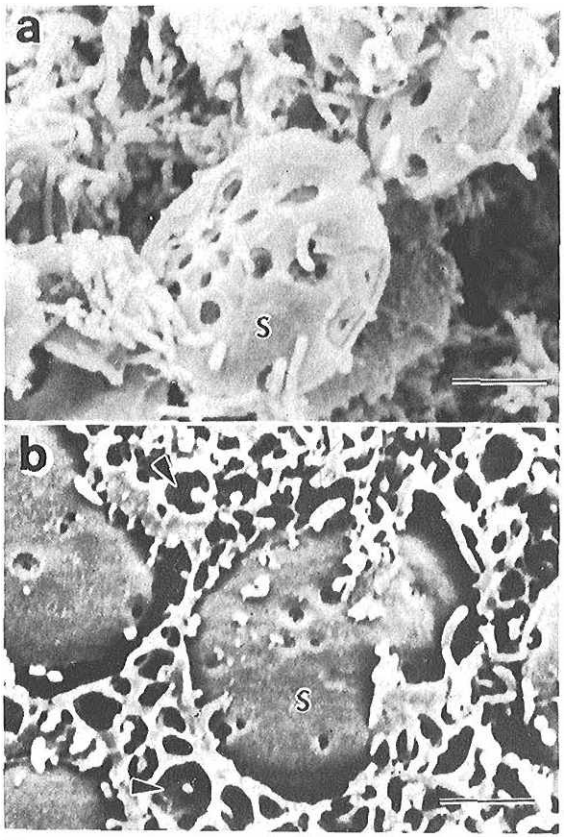

Figure 2. SEM of the endosperm of barley after 24 h of incubation. Note that larger starch granules (S) in untreated barley (2a) are free of the protein matrix while those in formaldehyde treated barley (2b) are still embedded. Smaller starch granules have been digested leaving behind an intact protein matrix (arrows). Bar = 5.0μm.

increased the resistance of barley protein to microbial digestion. Examination by SEM of the endosperm after 24 h incubation showed that the protein matrix surrounding large starch granules in B (Fig. 2a) was digested, exposing the granules, while large starch granules in FB (Fig. 2b) were still embedded. Smaller starch granules in FB appeared to be digested, leaving behind an intact protein matrix (Fig. 2b).

Discussion

The microbial digestion of starch in FB was effectively reduced, as compared to B, between 4 and 24 h. Measurements of NH_3 release suggest that formaldehyde reduced the susceptibility of barley protein to microbial digestion. SEM indicates that the reduced digestibility of the protein matrix inhibits the access of bacteria to underlying starch granules. In treated barley, rumen bacteria gain access to underlying starch granules primarily through the digestion of small starch granules whic lie on the surface of endosperm cells. As this process continues, more starch granules are removed and an intact protein matrix is left behind.

The present study indicates that formaldehyde treatment of barley may reduce the ruminal digestion of barley starch and protein. This would increase the passage of barley protein and starch into the small intestine. Owens et al. (1986) showed that starch digested in the small intestine provided 30 to 50% more energy for the ruminant. In addition, a reduction in ruminal starch digestion may reduce the occurrence of digestive disturbances and result in a pH more favorable for fiber digestion in cattle fed readily fermentable cereal diets. Studies are currently being conducted to determine the effects of formaldehyde treatment of barley on the rate of microbial starch digestion in the whole animal.

(Key Words: Starch, Rumen bacteria, Formaldehyde)

Literature Cited

Barry, T.N. 1976. The effectiveness of formaldehyde in protecting dietary protein from rumen microbial degradation. Proc. Nutr. Soc. 35:221-229.

Orskov, E.R. 1986. Starch digestion and utilization in ruminants. J. Anim. Sci. 63:1624-1633.

Owens, F.N., Raney, R.Y. and Tremblay, J.C. 1986. Influence of level of feed intake and roughage on small intestine digestion and rate of passage in steers. Oklahoma Agri. Exp. Sta. MP-118:161-165.

Waldo, D.R. 1973. Extent and partition of cereal grain starch digestion in ruminants. J. Anim. Sci. 37:1062-1074.