Differences in Blood Physiological and Biochemical Indices and Growth Performance between Low-Altitude Trans-Regional Fattening Yaks and Local Hybrid Beef Cattle (Qinchuan × Simmental) under Different Dietary Non-Protein Nitrogen Levels: A Postprint

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Abstract

To investigate the off-site fattening yak model, this experiment compared the differences in blood physiological and biochemical indices and growth performance between yaks and local hybrid beef cattle (Qinchuan × Simmental) under identical conditions.

Full Text

Preamble

Differences in Blood Physiological and Biochemical Indices and Growth Performance Between Low-Altitude Allopatric Fattening Yak and Local Crossbred Beef Cattle (Qinchuan × Simmental) Under Different Dietary Non-Protein Nitrogen Levels

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Abstract: To explore the allopatric fattening model for yaks, this study compared differences in blood physiological and biochemical indices and growth performance between local crossbred beef cattle (Qinchuan × Simmental) and yaks under identical conditions. Eight 1-year-old crossbred beef cattle (Qinchuan × Simmental) and eight 4-year-old Qinghai yaks, all with similar body weight, were each divided into two groups of four animals. Within each breed, the two groups were fed either a low non-protein nitrogen diet (LNPN, containing 1.0% slow-release urea on a dry matter basis) or a high non-protein nitrogen diet (HNPN, containing 1.5% slow-release urea on a dry matter basis). The trial consisted of a 10-day adaptation period followed by a 50-day data collection period. The results showed that both yaks and beef cattle exhibited the highest average daily feed intake and lowest feed-to-gain ratio under LNPN conditions. Dietary non-protein nitrogen level did not significantly affect blood routine indices in either species ($P>0.05$). However, across all dietary treatments, yaks showed significantly higher neutrophil count (Gran#), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), red blood cell distribution width-standard deviation (RDW-SD), mean platelet volume (MPV), and platelet distribution width (PDW) compared to beef cattle ($P<0.05$), while mean corpuscular hemoglobin concentration (MCHC) and platelet count (PLT) were significantly lower ($P<0.05$). Dietary non-protein nitrogen level did not significantly affect serum biochemical indices in either species ($P>0.05$). Across all treatments, yaks exhibited significantly higher serum total protein (TP), urea nitrogen (UN), creatinine (GREA), immunoglobulin A (IgA), immunoglobulin M (IgM), and immunoglobulin G (IgG) levels compared to beef cattle ($P<0.05$). Yak serum albumin (ALB) level under HNPN was significantly lower than under LNPN ($P<0.05$). These results indicate that supplementing beef cattle and yak fattening diets with 1.0% slow-release urea as a protein replacement is feasible, and low-altitude allopatric fattening does not adversely affect yak health.

Keywords: non-protein nitrogen; beef cattle; yak; blood physiological and biochemical indices; allopatric fattening; growth performance

Yak is a unique bovine species endemic to the alpine regions of the Qinghai-Tibet Plateau, primarily distributed in areas above 3,000 m altitude with annual average temperatures below 0°C. As the principal livestock and economic resource for plateau herders, yaks face severe forage-livestock imbalances due to the harsh climate. The grass growing season lasts less than five months, while the withered grass period extends for seven months. The scarcity of forage during winter and spring, combined with severe weather conditions, forces yaks to expend substantial nutrients and energy to survive, resulting in significant weight loss and even mortality. Transferring cattle and sheep to low-altitude agricultural areas for short-term allopatric fattening during the forage-deficient winter and spring seasons can utilize abundant crop straw resources while benefiting from milder temperatures and better housing conditions. As early as 1995, Bian Shouyi et al. [1] demonstrated the feasibility of transferring yaks from alpine pastoral areas to low-altitude regions for allopatric fattening, enabling slaughter 1–2 years earlier. Cui Xiaoqin et al. [2] similarly confirmed significant weight gain effects of allopatric fattening for Tibetan sheep in Linxia. Tang Yongchang [3] reported that the "pastoral area breeding, agricultural area fattening, urban sales" model generates substantial economic benefits.

Non-protein nitrogen (NPN) has been widely used as an economical nitrogen source in ruminant feed. Replacing protein feed with NPN can substantially reduce production costs, conserve protein resources, and improve slaughter rates. Therefore, investigating the feasibility and optimal supplementation level of NPN in diets for beef cattle and allopatric fattening yaks can enhance feeding efficiency and reduce costs. Studying the effects of varying NPN levels on blood physiological and biochemical indices and growth performance will clarify the impacts on metabolism and determine appropriate supplementation rates, while confirming the viability of NPN application in fattening diets for both cattle types.

1. Materials and Methods

1.1 Experimental Time and Location

The trial was conducted from November 6, 2016, to January 4, 2017, at Dingxi Fulai Livestock Breeding Co., Ltd. in Gansu Province (35°07' 34" N, 104°59' 23" E, altitude 1,899 m). This region belongs to the mid-temperate semi-arid zone, with an annual average temperature of 5.7-7.7°C, a frost-free period of 122–160 days, and annual precipitation of 350–600 mm.

1.2 Experimental Animals and Management

This experiment employed a two-factor crossover design. Eight 1-year-old crossbred beef cattle (Qinchuan × Simmental) with similar body weight [(230$±30)kg]weredividedintotwogroupsoffouranimalseach, feddietscontainingdifferentslow−releaseurealevels : lowNPNdiet(LNPN)with1.0±$30) kg] were divided into two groups of four animals each and fed LNPN and HNPN diets, respectively. The yaks were transported from Datong County, Qinghai Province (altitude 3,360 m) to the experimental site one month before the trial for acclimatization.

Experimental diets were formulated with identical energy and nitrogen levels according to NRC (2001) beef cattle nutritional requirements. Diet composition and nutrient levels are presented in Table 1 . Daily feed allowances for yaks and beef cattle were calculated based on body weight and NRC (2001) recommendations, ensuring a small daily residual. Animals were individually housed with ad libitum access to feed and water. The feeding regimen involved fresh mixing and immediate delivery, with concentrate and roughage fed together twice daily at 07:00 and 18:00. During the formal trial period, residual feed was collected before morning feeding each day for intake determination.

The slow-release urea product (33% nitrogen content) was manufactured by Hebei Xingmu Agricultural Products Technology Co., Ltd., using corn starch and urea coagulant to achieve a slow-release degree of 65°. The silage used was sweet sorghum ensiled by Dingxi Fulai Livestock Breeding Cooperative. The trial consisted of a 10-day preliminary period and a 50-day formal period, with regular deworming and disinfection of animals and facilities throughout.

1.3 Blood and Feed Sample Collection and Analysis

Blood samples were collected via tail vein and body weight was measured on days 1, 25, and 50 before morning feeding. Blood was collected into anticoagulant tubes [containing dipotassium ethylenediaminetetraacetic acid (EDTA-K2)] and vacuum tubes (Jiangsu Kangjian Medical Supplies Co., Ltd.). Anticoagulant tubes were immediately inverted 4–5 times to ensure thorough mixing and analyzed within 4 hours at room temperature. A Mindray BC-3000plus automatic hematology analyzer was used to determine white blood cell count (WBC), lymphocyte count (LYMPH#), intermediate cell count (Mid#), neutrophil count (Gran#), lymphocyte percentage (LYMPH%), intermediate cell percentage (Mid%), neutrophil percentage (Gran%), hemoglobin concentration (HGB), red blood cell count (RBC), hematocrit (HCT), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), red blood cell distribution width-coefficient of variation (RDW-CV), red blood cell distribution width-standard deviation (RDW-SD), platelet count (PLT), mean platelet volume (MPV), platelet distribution width (PDW), and plateletcrit (PCT).

Vacuum tube samples were centrifuged at 1,800×g for 15 minutes, and serum was stored at -80°C. Serum INS and GH levels were analyzed by enzyme-linked immunosorbent assay, while TP, ALB, GLB, UN, GLU, FFA, CREA, IgA, IgG, and IgM levels were determined by colorimetric methods at Beijing Huaying Biotechnology Research Institute.

Rectal temperature was measured with an electronic thermometer every Friday at 09:00 during the formal period. Feed samples were collected biweekly, dried at 65°C for 48 hours, and ground through a 1 mm sieve. Dry matter (DM), crude protein (CP), and crude ash contents were determined according to AOAC (1990) [4]. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were analyzed using an ANKOM-2000i fiber analyzer (USA) following Van Soest et al. [5], without heat-stable amylase for NDF determination.

1.4 Statistical Analysis

Feed nutrient data were processed using Excel 2007. SPSS 20.0 General Linear Model (GLM) and independent samples t-test were used to analyze main effects and significance of body temperature, blood routine indices, growth performance, and serum biochemical indices across diets and breeds, as well as within diets across breeds and within breeds across diets. Significance was declared at $P<0.05$, and results are expressed as means with root mean square error (SEM).

2. Results

2.2 Body Temperature of Beef Cattle and Yaks

As shown in Table 3 , both diet and breed had significant effects on body temperature ($P<0.05$), while the diet × breed interaction did not ($P>0.05$). Yak body temperature was significantly higher than that of beef cattle under both LNPN and HNPN conditions ($P<0.05$). Both species exhibited significantly higher body temperature under HNPN than LNPN ($P<0.05$).

2.3 Blood Routine Indices of Beef Cattle and Yaks

As shown in Table 4 , diet effect and the diet × breed interaction had no significant effects on blood routine indices ($P>0.05$). Breed effect did not significantly influence LYMPH#, Mid%, HGB, RBC, HCT, or PCT ($P>0.05$), but significantly affected WBC, Mid#, Gran#, LYMPH%, Gran%, MCV, MCH, MCHC, RDW-CV, RDW-SD, PLT, PDW, and MPV ($P<0.05$). Under LNPN, beef cattle had significantly higher MCHC and PLT than yaks ($P<0.05$), while WBC, Mid#, Gran#, MCV, MCH, MPV, RDW-SD, and PDW were significantly lower ($P<0.05$). Under HNPN, beef cattle had significantly lower Gran#, Gran%, MCV, MCH, RDW-CV, MPV, RDW-CV, RDW-SD, and PDW than yaks ($P<0.05$), while LYMPH%, MCHC, and PLT were significantly higher ($P<0.05$).

2.3 Serum Biochemical Indices of Beef Cattle and Yaks

As shown in Table 5 , diet effect significantly influenced only serum ALB level ($P<0.05$), while the diet × breed interaction significantly affected only serum INS level ($P<0.05$). Breed effect significantly impacted serum TP, ALB, UN, CREA, GLU, IgA, IgM, and IgG levels ($P<0.05$). Under LNPN, beef cattle had significantly lower serum TP, ALB, and UN than yaks ($P<0.05$), while serum GLU was significantly higher ($P<0.05$). Under HNPN, beef cattle had significantly lower serum TP and UN than yaks ($P<0.05$). Additionally, yaks had significantly higher serum CREA, IgA, IgG, and IgM levels than beef cattle across all diets ($P<0.05$). Yak serum ALB level under HNPN was significantly lower than under LNPN ($P<0.05$).

3. Discussion

3.1 Differences in Growth Performance Between Beef Cattle and Yaks

To prevent ammonia poisoning in ruminants, dietary NPN should not exceed 1.0–1.5% of dry matter [6], and urea should generally not surpass 2% of adult cattle diets [7]. Yang Jiadong et al. [8] reported that appropriate slow-release urea supplementation could increase feed intake, but excessive levels reduce intake due to poor palatability [9]. In this study, the two urea levels did not significantly affect dry matter intake, but average daily gain under HNPN was significantly reduced for both species, indicating that 1.5% slow-release urea decreased nutrient utilization efficiency. Beef cattle outperformed yaks in growth performance, primarily because beef cattle are long-adapted to low-altitude conditions and were selected breeds with superior fattening characteristics.

3.2 Differences in Body Temperature Between Beef Cattle and Yaks

Body temperature is a crucial health indicator. Both species are homeothermic, requiring relatively constant temperatures for normal physiological function. Normal beef cattle body temperature ranges 37–39°C [10], which our results confirmed. Previous studies reported yak body temperatures of 38.8°C in Qinghai Lake area [11] and 38.18°C in Linzhi, Tibet [12]; our yak measurements fell within this range. Yaks had significantly higher body temperature than beef cattle, attributable to specialized adaptations to alpine environments including body surface, hair coat, skin, sweat glands, and respiration that reduce heat dissipation [13]. The significantly higher body temperature under HNPN for both species may result from elevated rumen ammonia nitrogen concentration affecting nitrogen and energy metabolism and consequently blood circulation, though the mechanism requires further investigation.

3.3 Differences in Blood Routine Indices Between Beef Cattle and Yaks

White blood cells, comprising monocytes, neutrophils, eosinophils, and lymphocytes, directly reflect immune capacity [14] and are vital formed elements for maintaining normal blood circulation and responding to cold and immune stress. Yin Xuhui et al. [15] found that cold exposure causes blood concentration and increased WBC. The higher WBC, Gran#, and Mid# in yaks indicate superior immune levels and adaptability to harsh environments and low-quality forage, reflecting long-term adaptation to the Qinghai-Tibet Plateau.

RBC, HGB, and HCT reflect blood oxygen and carbon dioxide transport capacity [16]. Jiang Jiachun et al. [17] reported that plateau animals have more RBC but smaller MCV to enhance oxygen contact in lungs for hypoxia adaptation. Jiang Shengcheng et al. [18] found no significant RBC difference between yaks and yellow cattle at the same altitude. Our results similarly showed that RBC and HGB were not significantly affected by diet, breed, or their interaction, indicating similar oxygen transport capacity in weight-matched yaks and beef cattle at the same low altitude.

MCH, MCHC, RDW, and MCV reflect red blood cell pigment content, saturation, variation, and volume, respectively. MCH, MCHC, and MCV constitute the three anemia indicators; lower values combined with higher RDW typically indicate iron deficiency anemia [19]. The lower MCH, MCV, MCHC, and RDW in beef cattle represent long-term yak adaptation to alpine hypoxia [15] and cannot be interpreted as anemia in beef cattle. Yaks had lower RBC and higher MCV than reported by Jiang Jiachun et al. [17], reflecting adaptation to low-altitude high oxygen pressure. Higher RDW-SD and RDW-CV in yaks result from increased MCV at low altitude, as larger red blood cells experience greater vascular compression and damage [20].

3.4 Differences in Serum Biochemical Indices Between Beef Cattle and Yaks

Creatinine (CREA), a muscle metabolism product excreted via glomerular filtration, is a clinical indicator of kidney function. The breed effect significantly affected serum CREA, with higher levels in yaks than beef cattle, suggesting lower glomerular filtration rates in yaks that cannot be interpreted as pathological.

Glucose (GLU) and free fatty acids (FFA) are key energy metabolites. Elevated GLU stimulates insulin (INS) secretion, promoting glycogen synthesis, while low GLU reduces INS and increases lipolysis to FFA. Growth hormone (GH), a hypothalamus-regulated pituitary protein hormone, promotes bone and muscle growth and nutrient metabolism. Richard et al. [26] showed that most NH3-N is absorbed across the rumen wall and posterior gastrointestinal tract, converted to UN in the liver, elevating blood UN. The body excretes excess UN via urine, resulting in lower TP and ALB under HNPN because rumen microbes utilize only one-quarter of released ammonia for protein synthesis, causing nitrogen deficiency and impaired protein synthesis.

Breed significantly affected serum TP, ALB, and UN. Yaks consistently showed higher TP, ALB, and UN than beef cattle across all diets, reflecting efficient nitrogen utilization mechanisms developed through generations on the Qinghai-Tibet Plateau with its 7-month withered grass period [24-25] and enhanced hepatic nitrogen recycling. Although yaks have superior UN recycling capacity, beef cattle showed better growth performance due to higher feed intake.

Immunoglobulins IgA, IgG, and IgM are important immune effectors. Analysis of blood physiological and biochemical data indicated that both LNPN and HNPN diets did not significantly affect yak or beef cattle health, with yaks demonstrating higher immune levels than beef cattle under both dietary conditions, consistent with hematology results.

4. Conclusion

Analysis of blood physiological and biochemical indices demonstrated that both LNPN and HNPN diets did not significantly affect yak or beef cattle health, with yaks exhibiting higher immune levels than beef cattle under both conditions. Although yaks possess greater UN recycling capacity, beef cattle showed superior growth performance due to higher feed intake. Supplementation with 1% slow-release urea yielded lower feed-to-gain ratios and higher average daily gains for both species. Therefore, 1% slow-release urea can be incorporated into beef cattle and allopatric fattening yak diets to replace partial protein feed.

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Note: Figure translations are in progress. See original paper for figures.