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Effects of dietary supplementation of montmorillonite and yeast cell wall on lipopolysaccharide adsorption, nutrient digestibility and growth performance in beef cattle

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ABSTRACT

The study was carried out to evaluate the effects of dietary supplementation of montmorillonite (MMT) and yeast cell wall (YCW) on lipopolysaccharide (LPS) adsorption, apparent nutrient digestibility and growth performance in beef cattle. Eighteen beef steers (Simmental × Luxi) with an initial body weight (means ± standard deviation) of 335 ± 7.5 kg and similar body condition were randomly assigned to one of three treatments for 50 days in a completely randomized design. The treatments consisted of (1) the basal diet (control), (2) the basal diet + 2 g/kg MMT, and (3) the basal diet + 2 g/kg YCW on a dry matter basis. Fecal grab samples were collected for five consecutive days on days 41–45 after the morning feeding; jugular vein blood was collected on day 45 before the morning feeding, and beef steers were slaughtered at the end of the 50-day trial and dissected to collect samples of ruminal fluid and digesta of different intestinal sectors (the duodenum, jejunum, ileum, cecum and colon). Results showed that dietary MMT supplementation decreased ($P < 0.05$) free LPS concentrations in plasma, feces, and the digesta of different sectors of the gastrointestinal tract except the cecum. Dietary YCW supplementation decreased ($P < 0.05$) free LPS concentrations in plasma, feces, and the digesta of the lower gut including the ileum, cecum and colon. Correspondingly, the levels of acute phase proteins (serum amyloid-A, haptoglobin, C-reactive protein, and LPS-binding protein) in plasma were also decreased ($P < 0.05$) by dietary supplementation of MMT and YCW. Dietary supplementation of YCW increased ($P < 0.05$) apparent digestibilities of acid detergent fiber and total phosphorus and improved ($P < 0.05$) average daily gain and feed efficiency. Dietary supplementation of MMT only improved feed efficiency ($P < 0.05$). Results suggest dietary supplementation of MMT and YCW can effectively bind LPS in the digestive tract, reduce the translocation of LPS from the digestive tract into the circulation, and thus improve growth performance in beef cattle. Dietary supplementation of YCW at a dose of 2 g/kg was more effective than that of MMT at the same dose in reducing plasma acute phase protein levels and in improving growth performance.

1. Introduction

In practical production, beef cattle are frequently fed diets containing low proportions of forage because of the regional and seasonal lack of forages (especially high-quality forages) and high proportions of concentrates (particularly grains) to meet the energy need of beef cattle.

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As a result, ruminal pH decreased and the microbial ecology was altered (Keunen et al., 2002). When rumen pH is lower than the normal level, ruminal acidosis can occur, and a large amount of endotoxin (lipopolysaccharide, LPS) will be released from Gram-negative bacteria in the rumen and the lower gut (Dong et al., 2011; Gozho et al., 2006; Plaizier et al., 2008, 2012; Nagaraja and Titgemeyer, 2007). High concentrations of LPS can be translocated into the bloodstream across the epithelium of the digestive tract (Dong et al., 2011; Emmanuel et al., 2008; Plaizier et al., 2008, 2012), which subsequently elicits inflammatory responses including an increase in concentrations of the acute phase proteins such as serum amyloid-A (SAA), haptoglobin (Hp), LPS-binding protein (LBP), and C-reactive protein (CRP) in blood (Gozho et al., 2006). Meanwhile, entry of free LPS into blood can also result in metabolic disturbances. Blood glucose and non-esterified fatty acid concentrations increased accompanying a rise of blood LPS after increasing the amount of grain in the diet, which adversely affects feed intake of cattle. In addition, patterns of plasma β-hydoxybutyric acid, cholesterol, and minerals (Ca, Fe, and Zn) are also perturbed (Ametaj et al., 2009; Zebeli et al., 2010). As a result, the growth performance of cattle may be adversely affected. Therefore, reducing free LPS release in the digestive tract and translocation across the epithelium could minimize the adverse effects of LPS in beef cattle.

Montmorillonite (MMT) and yeast cell wall (YCW) have been used as inorganic and organic adsorbent additives in animal feed. Ditter et al. (1983) extracted the LPS from animal internal organs and carried out tests in vitro and in vivo in mice for verification of the adsorption effects of various adsorbents, which showed that bentonite (its main component is MMT; Ramos and Hernandez, 1996; Spieker, 2010) was able to bind LPS. Spieker (2010) further carried out an in vitro study on the effects of MMT on the adsorption of LPS using buffers and rumen fluids, and their results showed that MMT had an effect to bind LPS. Other studies have demonstrated that YCW can bind mycotoxins in the diets of broilers (Swamy et al., 2002) and laying hens (Zaghini et al., 2005). However, whether YCW can effectively bind LPS remains unclear. It is hypothesized that adding MMT and YCW into the diet of beef cattle could bind the LPS released in the digestive tract, and thus reduce its translocation from the gut into the body and improve performance in beef cattle.

Therefore, the objective of this study was to evaluate the effects of dietary supplementation of MMT and YCW on LPS adsorption and translocation in the digestive tract, as well as on apparent nutrient digestibility and growth performance in finishing steers.

2. Materials and methods

2.1. Animals and diets

The use of the animals and the experimental procedures were in accordance with the Regulation on the Care of Experimental Animals issued by the Science and Technology Commission of Chongqing Municipality.

Table 1
Ingredients and chemical composition of the basal diet.

Ingredients (g/kg of dry matter)	
Rice straw	115.0
Sorghum distiller's grains	285.0
Corn grain	481.0
Rapeseed meal	84.9
Salt	3.0
Limestone	20.5
Sodium bicarbonate	7.8
Premix[a]	2.8
Chemical composition (g/kg of dry matter)	
Organic matter	868.0
Crude protein	143.3
Ether extract	102.2
Ash	75.3
Neutral detergent fiber	380.1
Acid detergent fiber	263.1
Calcium	6.9
Total phosphorus	2.3

[a] The premix provides per kg diet: Fe (as ferrous sulfate) 70 mg, Cu (as sulfate) 100 mg, Zn (as sulfate) 60 mg, Mn (as sulfate) 20 mg, Co (as chloride) 0.1 mg, I (as iodate) 0.5 mg, Se (as selenite) 0.1 mg, Vitamin A 400 IU, Vitamin D 3500 IU, and Vitamin E 40 IU.

Eighteen beef steers (Simmental × Luxi) with an initial body weight (BW) of 335 ± 7.5 kg (means ± standard deviation) and similar body condition were randomly assigned to one of three experimental treatments ($n=6$/treatment) for a 50-day trial in a completely randomized design. The experimental treatments consisted of (1) the basal diet (control), (2) the basal diet + 2 g/kg MMT, and (3) the basal diet + 2 g/kg YCW on a dry matter basis. The MMT was provided by Hezhengmei Feed Additives Co., Chifeng, China, and the content of MMT was ≥ 97.8%. The YCW was purchased from Alltech Beijing, China (dry matter ≥ 94.0%, β-glucan ≥ 30.0%, and mannan-oligosaccharide ≥ 20.0%). The ingredients and chemical composition of the basal diet were given in Table 1. During the trial, cattle were housed in individual tie stalls, and diets with a forage to concentrate ratio (*F*:*C*) of 40:60 were mixed and offered twice daily. Cattle were allowed free access to feed and water. Orts were recorded and discarded before the next feeding each day.

2.2. Sampling procedure

Fecal grab samples were collected once a day for five consecutive days on days 41–45 of the experimental period after the morning feeding. Approximately 50 g of sample per animal each day was collected into a sterile and depyrogenated glass tube (previously heated at 100 °C for 4 h). A subsample of 10 g was transferred into a pyrogen-free tube and mixed thoroughly with an equal amount of physiological saline (9 g/L NaCl). The mixture was then immediately processed for LPS assay using the same procedure as described below for rumen fluid and intestinal digesta samples. Another 100 g fecal sample per cattle each day was mixed with 20 ml 100 mg/g sulfuric acid and stored at −20 °C for chemical analysis.

On day 45 of the experiment, 10 ml blood sample was collected from the jugular vein of each animal before the