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Effects of volume weight, processing method and processing index of barley grain on in situ digestibility of dry matter and starch in beef heifers

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ABSTRACT

The objectives of this study were to evaluate the effects of volume weight (VW; g/L), processing method (PM; control vs. precision processing [PP]), and processing index (PI; VW after rolling/VW before rolling) of barley grain on in situ ruminal kinetics and *in vitro* intestinal digestion. The study was designed as a $2 \times 2 \times 2$ factorial arrangement of treatments: VW (low vs. high), PM (control vs. PP) and PI (0.75 vs. 0.85). Ten barley samples, 5 low (580 g/L) and 5 high (680 g/L) VW, were either dry-rolled with a single roller setting (control) or screened into two fractions of small or large kernels using a 4-mm sieve, and then dry-rolled (i.e., PP). Each sample was dry-rolled moderately or coarsely with PI of 0.75 or 0.85. Three beef heifers (650 ± 25.5 kg body weight) fitted with rumen cannulas and fed a diet consisting of 700 g/kg barley silage and 300 g/kg concentrate mix (dry matter [DM] basis) were used for the in situ study. In situ degradation kinetics of DM and starch were estimated after 0, 3, 6, 12, 24 and 48 h of ruminal incubation. Data from DM and starch degradation at different times of incubation were fitted to a model $y = a + b(1 - e^{-c(t-L)})$. *in vitro* intestinal disappearances of DM and starch of ruminal residue after 12 h of incubation were determined using a modified three-step procedure. Interactions between VW and PM on effective degradability (ED; $P<0.01$) and between PM and PI on the degradation kinetics ($P<0.05$) were observed. The VW of barley grain did not affect the degradation kinetics of DM and starch whereas ED of DM was greater ($P<0.01$) in high versus low VW in the control samples. For in situ DM disappearance, *a* ($P<0.01$) and *b* ($P<0.07$) fractions were lower, but *c* and ED were higher ($P<0.01$) in PP versus control samples. Increased processing of barley consistently resulted in greater ($P<0.01$) values of degradation kinetics and ED compared with less processed barley. Intestinal DM disappearance of rumen residues was affected by all three factors (VW, PM and PI). Regression results showed that the rate of DM disappearance was correlated to the particle size distribution and the fine particles were the primary

Abbreviations: ADF, acid detergent fibre; CP, crude protein; DM, dry matter; DMD, dry matter disappearance; ED, effective degradability; aNDF, neutral detergent fibre; OM, organic matter; PI, processing index; PM, processing method; PP, precision processing; VW, volume weight.

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predictor. The results demonstrated that the PP approach and manipulating PI are effective ways to optimize rumen digestion of barley grain. This suggests that a concise and reliable method to predict rumen digestion of barley may be developed based on measuring the fines content of processed barley.

1. Introduction

Barley grain is the major energy source used in the diets of dairy and beef cattle in western Canada. As much as 0.80 of all barley grain grown in Alberta enters the feed chain for cattle and swine (Alberta Agriculture and Rural Development, 2010). Differences in digestibility explain most of the variation in energy content of a feed. Digestibility of whole barley in cattle is much less than its potential because of its fibrous hull and intact pericarp which are very resistant to bacterial attachment and digestion in the rumen (Beauchemin et al., 1994; McAllister et al., 1994). Hence, barley grain needs to be processed prior to feeding to expose the endosperm, encased within indigestible pericarp and hull layers, to the microbial population in the rumen (Wang and McAllister, 2000). Degree of grain processing affected the site and extent of digestion, rumen health and productivity of cattle (Yang et al., 2000; Dehghan-banadaky et al., 2007). Over-processing can cause digestive disturbances such as bloat and acidosis (Owens et al., 1997) and reduce feed intake, and conversely, under-processing reduces digestibility. The degree of processing can be quantified using a processing index (PI), which is calculated as the volume weight (VW; g/L) of barley after processing divided by its VW before processing (Yang et al., 2000). This index reflects the fact that the more extensively barley is processed (i.e., the higher the degree of processing), the finer the particle, hence, the lower the VW and consequently the lower the PI. Numerous studies have shown significant relationship between PI and feed value of barley grain (Yang et al., 2000; Beauchemin et al., 2001; Koenig et al., 2003).

However, PI is affected by the processing method (PM; McAllister et al., 2011), and is likely unable to differentiate the feed value of processed barley that varies in VW or kernel uniformity (Yang et al., 2013). The quality of processed barley and its particle size distribution is particularly affected by kernel uniformity. The size of barley kernels varies considerably among barley varieties and harvesting year (McAllister et al., 2011). Commercially, light weight barley is commonly blended with heavier weight barley to create a mid-weight barley that is more acceptable to the market. This variability in kernel size makes it difficult to achieve optimal processing with a single roller setting. Processing barley grain based on kernel size is referred to as precision processing (PP) and improves nutrient digestibility (Ahmad et al., 2010; Yang et al., 2013). Additionally, feeding value of barley grain is affected by the quality of barley grain prior to processing (Mathison et al., 1991; Hunt, 1996). The VW is easily measured and commonly used to assess a relative market value of barley grain. High VW barley often has greater starch and less fibre concentrations than light VW barley (Mathison et al., 1991; Engstrom et al., 1992), resulting in the assumption that greater VW provides more energy in the form of readily fermentable carbohydrate to the animal. We hypothesized that incorporating additional factors of VW and PM with PI would help to improve prediction of the feeding value of processed barley grain. The objectives of this study were to: (1) determine the effects of dry-rolled barley grain that varied in VW, PM and PI on in situ rumen degradation kinetics of dry matter (DM) and starch, and *in vitro* intestinal digestibility; and (2) develop a model to predict the rate of DM degradation of dry rolled barley grain.

2. Materials and methods

2.1. Barley sample collection and processing

Barley samples used in this study were the same samples used in Anele et al. (2014). Barley grain was cleaned at the feedlot prior to sampling. A total of 10 lots of barley consisting of the 5 highest (high) and the 5 lowest (low) in VW (g/L) were selected from a pool of 120 samples that were collected monthly for one year from 10 different feedlots located in Southern Alberta. Subsequently, a portion of each of these 10 samples was manually sieved using a 4-mm sieve into small and large kernels. Un-sieved samples were processed using a single roller setting that hereafter will be designated as control. The sieved small and large kernels were rolled with a roller setting based on the kernel size of each fraction and then recombined according to the original weight proportions that hereafter is designated as PP. All 20 samples were dry-rolled using a laboratory scale roller (Model R250.6, Kal Rob Machining, Picture Butte, AB, Canada) with 2 extent of processing expressed as PI of 0.75 and 0.85. Thus, total 40 samples: 10 samples (5 low and 5 high VW) $\times$ 2 PM (control and PP) $\times$ 2 PI (0.75 and 0.85) were evaluated in in situ study; the experiment was designed as a $2 \times 2 \times 2$ factorial arrangement of treatments. Particle size distribution of processed samples was measured using a series of sieves at 3.35, 2.36, 1.18, 0.85 mm, and a pan in a Ro-Tap machine (RX-29, W. S. Tyler, Mentor, OH, USA).

2.2. In situ procedures

All animal procedures were in accordance with the guidelines of the Canadian Council on Animal Care (2009). Three beef heifers (650 ± 25.5 kg of body weight) fitted with rumen cannulas (Bar Diamond Inc., Parma, ID, USA) with internal diameter