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Altering Dietary Soluble Protein Levels With Decreasing Crude Protein May Be a Potential Strategy to Improve Nitrogen Efficiency in *Hu* Sheep Based on Rumen Microbiome and Metabolomics

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Ruminants account for a relatively large share of global nitrogen (N) emissions. It has been reported that nutrition control and precise feeding can improve the N efficiency of ruminants. The objective of the study was to determine the effects of soluble protein (SP) levels in low-protein diets on growth performance, nutrient digestibility, rumen microbiota, and metabolites, as well as their associations of N metabolism in fattening *Hu* sheep. Approximately 6-month-old, 32 healthy fattening male *Hu* sheep with similar genetic merit and an initial body weight of 40.37 ± 1.18 kg were selected, and divided into four groups ($n = 8$) using the following completely randomized design: the control diet (CON) with a 16.7% crude protein (CP) content was prepared to meet the nutritional requirements of fattening sheep [body weight (BW): 40 kg, average daily gain (ADG): 200–250 g/d] according to the NRC recommendations; other three include low protein diets (LPA, LPB, and LPC) of CP decreased by ∼10%, with SP proportion (%CP) of 21.2, 25.9, and 29.4 respectively. The feeding trial lasted for 5 weeks including the first week of adaptation. The results showed no difference in the growth performance ($P > 0.05$); DM and CP digestibility were higher in LPB and LPC, with maximum organic matter digestibility in LPB ($P < 0.05$). Low-protein diets decreased serum urea-N whereas urinary urea-N was lower in LPB and LPC ($P < 0.05$), while N retention and the biological value of N were higher in LPB and LPC ($P < 0.05$). Ruminal NH_3-N concentration in LPA and LPB was low than CON ($P < 0.05$), while total volatile fatty acid (TVFA), acetate, propionate, and butanoate were all lowest in LPA ($P < 0.05$). In the rumen microbiome, LPB increased the community richness in Prevotellaceae and *Prevotella_1* ($P < 0.05$); Metabolomics analysis revealed low-protein diets downregulated the amino acid metabolism pathways, while the biosynthesis of unsaturated fatty acids along with vitamin B6 metabolism were upregulated with increased SP. These findings could help us understand the role of different SP levels in the regulation of rumen microbial metabolism and N efficiency.