Effects of Different Dietary Protein and Fat Levels in Pelleted Feed on Growth Performance, Nutrient Digestibility, Nitrogen Metabolism, and Fur Quality of Mink during the Winter Fur Growth Period: Postprint

Authors: Zhang Tietao, Sun Haoran, Yang Yahan, Narenhua, Wang Kaiying, Li Guangyu, Gao Xiuhua

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Abstract

This experiment aimed to investigate the effects of pelleted feeds with different protein and fat levels on growth performance, nutrient digestibility, nitrogen metabolism, and fur quality of mink during the winter fur period. Seventy-two healthy male mink at (135±5) days of age were selected and randomly divided into 6 groups with 12 mink per group. Using a two-factor experimental design, six experimental diets were formulated and pelleted according to the following compositions: 34% crude protein and 18% crude fat (Group), 34% crude protein and 16% crude fat (Group), 32% crude protein and 18% crude fat (Group), 32% crude protein and 16% crude fat (Group), 30% crude protein and 18% crude fat (Group), and 30% crude protein and 16% crude fat (Group). The preliminary period was 7 days, and the formal experimental period was 60 days. The results showed that the average daily gain (ADG) of mink in Groups and was extremely significantly higher than that in Groups , , and (P<0.01); the final body weight of mink in the 18% fat group was significantly higher than that in the 16% fat group (P<0.05), and the ADG of mink in the 18% fat group was extremely significantly higher than that in the 16% fat group (P<0.01). The protein digestibility of mink in Group was extremely significantly lower than that in all other groups (P<0.01); the protein digestibility of mink in the 18% fat group was extremely significantly higher than that in the 16% fat group (P<0.01); the protein digestibility of mink in the 34% and 32% protein groups was extremely significantly higher than that in the 30% protein group (P<0.01). The nitrogen retention and protein biological value of mink in Group were significantly higher than those in Group (P<0.05); the net protein utilization of mink in Groups , , and

was significantly higher than that in Group (P<0.05); dietary fat level had no significant effect on nitrogen metabolism-related indices of mink (P>0.05), while dietary protein level significantly affected the net protein utilization of mink (P<0.05). The body length of mink in the 34% and 32% protein groups was significantly higher than that in the 30% protein group (P<0.05); the pelt length of mink in the 34% protein group was significantly higher than that in the 30% protein group (P<0.05), but dietary fat level, protein level, and their interaction had no significant effect on the pelt length of mink (P>0.05). Based on the comprehensive experimental results, it was concluded that dietary fat level affected the final body weight of mink during the winter fur period, while dietary protein level influenced the body length of mink during this period; under the conditions of this experiment, feeding mink in the winter fur period with pelleted feed containing 18% fat and 32%~34% protein could achieve better growth performance and fur quality.

Full Text

Effects of Granulated Feeds with Different Protein and Fat Levels on Growth Performance, Nutrient Digestibility, Nitrogen Metabolism and Fur Quality of Minks in Pelting Period

ZHANG Tietao[1], SUN Haoran[1], YANG Yahan[1], NA Renhua[2], WANG Kaiying[1], LI Guangyu[1], *GAO Xiuhua[2]* [1]Institute of Special Economic Animal and Plant Sciences, Jilin Provincial Key Laboratory of Special Economic Animal Molecular Biology, Chinese Academy of Agricultural Sciences, Changchun 130112, China
[2]Feed Research Institute, Chinese Academy of Agricultural Sciences, Beijing 100081, China

Abstract: This study investigated the effects of granulated feeds with different protein and fat levels on growth performance, nutrient digestibility, nitrogen metabolism, and fur quality of minks during the pelting period. Seventy-two healthy male minks aged (135±5) days were randomly divided into 6 groups with 12 minks each. A 2×3 factorial design was employed to formulate six experimental diets: 34% crude protein (CP) with 18% ether extract (EE) (Group I), 34% CP with 16% EE (Group II), 32% CP with 18% EE (Group III), 32% CP with 16% EE (Group IV), 30% CP with 18% EE (Group V), and 30% CP with 16% EE (Group VI), which were then processed into granulated feed. The pre-trial period lasted 7 days, followed by a 60-day formal trial. The results showed that average daily gain (ADG) in Groups I and III was significantly higher than in Groups II, IV, and VI (P<0.01). Minks fed the 18% fat diet had significantly higher final body weight than those fed the 16% fat diet (P<0.05), and ADG in the 18% fat group was significantly higher than in the 16% fat group (P<0.01). Protein digestibility in Group VI was significantly lower than in all other groups (P<0.01). The 18% fat group exhibited significantly higher

protein digestibility than the 16% fat group (P<0.01), and protein digestibility in both the 34% and 32% protein groups was significantly higher than in the 30% protein group (P<0.01). Nitrogen retention and protein biological value in Group II were significantly higher than in Group IV (P<0.05). Net protein utilization in Groups II, III, and IV was significantly higher than in Group VI (P<0.05). Dietary fat level did not significantly affect nitrogen metabolism indices (P>0.05), whereas dietary protein level significantly influenced net protein utilization (P<0.05). Live body length in the 34% and 32% protein groups was significantly greater than in the 30% protein group (P<0.05). Fur length in the 34% protein group was significantly longer than in the 30% protein group (P<0.05), though dietary fat and protein levels and their interaction had no significant effect on fur length (P>0.05). Based on these results, dietary fat level affects final body weight of minks during the pelting period, while dietary protein level influences live body length. Under the conditions of this experiment, feeding granulated feed containing 18% fat and 32%–34% protein yielded optimal growth performance and fur quality in pelting period minks.

Keywords: protein; fat; minks; growth performance; fur quality; granulated feed

Mink is a valuable fur-bearing animal widely raised in northern China. Due to the high cost and susceptibility to microbial contamination of fresh feed, research on dry powder and granulated feeds has been conducted successively. Granulated feed is produced from powder-based materials through high-temperature and high-pressure steam conditioning, pelleting, and cooling, which reduces feed volume, facilitates storage and transportation, prevents ingredient segregation, and ensures complete nutritional value. Zhang et al. [1] reported that male minks fed granulated feed with 11%–14% fat failed to achieve breed-standard body weight at trial conclusion. Zhou et al. [2] found that dry powder feeding of young minks resulted in comparable development and weight gain to fresh feed groups, with no significant differences in pregnancy and litter performance. Previous studies have shown that dry powder feeding during the growing and pelting periods meets production requirements for growth performance and pelt area [3-4]. Selective trials of compounded granulated feed for adult minks [5] and screening tests of compounded extruded feed [6] have demonstrated the feasibility of using complete feeds, with feeding effects during gestation and lactation approaching those of fresh fish mixed with plant-based feed paste. Feng [7] noted that research on mink complete feed remains in its initial stages, with nutritional characteristics yet to be reported and comprehensive comparative studies on pelt quality still lacking. Given the sluggish fur market and high cost of fresh feed, granulated feeding offers a simpler approach that reduces labor costs and fresh feed storage expenses. However, as a novel feed type, systematic research on granulated feed effects in minks is lacking. Based on previous reports [4,8-9], this experiment designed granulated feeds with different protein and fat levels to investigate their effects on growth performance, nitrogen metabolism, and fur quality in pelting period minks, aiming to determine optimal protein and fat levels for

practical production guidance.

1.1 Experimental Design

Seventy-two healthy male minks aged (135±5) days were randomly allocated to 6 groups (12 minks per group) and housed individually in cages, with no significant differences in initial body weight among groups (P>0.05). A 2×3 factorial design was employed to formulate six experimental diets: 34% crude protein and 18% ether extract (Group I), 34% crude protein and 16% ether extract (Group II), 32% crude protein and 18% ether extract (Group III), 32% crude protein and 16% ether extract (Group IV), 30% crude protein and 18% ether extract (Group V), and 30% crude protein and 16% ether extract (Group VI), which were processed into granulated feed. Minks were vaccinated before the trial. Throughout the experiment, fixed personnel managed feeding at 07:30 and 15:30 daily with ad libitum water access. The pre-trial period began on September 13, 2013 and lasted 7 days, followed by a 60-day formal trial period.

1.2 Experimental Diets

Based on NRC (1982) nutrient requirements for minks and domestic reports [4,8-9], experimental diets for the growing period were formulated with composition and nutrient levels shown in Table 1 .

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

Items	Groups
Ingredients	
Extruded corn	
Soybean meal	
Corn gluten meal	
Meat and bone meal	
Fish meal	
Cheese meal	
Feather meal	
Blood meal	
Soybean oil	
NaCl	
Lys	
Met	
Premix[1]	
Total	
Nutrient levels[2]	
ME/(MJ/kg)	
CP	
EE	

Items	Groups
Ca	
TP	
Lys	
Met+Cys	

[1]Per kilogram of premix contained: VA 1,000,000 IU, VD 200,000 IU, VE 6,000 IU, VB 600 mg, VB 800 mg, VB 300 mg, VB 10 mg, VK 100 mg, VC 40,000 mg, niacin acid 4,000 mg, pantothenic acid 1,200 mg, biotin 20 mg, folic acid 80 mg, choline 30,000 mg, Fe 8,200 mg, Cu 800 mg, Mn 1,200 mg, Zn 5,200 mg, I 50 mg, Se 20 mg, Co 50 mg.

[2]Values of CP, EE, Ca, TP and AA were measured, while ME was calculated.

1.3 Digestion and Metabolism Trial

After 30 days of the formal trial, 8 minks from each group were selected for a digestion and metabolism trial using the total fecal collection method. Feces and urine were collected continuously for 4 days under the same management conditions as daily feeding. Collected feces were weighed daily, mixed with 10% sulfuric acid solution at 5% of fresh weight, preserved with a small amount of toluene, and stored at -20°C. Urine was collected daily with 20 mL of 10% sulfuric acid added per 100 mL urine, preserved with 4 drops of toluene, and stored at -20°C.

1.4 Measured Indices

Daily feed allowance and residual feed were recorded for each mink to calculate individual and group average daily feed intake (ADFI). Initial body weight was recorded at the start of the formal trial (September 20, 2013). Body weight was measured at 2-week intervals (October 5, 2013; October 20, 2013; November 4, 2013) in the morning after overnight fasting, with final body weight recorded at trial conclusion (November 19, 2013). After final weighing, minks were pelted to measure guard hair length, underhair length, and fur length.

1.5 Measurement Methods

Dry matter content was determined by oven-drying method according to GB/T 6345-2006. Crude protein content was measured by Kjeldahl method using a Kjeltec 8400 automatic analyzer according to GB/T 6432-1994. Crude fat content was determined by Soxhlet extraction method using a VELP SER-148 fat extractor according to GB/T 6433-2006. Amino acid content was analyzed using a Hitachi L-8900 amino acid analyzer.

Guard hair and underhair lengths were measured from the skin surface after straightening on a glass slide using vernier calipers. Fur length was measured

as the distance from nose tip to tail base after pelt boarding.

1.6 Calculation Formulas

Average daily gain (g/d) = (final weight - initial weight) / trial days
Average daily feed intake (g/d) = total feed intake during trial / trial days
Dry matter digestibility (%) = [(dry matter intake - dry matter excretion) / dry matter intake] × 100
Protein digestibility (%) = [(protein intake - protein excretion) / protein intake] × 100
Fat digestibility (%) = [(fat intake - fat excretion) / fat intake] × 100
Nitrogen retention (g/d) = nitrogen intake - fecal nitrogen - urinary nitrogen
Net protein utilization (%) = (nitrogen retention / nitrogen intake) × 100
Protein biological value (%) = [nitrogen retention / (nitrogen intake - fecal nitrogen)] × 100
Metabolizable energy (MJ/kg) = crude protein × 4.5 × 4.184 + crude fat × 9 × 4.184 + carbohydrate × 4 × 4.184

1.7 Statistical Methods

Data were processed using SAS 9.1 software and presented as mean ± standard deviation. One-way ANOVA was used for significance testing, and GLM was employed for two-factor effect analysis. Differences were considered significant at $P<0.05$, highly significant at $P<0.01$, and not significant at $P>0.05$.

2.1 Growth Performance of Minks

As shown in Table 2 , on October 5, 2013, body weight in Group I was significantly higher than in Group II ($P<0.05$). On November 4, 2015, body weight in Group I was significantly higher than in Group VI ($P<0.01$). On November 19, 2013, no significant differences in body weight were observed among groups ($P>0.05$), though Groups I and III showed higher values. ADG in Groups I and III was significantly higher than in Groups II, IV, and VI ($P<0.01$). Final body weight in the 18% fat group was significantly higher than in the 16% fat group ($P<0.05$), and ADG in the 18% fat group was significantly higher than in the 16% fat group ($P<0.01$). Neither protein level nor the protein-fat interaction significantly affected body weight or ADG ($P>0.05$).

Table 2 Growth performance of minks in groups

Items	Groups	Body weight/g	ADG/(g/d)
	I	1,774a	1,964a
	II	1,621b	1,897ab
	III	1,724ab	1,925ab
	IV	1,750ab	1,772ab
	V	1,657ab	1,833ab

Items	Groups	Body weight/g	ADG/(g/d)
	VI	1,652ab	1,738b
Fat level/%	18	1,904a	6.58A
	16	1,781b	4.35B
Protein level/%	34	1,930a	5.69A
	32	1,849ab	5.53A
	30	1,745b	5.20A
P-value	Group	<0.001	<0.001
	Fat level	<0.001	<0.001
	Protein level	0.002	0.512
	Interaction	0.004	0.002

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

2.2 Nutrient Digestibility of Minks

As shown in Table 3 , no significant differences were observed among groups in dry matter intake, dry matter excretion, or dry matter digestibility (P>0.05). Dietary fat level, protein level, and their interaction had no significant effects on dry matter indices (P>0.05). Protein digestibility in Group VI was significantly lower than in all other groups (P<0.01). The 18% fat group showed significantly higher protein digestibility than the 16% fat group (P<0.01). Dry matter digestibility in the 34% and 32% protein groups was significantly higher than in the 30% protein group (P<0.01). Dietary fat level, protein level, and their interaction all significantly affected protein digestibility (P<0.01). No significant differences in fat digestibility were found among groups (P>0.05), and dietary fat level, protein level, and their interaction did not significantly affect fat digestibility (P>0.05).

Table 3 Nutrient digestibility of minks in groups

Items	Groups	Dry matter intake/(g/d)	Dry matter excretion/(g/d)	Dry matter digestibility/%	Protein digestibility/%	Fat digestibility/%
	I	75.18A	77.07A	75.57A	75.48A	
	II	75.48A	74.98A	65.02B	75.84A	
	III	76.13Aa	75.52Aa	70.01Bb		
	IV	71.92B	76.13Aa	75.52Aa	70.01Bb	
	V	75.52Aa	70.01Bb			
	VI	71.92B				

Items	Groups	Dry matter intake/(g/d)	Dry matter excretion/(g/d)	Dry matter digestibility/%	Protein digestibility/%	Fat digestibility/%
P-value	Group	<0.001	<0.001	<0.001		
	Fat level	<0.001	<0.001	<0.001		
	Protein level	<0.001	<0.001	<0.001		
	Interaction	<0.001	<0.001	<0.001		

2.3 Nitrogen Metabolism of Minks

As shown in Table 4 , nitrogen intake in Groups II, III, and V was significantly higher than in Group VI (P<0.05). Fecal nitrogen excretion in Group VI was significantly higher than in Group IV (P<0.05). Nitrogen retention and protein biological value in Group II were significantly higher than in Group IV (P<0.05). Net protein utilization in Groups II, III, and IV was significantly higher than in Group VI (P<0.05). Dietary fat level did not significantly affect nitrogen metabolism indices (P>0.05), while dietary protein level significantly influenced net protein utilization (P<0.05). The interaction between dietary protein and fat levels significantly affected nitrogen retention (P<0.01). Fecal nitrogen excretion in the 32% protein group was significantly lower than in the 30% group (P<0.05). Urinary nitrogen excretion and nitrogen retention in the 34% protein group were significantly higher than in the 30% protein group (P<0.05). Net protein utilization in both the 34% and 32% protein groups was significantly higher than in the 30% protein group (P<0.05).

Table 4 Nitrogen metabolism of minks in groups

Items	Groups	Nitrogen intake/(g/d)	Fecal nitrogen output/(g/d)	Urinary nitrogen output/(g/d)	Nitrogen retention/(g/d)	BV of protein/%	NPU/%
	I	7.16ab	1.77ab	1.47ab	26.06ab	19.79ab	
	II	7.70a	1.75ab	1.65a	30.06a	27.80a	
	III	7.41a	1.80ab	1.55ab	24.40ab	21.49a	
	IV	6.64ab	1.63b	1.37ab	27.39ab	20.23a	
	V	7.48a	1.86ab	1.60ab	27.28ab	18.89ab	
	VI	6.10b	2.07a	1.11b	21.67b	15.07b	
P-value	Group	1.77ab	4.13a	1.73a	20.80a		
	Fat level	1.71b	4.02ab	1.46ab	20.86a		

Items	Groups	Nitrogen intake/(g/d)	Fecal nitrogen output/(g/d)	Urinary nitrogen output/(g/d)	Nitrogen retention/(g/d)	BV of protein/%	NPU/%
	Protein level	1.96a	3.47b	1.38b	17.15b		
	Interaction	0.004	0.002	0.001	0.003		

2.4 Fur Quality of Minks

As shown in Table 5 , no significant differences were observed in live body length among groups (P>0.05). Dietary fat level did not significantly affect live body length (P>0.05). Live body length in the 34% and 32% protein groups was significantly greater than in the 30% protein group (P<0.05). Fur length in the 34% protein group was significantly longer than in the 30% protein group (P<0.05), though dietary fat level and the protein-fat interaction had no significant effect on fur length (P>0.05). No significant differences were found in guard hair length, underhair length, or guard/underhair ratio among groups (P>0.05), and dietary protein and fat levels and their interaction did not significantly affect these three indices (P>0.05).

Table 5 Fur quality of minks in groups

Items	Groups	Live body long/cm	Fur long/cm	Guard hair long/cm	Underhair long/cm
	I	48.58a	71.00a		
	II	47.25a	68.33ab		
	III	40.50b	58.67b		
P-value	Group	0.002	0.001		
	Fat level	0.512	0.421		
	Protein level	0.003	0.002		
	Interaction	0.421	0.512		

3.1 Effects of Different Protein and Fat Levels on Growth Performance

Wang et al. [10] compared complete granulated and powder feeds in Laoshan dairy goats, finding that granulated feed significantly increased dry matter intake and milk yield compared to powder feed, though initial and final body weights did not differ significantly. Granulated feed demonstrated superior palatability, enhancing feed intake and milk production. Liu [11] reported that

pelleted feed promoted more developed jejunum and ileum in broilers and improved average daily feed intake and average daily gain. Previous studies have shown that dietary fat source and energy level did not significantly affect body weight in pelting period minks [12]. Excessive dietary fat supplementation in pelting period silver foxes reduced average daily gain, though moderate fat levels promoted growth and decreased feed conversion ratio [13]. Dietary protein levels below 30% significantly affected mink growth and development, increasing feed consumption and reducing feed conversion efficiency [14]. The present results indicate significant differences in average daily gain among groups, with dietary fat level affecting body weight and higher fat levels promoting mink growth. Minks in the 18% fat group consistently showed higher body weight and average daily gain throughout the trial compared to the 16% fat group, while protein level had relatively minor effects on body weight.

3.2 Effects on Nutrient Digestibility

The NRC (1982) standards indicate that dietary palatability and energy level significantly affect mink feed intake [9]. Feed intake in gestating minks tended to decrease with increasing dietary fat levels [15]. Dietary fat level significantly affected average daily feed intake in pelting period silver foxes, which decreased as dietary fat level increased [13]. In this trial, dry matter intake in the 18% fat group was lower than in the 16% fat group, whereas the opposite trend was observed for protein level, with higher protein groups showing better dry matter intake. This may be attributed to higher animal-derived feed content in high-protein diets, which improved palatability—consistent with NRC (1982) conclusions. Protein digestibility is influenced by multiple factors, with mink utilization of dietary protein depending primarily on protein source, quality, and amino acid composition and ratio [16]. Studies have shown that -3 fatty acid supplementation in reproducing female minks reduced stress from decreased protein levels, maintained nitrogen balance, and decreased reproductive disorders [17]. Blue foxes fed different dietary fat levels showed no significant effects on dry matter or fat digestibility [18]. Research on protein requirements during growing and pelting periods demonstrated that higher dietary protein levels improved protein digestibility in minks [3,14]. The present results align with these findings, showing that dietary fat and protein levels did not significantly affect dry matter or fat digestibility, while higher dietary protein levels enhanced protein digestibility.

3.3 Effects on Nitrogen Metabolism

Nitrogen metabolism reflects protein utilization efficiency in animals. Optimal proportions of dietary protein, fat, and carbohydrates can improve nitrogen deposition [19]. Pfeiffer et al. [20] reported a strong correlation between protein intake and urinary nitrogen excretion. Kerr et al. [21] noted that urinary energy increased with dietary protein level. Protein intake in pelting period minks positively correlated with dietary protein level, with higher protein levels

increasing nitrogen intake at the same energy level [4]. In this trial, neither dietary protein nor fat level significantly affected nitrogen intake, though their interaction showed some influence. Dietary fat level did not significantly affect nitrogen metabolism indices, but minks fed higher protein diets exhibited relatively higher fecal and urinary nitrogen excretion. The interaction between dietary protein and fat levels significantly affected nitrogen retention, indicating that higher fat levels promoted protein utilization—consistent with previous research.

3.4 Effects on Fur Quality

Rouvinen [22] reported that dietary fat level affected physical characteristics of mink and blue fox pelts. Bassett [23] demonstrated that high-fat, high-energy diets (40% fat on a dry matter basis) improved blue fox body weight and fur quality, though some animals developed hepatic and splenic vacuolation and fatty degeneration. Insufficient protein supply in fur-bearing animals causes weight loss, reduced hair production, and decreased fur quality, while dietary fat source influences hair follicle development and regeneration in minks [24]. In this trial, dietary protein and fat levels and their interaction did not significantly affect guard hair length, underhair length, or guard/underhair ratio. Dietary protein level significantly affected live body length and fur length, with fur length being an important parameter for pelt grading. Higher dietary protein levels improved the proportion of high-quality pelts.

Conclusions:

1. Dietary fat level affects final body weight of minks during the pelting period, while dietary protein level influences live body length.
2. Under the conditions of this experiment, feeding pelting period minks with granulated feed containing 18% fat and 32%–34% protein yielded optimal growth performance and fur quality.

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