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Molasses level in lamb high-energy diets on productive performance, blood chemistry, liver minerals and histopathology

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A B S T R A C T

The objective of this study was to determine the effect of increasing levels of molasses on growth performance, carcass characteristics, blood chemistry, liver minerals and histopathology of lambs. Twenty intact male pelibuey lambs with an average weight of 22.4 ± 2.8 kg were randomly assigned to one of the four experimental diets containing 0, 60, 120 and 180 g molasses/kg feed (as fed basis) in a completely random design. Lambs were individually confined to 1.5 m^2 pens. The experiment had a 15-day adaptation period and a 60-day experimental period. As molasses content in the ration increased from 0 to 180 g/kg, S increased from 1.1 to 2.1 g/kg DM, whereas Cu concentration ranged from 17.3 to 18.4 mg/kg DM. All diets contained high concentrations of Fe (198–252 mg/kg DM) and Zn (85–104 mg/kg DM), and low Mo contents (1.4–1.5 mg/kg DM). Molasses level had no effect ($P > 0.05$) on DM intake, average daily gain, gain:feed, slaughter weight, full or empty gastrointestinal tract weight, digesta-free weight, hot and chilled carcass weights, dressing percent, longissimus muscle area, marbling, back-fat thickness, yield grade or KPH fat. Most of the lamb carcasses of this study were graded with small to slight marbling. The clinical status of the lambs was evaluated through histological and blood chemistry tests, obtaining samples on days 0, 15, 30 and 60. Although most blood parameters were within normal ranges, blood urea nitrogen, creatinine and cholesterol concentrations decreased (linear; $P < 0.05$) as molasses increased in the diet. Concentrations of the enzymes serum glutamic oxaloacetic transaminase, alkaline phosphatase and creatine phosphokinase were also reduced (linear; $P < 0.05$). Concomitant reductions ($P < 0.01$) in liver Zn and Mo concentrations were also noticed. Although no differences ($P > 0.05$) were observed in liver histopathological observations between treatments, Cu-related sub-lethal hepatic damage was evident in all animals, in absence of clinical signs. Special stain showed fine grained Cu deposits within hepatocytes in three cases belonging to different treatments. It appears that lambs consuming the control diet without molasses with a low S content (0.11%) were as susceptible to a pre-hemolytic copper poisoning (Pre-HCP) as those consuming the other diets containing higher Cu concentrations.

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1. Introduction

Black strap cane molasses is a by-product of the sugar refinement process (AAFCO, 2000; AFIA, 1994). A review of early studies on the use of black strap molasses in beef finishing diets shows a very obvious advantage in rate of gain and/or dry matter utilization from the addition of 20-100 g/kg cane molasses to high concentrate diets fed to finishing cattle. The data strongly supports the conclusions that limited amounts of molasses to finishing diets stimulated microbial activity, digestibility of energy and fiber, and nitrogen utilization (Pate, 1983).

Frequently, the cost of molasses is much lower than that of the cereal grains. However, the use of molasses in the ration of ruminants is limited since high levels may cause digestive upset, diarrhea and low animal performance (Pate, 1983; The Merck Veterinary Manual, 1991). Diarrhea is in part caused by a high level of potassium, magnesium and other mineral salts (Arthington and Pate, 2002).

Molasses is a good source of energy and trace minerals. Copper levels in molasses are high, increasing the risk of toxicity in sheep (NRC, 2007). Copper toxicosis is primarily due to poor Cu homeostasis, resulting in liver Cu accumulation (NRC, 2005). Levels usually required by cows and pigs may be toxic to sheep. Copper metabolism in sheep is complex because of the narrow range between its required level and the level at which toxicity can occur (Bremner, 1998). Furthermore, there is a wide breed susceptibility and still poorly understood interactions between Cu and molybdenum (Mo) and Cu with S-related compounds (sulfates, SO_4) (Spears, 2003). Generally, growing lambs have a minimum requirement of approximately 6 mg/kg of Cu on a DM basis (NRC, 2007). The toxicity risk has influenced nutritionists to be cautious when Cu-supplemented diets are provided to confined sheep (Suttle and Jones, 2000). The maximum tolerable Cu concentration for sheep is 15 mg/kg DM with diets that contain normal Mo (1–2 mg/kg DM) and S (0.15–0.25%) concentrations (NRC, 2005). However, subclinical toxicity may occur with diets containing 12 mg/kg (Angus, 2000).

Dietary Mo levels also affect Cu requirements, as Mo forms an insoluble complex with Cu to prevent Cu absorption. If Mo levels are low (<1 ppm), sheep are more susceptible to Cu toxicity. If Mo intakes exceed 10 ppm, Cu deficiency may occur on diets that would normally be adequate. Sulfur further complicates the Cu:Mo relationship by binding with Mo and forming thiomolybdates (Bremner, 1998; Spears, 2003). Nonetheless, independent from its role in the Mo–Cu interaction, S reduces Cu bioavailability. Sulfur in the form of sulfide is believed to reduce Cu bioavailability via formation of insoluble Cu sulfide in the gut (Spears, 2003).

Copper toxicosis in sheep consists of a prehemolytic, and hemolytic phase (Howell and Gooneratne, 1987). Although Cu is accumulated in the liver and to a lesser extent in the kidney during the prehemolytic phase, the animal is clinically normal, and depressed animal performance is generally not evident until at least shortly before the hemolytic phase occurs. During the prehemolytic phase, liver necrosis occurs and enzymes (serum glutamic oxaloacetic transaminase, aspartate aminotransferase, glutamate dehydrogenase, and sorbitol dehydrogenase) indicative of liver damage may become elevated in serum, but blood copper is generally normal (Howell and Gooneratne, 1987). Sheep show histological and biochemical evidence of liver damage at liver copper concentrations as low as 350 mg Cu/kg DM; however, clinical signs of toxicosis do not usually occur until liver concentrations of 1000 mg Cu/kg DM or higher are reached (Underwood and Suttle, 1999). Animals that die from copper toxicosis often have liver concentrations that exceed 2000 mg Cu/kg DM.

Chronic Cu toxicity in sheep usually results from the accumulation of excess Cu in the liver over a period of a few weeks to more than a year in absence of clinical signs, followed by a sudden release of Cu stored in liver to cause hemolysis (NRC, 2005). In these situations, toxicity may result from excessive Cu intakes or from low intakes of Mo, S, iron, zinc, or following liver damage. Stressful conditions, such as abrupt weather changes, poor nutrition, transportation and handling, can also induce hepatocytes to release the stored Cu into the bloodstream (Angus, 2000).

Some minerals in molasses, such as sulfur, molybdenum and iron, may actually increase Cu requirements of beef cattle by reducing its accumulation in the liver (Arthington and Pate, 2002; Arthington et al., 2003), since cattle and goats are less susceptible to copper toxicity than sheep (NRC, 2005). Based on this evidence, we hypothesize that S-compounds and other minerals found in molasses would decrease the liver accumulation of Cu as well as ameliorate, or even eliminate, the negative effects of a Pre-HCP. Therefore, the objective of this study was to test the effects of replacing sorghum grain with blackstrap cane molasses to a level of 18%, on growth performance, carcass characteristics, serum enzyme concentrations, blood chemistry, liver minerals and histopathology observations.

2. Material and methods

2.1. Animals, diets and sampling procedures

This experiment was approved by the internal council of the School of Veterinary Medicine of the Autonomous University of Nuevo León, following the guidelines of the Mexican Association of Laboratory Animal Specialists.

Twenty intact male Pelibuey lambs, 5-months old and an average weight of 22.4 ± 2.8 kg were randomly assigned to one of four treatments according to a completely randomized design. Treatments were four experimental diets containing incremental levels of molasses: 0, 60, 120 and 180 g/kg blackstrap molasses (Table 2).

Lambs were confined to individual pens ($1\ m \times 2\ m$) equipped with water and feed troughs. Diets were formulated to contain approximately 170 g CP/kg DM (Table 1). Other main diet ingredients were soybean hulls, soybean meal and sorghum grain, as well as a base mix (25 g/kg) with vitamins, minerals, and urea. Sorghum grain was included half ground and half whole to increase chewing. The base mix included in all experimental diets had no sulfur added and provided 7 mg Cu/kg DM in all diets. The ionophore, sodium lasalocid (30 mg/kg feed DM),