

## Effects of Different Dietary Protein Levels on Growth Performance, Serum Biochemical Parameters and Fur Characteristics of Minks in Winter Growing-furring Period

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**Abstract:** The study investigated the effects of different dietary protein levels on growth performance, nutrient digestion and absorption, fur characteristics, as well as serum biochemical parameters in growing-furring minks. Seventy healthy male minks were subjected to 5 experimental dietary protein treatments as P32, P28, P24, P20 and P16 [32%, 28%, 24%, 20% and 16% crude protein (CP), respectively], and the measured protein contents of the diets were 326.4, 284.7, 249.3, 203.9 and 172.8 g/kg dry matter (DM), respectively. The results showed that from mid-September to pelting, the digestibility of CP declined with the dietary protein level reducing ( $P < 0.01$ ); digestibility of ether extract in treatment P16 was significantly lower than that in the other groups ( $P < 0.01$ ); nitrogen (N) intake, urinary N excretion and N retention increased linearly with the dietary protein level increasing; serum urea nitrogen decreased linearly with the dietary protein level declining ( $P < 0.05$ ); there was no significant difference in serum total protein among all groups ( $P > 0.05$ ); body length, skin length and dry skin weight declined along with the decrease of dietary protein level; and the length of guard-fur and under-fur were not affected by different dietary protein levels ( $P > 0.05$ ). Considering all the factors, the level of dietary protein should be at about 284.7 g/kg DM, and 244.5 g/kg (DM basis) digestible protein could meet the requirement of minks in growing-furring period. Furthermore, the urinary N could be decreased by 22.45% in this period when dietary protein level declined from 32% to 28%, which would be beneficial to reduce the feed costs and lower nitrogen emissions to the environment.

**Key words:** minks; protein levels; fur characteristics; growth performance; serum biochemical parameters

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Considering today's growing environmental concerns and increasing feed costs, feeding appropriate dietary crude protein content is of the utmost importance in the feed industry. Mink needs protein, for maintenance at first, and then for body growth and the skin development. Furthermore, protein can be used as a source of energy<sup>[1-2]</sup>. According to Glem-

Hansen<sup>[3]</sup>, the mink's requirement for digestible protein during the growth period was usually met if 30% of metabolic energy (ME) comes from protein. In the present Finnish recommendation for mink feed composition, the dietary protein could be reduced to about 35% of ME after the beginning of September<sup>[4]</sup>. However, limited information exists on effects

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of different protein levels on long-term growth performance in minks. Furthermore, it is not economical to use protein as a source of energy, as fat can be added to fur animal diets in order to maintain the desired energy content. By optimizing the dietary protein supply, the feed intake and costs can be reduced, and moreover, environmental emission of nitrogen (N) could be minimized. To minimize the N excretion from feces and urine to the environment, the dietary protein supply should be as close to the requirement as possible, and high digestibility of N is preferable. Animal farming is of great environmental concerns due to its huge emission of feces and urine, thus technology to reduce the emission is a hot topic, and diet optimization is a focus in such, which should concern 1) the emission effects, 2) normal physiology of animals, 3) productivity and 4) cost effectiveness. Our hypothesis: adjusting crude protein may alter the above four indices, and we take the farmed mink as a model to test the hypothesis.

The objective of the study was to investigate the effects of dietary protein levels on growth performance, nutrient digestion and metabolism, serum biochemical parameters and fur characteristics in growing-furring minks, and to find the optimal protein level and digestible protein level of mink diet.

1 MATERIALS AND METHODS

The experiment was carried out at the fur animal farm of the Institute of Special Economic Animals and Plants, the Chinese Academy of Agricultural Science, during the period from September 16th to December 10th. The experimental minks were housed in roofed standard sheds with open sides.

1.1 Animals and experimental design

Seventy healthy male minks were selected randomly and assigned to 5 experimental dietary protein treatments as P32, P28, P24, P20 and P16 [32%, 28%, 24%, 20% and 16% crude protein (CP), respectively], and each group had 14 animals. The average ( $\pm$  SD) age and weight of the animals at the start were (126  $\pm$  6) d and (1.95  $\pm$  0.20) kg, respectively. The experiment was preceded by 1-week adjustment period in order to make the animals accustom to the experimental feed. The ingredients and composition of experimental diets were shown in Table 1. Nutrient levels of the diets were shown in Table 2. Contents of amino acids in diets were shown in Table 3. Animals had free access to drinking water and were fed twice a day at 08:00 and 16:00 (*Beijing* time) with the experimental diets. All training and testing of the animals were performed by the same person. Body weight (BW) and feed intake were determined.

Table 1 Composition of the experimental diets (fresh basis) %

Items	P32	P28	P24	P20	P16
Extrusion corn	11.00	12.00	14.00	16.00	18.00
Corvina	38.00	35.00	27.00	20.00	13.00
Poultry offal	5.00	7.00	5.00	5.00	5.00
Eggs	4.00	2.00	2.00	2.00	2.00
Pork	4.00	4.00	6.00	6.00	6.00
Hircine liver	5.00	4.00	4.00	3.00	2.00
NaCl	0.50	0.50	0.50	0.50	0.50
Premix	0.50	0.50	0.50	0.50	0.50
Water	32.00	35.00	41.00	47.00	53.00
Total	100.00	100.00	100.00	100.00	100.00

The premix provides the following per kg of diet: Fe (as FeSO<sub>4</sub> · H<sub>2</sub>O) 16 mg, Cu (as CuSO<sub>4</sub> · 5H<sub>2</sub>O) 4.0 mg, Zn (as ZnSO<sub>4</sub> · H<sub>2</sub>O) 10 mg, VA 300 IU, VB<sub>1</sub> 0.15 mg, VB<sub>2</sub> 0.40 mg, VB<sub>6</sub> 0.30 mg, folic acid 0.30 mg, nicotinic acid 1.60 mg, D-panthothenic acid 1.3 mg.

Table 2

Nutrient levels of the experimental diets

%

Items	P32	P28	P24	P20	P16
Dry matter	24. 11	25. 54	25. 33	24. 76	24. 54
In dry matter					
Ash	8. 58	7. 01	6. 38	6. 01	6. 42
Crude protein	32. 64	28. 47	24. 93	20. 39	17. 28
Ether extract	22. 50	21. 60	22. 98	22. 32	21. 83
Nitrogen free extract	36. 28	42. 92	45. 71	51. 28	54. 47
ME/( MJ/kg )	21. 48	21. 50	21. 88	21. 74	21. 52
Calcium	4. 95	3. 75	3. 98	3. 76	3. 34
Phosphorus	0. 79	0. 71	0. 64	0. 63	0. 61

ME was a calculated value, and the others were measured values.

Table 3

Contents of amino acids in the diets ( DM basis )

%

Items	P32	P28	P24	P20	P16
Aspartic acid	2. 05	2. 06	1. 72	1. 19	1. 22
Threonine	1. 45	1. 28	1. 04	0. 85	0. 86
Serine	1. 43	1. 35	1. 15	0. 84	0. 87
Glutamic acid	4. 75	4. 35	3. 58	2. 62	2. 68
Glycine	2. 09	2. 00	1. 49	1. 14	1. 28
Alanine	2. 04	1. 93	1. 55	1. 26	1. 34
Valine	1. 37	1. 32	1. 20	0. 85	0. 83
Methionine	0. 80	0. 76	0. 72	0. 42	0. 40
Isoleucine	1. 22	1. 21	0. 99	0. 72	0. 74
Leucine	2. 52	2. 38	2. 05	1. 68	1. 73
Tyrosine	0. 66	0. 74	0. 60	0. 39	0. 38
Phenylalanine	1. 49	1. 39	1. 24	0. 86	0. 81
Lysine	1. 42	1. 28	1. 03	0. 75	0. 68
Histidine	0. 55	0. 52	0. 48	0. 36	0. 32
Arginine	1. 33	1. 16	0. 99	0. 73	0. 73
Proline	1. 68	1. 56	1. 17	1. 29	1. 46

Blood samples were collected when the trial was ended. Eight animals’ blood was collected from heart in each group, and brought to the laboratory immediately, and centrifuged for 10 min at 5 000 r/min. Then serum were separated from the blood, transferred into Eppendorf centrifuge tubes, and kept at −20 ℃ until analysis.

1.2 N-balance experiments

The N-balance experiments were carried out with nine 18-week-old male kits from respective treatment groups. The fecal and urine collection lasted for 3 days ( October 25—27, 2009 ). The animals were kept in metabolism cages constructed for separate collection of feces and urine as described by Jørgensen et

al. [5]. Feces and urine were collected daily quantitatively and kept frozen at −20 ℃ for analyses. To avoid ammonia evaporation from the urine, 20 mL sulphuric acid ( 5% solution ) was added to the urine collection bottles and the urine collection trays were sprayed with citric acid ( 20% solution ) once per day. In the N-balance calculations, retained N was determined as ingested N − ( fecal N + urinary N ).

1.3 Chemical analyses

The chemical composition of feed and feces were analyzed by standard methods. Dry matter ( DM ), ash, CP ( Kjeldahl-N × 6. 25 ), calcium, and phosphorus contents were analyzed according to AOAC ( 2003 ) procedures [6]. Nitrogen free extract ( NFE )

was calculated as the difference by subtracting ash, CP and ether extract (EE) from the DM content. The calculation of ME content and the proportional composition of ME were based on the digestibility coefficients achieved and the following values of ME: CP 18.8 MJ/kg, EE 39.8 MJ/kg and NFE 17.6 MJ/kg<sup>[7]</sup>. The concentrations of amino acids were determined by Agilent 1100 high performance liquid chromatography (Agilent Technologies Inc., Santa Clara, USA). All chromatographic procedures were performed at room temperature, and the samples and standards were evaluated in duplicate as described by Sedgwick et al.<sup>[8]</sup>. Serum urea nitrogen (SUN) concentration and serum total protein (TP) were measured according to the method of Bardford<sup>[9]</sup> using kit (Nanjing Jiancheng Biotechnology Co. Ltd., Jiangsu, China) as the standard. The body length was measured from nose to basal tail, skin length and dry skin weight were measured when drying artifactitious process was over<sup>[10]</sup>.

1.4 Calculations and statistical analyses

All data were analyzed using the GLM procedure of SAS<sup>[11]</sup> appropriate for a randomized complete

block design. Data were represented as mean ± SD.

2 RESULTS

2.1 Growth performance and nutrient digestibility

Effects of different dietary protein levels on performance and nutrient digestibility were shown in Table 4. Initial weights and final weights of minks were similar in all groups ( $P > 0.05$ ). Average daily feed intake (ADFI) were significantly different among the dietary protein treatments ( $P < 0.05$ ), and there was a trend that the ADFI increased while the dietary protein level was reduced. Digestibility of DM was not affected by experimental diets ( $P > 0.05$ ), and the digestibility of CP and EE was significantly different among all treatments ( $P < 0.01$ ). Digestibility of CP declined with dietary protein level reduced, and the digestible proteins of the diets from P32 to P16 were 287.9, 244.5, 212.9, 167.9 and 136.4 g/kg (DM basis), respectively. Digestibility of EE in treatment P16 was significantly lower than that in the other groups ( $P < 0.05$ ).

Table 4 Effects of different dietary protein levels on performance and nutrient digestibility of minks

Items	P32	P28	P24	P20	P16	P-value
Initial weights/kg	1.94 ± 0.21	1.95 ± 0.23	1.92 ± 0.19	1.97 ± 0.27	1.95 ± 0.27	0.984 5
Final weights/kg	1.99 ± 0.36	2.08 ± 0.21	2.04 ± 0.17	2.02 ± 0.33	1.96 ± 0.30	0.833 5
ADFI/g	93.75 ± 11.30 <sup>ab</sup>	88.06 ± 17.45 <sup>b</sup>	96.94 ± 9.10 <sup>ab</sup>	103.15 ± 18.48 <sup>ab</sup>	104.45 ± 11.18 <sup>a</sup>	0.013 4
Digestibility of DM/%	82.96 ± 1.95	82.96 ± 1.06	82.60 ± 3.36	83.69 ± 1.36	81.32 ± 1.97	0.256 2
Digestibility of CP/%	88.20 ± 1.80 <sup>A</sup>	85.88 ± 1.10 <sup>B</sup>	85.39 ± 1.42 <sup>B</sup>	82.32 ± 2.22 <sup>C</sup>	78.91 ± 2.21 <sup>D</sup>	0.000 1
Digestibility of EE/%	94.71 ± 2.79 <sup>A</sup>	94.65 ± 2.16 <sup>A</sup>	94.26 ± 1.19 <sup>A</sup>	92.73 ± 2.85 <sup>A</sup>	89.71 ± 3.52 <sup>B</sup>	0.002 3

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

2.2 N-balance

Effects of different dietary protein levels on N-balance were shown in Table 5. N intake increased linearly with increased dietary protein level ( $P < 0.01$ ). Fecal N was not significantly different among all groups ( $P > 0.05$ ), while urinary N excretion was signifi-

cantly influenced by dietary protein content ( $P < 0.05$ ). Daily N retention (g per mink) was significantly influenced by dietary protein content ( $P < 0.01$ ), and values declined linearly with dietary protein levels reduced, but there was no significant difference among treatments P32, P28 and P24.

Table 5

Effects of different dietary protein levels on N-balance of minks

g/d

Items	P32	P28	P24	P20	P16	<i>P</i> -value
N intake	4.89 ± 0.59 <sup>A</sup>	4.01 ± 0.79 <sup>B</sup>	3.86 ± 0.36 <sup>BC</sup>	3.36 ± 0.60 <sup>CD</sup>	2.88 ± 0.30 <sup>D</sup>	0.000 1
Fecal N	0.58 ± 0.11	0.56 ± 0.09	0.57 ± 0.09	0.59 ± 0.08	0.60 ± 0.07	0.863 0
Urinary N	1.96 ± 0.66 <sup>a</sup>	1.52 ± 0.55 <sup>ab</sup>	1.41 ± 0.62 <sup>ab</sup>	1.38 ± 0.48 <sup>ab</sup>	1.12 ± 0.43 <sup>b</sup>	0.029 6
N retention	2.35 ± 0.70 <sup>A</sup>	1.93 ± 0.80 <sup>A</sup>	1.88 ± 0.75 <sup>A</sup>	1.39 ± 0.49 <sup>B</sup>	1.15 ± 0.48 <sup>B</sup>	0.001 9

2.3 Serum urea nitrogen and serum total protein

Effects of different dietary protein levels on SUN and serum TP of minks were shown in Table 6. SUN was affected by different dietary protein levels ( $P <$

0.05). SUN decreased linearly with declined dietary protein levels. TP was not significantly different among all groups ( $P > 0.05$ ).

Table 6

Effects of different dietary protein levels on serum urea nitrogen and serum total protein of minks

Items	P32	P28	P24	P20	P16	<i>P</i> -value
SUN/(mg/L)	228.90 ± 11.18 <sup>a</sup>	220.32 ± 37.15 <sup>a</sup>	218.25 ± 25.38 <sup>a</sup>	207.16 ± 22.27 <sup>ab</sup>	176.81 ± 43.19 <sup>b</sup>	0.0279
TP/(mg/mL)	75.46 ± 13.49	81.25 ± 6.80	84.00 ± 8.73	76.54 ± 7.47	81.67 ± 11.40	0.3835

2.4 Fur quality

Effects of different dietary protein levels on fur characteristics were shown in Table 7. Body length and dry skin weight were of significant differences ( $P < 0.05$ ), but they were similar among treatments P32, P28 and P24 ( $P > 0.05$ ), which declined along

with a decrease in dietary protein level. Different dietary protein levels significantly affected the skin length of animals ( $P < 0.01$ ). Guard-fur length and under-fur length were not affected by different dietary protein levels ( $P > 0.05$ ).

Table 7

Effects of different dietary protein levels on fur characteristics of minks

Items	P32	P28	P24	P20	P16	<i>P</i> -value
Body length/cm	45.14 ± 2.19 <sup>a</sup>	44.75 ± 1.16 <sup>ab</sup>	44.75 ± 1.28 <sup>ab</sup>	43.00 ± 0.58 <sup>c</sup>	42.25 ± 1.38 <sup>c</sup>	0.015 7
Skin length/cm	76.63 ± 2.97 <sup>A</sup>	76.13 ± 2.99 <sup>AB</sup>	74.37 ± 1.84 <sup>ABC</sup>	73.62 ± 3.02 <sup>BC</sup>	72.00 ± 1.51 <sup>C</sup>	0.005 9
Dry skin weight/kg	215.25 ± 29.00 <sup>a</sup>	206.87 ± 27.03 <sup>a</sup>	195.50 ± 18.18 <sup>ab</sup>	195.25 ± 20.85 <sup>ab</sup>	176.75 ± 16.56 <sup>b</sup>	0.023 6
Guard-fur length/cm	2.16 ± 0.09	2.14 ± 0.18	2.10 ± 0.18	2.09 ± 0.21	2.10 ± 0.07	0.873 2
Under-fur length/cm	1.44 ± 0.11	1.41 ± 0.09	1.36 ± 0.11	1.37 ± 0.19	1.34 ± 0.11	0.568 7

3 DISCUSSION

3.1 Performance and nutrient digestibility

Minks need protein, first of all for maintenance, but also for body growth and pelt development<sup>[12]</sup>. As previous studies reported, muscles and other tissues were primarily formed in the early growth phase of mink kits<sup>[2,13]</sup>, and in growing-furring period, dietary protein was mainly supplied for pelt development of minks. Our experimental results showed that initial weight and final weight of minks were similar in all groups, and high dietary protein level did not affect the late growth of minks. ADFI increased with

dietary protein level declined, which may be the minks to compensate for their protein requirements.

Our study showed that the digestibility of CP and EE decreased with declined dietary protein levels. In another fur animal, fox, the former study observed that the lower the dietary protein level, the lower the digestibility of DM, CP, EE and other nutrients<sup>[14]</sup>. The influence of protein level on the apparent digestibility of protein has been studied more. Research on ileal-fistulated blue foxes by Szymeczko et al.<sup>[15]</sup> showed a reduction in the apparent digestibility of CP at lower protein levels. Similar results were observed by Skrede<sup>[16]</sup> in minks. The influence of protein level

on the apparent digestibility of protein has been under intensive research in other animals, pigs in particular. A number of studies suggested that a reduction in dietary protein would lead to an increment in the relative amount of endogenous N secretion, which, in turn, reduced the apparent digestibility of protein<sup>[17-18]</sup>. In contrast, the results in pig showed that the apparent digestibility of protein was not influenced by dietary protein level<sup>[19]</sup>. In the study, the performance and digestibility of nutrients were not affected when the dietary protein level decreased from 32% to 28%, which means 244.5 g/kg digestible protein in the diet could meet the protein requirement of growing-furring minks.

### 3.2 N-balance

N intake, urinary N and N retention decreased with reduced dietary protein levels. According to our research, N excretion in urine declined significantly when the protein level in the diet was lowered from 32% to 28%, without affecting the performance of minks. The results were consistent with earlier findings that N excretion declined noticeably along with a reduction in dietary protein in pigs<sup>[20-21]</sup>. Our research showed that when the dietary protein level decreased from 32% to 28%, the urinary N excretion was decreased from 1.96 to 1.52 g/d, that is, about 22.45% reduction in growing-furring minks, which was beneficial to relieve the environmental pressure.

### 3.3 Serum urea nitrogen and serum total protein

SUN was affected by dietary protein levels. SUN decreased as dietary protein level decreased, indicating more efficient utilization of N. We have noted similar reduction in SUN in previous reports<sup>[22-24]</sup>. Serum TP did not differ significantly among all groups. The result was consistent with earlier findings in which Blome et al.<sup>[25]</sup> reported that TP concentration in plasma was not significantly different in pigs with different content of dietary protein.

### 3.4 Fur characteristics

In our study, dietary protein levels affected the fur characteristics of minks. The best fur quality was achieved in treatments P32 and P28. During the fur-growing period, the minks need protein for mainte-

nance and especially for pelt development<sup>[13]</sup>. Body length, skin length and dry skin weight declined with dietary protein level reduced. This may due to the lack of dietary essential amino acids, as observed by Børsting<sup>[26]</sup>, if the contents of essential amino acids were low, the dietary protein level in mink feed should be 40% of ME from protein to ensure good fur quality. On the other hand, minks developed equal fur quality with diet including only 30% of ME from protein if the contents of essential amino acids in the diet were relatively high. In addition, as previous study pointed out that the amount of protein supporting normal growth could be lower than that required for optimum pelt quality<sup>[27]</sup>. In our study, different dietary protein levels did not seem to cause visually detectable variation of fur quality in this limited sample of mink pelt. In general, protein deficiency was known to have different effects on hair texture depending on species<sup>[12]</sup>.

## 4 CONCLUSIONS

Based on the results from this experiment, we suggest that, in order to achieve normal fur quality and ensure low N emission, the level of dietary protein should be at about 284.7 g/kg (DM basis) and the digestible protein at about 244.5 g/kg (DM basis). Furthermore, compared with the high protein level, urinary N could be decreased by 22.45% in growing-furring minks.

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# 饲料蛋白质水平对冬毛生长期水貂生长性能、血清生化指标及毛皮质量的影响

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**摘 要:** 本文旨在探讨饲料蛋白质水平对水貂生长性能、营养物质消化吸收、毛皮品质和血清生化指标的影响。随机选取日龄体重相近的 70 只健康公水貂平均分至 5 组, 饲喂 5 个蛋白质水平的饲料(32%、28%、24%、20% 和 16%), 每千克干物质中含蛋白质分别为 326.4、284.7、249.3、203.9 和 172.8 g。试验组编号分别为 P32、P28、P24、P20 和 P16。从 9 月中旬至取皮, 粗蛋白质的消化率随饲料蛋白质水平的下降而降低( $P < 0.01$ ); P16 处理中粗脂肪消化率显著低于其他处理( $P < 0.01$ ); 日氮摄入量、日尿氮排出量和日氮沉积量随饲料蛋白质水平的增加呈线性增加; 血清尿素氮随饲料蛋白质水平的降低而显著下降( $P < 0.05$ ), 而饲料蛋白质水平对血清总蛋白质的影响各组间差异不显著( $P > 0.05$ ); 各组中水貂的体长、皮长和干皮重随饲料蛋白质水平的降低而呈下降趋势; 饲料蛋白质水平对水貂针毛和绒毛的长度影响差异不显著( $P > 0.05$ )。综合考虑各项指标, 饲料蛋白质水平为 284.7 g/kg 干物质, 可消化蛋白质水平为 244.5 g/kg 干物质时, 能够满足冬毛生长期水貂正常生产的需要。并且, 当饲料蛋白质水平从 32% 降低到 28% 时, 水貂尿氮排放量可降低 22.45%。因此, 合理降低饲料蛋白质水平不仅节约了饲养成本, 而且减轻了氮排泄对环境造成的污染。[动物营养学报, 2011, 23(1): 78-85]  
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**关键词:** 水貂; 蛋白质水平; 毛皮质量; 生长性能; 血清生化指标