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Intakes and excretion route of nitrogen, phosphorous and sulfur by finishing beef heifers fed increasing levels of wheat dried distillers grains with solubles to substitute for barley grain and barley silage

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ABSTRACT

A study was conducted to determine the fecal and urinary excretion of N, P and S with increasing inclusion of wheat dried distillers grains with solubles (DDGS) to substitute for barley grain and barley silage in finishing diet fed to growing beef heifers. Eight ruminally fistulated Angus heifers were assigned to a replicated 4 × 4 Latin square design with 21 d periods using diets consisting of barley silage, barley concentrate, and wheat DDGS in ratios of 150:850:0, 100:650:250, 50:650:300 and 0:650:350 (DM basis), respectively, for control (CON), low (DDGS25), medium (DDGS30) and high (DDGS35) DDGS diets. Heifers were fed a total mixed ration for ad libitum intake. Total collection of feces and urine were conducted for 5 d in each experimental period. Intake of N was higher for heifers fed DDGS diets than heifers fed CON diet with no differences among DDGS diets. The increased N intake resulted in an increase in N retention as well as increased N excretion. The N was primarily excreted in urine (~700 g/kg N excreted) with less in feces (~300 g/kg N excreted). Urinary N excretion linearly increased, whereas fecal N excretion linearly decreased, with increasing dietary DDGS inclusion. Intake of P was higher for DDGS than CON, but linearly decreased with increasing DDGS inclusion in the diets due to decreased DMI. Total P excretion was higher whereas P retention was lower in heifers fed DDGS than heifers fed CON diets. The majority of P was excreted by feces (from 897 to 634 g/kg P excreted) and linearly decreased with increasing dietary DDGS inclusion; conversely, the urinary P excretion linearly increased. Feeding DDGS diets considerably increased S intake with no differences among DDGS diets. Only a small part of S consumed was retained and the excretion of S via feces was lower, but the excretion via urine was higher, for heifers fed DDGS compared with heifers fed CON diet. Results indicate that inclusion 250 to 350 g/kg wheat DDGS in finishing diets substantially increased the intakes and excretion of N, P, and S. Increasing the excretion of N, P, and S is a primary environmental concern when using DDGS in feedlot cattle. Developing nutrient management programs that minimize N, P and S losses to the environment and maximize plant use need to be considered.

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1. Introduction

Incorporating dried distillers grains with solubles (DDGS) in feedlot finishing diets is practiced because of its high nutritional value and competitive price with grain. In western Canada and elsewhere, wheat is used as an alternative to corn for ethanol production, thus wheat-based DDGS are commonly used in cattle rations. During ethanol fermentation, the majority of starch in grain is removed to produce ethanol concentrating the remaining protein, fibre, fat and minerals in DDGS by approximately 3-fold (Nuez-Ortín and Yu, 2009). Compared with corn DDGS, wheat DDGS contain higher protein (Beliveau and McKinnon, 2008) and has higher protein degradability in the rumen (Li et al., 2011). Thus, diets with high inclusion of wheat DDGS in finishing diet often exceed the requirements of protein by feedlot finishing cattle fed barley grain-based diet. With the increased use of high protein feedstuffs in the diets of cattle, the potential for increased nitrogen (N) excretion is a concern. Nitrogen is excreted by cattle mainly as urea in urine (N in urine account for 60 to 80% of total N excretion) or in feces (Erickson and Klopfenstein, 2010). Urea can be rapidly hydrolyzed to CO_2 and NH_4 by urease (Bussink and Oenema, 1998). Ammonia volatilization is the largest N loss from many cattle farms and these emissions are detrimental to the agricultural economy, human health, and ecosystems. Fecal N can contribute ammonia emission as well, but at a much slower rate. As N intake increases or the dietary ratio of ruminally degradable to undegradable protein increases, excretion of urinary urea N increases (Walter et al., 2012).

Wheat DDGS contain high concentrations of phosphorus (P) and sulfur (S) (Li et al., 2011). The resulting manure from cattle fed wheat DDGS, with high P content, can be beneficial for crop production, but it may also have a negative environmental impact due to increased P accumulation in crop lands surrounding feedlots (Hao et al., 2009). Environmental concerns regarding P exctretion are primarily associated with pollution of surface water. Dietary P intake was positively associated with the amount of P excreted in livestock manure (Wu et al., 2000; Ebeling et al., 2002). Phosphorus losses from livestock farms account for as much as 470 g/kg of total P loading to bodies of surface water, depending on the watershed (Smith and Alexander, 2000). Concentration of S in wheat DDGS was reported to range of 3.9 to 11.4 g/kg dry matter (DM; Li et al., 2011; Nuez-Ortín and Yu, 2009). The high S in DDGS is mostly from chemicals added during the ethanol fermentation to control pH and for cleanup. Excess S consumption (above 4 g/kg diet DM) from feed and water can lead to polioencephalomalacia (PEM; Gould, 1998). In addition, excreted S can contribute to H_2S emissions from livestock manure (Shurson et al., 1998). Therefore, the effects of feeding high wheat DDGS to feedlot cattle on N, P and S excretion could help refine predictions of ammonia emissions and pollution of P and S. The objective of this study was to evaluate the effect of increasing feeding wheat DDGS to substitute for barley grain and barley silage in finishing feedlot cattle diets on the chemical forms and route of excretion of N, P and S. The effects of increasing wheat DDGS in finishing feedlot cattle diets on feed intake, ruminal fermentation, and nutrient digestibility were reported separately (Li et al., 2011).

2. Materials and methods

2.1. Animals, experimental design and diets

This study was approved by the Animal Care Committee of the Agriculture and Agri-Food Canada, Lethbridge Research Centre, Lethbridge, Alberta, and was conducted according to the guidelines of the Canadian Council on Animal Care (1993). Humane animal care and handling procedures were followed throughout the study.

Eight Angus heifers with ruminal fistula (initial body weight [BW], 455 ± 10.8 kg) were randomly assigned to one of four treatments in a replicated 4×4 Latin square experiment balanced for carry over effects. Each period consisted of 12 d of adaptation to the new diets and 9 d of experimental measurements. The four experimental diets consisted of barley silage, barley concentrate, and wheat DDGS in ratios of 150:850:0, 100:650:250, 50:650:300 and 0:650:350 (DM basis), respectively, for control (CON), low (DDGS25), medium (DDGS30) and high (DDGS35) DDGS diets (Table 1). The supplement contained protein, minerals and vitamins in meet of the National Research Council (NRC, 1996) nutrient requirements for beef cattle gaining 1.5 kg/d. A single lot of wheat DDGS obtained from Terra Grain Fuels, Regina, SK, Canada was used for the study. Diets were prepared daily using a feed mixer (Data Ranger, American Calan Inc., Northwood, NH, USA), and offered as total mixed ration (TMR) at ad libitum. The cattle were adapted to the experimental diets by gradually increasing the proportion of concentrate over a period of 4 weeks prior to starting the experiment.

The heifers were fed once daily (1100 h) at a level that ensured approximately 50 g/kg refusals. Feed offered and refused were recorded daily for each heifer for the entire experiment. The TMR and barley silage were sampled once a week to determine DM content and the diets were adjusted to account for these changes. Samples of barley grain and DDGS were also collected weekly and composited for each period. Refusals were collected during the last 7 d of each period. The samples were oven-dried at 55 °C for 48 h and ground through a 1-mm screen (standard model 4 Wiley Mill, Arthur Thomas Co., Philadelphia, PA, USA) for subsequent chemical analysis.

The heifers were housed in individual tie-stalls on rubber mattresses and bedded with wood shavings. However, no bedding was provided during the sample collection period. Water was available freely throughout the experiment. The heifers were exercised daily in an outdoor pen for 1 h as the measurement and sampling schedule permitted. Heifers were weighed at the beginning of the first period and at the end of each period.

2.2. Intake, total fecal and urine collection

Feed intake (kg/d) for each heifer was calculated as the difference between the feed offered and refused during the last 7 d of each period. Total collection of feces and urine were conducted during the last 5 consecutive days of