Livestock Science ▮ (▮▮▮▮) ▮▮▮–▮▮▮

Contents lists available at ScienceDirect

Livestock Science

journal homepage: www.elsevier.com/locate/livsci

Effect of replacing barley with wheat grain in finishing feedlot diets on nutrient digestibility, rumen fermentation, bacterial communities and plasma metabolites in beef steers

M.L. He [a,b], J. Long [a], Y. Wang [a], G. Penner [b], T.A. McAllister [a,*]

[a] Research Centre, Agriculture and Agri-Food Canada, Lethbridge, AB T1J 4B1, Canada
[b] Department of Animal and Poultry Science, University of Saskatchewan, Saskatoon, SK S7N 5E2, Canada

ARTICLE INFO

Article history:
Received 31 May 2014
Received in revised form
17 March 2015
Accepted 28 March 2015

Keywords:
Barley grain
Bacterial communities
Beef cattle
Rumen
Starch
Wheat

ABSTRACT

This study investigated the effect of substituting barley grain with wheat on rumen fermentation, bacterial communities, nutrient digestibility and plasma metabolites in finishing feedlots steers. The experiment was designed as a replicated 4×4 Latin square with 8 rumen cannulated steers (742 ± 44 kg) fed diets in which wheat was substituted for 0, 30%, 60% or 89% of barley grain dry matter (DM). All grains were dry-rolled to a processing index (PI) of 80% expressed as a percentage of volume weight of processed grain divided by the volume weight of unprocessed grain. The remaining dietary ingredients consisted of 6% barley silage and 5% supplement. Duration of pH below 5.8 linearly increased ($P=0.04$) with increasing levels of wheat, whereas average, minimum and maximum pH as well as the time and area under pH 5.5 ($P=0.08$) and 5.2 ($P=0.18$) did not differ among diets. Likewise, volatile fatty acids (VFA) profiles, concentrations of VFA, ammonia, numbers of protozoa and total tract digestibility of nutrients were unaffected ($P>0.05$) by this substitution. Increasing levels of wheat linearly increased copy numbers of 16S rRNA for total bacteria ($P=0.01$) and *Ruminococcus amylophilus* ($P=0.04$) per g of rumen contents. Inclusion of wheat in the diet linearly reduced plasma albumin ($P=0.03$) and urea nitrogen ($P=0.01$) concentrations, but did not affect ($P>0.05$) other major plasma metabolites. In conclusion, replacing barley grain with wheat in the diets of feedlot steers had little negative impact on nutrient digestibility or rumen fermentation, however, it increased the daily duration that rumen pH remained below 5.8. These data suggest that there is little difference in the ruminal fermentation or digestibility of barley vs wheat if both grains are processed to a similar degree.

1. Introduction

Cereal grains including corn and barley are the principal energy source in the diets of North American feedlot cattle (Owens et al., 1997). Wheat that fails to meet the quality grade for flour milling is used as livestock feed, an occurrence that has become increasingly frequent as a result of inclement weather on the plains of North America. Feed wheat is most commonly fed to swine and poultry and only a few studies have assessed the value of wheat in feedlot cattle diets (Zinn, 1994; Erjaei et al., 2012). Compared to barley, wheat is higher in metabolizable energy owing to its higher starch and lower fiber content (NRC, 1996; McAllister and Sultana, 2011). However, wheat is more rapidly digested in the rumen than barley (McAllister et al., 1990), a characteristic that has contributed to its reputation of increasing the

* Corresponding author.
E-mail address: Tim.Mcallister@agr.gc.ca (T.A. McAllister).

http://dx.doi.org/10.1016/j.livsci.2015.03.024
1871-1413/

risk of ruminal acidosis and feedlot bloat (Cheng et al., 1998). Researchers have recommended that wheat not exceed 40% of diet DM in feedlot diets (Lardy and Dhuyvetter, 2000) to avoid possible digestive upset. Little information is available on rumen fermentation and nutrient digestibility of feedlot diets where wheat replaces barley, the primary grain used for finishing cattle in western Canada. Compared to wheat for milling, feed wheat is typically lower in protein and higher in fiber and somewhat comparable to the composition of barley grain. Therefore, in this study we hypothesize that feed wheat can replace varying levels of barley grain in the diet with no adverse impact on nutrient digestion, rumen function, microbial communities or plasma metabolites in feedlot steers.

2. Materials and methods

2.1. Animal and experimental design

The protocols used in this study were approved by the Animal Care Committee at the Agriculture and Agri-Food Canada's (AAFC) Lethbridge Research Center (LRC) according to the guidelines set out by the Canadian Council on Animal Care (CCAC, 2009). The experiment was designed as replicated 4×4 Latin squares with a duration of 3 weeks for each period and 12 weeks for the entire experiment. Eight rumen cannulated steers with a body weight of 742 ± 44 kg were allocated to 4 dietary treatments within two Latin squares balanced for carry-over effects. During the overall experimental period the average body weight of steers increased 1.43 kg/day, resulting in an average final body weight of 862 ± 42 kg at the end of the experiment. Feed intake was determined during diet adaptation in each period (see below).and used to adjust intake to 95% of estimated ad libitum during the sampling period. The control (CON) diet consisted of (DM basis) 89% barley grain, 6% barley silage and 5% of a mineral and vitamin supplement. Wheat replaced barley grain so that the other diets contained 30%, 60% or 89% wheat on a DM basis (designated as 30 W, 60 W and 89 W; Table 1). Barley and wheat grain were dry-rolled to a processing index (PI = volume weight of processed grain divided by volume weight of unprocessed grain $\times$ 100) of 80% based on previous studies (Beauchemin et al., 2001; Wang et al., 2003). Diets were formulated to meet or exceed the requirements of beef cattle with an average BW of 750 kg and a gain of 1.5 kg/d (NRC, 1996).

2.2. Animal feeding and management

Steers were adapted to diets though a series of 3 step-up diets each fed for 4 days in which the substitution of wheat for barley was gradually increased: during the day (d) 1-d 4, d 5-d 8 and d 9-d 12 through provision of a mixture of the diet used in the last period and that scheduled for the upcoming period in ratios of 2:1 (33%), 1:1 (50%) and 1:2 (66%) , respectively. Steers were adapted to their final diet (100%) after 12 days, followed by a 9-day sampling period resulting in each period being 21 days. Feed was offered once daily as a total mixed ration (TMR) and samples of the barley silage, barley, wheat and the TMR were collected weekly and combined by period for the chemical analysis. Silage was monitored for DM, but content did not differ sufficiently to merit reformulation of the diet. Cattle had free access to water throughout the experiment.

2.3. Rumen content sampling, rumen pH and total tract digestibility measurement

Ruminal pH was measured every minute for a 5 d period (d 17–21) during each 3 wk period using the Lethbridge Research Center Ruminal pH Measurement System (LRCpH, Dascor, Escondido, CA; Penner et al., 2006). Data were summarized as mean, maximum, minimum, time (min/d) and area (pH $\times$ min/d) below pH thresholds of 5.8, 5.5 and 5.2 as described by Li et al. (2011).

Fermentation characteristics were measured 1 h before, and 3 and 5 h after feeding on d 16 and 17 of each period. Rumen contents were collected from four different sites within the rumen, strained through nylon mesh with a pore size of 355 μm, and preserved 5:1 v/v in 25% metaphosphoric acid or 1% sulfuric acid for determining concentrations of volatile fatty acids (VFA) and ammonia, respectively. Rumen fluid was also preserved in methyl green-formalin-saline solution (1:1 v/v) and stored at room temperature in the dark for later enumeration of protozoa. Additional ruminal contents (250 mL) were collected on two consecutive days from four different sites in the rumen at 1 h before and 3 and 5 h after feeding. Samples were freeze-dried and ball ground and DNA was extracted as described below.

Total tract nutrient digestibility was determined using chromium oxide (Cr_2O_3; 7 g/head/d) as an indigestible marker which was mixed with rolled barley or wheat grain and top-dressed each day from d 12 to 19 during each period. Feces were collected daily from the rectum at 1 h before and 3 and 5 h after feeding over a 5-d period and composited by steer within period on an equal DM basis. Nutrient digestibility (%) was calculated as 100 – [(Nutrient concentration in feces $\times$ Cr concentration in diet $\times$ DM intake $\div$ Cr concentration in feces) $\div$ (Nutrient concentration in diet $\times$ DM intake)] $\times$ 100.

Blood samples (10 mL) were taken from the jugular vein on d 21 of each period at 8 AM before feeding and plasma was isolated as described previously (He et al., 2011).

2.4. Rumen bacteria DNA extraction and RT–PCR analysis

Total DNA in mixed rumen contents (100 mg DM) was extracted using a Qiagen QIAamp DNA Stool Mini Kit (Qiagen Inc.,Valencia, CA, USA) based on the manufacturer's instructions, with minor modifications as outlined by Narvaez et al. (2013). Isolated bacterial fractions were lysed at 95 °C for 5 min and centrifuged at 13,000 $\times$ g for 5 min at room temperature. The supernatant was collected and stored in a refrigerator at 5 °C. Remaining pellets were reconstituted with potassium phosphate buffer (0.4 mol per L, pH 7), containing lysozyme (100 mg per mL) and mutanolysin (2.5 U per μL) and incubated at 37 °C for 30 min. The suspension was subsequently mixed with 20 μL of proteinase K and incubated at 37 °C for 1 h. Samples were bead beaten (300 rpm and 3 min) in a Qiagen tissue lyser (Retsch, Inc., Newton, PA, USA) and centrifuged at 13,000 $\times$ g for 1 min at room temperature.

Please cite this article as: He, M.L., et al., Effect of replacing barley with wheat grain in finishing feedlot diets on nutrient digestibility, rumen fermentation, bacterial communities and plasma metabolites in beef steers. Livestock Science (2015), http://dx.doi.org/10.1016/j.livsci.2015.03.024