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Effects of protein and/or energy restriction for six weeks on antioxidation capacity of plasma and gastrointestinal epithelial tissues of weaned kids

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ABSTRACT

Sixty weaned kids were allocated to four groups to investigate effects of protein and/or energy restrictions on antioxidation capacity of the plasma, rumen epithelium and jejunum mucosa. The four treatments were control, either energy restriction (ER) or protein restriction (PR), and combined energy and protein restriction (EPR). The experimental period consisted of 6 weeks nutrient restriction followed with 9 weeks nutrient recovery. Compared with antioxidation capacity of the plasma in control group, energy restriction decreased ($P<0.05$) the activities of catalase (CAT) on day 21 and glutathione reductase (GR) on day 41, and increased malondialdehyde (MDA) content ($P<0.05$) on days 21 and 41; protein restriction decreased ($P<0.05$) the GR activity on day 41, and increased ($P<0.05$) MDA content on day 21; combined energy and protein restriction decreased ($P<0.05$) the activities of CAT, superoxide dismutase (SOD) and GR on days 21 and 41, and increased ($P<0.05$) MDA content on days 21 and 41. Meanwhile, energy restriction decreased ($P<0.05$) the CAT activity of the rumen epithelium, GSH-Px activity of the jejunum mucosa, and GSH content of the rumen epithelium and jejunum mucosa; protein restriction decreased ($P<0.05$) the CAT activity of the rumen epithelium and GR activity of the jejunum mucosa, and GSH content of the rumen epithelium and jejunum mucosa; combined energy and protein restriction decreased ($P<0.05$) the CAT activities of the rumen epithelium and jejunum mucosa, SOD, GSH-Px and GR activities of the jejunum mucosa, GSH content of the rumen epithelium and jejunum mucosa. After 9 weeks nutrient recovery, there were no differences ($P>0.05$) in plasma antioxidation capacity among four groups; however, the SOD activities of the jejunum mucosa in ER, PR and EPR, GR activities of jejunum mucosa in PR and EPR, and the SOD mRNA level of the jejunum mucosa in ER, PR and EPR still remained lower ($P<0.05$) than those in control. The results indicate that antioxidation capacity of the plasma, rumen epithelium and jejunum mucosa can be reduced by energy and/or protein restrictions in weaned kids; the reduced antioxidation capacity of the rumen epithelium and jejunum mucosa by 6 weeks nutrient restriction can not fully be retrieved after 9 weeks nutrient recovery.

1. Introduction

The ruminant animals during pregnancy or from newborn up to three months old are often in face of the lack of protein

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and energy, especially in dry season and winter all over the world. Nutritional and metabolic exposures during these critical periods may have long-term programming effects on adulthood health. This viewpoint is supported by evidences from epidemiological studies in animal models and clinical intervention trials in humans (Aguilera et al., 2003; Fukuda et al., 2002; Petry et al., 2001).

After birth, the gastrointestinal tract (GIT) shows much faster growth and functional development in relation to the rest tissues and organs of the body, which is essential for optimal somatic growth and survival (Ebner et al., 1994). The influence of dietary nutrition on GIT development during the early period of growth is more critical because GIT of ruminants accounts for a greater proportion of the body weight compared to monogastric animals. Previous studies have proven that nutrient restriction such as energy and protein delays the development of GIT (McLeod and Baldwin, 2000; Shen et al., 2004).

Previous studies have also demonstrated that malnutrition would reduce the protein synthesis rate in the whole body or in tissues and organs (Harding et al., 2008; Wang et al., 2008; Yuan et al., 2008). We also found that the differentially expressed proteins related to translational and transcriptional regulation and the redox balance were likely to be responsible for the reduced protein synthesis rate and impaired development of the jejunum or other parts of GIT of goats in nutrient restriction groups (unpublished data). However, the mechanisms on the delay of GIT development caused by nutrient deficiency have not been clearly revealed.

Recent studies have further demonstrated that the reduced antioxidant capacity and enhanced free radical production, which are mainly caused by inadequate intakes of antioxidants (e.g., glutamine), imbalance of gut flora and abnormal changes in the neuroendocrine (Carroll et al., 2009; Petrovič et al., 2009), are frequently observed in weaned animals even if offered with the nutritionally balanced diets (Burke et al., 2009; Nieto et al., 2000). Diminished antioxidant defenses or excess oxidative species resulting from weaning stressors are deleterious to tissues, and may be linked to the manifestation of diseases (Burke et al., 2009).

Here, we supposed that nutrient deficiency might more easily result in the reduction of antioxidant capacity of early weaned ruminants, and the reduced antioxidant capacity might be one of main causes for the retardation of GIT development. Hence, the present study was carried out to investigate the effects of protein and energy restriction for up to six weeks, followed with nutrient recovery for nine weeks on antioxidation capacity of the rumen epithelium and jejunum mucosa of 28-d weaned kids.

2. Materials and methods

2.1. Animal use and care

The experiment was conducted according to the Animal Care and Use Guidelines of Institute of Subtropical Agriculture, the Chinese Academy of Sciences, Changsha.

Sixty healthy kids were obtained from 50 female Liuyang Black goat (local breed) nannies, with all offspring being born within two days. After birth, the kids were maintained with their mothers for nursing naturally, and weaned after four weeks. The weaned kids were kept in individually metabolic cages which were located in an animal house with ambient temperature controlled constantly at 21 °C.

2.2. Experimental diets

The weaned kids were randomly stratified by body weight to four dietary treatments (15 animals per treatment) with eight male and seven female per group and the twins were distributed into different groups. The four dietary treatments consisted of control (dried ryegrass hay+starter feed), energy restriction (ER, dried ryegrass hay+40% reduction of energy in starter feed), protein restriction (PR, dried ryegrass hay+40% reduction of protein in starter feed), and combined protein and energy restriction (EPR, dried ryegrass hay+40% reduction of both protein and energy in starter feed). The control diet (the forage plus the start feed) was formulated to meet 1.4 times of the maintenance requirement for metabolic energy according to Lu (1996). The ingredients and composition of the starter ration are given in Table 1. The crude protein (CP) content and calculated metabolizable energy (ME) of ryegrass hay were 14% and 8.04 MJ/kg in dry matter (DM), respectively.

The whole experiment lasted for sixteen weeks. After weaning, one week of acclimatization period was allowed for the kids to adapt to the control diet and environment. Then the nutrient restriction started (day 1) and lasted for six weeks (day 42), followed with a period of nine weeks for nutrient recovery, so there was a total of 105 days for formal experiment. During the nutrient recovery period, the diet for all animals was changed, ryegrass was replaced with maize stover (CP, 5.50%; ME, 5.80 MJ/kg) and the starter feed was replaced with the concentrate supplement, and to meet 1.3 times of the maintenance requirement for metabolic energy according to Lu (1996). The ingredients and composition of concentrate supplement are also shown in Table 1. During both periods of nutritional restriction and recovery, the same amounts of the feeds (ryegrass plus the starter feed, and maize stover plus the concentrate) were daily offered to the kids among the four groups, and the ratios of starter feed to ryegrass hay, and concentrate to maize stover were 40:60 and 50:50 in DM basis, respectively. The daily feeds were divided into two equal portions and fed to the kids at 07:00 h and 19:00 h. All kids had ad libitum access to fresh water.

2.3. Recording and sampling

During the entire experimental period, the amounts of feed offered and the refusal were daily recorded, and the daily feed intake was calculated. The kids were weighed on days 1, 42 and 105 prior to the morning feeding, and the averaged daily weight gains (BWG) were calculated over the periods of nutrient restriction and recovery.

On days 21, 41 and 104 prior to the morning feeding, blood samples from the jugular vein were collected from