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Plasma metabolites and nitrogen balance in *Lama glama* associated with forage quality at altitude

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Abstract

This study evaluated the effects of forage quality on blood metabolites and nitrogen balance in mature, intact male llamas ($n = 4$, 36 ± 4.4 months, 87 ± 17 kg) at high altitude (4267 m Letanias, Bolivia). Llamas were randomly fed barley hay (B), 80% barley/20% alfalfa hay (BA) and fresh cut grass pasture (P). Animals were housed in metabolism crates and diets were fed for a 7-day adjustment period followed by a 5-day collection period. Feed, feed refusal, feces and urine were collected, dried and N content determined by combustion analysis. Venous blood samples were collected on day 12 at 30 min intervals over a 6 h period. Plasma was harvested and analyzed for electrolytes (Na, K, Cl, Ca, Ca^{2+}, P, Mg) and metabolites (glucose, NEFA, urea N, creatinine, albumin, total protein (TPP), osmolality (Osm)). Plasma electrolytes (Na, K, Mg, P, Cl) and metabolites (glucose, Osm, albumin, creatinine, TPP) were unaffected by forage treatment. Dry matter digestibility was greater for the B and BA than P forage, and N digestibility was significantly higher for BA than either the B or P forages. Nitrogen balance varied significantly between diets. N intake was significantly different between each diet ($P < 0.0001$), with B having the least N (7.1 g/day), followed by P (14.4 g/day) and BA (19.0 g/day), which provided the most N. Urine N excretion was similar between P (7.7 g/day) and BA (10.6 g/day), similar between P (7.7 g/day) and B (6.2 g/day), but was different ($P < 0.04$) between B (6.2 g/day) and BA (10.6 g/day). Fecal N excretion was similar between BA (7.4 g/day) and P (8.9 g/day). Both of these treatments produced significantly higher quantities of fecal N than B (4.1 g/day; $P < 0.0004$). Nitrogen excretion followed the same trend as N intake. Total N excretion was highest in BA followed by P and B forages. Llamas were in negative N balance on the B and P diets. Llamas had an estimated daily maintenance requirement value of 0.58 g crude $N/W^{0.75}$ and a daily maintenance requirement of 106.2 g CP/day. Mineral intake varied significantly between diets. Overall, pasture provided higher amounts of minerals than the barley forages, except for copper, phosphorus and zinc. These data demonstrate the effects of feeding forages of varying quality on whole-body N utilization, and trends in blood metabolite and electrolyte patterns in llamas at altitude.

Keywords: Llamas; Bolivia; Nitrogen balance; Plasma metabolites

1. Introduction

South American camelids (SACs) play a vital role in the economy and culture of South American countries, including Argentina, Bolivia, Chile, Ecuador and Peru.

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In the high altitude zone (>3000 m) of these countries, many families rely solely on camelid herding for their survival (Sumar, 1988). The four species of South American camelids include llama, alpaca, vicuÒa and guanaco. Llamas and alpacas are the domesticated and economically important species. Llamas are used for pack, fiber, meat, and to guard other livestock such as sheep. Their productivity is limited by factors such as harsh climate and environment, overgrazing of rangelands, and lack of knowledge concerning their behavioral, nutritional and disease problems (Sumar, 1988).

Current camelid nutritional recommendations are usually extrapolated from requirements for domesticated sheep, goats and cattle (Carmalt, 2000). Very little is known about camelid nutritional requirements consuming locally grown forages (San Martin and Bryant, 1989). South American pastoralists tend to own small, mixed herds of camelids and ruminants, including llamas, alpacas, sheep and cattle. Research examining the differences between the digestive abilities of these high altitude tylopod pseudoruminants compared to domesticated pecoran ruminants has been published (Dulphy et al., 1994, 1998; Genin and Tichit, 1997; Lemosquet et al., 1996; Riera and Cardozo, 1970; Vernet et al., 1997). These studies suggest that llamas are better adapted to digest poor quality forages than their ruminant counterparts under the same conditions. Llamas had a higher dry matter, organic matter and NDF digestibility than do sheep, and these differences were greatest with poorer quality diets. However, the nutritional requirements for SACs at high altitude consuming locally raised forages of varying quality and protein levels are not well understood. The literature indicates that camelid digestive efficiency increases at higher altitudes (San Martin and Bryant, 1989; López and Raggi, 1992). That fact further complicates interpretation and application of available nutritional information as it relates to alpacas and llamas. Due to the positive altitudinal influence on camelid digestive efficiency, López and Raggi (1992) indicated that digestible protein values are more suitable to report than protein requirement for these species at a particular altitude.

Information concerning the nutritional status of llamas consuming locally raised forages at high altitude is needed to better understand local forage digestibility and protein levels needed to meet energy requirements, to maintain nitrogen balance and to improve health and productivity. The digestibility of forages needs to be further investigated to know the approximate levels of nutrient supplementation necessary. The purpose of this study was to determine the digestibility of three different forages and the effect on blood metabolites and nitrogen balance in llamas living on the Bolivian Altiplano at an altitude of 4267 m (14,000 ft) above sea level.

2. Materials and methods

2.1. Animals

Four intact adult llamas (36 ± 4 months, 87.7 ± 17 kg) were included in this study conducted at Letanias, Bolivia (altitude 4267 m). Animals were housed in metabolism crates with expanded metal flooring (Fig. 1), with skylights to provide approximately 12 h of natural lighting. All llamas were fed 100% barley hay (B) prior to onset of the study. During the first week of the study, llamas were adapted to the metabolism crates and first treatment. The second week, llamas continued consuming the treatment diet which was fed during the 5-day collection period. The animals were removed from the metabolism crates and exercised for 30 min twice daily in a paddock during the acclimation period. The animals were provided with water ad libitum and they were fed twice daily at 12 h intervals with the majority of the diet given in the morning. This was done to accommodate camelid diurnal eating patterns with the majority of their feed consumed during the day.

2.2. Treatments

The experimental design administered dietary treatments in random order to three repetitions of animals. Treatments consisted of three diets: barley hay (*Hordeum vulgare*) (B), 80% barley hay (*H. vulgare*)/20% alfalfa hay (*Medicago sativa*; (BA)) and grass pasture (P) made up of hycrested wheatgrass (*Agropyron cristatum*) and Siberian wheatgrass (*Agropyron sibirium)*. The B and BA hay were harvested in late summer (March in Bolivia), then chopped to 3–4 cm length to avoid selectivity. The pasture was locally grown and cut fresh daily. Forage composition was determined at the BYU Soil and Plant Analysis Laboratory (Provo, UT) using wet chemistry procedures with values expressed as a percent of dry matter (Table 1). Treatment periods were 12 days, with days 1–7 for diet adjustment and days 8–12 for data collection. A harness system with a fecal collection bag and urine funnel was placed on each animal on day 7 prior to starting the collection period. Each metabolism crate had a slanted receptacle tray for urine collection by gravity flow into a container (Fig. 1) with 50 ml 50/50 HCl acid added to fix N to prevent volatilization of ammonia. On days 8–12, feed intake, refused feed, fecal output