Effects of Different Dietary Digestible Energy and Crude Protein Levels on Lactation Performance of Yili Mares and Growth and Development of Their Foals during Early Lactation (Postprint)

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Abstract

This experiment aimed to investigate the effects of feeding diets with different digestible energy (DE) and crude protein (CP) levels on lactation performance, milk composition, and foal growth and development and plasma biochemical indices in Yili mares during early lactation, providing a reference basis for further exploring the energy and protein requirements of Yili mares during lactation. Twenty-five Yili mares with no genetic relationship, similar age, body weight, and parity, and in early lactation were selected and divided into 5 groups according to mare body weight, with 5 mares per group. The experimental period was 60 days, divided into 2 lactation months, with each 30 days constituting one lactation month. In the first lactation month, the DE and CP feeding levels for mares were 101.41 MJ/d, 1.38 kg/d (Group), 112.05 MJ/d, 1.50 kg/d (Group), 122.40 MJ/d, 1.63 kg/d (Group), 133.27 MJ/d, 1.75 kg/d (Group), and 143.84 MJ/d, 1.87 kg/d (Group); in the second lactation month, the DE and CP feeding levels were 129.73 MJ/d, 1.82 kg/d (Group), 140.37 MJ/d, 1.94 kg/d (Group), 150.72 MJ/d, 2.07 kg/d (Group), 161.60 MJ/d, 2.19 kg/d (Group), and 172.17 MJ/d, 2.31 kg/d (Group). Days 1-14 of each lactation month served as the preliminary period, and the last 10 days as the sampling period. The results showed that feeding diets with different DE and CP levels had no significant effect on milk yield, conventional milk composition, and milk somatic cell count in Yili mares during early lactation ($P>0.05$). There were no significant differences in saturated fatty acid content in milk fat among groups ($P>0.05$), the unsaturated fatty acid content in Groups and was significantly higher than in Group ($P<0.05$), there were no significant differences

in monounsaturated fatty acid content among groups (P>0.05), and the polyunsaturated fatty acid content in Group was significantly lower than in Groups , , and (P<0.05). After increasing dietary DE and CP levels, the contents of palmitic acid (C16:0), palmitoleic acid (C16:1), and linoleic acid (C18:2n6c) in milk fat changed significantly (P<0.05), wherein the contents of palmitic acid and palmitoleic acid in Group were significantly higher than in other groups (P<0.05), and the content of linoleic acid in Group was significantly lower than in Groups , , and (P<0.05). Feeding diets with different DE and CP levels to Yili mares during early lactation had no significant effects on foal body weight, body length, chest circumference, or cannon circumference (P>0.05), but foal wither height in Group was significantly higher than in Groups and (P<0.05). Plasma physiological and biochemical indices of foals showed no significant differences in plasma triglyceride, total protein, albumin, or urea nitrogen contents among groups (P>0.05). Thus, it can be seen that in the first and second lactation months, DE feeding levels of 101.41 and 129.73 MJ/d and CP feeding levels of 1.38 and 1.82 kg/d, respectively, could already meet the nutritional requirements for Yili horse lactation, and increasing dietary DE and CP levels could reduce the contents of palmitic acid and palmitoleic acid in mare milk and increase the content of linoleic acid.

Full Text

Effects of Feeding Different Levels of Digestible Energy and Crude Protein on Milk Performance of Yili Mares during Early Lactation and Growth Development of Foals

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Abstract

This study investigated the effects of feeding different digestible energy (DE) and crude protein (CP) levels on milk performance, milk composition of Yili mares during early lactation, and growth development and plasma biochemical indices of their foals, to provide reference for determining energy and protein requirements of lactating Yili mares.

Twenty-five Yili mares in early lactation without genetic relationship and with similar age, body weight, and parity were selected and divided into five groups (n=5) based on body weight. The 60-day trial period comprised two lactation months, with each month lasting 30 days. In the first lactation month, DE and CP feeding levels were 101.41 MJ/d and 1.38 kg/d (Group I), 112.05 MJ/d and 1.50 kg/d (Group II), 122.40 MJ/d and 1.63 kg/d (Group III), 133.27 MJ/d and 1.75 kg/d (Group IV), and 143.84 MJ/d and 1.87 kg/d (Group V). In the second lactation month, DE and CP feeding levels were 129.73 MJ/d and 1.82 kg/d (Group I), 140.37 MJ/d and 1.94 kg/d (Group II), 150.72 MJ/d and 2.07 kg/d (Group III), 161.60 MJ/d and 2.19 kg/d (Group IV), and 172.17 MJ/d and 2.31 kg/d (Group V). Each lactation month included a 14-day pre-trial period followed by a 10-day sampling period.

Results showed that feeding different DE and CP levels had no significant effects on milk yield, conventional milk composition, or milk somatic cell count (P>0.05). Saturated fatty acid content in milk fat did not differ among groups (P>0.05), while Groups II and IV had significantly higher unsaturated fatty acid content than Group I (P<0.05). Monounsaturated fatty acid content showed no significant differences among groups (P>0.05), but Group I had significantly lower polyunsaturated fatty acid content than Groups II, IV, and V (P<0.05). Increasing dietary DE and CP levels significantly altered palmitic acid (C16:0), palmitoleic acid (C16:1), and linoleic acid (C18:2n6c) contents (P<0.05). Specifically, palmitic and palmitoleic acid contents in Group I were significantly higher than other groups (P<0.05), while linoleic acid content was significantly lower in Group I than in Groups II, IV, and V (P<0.05).

Feeding different DE and CP levels to Yili mares during early lactation had no significant effects on foal body weight, body length, heart girth, or cannon circumference (P>0.05), but foal body height in Group I was significantly higher than in Groups II and III (P<0.05). Plasma triglyceride, total protein, albumin, and urea nitrogen concentrations in foals did not differ significantly among groups (P>0.05).

In conclusion, DE feeding levels of 101.41 and 129.73 MJ/d and CP feeding levels of 1.38 and 1.82 kg/d in the first and second lactation months, respectively, met the nutritional requirements for lactating Yili mares. Increasing dietary DE and CP levels reduced palmitic and palmitoleic acid contents while increasing linoleic acid content in mare’ s milk.

Keywords: Yili mare; digestible energy; crude protein; milk composition; foals; plasma physiological-biochemical indices

Introduction

Energy and protein are closely related to animal growth, reproduction, and lactation performance. During early lactation, energy and protein supply should meet the maintenance, lactation, and gestation requirements of mares. Both deficiency and excess of dietary energy and protein can cause adverse effects. Previous research has shown that energy deficiency leads to weight loss, poor body condition, delayed estrus in mares, and impaired growth of foals, while excess energy often results in obesity, increased stress susceptibility, laminitis, reduced reproductive rate, and shortened lifespan [1]. Feeding low-protein diets to lactating mares adversely affects foal growth and causes weight loss in mares [2]. Studies have demonstrated that feeding Yili mares appropriate DE and CP levels during late lactation can increase milk yield, milk protein, and milk fat percentage [3], and promote foal body length growth [4]. Feeding appropriate DE (91.28 MJ/d) and CP (0.92 kg/d) levels during late gestation can increase polyunsaturated fatty acid (PUFA) content in colostrum [5]. Early lactation is the period when mares have the highest nutritional requirements, needing to meet both lactation demands and nutrient reserves for gestation. Therefore, formulating diets with appropriate DE and CP levels for mares during early lactation is of great significance. This study investigated the effects of different DE and CP levels on milk performance of Yili mares during early lactation and on growth development and plasma physiological-biochemical indices of foals, providing a scientific basis for feeding management and feed formulation for Yili mares during early lactation.

1.1 Experimental Animals and Diets

Twenty-five Yili mares without genetic relationship, with similar parity, aged 16-17 years, body weight (340±35) kg, and within 7 days postpartum were selected from Zhaosu Horse Farm in Xinjiang. The mares were divided into five groups (n=5) based on body weight, with their foals included in the trial. Five diets with different DE and CP levels were formulated according to NRC (2007) [6] for lactating mares with mature body weight of 400 kg. Dietary nutrient levels were calculated based on the "Chinese Feed Composition and Nutritional Value Table (27th Edition, 2016)" [7].

In the first lactation month, DE and CP feeding levels were 101.41 MJ/d and 1.38 kg/d (Group I), 112.05 MJ/d and 1.50 kg/d (Group II), 122.40 MJ/d and 1.63 kg/d (Group III), 133.27 MJ/d and 1.75 kg/d (Group IV), and 143.84 MJ/d and 1.87 kg/d (Group V). In the second lactation month, DE and CP feeding levels were 129.73 MJ/d and 1.82 kg/d (Group I), 140.37 MJ/d and 1.94 kg/d (Group II), 150.72 MJ/d and 2.07 kg/d (Group III), 161.60 MJ/d and 2.19 kg/d (Group IV), and 172.17 MJ/d and 2.31 kg/d (Group V). The diet composition, nutrient levels, and DE and CP feeding levels for early lactation mares are shown in Table 1 . Foal concentrate was formulated according to the formula reported by Jin Weixing et al. [3].

1.2 Feeding Management

Based on nutritional requirements of early lactation mares, roughage feeding amounts were 11.00 kg/d in the first lactation month and 15.00 kg/d in the second lactation month. Alfalfa hay and wheat straw were mixed at an 8:3 ratio using a total mixed ration (TMR) mixer for 30 minutes. Roughage was fed four times daily: in the first lactation month, 5.00 kg at 02:00 and 2.00 kg at 09:30, 13:30, and 18:00; in the second lactation month, 5.00 kg at 02:00, 4.00 kg at 09:30, and 3.00 kg at 13:30 and 18:00. Concentrate was fed twice daily at 11:30 and 20:00, each providing half of the daily amount. Groups I and II received 2.00 and 2.78 kg/d, respectively, while Groups III, IV, and V received 3.00 kg/d. Horses were housed individually with free access to water. Foals suckled milk freely except during milk sampling and were supplemented twice daily at 10:00 and 18:00 using feed bags, receiving 200 g/d in the first lactation month and 400 g/d in the second lactation month.

1.3 Sample Collection

Milk sampling followed the method described by Yu Quanping et al. [8]. Sampling began 2 hours after morning feeding, with manual milking every 4 hours by trained personnel until complete emptying. On the second day after each trial period, before morning feeding, foals were restrained and 10 mL blood was collected via jugular venipuncture into heparinized tubes. Plasma was separated by centrifugation at 3,500 r/min for 15 minutes and stored at -20°C for analysis.

1.4 Measurement Indicators

Daily milk yield of mares was calculated using the method of Jin Weixing et al. [3]. Milk composition and fatty acid composition were determined following the method of Wang Xiandong et al. [5]. Foal body weight, body length, body height, heart girth, and cannon circumference were measured at birth, end of month 1, and end of month 2. Plasma total protein (TP), albumin (ALB), triglyceride (TG), and urea nitrogen (UN) concentrations were measured using kits from Beijing Huaying Biotechnology Institute.

1.5 Data Analysis

Data were analyzed using two-way ANOVA in SPSS 18.0 with the model: Xij = + i + j + i× j + ij, where Xij is the observed value, is the overall mean, i (i=1,2,3,4,5) is the diet effect, j (j=1,2) is the lactation month effect (or foal age effect), i× j is the interaction effect, and ij is the error term. Duncan's multiple range test was used for pairwise comparisons. Data are expressed as means and SEM, with significance set at P<0.05. As the study focused on dietary effects, only P-values for diet effects are presented; P-values for lactation month (or foal age) effects and interaction effects are not shown.

2.1 Effects of Feeding Different DE and CP Levels on Milk Performance of Yili Mares during Early Lactation

As shown in Table 2 , feeding different DE and CP levels had no significant effects on average milking volume per session, estimated daily milk yield, milk fat percentage, milk protein percentage, lactose percentage, milk total solids content, or milk somatic cell count in Yili mares during early lactation (P>0.05).

2.2 Effects of Feeding Different DE and CP Levels on Fatty Acid Composition in Milk Fat of Yili Mares during Early Lactation

A total of 29 fatty acids were detected in mare milk fat, including 14 saturated fatty acids (SFA), 8 SFAs with concentration below 1.0%, 6 monounsaturated fatty acids (MUFA), 3 MUFAs with concentration below 0.5%, and 9 polyunsaturated fatty acids (PUFA), 7 PUFAs with concentration below 0.5%.

As shown in Table 3 , SFA content did not differ among groups (P>0.05), but palmitic acid (C16:0) content in Group I was 20.89%, 15.67%, 16.75%, and 15.92% higher than Groups II, III, IV, and V, respectively (P<0.05). Unsaturated fatty acid (UFA) content in Groups II and IV was 11.00% and 10.19% higher than Group I (P<0.05). Monounsaturated fatty acid content showed no significant differences among groups (P>0.05), but palmitoleic acid (C16:1) content in Group I was 47.34%, 3.88%, 37.32%, and 36.56% higher than Groups II, III, IV, and V, respectively (P<0.05). Polyunsaturated fatty acid content in Group I was 25.52%, 27.22%, and 18.86% lower than Groups II, IV, and V, respectively (P<0.05), while Groups II and IV were 18.62% and 21.39% higher than Group III (P<0.05). Linolenic acid (C18:3n3) and PUFAs below 0.5% did not differ among groups (P>0.05). Linoleic acid (C18:2n6c) content in Groups II, IV, and V was 72.37%, 63.37%, and 66.29% higher than Group I, respectively (P<0.05).

2.3 Effects of Feeding Different DE and CP Levels on Growth Development of Foals

As shown in Table 4 , feeding different DE and CP levels to Yili mares during early lactation had no significant effects on foal body weight, body length, heart girth, or cannon circumference (P>0.05). However, foal body height in Group I was significantly higher than in Groups II and III (P<0.05), with no significant differences among other groups (P>0.05).

2.4 Effects of Feeding Different DE and CP Levels on Plasma Physiological-Biochemical Indices of Foals

As shown in Table 5 , feeding different DE and CP diets to Yili mares during early lactation had no significant effects on plasma total protein, albumin, triglyceride, or urea nitrogen concentrations in foals (P>0.05).

3.1 Effects of Feeding Different DE and CP Levels on Milk Performance of Yili Mares during Early Lactation

Research on dietary DE and CP levels affecting mare milk performance is limited. Pagan et al. [9] found that increasing dietary energy level did not significantly affect milk yield. Other studies reported that mares fed high-concentrate, high-energy diets had 10% higher milk yield than those fed high-forage diets [10]. However, research findings on the effects of dietary DE and CP levels on milk yield are inconsistent. In this study, increasing dietary DE and CP levels did not affect milk yield or conventional milk composition of Yili mares during early lactation, indicating that DE levels of 101.41 and 129.73 MJ/d and CP levels of 1.38 and 1.82 kg/d in the first and second lactation months, respectively, met the nutritional requirements for lactating Yili mares. It should be noted that due to experimental constraints, the biological replication was only five mares per group, so these results require further verification. Previous studies found that increasing dietary energy level decreased total solids, protein, fat, and total energy in milk composition while improving mare body condition score [9]. Emery [11] reported that each 1% increase in dietary CP level increased milk protein percentage by 0.02%, while Leonardi et al. [12] noted that milk protein percentage does not increase indefinitely with dietary CP level. Wang Xiandong et al. [4] found that feeding different DE and CP levels during late lactation had no significant effects on colostrum fat, protein, total solids, or somatic cell count, though lactose content tended to increase with DE and CP levels. In this study, different DE and CP levels had no significant effects on milk fat, protein, lactose, total solids, or somatic cell count during early lactation, which may be related to the lactation stage. Jin Weixing et al. [3] reported no significant effect of different DE and CP levels on lactose percentage during late lactation. Additionally, research shows that milk fat and protein percentages decrease with advancing lactation, while lactose percentage increases [13].

3.2 Effects of Feeding Different DE and CP Levels on Fatty Acid Composition in Milk Fat of Yili Mares during Early Lactation

Milk fatty acids are obtained through two main pathways: de novo synthesis in mammary cells and direct uptake from blood. The composition of long-chain fatty acids in mare milk is directly related to dietary fatty acid content, with low-forage diets decreasing saturated fatty acid proportion and increasing oleic, linoleic, and linolenic acids [14]. Doreau et al. [10] found that mare' s milk from mares fed forage-based diets (95% hay, 5% concentrate) had higher fat, protein, and linolenic acid contents but lower linoleic acid content compared to mares fed concentrate-based diets (50% hay, 50% concentrate). High protein intake during early lactation affects fat metabolism and increases long-chain fatty acid content in milk [15]. Studies have shown that adding roasted soybeans, palm oil, or hydrogenated tallow to diets decreased short- and medium-chain fatty acids (6-14 carbons) and increased long-chain fatty acids (16+ carbons) in cow milk [16]. Huang Yanling et al. [17] reported that forage in diets increased PUFA content in milk, particularly affecting linoleic and linolenic acid contents. This study' s findings that different DE and CP levels significantly affected palmitic, palmitoleic, and linoleic acid contents in milk fat of Yili mares during early lactation are consistent with these results.

3.3 Effects of Feeding Different DE and CP Levels on Growth Development of Foals

During the first few months after birth, mare' s milk is the sole nutrient source for foals, with 10 kg of milk required for each 1 kg of weight gain during the first 1-2 months [18]. Wang Xiandong et al. [4] reported that feeding different DE and CP levels during late lactation had no significant effects on foal body weight, body height, or cannon circumference, though Group IV had the longest body length. Studies on lactating sows showed that three dietary protein levels (14%, 16.5%, 19%) had no significant effects on piglet weight gain [19]. Ayishayila et al. [20] found that foal supplementation increased weight gain and body height, accelerating long bone growth, with average daily gain and body height increasing by 13.35% and 7.54% compared to the control group. Li Xin et al. [21] reported that 18% dietary protein level was superior to 16% and 20% for lambs, with significantly higher daily gains in body height, body length, and heart girth compared to 16% protein level. This study showed that different DE and CP levels fed to Yili mares during early lactation had no significant effects on foal body weight, but the low DE and CP level diet promoted foal body height growth, possibly due to slightly higher milk yield in the low DE and CP level group.

3.4 Effects of Feeding Different DE and CP Levels on Plasma Physiological-Biochemical Indices of Foals

Few studies have reported on the effects of mare nutrition on foal plasma physiological-biochemical indices. Research on 2-year-old Yanqi horses showed that increasing dietary protein level had no significant effects on plasma total protein, albumin, globulin, or urea nitrogen [22]. Studies on piglets showed that decreasing dietary energy level had no significant effects on serum total cholesterol, triglyceride, high-density lipoprotein cholesterol, or low-density lipoprotein cholesterol [23]. Feeding diets with energy levels of 13.7 and 14.0 MJ/kg had no significant effects on serum triglyceride and total cholesterol in piglets [24]. Wang Xiandong et al. [4] found that feeding different DE and CP levels to Yili mares had no significant effects on blood lipid metabolism indices in foals. This study' s finding that different DE and CP levels fed to Yili mares during early lactation had no significant effects on plasma total protein, albumin, triglyceride, or urea nitrogen concentrations in foals is consistent with these results.

4 Conclusion

During the first and second lactation months, DE feeding levels of 101.41 and 129.73 MJ/d and CP feeding levels of 1.38 and 1.82 kg/d, respectively, met the nutritional requirements for lactating Yili mares. Increasing dietary DE and CP levels reduced palmitic and palmitoleic acid contents while increasing linoleic acid content in mare' s milk.

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