Effects of Starvation and Refeeding on Growth Performance, Apparent Nutrient Digestibility, and Serum Indices in Yaks (Postprint)

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Abstract

This experiment aimed to investigate the changes in growth and digestive metabolism of yaks under normal feeding, starvation, and refeeding conditions. Six healthy 3-year-old yaks with an average body weight of (183.60±15.62) kg were selected as experimental animals. The experiment was divided into a normal feeding period (7 d), a starvation period (fasting for 7 d), and a refeeding period (28 d). The results showed: 1) After 7 d of starvation, yaks lost approximately 10.06% of their body weight. During the first 3 weeks of the refeeding period, the dry matter intake and feed conversion ratio of yaks were significantly lower than those during the normal feeding period ($P<0.05$), while the average daily gain during the first 2 weeks of the refeeding period was significantly higher than that during the normal feeding period ($P<0.05$). In the first week of the refeeding period, the apparent digestibility of crude protein and crude fat in yaks was significantly higher than that during the normal feeding period ($P<0.05$); in the fourth week of the refeeding period, there were no significant differences in dry matter intake, feed conversion ratio, average daily gain, and apparent digestibility of crude fat between yaks and those during the normal feeding period ($P>0.05$). 2) During the starvation period, serum glucose, triglyceride, urea nitrogen, and creatinine levels in yaks were significantly lower than those during the normal feeding period ($P<0.05$), while serum non-esterified fatty acid content was significantly higher than that during the normal feeding period ($P<0.05$). During the refeeding period, serum glucose content in yaks was significantly higher than that during the normal feeding period in weeks 1 and 3 ($P<0.05$); serum non-esterified fatty acid and total protein contents were significantly higher than those during the normal feeding period in weeks 1 and 2 ($P<0.05$); serum triglyceride content was significantly lower than that during the normal feeding period in weeks 2 and 3 ($P<0.05$); in week 4, there were no significant differences in serum metabolite contents between yaks and those during the normal feeding period (P>0.05). 3) During the starvation period, serum insulin, growth hormone, and insulin-like growth factor I contents in yaks were significantly lower than those during the normal feeding period (P<0.05). During the refeeding period, serum insulin content in yaks was significantly higher than that during the normal feeding period in week 2 (P<0.05); serum insulin-like growth factor I content was significantly higher than that during the normal feeding period in weeks 1, 2, and 3 (P<0.05); in week 4, there were no significant differences in serum growth hormone and insulin-like growth factor I contents between yaks and those during the normal feeding period (P>0.05). It can thus be concluded that during the starvation period, yaks adapted to starvation by reducing glucose and protein metabolism levels and enhancing fat decomposition. Moreover, the first 3 weeks of the refeeding period represent a crucial phase for compensatory growth in yaks.

Full Text

Effects of Starvation and Refeeding on Growth Performance, Nutrient Apparent Digestibility, and Serum Indices of Yaks

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Abstract

This study investigated the changes in growth, digestibility, and metabolism of yaks under normal feeding, starvation, and refeeding conditions. Six healthy three-year-old yaks with an average body weight of (183.60±15.62) kg were selected as experimental animals. The trial was divided into three phases: a normal feeding period (7 days), a starvation period (7 days of fasting), and a refeeding period (28 days). The results showed: (1) After 7 days of starvation, yaks lost approximately 10.06% of their body weight. During the first three weeks of refeeding, dry matter intake (DMI) and feed/gain ratio (F/G) were significantly lower than during the normal feeding period (P<0.05). Average daily gain (ADG) during the first two weeks of refeeding was significantly higher than during the normal feeding period (P<0.05). In the first week of refeeding, the apparent digestibility of crude protein and ether extract was significantly improved compared to the normal feeding period ($P<0.05$). By the fourth week of refeeding, no significant differences were observed in DMI, F/G, ADG, or ether extract apparent digestibility compared to the normal feeding period ($P>0.05$). (2) During starvation, serum glucose, triglyceride, urea nitrogen, and creatinine concentrations were significantly decreased ($P<0.05$), while serum non-esterified fatty acid concentration was significantly increased ($P<0.05$) compared to normal feeding. During refeeding, serum glucose concentration was significantly higher in weeks 1 and 3 ($P<0.05$); serum non-esterified fatty acids and total protein were significantly elevated in weeks 1 and 2 ($P<0.05$); serum triglyceride was significantly reduced in weeks 2 and 3 ($P<0.05$); and by week 4, all serum metabolite concentrations showed no significant differences from the normal feeding period ($P>0.05$). (3) Serum insulin, growth hormone, and insulin-like growth factor I concentrations were significantly reduced during starvation ($P<0.05$). During refeeding, serum insulin concentration was significantly higher in week 2 ($P<0.05$), while insulin-like growth factor I was significantly elevated during the first three weeks ($P<0.05$). By week 4, serum growth hormone and insulin-like growth factor I concentrations showed no significant differences from the normal feeding period ($P>0.05$). These findings indicate that yaks adapt to starvation by reducing glucose and protein metabolism while enhancing lipid catabolism. The first three weeks of refeeding represent a critical period for compensatory growth in yaks.

Keywords: yaks; starvation; refeeding; growth performance; nutrient apparent digestibility; serum indices

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Introduction

Yaks are the dominant livestock species on the Qinghai-Tibetan Plateau, serving as essential production and living resources for local people and making significant contributions to the regional economy. However, yak farming still relies primarily on traditional grazing systems, making feed sources and nutrient supply entirely dependent on the seasonal growth cycles of pasture grasses. Due to the unique geographical conditions of the Qinghai-Tibetan Plateau, extreme climates with heavy snow and freezing conditions frequently occur during the long cold season, leaving yaks vulnerable to hunger and even starvation. This natural constraint creates a vicious cycle described as "alive in summer, fat in autumn, thin in winter, and dead in spring." After a single cold season of forage shortage, yak body weight loss can reach up to 30%. Therefore, hunger represents a critical challenge in yak grazing systems.

Starvation is defined as a biological state where an animal, after nutrient digestion and metabolism, is capable of and desires to eat but cannot do so due to limited external food resources. During starvation, animals utilize glucose to meet metabolic demands, leading to decreased blood glucose levels. To maintain stable blood glucose, the body primarily relies on hepatic glycogenolysis and gluconeogenesis for energy provision. As starvation prolongs, animals eventually deplete their stored glycogen reserves, subsequently mobilizing fat stores with increased triglyceride content for -oxidation energy supply. Protein serves as the final energy reserve, and prolonged starvation can cause severe damage or even death. Research has shown that ruminants exhibit a period of rapid growth following nutritional restriction, a phenomenon known as compensatory growth. Given that hunger is common in yaks during the cold season with limited energy availability, compensatory growth holds significant research value in yak grazing systems. While studies on yak starvation exist, information on yak recovery after starvation remains unreported. This trial aimed to compare changes in growth performance, nutrient apparent digestibility, serum metabolites, and related hormone concentrations across three phases—normal feeding, starvation, and refeeding—to elucidate yak adaptation during starvation and refeeding. The findings will provide theoretical basis and data reference for improving yak resistance to harsh environments and reducing body weight loss during cold season starvation, thereby enhancing yak production performance.

Materials and Methods

1.1 Experimental Animals Six healthy three-year-old Jiulong yaks with similar body weight [average initial weight (183.60±15.62) kg] were selected as experimental subjects.

1.2 Experimental Design Following the experimental design of Belanche et al., the six yaks were treated as a single group. The total trial lasted 56 days, including a 14-day preliminary period and a 42-day formal experimental period. The formal period was divided into three phases: normal feeding period (NFP, 7 days), starvation period (SP, 7 days), and refeeding period (RFP, 28 days). During the starvation period, yaks were deprived of feed, following the protocols established by Yu et al. and Ren et al. for a 7-day fasting period.

1.3 Experimental Diet The same experimental diet was used during the preliminary period, normal feeding period, and refeeding period. Diet formulation was based on the nutritional requirements for beef cattle weighing 200 kg with a daily gain of 0.8 kg/d according to China' s "Feeding Standard of Beef Cattle" (NY/T 815-2004), referencing formulations from Yu et al. and Ren et al. The diet consisted of distilled grains + rice straw + concentrate supplement, mixed at a concentrate-to-forage ratio of 30:70 (dry matter basis). The concentrate supplement primarily comprised corn, wheat bran, soybean meal, rapeseed meal, calcium hydrogen phosphate, calcium carbonate, salt, and premix, while the forage consisted of rice straw and distilled grains. Diet composition and nutrient levels are presented in .

TABLE:1 Composition and nutrient levels of the experimental diet (air-dry basis)

Note: The premix provided per kg of diet: Co (as cobaltous chloride 6-hydrate) 0.12 mg, Cu (as copper sulfate) 11.67 mg, I (as calcium iodate) 0.58 mg, Fe (as ferrous sulfate) 58.33 mg, Mn (as manganese sulfate) 23.33 mg, Se (as sodium selenite) 0.23 mg, Zn (as zinc sulfate) 35.00 mg, VA 3.00×10 IU, VD 1.20×10 IU, VE 90.00 IU. The comprehensive net energy (NEmf) was a calculated value [NEmf=DE×Kmf; Kmf=Km×Kf×1.5/(Kf+0.5×Km), where Kmf is the conversion efficiency of digestible energy to net energy, DE is digestible energy, 1.5 is the feeding level value, Km is the conversion efficiency of DE to net energy for maintenance, and Kf is the conversion efficiency of DE to net energy for gain, calculated according to China' s Feeding Standard of Beef Cattle (NY/T 815-2004)], while other values were measured.

1.4 Animal Management The trial was conducted at the experimental farm of Sichuan Agricultural University. Prior to the trial, yaks were vaccinated, dewormed, disinfected, and ear-tagged. Sheds were regularly disinfected throughout the trial period. Yaks were individually housed in separate stalls with individual feeding troughs. During the normal feeding and refeeding periods, animals were fed at 09:00 and 16:00 daily with ad libitum access to feed. Feed was provided based on intake determined during the preliminary period, ensuring approximately 10% residual feed remained after each feeding. All animals had free access to water throughout the trial.

1.5 Sample Collection During the normal feeding and refeeding periods, digestion trials were conducted using the total fecal collection method on days 2–6 of each week. Starting from day 1 of the experimental period, blood samples were collected via jugular venipuncture before 09:00 on day 1 of each week. Blood samples were left to stand in a cool place for over 30 minutes, then centrifuged at 1,006.2×g for 15 minutes to obtain serum, which was rapidly frozen and stored at -20°C until analysis.

1.6.1 Growth Performance and Nutrient Apparent Digestibility Daily feed intake was recorded and converted to dry matter intake (DMI). Yaks were weighed after an overnight fast before each blood collection, and weekly average daily gain (ADG) was calculated along with feed/gain ratio (F/G). Diet and fecal samples collected during digestion trials were analyzed for moisture, organic matter (OM), crude protein (CP), ether extract (EE), acid detergent fiber (ADF), calcium (Ca), and phosphorus (P) according to AOAC (2002) standards. Crude fiber (CF) content was determined according to GB/T 6434-2006, while neutral detergent fiber (NDF) was analyzed using the method of Van Soest et al. with a Foss Fibertec 2010 (Denmark). Nutrient apparent digestibility was calculated as:

Nutrient apparent digestibility (%) = 100 × [nutrient intake (g) -fecal nutrient output (g)] / nutrient intake (g).

1.6.2 Serum Biochemical Indices Serum glucose (GLU) [kit No. DRE-B1045c], triglyceride (TG) [kit No. DRE-B6210c], non-esterified fatty acids (NEFA) [kit No. DRE-B0793c], total protein (TP) [kit No. DRE-B6210c], urea nitrogen (UN) [kit No. DRE-B0544c], and creatinine (CRE) [kit No. DRE-B0781c] were measured using ELISA kits (Kamai Shu (Shanghai) Biotechnology Co., Ltd.) with a double-antibody sandwich method and microplate reader, following the manufacturer' s instructions.

1.6.3 Serum Hormone Indices Serum insulin (INS) [kit No. DRE-B6410c], glucagon (GC) [kit No. DRE-B6449c], growth hormone (GH) [kit No. DRE-B6427c], and insulin-like growth factor I (IGF-I) [kit No. DRE-B0732c] were measured using ELISA kits (Kamai Shu (Shanghai) Biotechnology Co., Ltd.) with a double-antibody sandwich method and microplate reader, following the manufacturer' s instructions.

1.7 Statistical Analysis Data were organized using Excel 2010. Normality was tested using the Proc univariate procedure of SAS 8.1, followed by one-way ANOVA using Proc GLM and Duncan' s multiple comparison tests. Data were expressed as "mean ± standard deviation," with $P<0.05$ considered statistically significant. Correlations between indices were analyzed using Proc CORR, where $P<0.05$ indicated significant correlation and correlation coefficient magnitude indicated the strength of association.

Results

2.1 Effects of Starvation and Refeeding on Yak Growth Performance As shown in , yak body weight decreased after 7 days of starvation, with weight loss reaching approximately 10.06% of initial body weight ($P>0.05$). During the first three weeks of refeeding, DMI and F/G were significantly lower than during the normal feeding period ($P<0.05$). ADG during the first two weeks of refeeding was significantly higher than during the normal feeding period ($P<0.05$). By the fourth week of refeeding, no significant differences were observed in DMI, F/G, or ADG compared to the normal feeding period ($P>0.05$).

TABLE:2 Effects of starvation and refeeding on growth performance of yaks

Note: In the same row, values with the same or no letter superscripts indicate no significant difference (P>0.05), while different letter superscripts indicate significant difference (P<0.05). The same applies below.

2.2 Effects of Starvation and Refeeding on Nutrient Apparent Digestibility As shown in , during the first week of refeeding after starvation, apparent digestibility of CP, EE, CF, ADF, and P was significantly higher than during the normal feeding period (P<0.05), while Ca apparent digestibility was significantly lower (P<0.05). In the second week, CP and P apparent digestibility remained significantly elevated (P<0.05). In the third week, Ca apparent digestibility was significantly lower than during normal feeding (P<0.05). By the fourth week, except for significantly higher ADF apparent digestibility (P<0.05) and significantly lower NDF apparent digestibility (P<0.05), other nutrient apparent digestibility values showed no significant differences from the normal feeding period (P>0.05). DM and OM apparent digestibility remained unchanged throughout the refeeding period compared to normal feeding (P>0.05).

TABLE:3 Effects of starvation followed by refeeding on nutrient apparent digestibility of yaks (%)

2.3.1 Changes in Serum Metabolite Concentrations As shown in , during starvation, serum GLU, TG, UN, and CRE concentrations were significantly decreased (P<0.05), while serum NEFA concentration was significantly increased (P<0.05) compared to normal feeding. Serum TP concentration showed no significant difference (P>0.05). During refeeding, serum NEFA and TP concentrations were significantly higher than normal feeding during the first two weeks (P<0.05). Serum GLU concentration was significantly lower in weeks 1 and 3 (P<0.05). Serum TG concentration was significantly reduced in weeks 2 and 3 (P<0.05). Serum UN and CRE concentrations were significantly lower than normal feeding in weeks 2 and 3, respectively (P<0.05). By week 4, all these indices showed no significant differences from the normal feeding period (P>0.05).

TABLE:4 Effects of starvation and refeeding on serum metabolite contents of yaks

2.3.2 Changes in Serum Hormone Concentrations As shown in and , during starvation, serum INS, GH, and IGF-I concentrations and INS/GC ratio were significantly decreased (P<0.05) compared to normal feeding. During refeeding, serum IGF-I concentration was significantly higher than normal feeding during the first three weeks (P<0.05). Serum INS concentration was significantly elevated in week 2 (P<0.05). By week 4, serum INS and GC concentrations and INS/GC ratio were significantly lower than normal feeding (P<0.05). Correlation analysis between serum GH and IGF-I showed a significant high positive correlation during normal feeding (P<0.05), no significant correlation during starvation and weeks 1-2 of refeeding (P>0.05), a significant moderate positive correlation in week 3 of refeeding (P<0.05), and a significant moderate negative correlation in week 4 of refeeding (P<0.05).

TABLE:5 Effects of starvation and refeeding on serum hormone contents of yaks

TABLE:6 Changes of correlation between serum GH and IGF-I content

Note: r>0 indicates positive correlation, r<0 indicates negative correlation.

When |r| 0.8, variables are considered highly correlated; 0.5 |r|<0.8 indicates moderate correlation; 0.3 |r|<0.5 indicates low correlation; 0 |r|<0.3 indicates weak or negligible correlation. P-value indicates significance: P<0.05 means significant correlation, P>0.05 means no significant correlation.

Discussion

3.1 Effects of Starvation and Refeeding on Yak Growth Performance
The two most common terms used to describe animals that cannot ingest food after nutrient absorption are starvation and fasting. Starvation primarily refers to physiological responses caused by changes in food availability (from abundant to scarce), whereas fasting refers to physiological responses regulated by internal mechanisms, often occurring during predator avoidance, thermoregulation, molting, and reproduction-related activities such as mate seeking and territorial defense. Starvation research primarily considers two factors: duration and intensity. Due to the lack of uniform standards for starvation studies and the difficulty in determining starvation duration and intensity during yak cold-season growth, with extreme climates even causing complete feed and water deprivation, this study implemented a 7-day fasting protocol based on relevant research from our group.

Body weight loss is the most significant change following starvation. Loss of organic matter is inevitable during starvation, and the degree of weight loss depends primarily on initial body weight and allocation of various energy resources. The magnitude and rate of body weight reduction during starvation can measure an animal' s adaptive capacity. Previous studies reported that pigs lost 24% of initial body weight after 4 days of restricted feeding at 25% below maintenance level, chickens lost 35% after 6 days of starvation, and goats lost 16% after just 2 days of starvation. Compensatory growth refers to the physiological process where animals exhibit faster growth potential after a period of restricted feed intake. Research indicates that changes in liver and gastrointestinal tract size correlate proportionally with feed intake changes. Studies show that after nutritional restriction, animal visceral organs become smaller and growth slows, reducing maintenance energy requirements. During refeeding, visceral organs do not immediately recover. The liver and gastrointestinal tract significantly influence whole-animal energy utilization efficiency. During refeeding, previously starved cattle showed significantly higher ADG than controls, with elevated expression of genes related to cellular metabolism, oxidative phosphorylation, and the tricarboxylic acid cycle. The fastest weight gain occurs during the early compensatory growth phase. In this study, yaks lost 10.06% body weight after 7 days of fasting. Compared with other starvation studies, yaks experienced higher starvation intensity and duration but lower weight loss, indicating good adaptation to starvation. During the first two weeks of refeeding, ADG was significantly higher than normal feeding, demonstrating clear compensatory growth. DMI and F/G were significantly lower during the first three weeks of refeeding, likely because smaller visceral organs improved energy utilization efficiency. By week 4 of refeeding, ADG, DMI, and F/G showed no significant differences from normal feeding, indicating that compensatory growth primarily occurs during the first three weeks of refeeding.

3.2 Effects of Starvation and Refeeding on Nutrient Apparent Digestibility Jones et al. found that protein synthesis and degradation accelerated in mice after nutritional restriction and refeeding. Turgeon et al. reported that lambs exhibited compensatory growth after starvation, with higher protein deposition rates during early refeeding. Lippens et al. also found that refeeding after nutritional restriction accelerated protein turnover and improved protein utilization efficiency. Heitz et al. suggested that decreased Ca digestibility combined with increased P digestibility would enhance body acidification, reducing body fat content and accelerating protein synthesis. Mehrez et al. found that reduced NDF apparent digestibility was associated with decreased fiber-degrading bacteria and protozoa in the rumen, with similar results reported in young goats. NDF promotes chewing, saliva secretion, and rumen activity in ruminants, ensuring a stable rumen environment for microbial growth. In this study, DM and OM apparent digestibility showed no significant differences from normal feeding throughout refeeding, consistent with Ma et al. During week 1 of refeeding, apparent digestibility of CP and EE increased, while Ca and P apparent digestibility changed during weeks 1-2, facilitating fat decomposition and protein synthesis to promote compensatory growth. By week 4, except for ADF and NDF apparent digestibility, other nutrient apparent digestibility values showed no significant differences from normal feeding. NDF apparent digestibility was significantly reduced during weeks 2-4 of refeeding, possibly related to changes in rumen environment and microorganisms.

3.3 Effects of Starvation and Refeeding on Serum Metabolite Concentrations All tissues utilize glucose, which is the preferred energy source for the central nervous system, renal medulla, and mature red blood cells, requiring continuous supply. During starvation, insufficient exogenous energy leads to continuous consumption of body glucose reserves, ultimately reducing blood glucose levels. Starving animals primarily generate glucose through hepatic glycogenolysis and maintain glucose homeostasis via gluconeogenesis. In liver and kidneys, glucose can be synthesized de novo from amino acids (primarily alanine), glycerol (mainly from TG hydrolysis), ketone bodies, and circulating lactate and pyruvate. During refeeding, increased food intake elevates serum glucose and insulin secretion, which promotes glucose uptake and transport to specific cells for utilization, ultimately reducing blood glucose levels. In this study, serum glucose concentration significantly decreased during starvation, likely representing an adaptation to reduce glucose metabolism. During refeeding, serum glucose was significantly lower in weeks 1 and 3, possibly because high energy demands of compensating tissues increased glucose utilization.

Under hypoglycemic conditions, fatty acids serve as a viable energy source.

Blum et al. found that nutrient-restricted cattle had significantly higher serum non-esterified fatty acid concentrations than non-restricted animals, demonstrating strong lipid mobilization. Enhanced fat mobilization during starvation ensures adequate energy provision while preserving essential protein content. Dimarco et al. found that serum NEFA concentrations remained elevated for the first 8 days of refeeding in previously starved cattle, indicating that lipid metabolism had not returned to normal levels at the start of refeeding. In this study, changes in serum TG and NEFA concentrations during starvation reflected strong lipid mobilization. During the first three weeks of refeeding, serum NEFA remained significantly higher than normal feeding in weeks 1-2, then significantly lower in week 3, while serum TG was significantly reduced in weeks 2-3, indicating that metabolic status had not fully recovered to normal levels and maintained high lipid catabolism during the first three weeks.

Serum UN concentration is an important indicator of protein turnover metabolism, with elevated UN indicating accelerated protein turnover. Creatinine is a breakdown product of phosphocreatine and the end product of muscle creatine metabolism; decreased serum CRE indicates reduced muscle protein catabolism. In this study, serum UN significantly decreased during starvation, similar to findings in prairie dogs and elephant seals, indicating reduced protein turnover during starvation. Decreased serum CRE suggested slowed muscle protein catabolism. Thus, yaks reduced protein metabolism to minimize protein consumption during starvation. During refeeding, serum TP was significantly elevated during the first two weeks, indicating increased protein deposition that facilitates compensatory growth.

3.4 Effects of Starvation and Refeeding on Serum Hormone Concentrations Insulin promotes glucose uptake and transport in target cells, reducing blood glucose levels. Glucagon promotes adipose tissue lipolysis and increases blood glucose, antagonizing insulin. Elevated blood glucose reduces the INS/GC ratio, thereby increasing blood glucose levels. Many starvation metabolism studies have observed significantly decreased blood insulin concentrations, which, combined with increased glucagon, facilitates fat utilization and blood glucose maintenance. Ahmed et al. reported that nutrient-restricted cattle showed rapid insulin elevation during refeeding, associated with accelerated amino acid transport, reduced oxidation, and decreased protein degradation. Blum et al. observed similar trends, where increased insulin secretion during refeeding initiated anabolic signals and enhanced synthetic metabolism. Shaw et al. reported that insulin is the most important hormone promoting intramuscular fat synthesis. In this study, serum insulin concentration and INS/GC ratio significantly decreased during starvation, facilitating energy provision through fat catabolism. After refeeding, serum insulin significantly increased in week 2, promoting anabolism and contributing to compensatory growth.

After feeding, GH secretion stimulates hepatic IGF-I synthesis, which promotes tissue and whole-body growth by allocating various nutrients. Studies show that the relationship between GH and IGF-I becomes complex after feed restriction. Keogh et al. suggested that altered GH-IGF-I correlations might result from reduced liver size during nutritional restriction. Li et al. reported that during energy restriction, GH and its high-affinity receptor concentrations significantly decreased, along with reduced specific binding capacity in liver, while IGF-I decreased more slowly than growth hormone receptors. Some studies found significantly reduced IGF-I but non-significant GH changes in nutrient-restricted animals. Reduced IGF-I may represent an adaptation to nutritional restriction, slowing cell growth to allocate limited energy to essential cellular functions such as tissue maintenance and repair. Bell et al. speculated that such metabolic changes ensure homeostasis during nutritional restriction. In this study, significantly reduced serum GH and IGF-I concentrations and altered correlations during starvation helped slow cell growth, conserve energy, and maintain metabolic stability to adapt to starvation. After refeeding, serum GH returned to normal feeding levels, while IGF-I remained significantly elevated during the first three weeks. The changing GH-IGF-I correlations during refeeding may reflect persistent metabolic relationships from the starvation period due to incomplete liver recovery, which could facilitate compensatory growth.

Conclusion

Yaks demonstrated good adaptation to nutritional restriction after 7 days of starvation. During starvation, yaks adapted by reducing glucose metabolism and protein turnover while enhancing lipid catabolism. Based on evaluations of ADG, F/G, and serum biochemical indices, compensatory growth in yaks after starvation occurred primarily during the first three weeks of refeeding, with no significant differences from normal feeding observed by week 4.

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