Effects of Dietary Crude Protein and Crude Fat Levels on Growth Performance, Nutrient Digestibility, and Nitrogen Metabolism in Male Mink during the Winter Fur Period (Postprint)

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Abstract

This experiment was conducted to investigate the effects of dietary crude protein (CP) and ether extract (EE) levels on growth performance, nutrient digestibility, and nitrogen metabolism in male mink during the winter fur period, and to determine the appropriate dietary CP and EE levels for this period. A 2$\times$3$factorialdesignwasemployed, consistingoftwoCPlevels$(32$\pm$5) days of age were selected and randomly allocated into six groups with 14 replicates per group and one mink per replicate. The experiment included a 7-day preliminary period followed by an 85-day formal experimental period. The results showed that: the 32% CP group exhibited significantly or extremely significantly lower average daily gain (ADG), protein digestibility, fat digestibility, carbohydrate digestibility, and all nitrogen metabolism indices compared to the 36% CP group (P<0.05 or P<0.01). The 30% EE group demonstrated significantly or extremely significantly higher final body weight, ADG, and nitrogen retention compared to the 10% EE group (P<0.05 or P<0.01); while the 30% EE group showed significantly or extremely significantly lower average daily feed intake, feed conversion ratio, dry matter digestibility, protein digestibility, carbohydrate digestibility, nitrogen intake, and fecal nitrogen excretion compared to the 10% EE group (P<0.05 or P<0.01). A significant interaction effect between dietary CP and EE levels was observed on fat digestibility in mink (P<0.05). Based on these comprehensive indicators, under the conditions of this experiment, dietary CP level of 36% and EE level of 20% or 30% could achieve optimal growth performance in winter fur period mink and improve protein utilization efficiency.

Full Text

Effects of Dietary Crude Protein and Ether Extract Levels on Growth Performance, Nutrient Digestibility, and Nitrogen Metabolism of Male Minks during the Winter Fur-Growing Period

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Abstract

This experiment investigated the effects of dietary crude protein (CP) and ether extract (EE) levels on growth performance, nutrient digestibility, and nitrogen metabolism in male minks during the winter fur-growing period to determine optimal dietary CP and EE levels. A 2\$×3*factorialdesignwasemployedwithtwoCPlevels*(32±\$5) days were randomly allocated into six groups with 14 replicates per group and one mink per replicate. The adaptation period lasted 7 days, followed by an 85-day formal experimental period. The results showed that minks in the 32% CP group exhibited significantly or extremely significantly lower average daily gain (ADG), protein digestibility, fat digestibility, carbohydrate digestibility, and all nitrogen metabolism indices compared to the 36% CP group ($P<0.05$ or $P<0.01$). Minks in the 30% EE group had significantly or extremely significantly higher final weight, ADG, and nitrogen deposition content than those in the 10% EE group ($P<0.05$ or $P<0.01$), while their average daily feed intake, feed-to-gain ratio, dry matter digestibility, protein digestibility, carbohydrate digestibility, nitrogen intake, and fecal nitrogen excretion were significantly or extremely significantly lower ($P<0.05$ or $P<0.01$). A significant interaction between dietary CP and EE levels was observed for fat digestibility ($P<0.05$). Based on comprehensive evaluation of all indices, dietary CP at 36% and EE at 20% or 30% yielded optimal growth performance and improved protein utilization in winter fur-growing male minks under the conditions of this experiment.

Keywords: male minks; protein; fat; winter fur-growing period

Minks are valuable fur-bearing animals, and protein and fat represent crucial nutritional components in mink diets that directly influence feed costs and animal performance. Therefore, determining appropriate dietary crude protein (CP) and ether extract (EE) levels is essential for rational diet formulation and improving economic efficiency in mink production. While numerous studies have investigated CP requirements [1-3] and EE requirements [4-6] for minks,

research on optimal combinations of dietary CP and EE levels remains limited. Zhang et al. [7] reported optimal dietary CP and EE levels for winter fur-growing minks using dry powder diets. However, fresh feed formulations are predominantly used in Chinese mink production, offering better nutrient absorption and utilization and supporting superior fur quality. Protein feed ingredients constitute the most expensive component of mink diets; insufficient CP fails to meet requirements for growth, maintenance, and fur development, while excessive CP wastes energy through conversion to energy or metabolic consumption. Research indicates that metabolizable energy derived from fat provides greater production value than that from other nutrients [6]. Supplementing animal diets with non-protein energy sources like fat can spare protein from catabolism for energy, thereby improving protein utilization [7-8], enhancing growth performance, and reducing feed costs. Consequently, this experiment evaluated different dietary CP and EE levels in winter fur-growing male minks by assessing growth performance, nutrient digestibility, and nitrogen metabolism to establish optimal dietary levels, provide a foundation for improving Chinese mink nutrition standards, and offer scientific guidance for rational feed formulation in mink farming.

1. Materials and Methods

1.1 Experimental Animals Eighty-four healthy male minks aged (120$±$5) days with similar body weights were selected from the fur animal base at the Key Field Scientific Observation and Experiment Station of Changbai Mountain Wildlife Resources, Ministry of Agriculture.

1.2 Experimental Design The 84 minks were randomly divided into six groups with 14 replicates per group and one mink per replicate. A 2$×$3 factorial design was employed with two CP levels (32% and 36%) and three EE levels (10%, 20%, and 30%), yielding six experimental diets: 32% CP and 10% EE (Group I), 32% CP and 20% EE (Group II), 32% CP and 30% EE (Group III), 36% CP and 10% EE (Group IV), 36% CP and 20% EE (Group V), and 36% CP and 30% EE (Group VI).

1.3 Experimental Diets The experimental diets were formulated using extruded corn, corvina, chicken by-products, pork, and soybean oil as primary ingredients to achieve the target CP and EE levels. Diet composition and nutrient levels are presented in Table 1 .

Table 1 Composition and nutrient levels of experimental diets (air-dry basis), %

Items	Groups
Ingredients	
Corvina	

Items	Groups
Jarding pork	
Extrusion corn	
Poultry offal	
Ox liver	
Soybean oil	
NaCl	
Premix[1])	
Total	
Nutrient levels[2])	
Metabolic energy/(MJ/kg)	
Crude protein	
Ether extract	
Carbohydrate	
Calcium	
Total phosphorus	

[1]) One kilogram of premix contained the following: VA 200,000 IU, VD_3 40,000 IU, VE 5,000 IU, VB_1 125 mg, VB_2 200 mg, VB_6 200 mg, VB_{12} 2.5 mg, VK_3 40 mg, VC 7,500 mg, niacin acid 500 mg, pantothenic acid 800 mg, folic acid 100 mg, choline 10,000 mg, biotin 7.5 mg, Fe 2,000 mg, Cu 500 mg, Mn 400 mg, Zn 1,500 mg, I 15 mg, Se 5 mg, Co 7.5 mg.

[2]) Crude protein, ether extract, calcium, and total phosphorus were measured values, while carbohydrate and metabolic energy were calculated values.

1.4 Animal Management Prior to the experiment, minks were vaccinated against canine distemper and parvovirus. Minks were housed individually in cages and fed twice daily at 08:00 and 16:00 with ad libitum access to feed and water. Daily feed intake was recorded. The adaptation period lasted 7 days, followed by an 85-day formal experimental period.

1.5 Digestion and Metabolism Trial Twenty-five days after the formal period began, nine healthy minks with similar body weights were selected from each group for a 4-day digestion and metabolism trial. The total feces collection method [4] was used. Urine and feces were collected separately, mixed thoroughly over the 4-day period, and sampled. Feces were sterilized at 80°C for 2 hours, then dried at 65°C to constant weight, ground to pass through a 40-mesh sieve, and prepared as air-dry samples for laboratory analysis.

1.6 Measurements and Methods Initial body weight was recorded on day 1 of the formal period, and final body weight was recorded at the end of the experiment to calculate average daily gain (ADG) for each mink. Feed intake was recorded to calculate average daily feed intake (ADFI). Feed-to-gain ratio (F/G)

was calculated based on ADG and ADFI. Analytical methods for dry matter, CP, EE, ash, calcium, and phosphorus content in diets, as well as measurements of growth performance, nutrient digestibility, and nitrogen metabolism, followed Zhang et al. [9]. Methods for determining carbohydrate content and metabolizable energy in diets followed Zhang et al. [10].

1.7 Statistical Analysis Data were analyzed using SAS 9.0 software. Differences were tested for significance using two-way ANOVA. Results are expressed as "mean ± standard deviation," where P<0.05 indicates significant difference and P<0.01 indicates extremely significant difference.

2. Results

2.1 Effects of Dietary CP and EE Levels on Growth Performance of Male Minks during the Winter Fur-Growing Period As shown in Table 2 , initial weights did not differ significantly among groups (P>0.05). Final weights in Groups III and VI were significantly higher than those in Groups I, IV, and V (P<0.05). Minks in Group VI had the highest ADG, which was significantly higher than that in Groups I and IV (P<0.05). ADFI in Groups III and VI was significantly lower than in other groups (P<0.05), and F/G in Groups III and VI was significantly lower than in other groups (P<0.05). Dietary CP level significantly affected ADG (P<0.05), with the 32% CP group showing significantly lower ADG than the 36% CP group (P<0.05). Dietary EE level significantly affected final weight, ADFI, and F/G (P<0.05) and extremely significantly affected ADG (P<0.01). Minks in the 30% EE group had significantly higher final weight than those in the 10% EE group (P<0.05), extremely significantly higher ADG (P<0.01), and significantly lower ADFI and F/G (P<0.05). No significant interaction between dietary CP and EE levels was observed for any growth performance indices (P>0.05).

Table 2 Effects of dietary CP and EE levels on growth performance of male minks during winter fur-growing period

<table>
<tr><th>Items</th><th>Groups</th><th>Initial weight/kg</th><th>Final weight/kg</th><th>ADG/g</th><th>ADFI/g</th><th>F/G</th></tr>
<tr><td></td><td>I</td><td>1.76$±0.12|2.15±0.14^b|4.59±0.62^b|95.17±1.23^a|20.61±0.57^a|||II|1.77±0.08|2.27±0.21^ab|5.86
Maineffect
*||||||||DietaryCPlevel/±0.11|2.24±0.12|5.60±0.69^b|91.86±1.41|16.53±0.52|||36|1.76±0.10|2</td><td></td><td></td><td></td><td></td></tr>
<tr><td>P-value</td><td>Dietary CP level</td><td></td><td></td><td><0.0001</td><td></td><td></td></tr>
<tr><td></td><td>Dietary EE level</td><td></td><td></td><td><0.0001</td><td></td><td></td></tr>
<tr><td></td><td>Interaction</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

In the same item and column, values with different small letter superscripts indicate significant difference (P<0.05), and different capital letter superscripts indicate extremely significant difference (P<0.01), while the same or no letter superscripts indicate no significant difference (P>0.05). The same applies below.

2.2 Effects of Dietary CP and EE Levels on Nutrient Digestibility of Male Minks during the Winter Fur-Growing Period As shown in Table 3 , dry matter digestibility in Group IV was significantly higher than in Group III (P<0.05) but did not differ significantly from other groups (P>0.05). Protein digestibility in Group IV was not significantly different from Group I (P>0.05) but was significantly higher than other groups (P<0.05). Fat digestibility in Group V was extremely significantly higher than in Groups I and III (P<0.05) but did not differ significantly from other groups (P>0.05). Carbohydrate digestibility was highest in Group IV, which was significantly higher than Groups II and III (P<0.05). Dietary CP level significantly or extremely significantly affected protein digestibility, fat digestibility, and carbohydrate digestibility (P<0.05 or P<0.01), with the 32% CP group showing significantly or extremely lower values than the 36% CP group (P<0.05 or P<0.01). Dietary EE level significantly affected dry matter digestibility, protein digestibility, fat digestibility, and carbohydrate digestibility (P<0.05). The 30% EE group had significantly lower dry matter digestibility, protein digestibility, and carbohydrate digestibility than the 10% EE group (P<0.05), while the 20% EE group had significantly higher fat digestibility than both 10% and 30% EE groups (P<0.05). A significant interaction between dietary CP and EE levels was observed for fat digestibility (P<0.05).

Table 3 Effects of dietary CP and EE on nutrient digestibility of male minks during winter fur-growing period

Items	Groups	DM digestibility/%	Protein digestibility/%	Fat digestibility/%	Carbohydrate digestibility/%
	I	75.65$±1.45^{ab}\|76.87±1.20^{ab}\|91.12±0.87^{Bb}\|67.31±1.25^{ab}\|\|\|II\|74.87±1.31^{ab}\|73.32±1.87^{b}|92.13±0.			
		$*Maineffect*$			
		$*$||||||$DietaryCPlevel$/±1.27|73.16±1.11^{b}|91.07±0.97^{B}|64.15±1.21^{b}|||36|75.81±1.04|75.27±1.24			
P-value	Dietary CP level		<0.0001		
	Dietary EE level				
	Interaction				

2.3 Effects of Dietary CP and EE Levels on Nitrogen Metabolism of Male Minks during the Winter Fur-Growing Period As shown in Table

4 , nitrogen intake in Groups IV and V was significantly higher than in Group III (P<0.05) but did not differ significantly from other groups (P>0.05). Fecal and urinary nitrogen excretion in Group III was significantly lower than in Group IV (P<0.05) but did not differ significantly from other groups (P>0.05). Nitrogen deposition content was highest in Group V, which was not significantly different from Groups IV and VI (P>0.05) but was significantly higher than other groups (P<0.05). Biological value of protein was highest in Group V, which was significantly higher than Groups I, II, and IV (P<0.05). Dietary CP and EE levels significantly or extremely significantly affected all nitrogen metabolism indices (P<0.05 or P<0.01). The 32% CP group showed significantly or extremely significantly lower nitrogen metabolism indices than the 36% CP group (P<0.05 or P<0.01). The 30% EE group had significantly or extremely significantly lower nitrogen intake and fecal nitrogen excretion than the 10% EE group (P<0.05 or P<0.01). The 20% EE group had significantly higher urinary nitrogen excretion than both 10% and 30% EE groups (P<0.05). The 10% EE group had significantly lower nitrogen deposition content than both 20% and 30% EE groups (P<0.05), and significantly lower biological value of protein than the 20% group (P<0.05). No significant interaction between dietary CP and EE levels was observed for any nitrogen metabolism indices (P>0.05).

Table 4 Effects of dietary CP and EE levels on nitrogen metabolism of male minks during winter fur-growing period

Items	Groups	Nitrogen intake/(g/d)	Fecal nitrogen/(g/d)	Urine nitrogen/(g/d)	Nitrogen deposition/(g/d)	BV of protein/%
	I	4.87$±0.52^{ab}\|0.86±0.09^{ab}\|2.22±0.25^{ab}\|1.75±0.11^{c}\|43.96±2.14^{c}\|\|\|II\|4.81±0.24^{ab}\|0.81±0.15^{ab}|2.16±				
		$*Maineffect*$				
		$*\|\|\|\|\|\|\|\|DietaryCPlevel/$±0.48^{B}|0.81±0.09^{b}|1.82±0.37^{b}|2.09±0.16^{b}|46.74±1.52^{b}|||36|5.38±0.33^{A}|0.				
P-value	Dietary CP level	<0.0001				
	Dietary EE level					
	Interaction					

3. Discussion

3.1 Effects of Dietary CP and EE Levels on Growth Performance of Winter Fur-Growing Male Minks Dietary CP and EE levels significantly influenced growth performance in winter fur-growing minks. The present results demonstrated that ADG in the 32% CP group was significantly lower than in the 36% CP group. Numerous studies have reported that increasing dietary CP levels significantly improves mink growth performance [11-12], a conclusion supported by our findings. Although minks do not require large amounts of protein

for tissue synthesis during the winter fur-growing period, they need substantial protein for fur growth, resulting in continued high protein requirements during this stage. In this experiment, growth performance improved with increasing dietary EE levels, though no significant difference was observed between the 20% and 30% EE groups. Studies by Yang et al. [13-14] that fixed dietary CP levels while adjusting EE levels to modify dietary metabolizable energy reported that increasing EE levels improved mink growth performance. Their research indicated that growing female minks fed complete dry powder diets achieved satisfactory performance when metabolizable energy was not less than 14% and EE level not less than 17.87%, and winter fur-growing female minks performed well with metabolizable energy at 14.5 MJ/kg and EE at 18.83%. These findings align with the trends observed in our study. Our experiment used fresh feed ingredients, and compared with the aforementioned studies using dry powder diets, minks achieved superior growth performance with fresh feeds despite similar initial weights. This suggests that under our experimental conditions, dietary CP at 36% and EE at 20% or 30% supported optimal growth performance.

3.2 Effects of Dietary CP and EE Levels on Nutrient Digestibility of Winter Fur-Growing Male Minks Our results showed that dietary CP and EE levels significantly or extremely significantly affected protein, fat, and carbohydrate digestibility, with higher CP levels resulting in greater nutrient digestibility—consistent with previous research on minks and other animals [15-17]. Higher EE levels reduced dry matter digestibility. Previous studies have demonstrated that dietary composition alters nutrient digestibility by changing gastrointestinal transit time [18], and the digestive tract structure and function of carnivorous animals like minks adapt according to dietary composition [19]. Our results revealed no significant interaction between dietary CP and EE levels for dry matter, protein, or carbohydrate digestibility, but a significant interaction for fat digestibility, suggesting that CP and EE levels may primarily influence mink growth performance through modulation of fat digestion and utilization. Comprehensive analysis indicates that nutrient digestibility in minks is mainly affected by dietary EE and energy levels, with EE at 20% or 30% achieving satisfactory digestibility. These findings are consistent with Hoie [5], who reported that dietary EE levels of 7%-33% could improve mink growth performance, while our results provide more specific optimal EE levels.

3.3 Effects of Dietary CP and EE Levels on Nitrogen Metabolism of Winter Fur-Growing Male Minks Our results demonstrated that higher dietary CP levels increased nitrogen intake, urinary nitrogen excretion, nitrogen deposition, and biological value of protein. However, nitrogen intake decreased with increasing EE levels, indicating that changes in nitrogen intake were primarily driven by dietary EE levels and feed intake differences [6]. The ratio of metabolic fecal nitrogen to dietary dry matter is relatively constant; therefore, higher dietary protein content results in relatively less protein loss through metabolic fecal nitrogen and greater protein digestion [10]. Under our experi-

mental conditions, protein digestibility was highest when dietary EE was 10% with CP at 32% or 36%, but fecal nitrogen excretion was lowest in the 32% CP and 30% EE group, suggesting that minks may enhance protein utilization through physiological regulation. Research indicates a strong correlation between protein intake and urinary nitrogen excretion, with excess protein supply or amino acid imbalance causing increased urinary nitrogen excretion and reduced nitrogen utilization efficiency [20]. Minks excrete approximately 80% of nitrogen through urine during the growing period [21]. In our study, urinary nitrogen excretion increased with dietary CP level, indicating that minks can regulate protein and energy metabolism by catabolizing excess protein for energy and excreting it via urine [22]. Under our conditions, urinary nitrogen excretion was relatively low in the 36% CP group with 20% or 30% EE. Biological value of protein measures the degree of dietary protein utilization and animal protein requirements [23]. In our experiment, biological value of protein increased with both dietary CP and EE levels, indicating that higher CP and EE levels improved protein utilization efficiency. No significant interaction between dietary CP and EE levels was observed for nitrogen metabolism indices, but increasing EE levels elevated nitrogen deposition content and biological value of protein, demonstrating that EE level can enhance protein utilization. Based on comprehensive evaluation, dietary CP at 36% and EE at 20% or 30% supported superior protein utilization and reduced urinary nitrogen excretion in winter fur-growing male minks under our experimental conditions.

Conclusion

Comprehensive evaluation of all indices indicates that dietary CP at 36% and EE at 20% or 30% supported optimal growth performance and improved protein utilization in winter fur-growing male minks under the conditions of this experiment.

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