Effects of Wet-Mixed Feed with Different Feed-to-Water Ratios on Feed Intake, Nutrient Digestibility, Nitrogen Metabolism, and Body Weight of Growing Silver Foxes (Postprint)

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Abstract

This experiment aimed to investigate the effects of wet mixed feed with different feed-to-water ratios on feed intake, nutrient digestibility, nitrogen metabolism, and body weight of growing silver foxes. Thirty healthy silver foxes at approximately 12 weeks of age with an average body weight of (3.44$±$0.19) kg were selected and randomly divided into 3 groups with 10 foxes per group, half male and half female. The three groups were fed wet mixed feed with feed-to-water ratios of 1.0:2.5 (Group), 1.0:3.5 (Group), and 1.0:4.5 (Group), respectively, with a 7-day preliminary period and a 48-day formal experimental period. The results showed: 1) With the increase of water addition ratio in wet mixed feed, the average daily dry matter intake of silver foxes at all ages increased to varying degrees, among which the average daily dry matter intake of Group was extremely significantly higher than that of Group and Group at 14, 15, 17, 18, and 19 weeks of age (P<0.01), and significantly higher than that of Group at 16 weeks of age (P<0.05); the total dry matter intake of Group was extremely significantly higher than that of Group and Group (P<0.01), and Group also showed a trend of being higher than Group , but the difference was not significant (P>0.05). 2) The dry matter digestibility of Group was significantly higher than that of Group (P<0.05); there was no significant difference in protein digestibility among groups (P>0.05), but Group increased by 4.62% compared with Group , and Group increased by 5.42% compared with Group ; there was no significant difference in fat digestibility among groups (P>0.05), but Group increased by 4.03% compared with Group , and Group increased by 4.46% compared with Group . 3) Nitrogen intake in Group was extremely significantly higher than that in Group and Group (P<0.01), and Group also showed a trend of being higher than Group , but the difference was not

significant (P>0.05); urine volume increased significantly or extremely significantly with the increase of water addition ratio in wet mixed feed (P<0.05 or P<0.01); there was no significant difference in nitrogen retention among groups (P>0.05); with the increase of water addition ratio in wet mixed feed, fecal nitrogen and urinary nitrogen excretion showed an increasing trend, while net protein utilization showed a decreasing trend, but the differences among groups were not significant (P>0.05); the biological value of protein in Group was significantly higher than that in Group and Group (P<0.05). 4) Wet mixed feed with different feed-to-water ratios had no significant effect on the average body weight of silver foxes at different weeks, average daily gain at each stage, or total weight gain (P>0.05); for feed-to-gain ratio, Group decreased by 4.30% compared with Group , and Group decreased by 1.21% compared with Group , but the differences among groups were not significant (P>0.05). Based on comprehensive indicators, from the perspective of reducing environmental pollution and feed costs while ensuring body weight gain of silver foxes, a feed-to-water ratio of 1.0:2.5 in wet mixed feed for growing silver foxes is appropriate.

Full Text

Effects of Different Feed-to-Water Ratios of Wet Mash on Feed Intake, Nutrient Digestibility, Nitrogen Metabolism, and Body Weight of Growing Silver Foxes

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Abstract

This experiment investigated the effects of different feed-to-water ratios of wet mash on feed intake, nutrient digestibility, nitrogen metabolism, and body weight of growing silver foxes. Thirty healthy 12-week-old silver foxes with an average body weight of (3.44$±$0.19) kg were randomly divided into three groups (n=10 per group, half male and half female). The three groups were fed wet mash with feed-to-water ratios of 1.0:2.5 (Group I), 1.0:3.5 (Group II), and 1.0:4.5 (Group III). The experiment consisted of a 7-day adaptation period followed by a 48-day trial period. The results showed: (1) As the water proportion in wet mash increased, the average daily dry matter intake (ADFI) at various weeks of age increased to varying degrees. Specifically, Group III's ADFI was extremely significantly higher than Groups I and II at 14, 15, 17, 18, and 19 weeks of age (P<0.01), and significantly higher than Group I at 16 weeks (P<0.05). Group III' s total dry matter intake was extremely significantly higher than

Groups I and II (P<0.01), while Group II showed a higher trend than Group I, though not significantly (P>0.05). (2) Group I' s dry matter digestibility was significantly higher than Group III' s (P<0.05). Protein digestibility did not differ significantly among groups (P>0.05), but was 4.62% higher in Group I than Group II, and 5.42% higher in Group II than Group III. Fat digestibility also showed no significant differences among groups (P>0.05), but was 4.03% higher in Group I than Group III, and 4.46% higher in Group II than Group III. (3) Nitrogen intake in Group III was extremely significantly higher than in Groups I and II (P<0.01), with Group II showing a higher trend than Group I (P>0.05). Urine volume increased significantly or extremely significantly with higher water ratios (P<0.05 or P<0.01). While nitrogen retention, net protein utilization, and fecal/urinary nitrogen excretion showed no significant differences among groups (P>0.05), fecal nitrogen, urinary nitrogen, and urine volume tended to increase, whereas net protein utilization tended to decrease with higher water ratios. Group I' s protein biological value was significantly higher than Groups II and III (P<0.05). (4) Different feed-to-water ratios had no significant effects on average body weight at different weeks, average daily gain at various stages, or total weight gain (P>0.05). Feed-to-gain ratio showed no significant differences among groups (P>0.05), though it was 4.30% lower in Group II than Group III, and 1.21% lower in Group I than Group II. Based on comprehensive evaluation of all indices, a feed-to-water ratio of 1.0:2.5 is recommended for growing silver foxes to minimize environmental pollution and feed costs while maintaining adequate weight gain.

Keywords: silver foxes; wet mash; feed-to-water ratio; digestibility and metabolism; body weight

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Silver foxes, also known as silver-black foxes or Xuan foxes, produce long, lustrous guard hairs with fine, abundant underfur. Their lightweight yet highly insulating pelts represent premium raw material for various fur garments, collars, shawls, vests, and accessories, making them highly prized. China' s economic development has increased demand for fur products, thereby promoting the growth of the fox farming industry.

Current research on silver fox diets has primarily focused on nutritional aspects while largely neglecting feeding methods and dietary physical forms. Complete dry powder compound feeds are widely used in fur animal production due to advantages in transportation, storage, processing, and the absence of refrigeration requirements. Dry powder feed for fur animals is typically mixed with water and fed as wet mash. Some farmers employ a "thin gruel feeding" method, believing that diluted feed can save feed costs while eliminating the need for separate water provision. Studies on growing Ussuri raccoon dogs and weaned piglets have shown that relatively diluted feed can increase feed intake and weight gain. However, research on fattening squabs, fattening pigs, and growing blue foxes does not recommend overly diluted feed. These findings indicate that optimal dietary moisture levels vary among species and developmental stages.

This experiment established three common feed-to-water ratios (1.0:2.5, 1.0:3.5, and 1.0:4.5) based on actual farmer practices. The 1.0:2.5 ratio represents the minimum water needed for uniform mixing, 1.0:4.5 simulates the condition where farmers provide only diluted feed without drinking water, and 1.0:3.5 represents an intermediate state. By examining effects on feed intake, nutrient digestibility, nitrogen metabolism, and body weight in growing silver foxes, this study aimed to determine the optimal feed-to-water ratio for scientific silver fox feeding.

1.1 Experimental Design

Thirty healthy 12-week-old silver foxes with an average body weight of (3.44$±$0.19) kg were used in a single-factor experiment. Animals were randomly divided into three groups (n=10 per group, half male and half female) with no significant differences in initial body weight among groups (P>0.05). Groups I, II, and III were fed wet mash with feed-to-water ratios of 1.0:2.5, 1.0:3.5, and 1.0:4.5, respectively. The experiment included a 7-day adaptation period and a 48-day trial period.

1.2 Experimental Diet

The experimental diet was formulated according to NRC (1982) fox feeding standards and adjusted based on actual farming conditions in China, then processed by Shenyang Shuangliang Feed Co., Ltd. Diet composition and nutrient levels are shown in Table 1 .

Table 1 Composition and Nutrient Levels of the Experimental Diet (Air-Dry Basis), %

Note: 1) Each kilogram of premix contained: NaCl 300,000 mg, Lys 150,000 mg, Met 200,000 mg, $CaHPO_4$ 50,000 mg, VA 300,000 IU, VD_3 200,000 IU, VE 4,000 mg, VK_3 50 mg, VB_1 400 mg, VB_2 500 mg, VB_6 200 mg, VB_{12} 4.2 mg, folic acid 50 mg, pantothenic acid 2,200 mg, biotin 1,600 mg, choline chloride 120 mg, VC 12,000 mg, Fe 4,000 mg, Zn 3,200 mg, Mn 1,600 mg, I 80 mg, Se 12 mg, Cu 500 mg. 2) ME was a calculated value [8], while other nutrient levels were measured values.

1.3 Feeding Management

All silver foxes were housed individually in cages (70 cm × 60 cm × 55 cm). The experiment was conducted under natural outdoor lighting conditions. Fixed personnel performed all feeding and routine immunizations throughout the trial to eliminate environmental and management variations. Animals were fed and watered twice daily at 07:00 and 16:00.

1.4 Digestion and Metabolism Trial

Twenty-four days after the trial period began, six foxes with similar body weight were randomly selected from each group for a 3-day digestion and metabolism trial. The total feces collection method was used. Feeding management remained consistent with daily practices. Collected feces were weighed daily, and 5% of fresh weight of 10% sulfuric acid solution was added. Three-day fecal samples were mixed, dried at 65°C, ground, and passed through a 40-mesh sieve (0.45 mm aperture) for analysis. For urine collection, 2 mL of 10% sulfuric acid was added per 100 mL of urine to fix nitrogen. Three-day urine samples were mixed, filtered, and 10 mL was stored at -20°C for analysis.

1.5 Measurements

1.5.1 Feed Intake Based on individual consumption, morning and evening feeding amounts were adjusted throughout the trial. Individual feed intake was recorded to calculate weekly total dry matter intake and average daily feed intake (ADFI).

1.5.2 Nutrient Digestibility Dry matter, crude protein, crude ash, and crude fat in diets and feces, as well as crude protein in urine, were analyzed according to *Feed Analysis and Feed Quality Detection Technology* [9]. Nutrient digestibility was calculated as follows:

- Dry matter digestibility (%) = 100 × (dry matter intake -dry matter excretion) / dry matter intake
- Protein digestibility (%) = 100 × (crude protein intake -fecal crude protein) / crude protein intake
- Fat digestibility (%) = 100 × (crude fat intake -fecal crude fat) / crude fat intake

1.5.3 Nitrogen Metabolism Calculations were performed as follows: - Nitrogen retention (g/d) = nitrogen intake -fecal nitrogen output -urinary nitrogen output - Net protein utilization (%) = 100 × (nitrogen retention / nitrogen intake) - Protein biological value (%) = 100 × nitrogen retention / (nitrogen intake -fecal nitrogen output)

1.5.4 Body Weight Body weight was measured before morning feeding at 12, 14, 16, and 19 weeks of age. Average daily gain (ADG) was calculated for periods 12–14, 14–16, 16–19, and 12–19 weeks, along with total weight gain and feed-to-gain ratio.

1.6 Data Processing

Data were analyzed using one-way ANOVA in SAS 9.1 software. Results are expressed as means ± standard deviation. Differences were considered significant at $P<0.05$, extremely significant at $P<0.01$, and not significant at $P>0.05$.

2.1 Effects of Different Feed-to-Water Ratios on Feed Intake of Growing Silver Foxes

As shown in Table 2 , increasing the water proportion in wet mash elevated the average daily dry matter intake at various weeks of age. Group III' s ADFI was extremely significantly higher than Groups I and II at 14, 15, 17, 18, and 19 weeks ($P<0.01$), and significantly higher than Group I at 16 weeks ($P<0.05$). No significant differences were observed at 12 and 13 weeks ($P>0.05$), though Group III > Group II > Group I trends were evident. Group III' s total dry matter intake was extremely significantly higher than Groups I and II ($P<0.01$), while Group II showed a higher trend than Group I without significant difference ($P>0.05$).

Table 2 Effects of Different Feed-to-Water Ratios of Wet Mash on Average Daily Feed Intake and Total Feed Intake of Growing Silver Foxes (Dry Matter Basis)

Note: In the same row, values without letter or with the same letter superscripts indicate no significant difference (P>0.05), different lowercase letters indicate significant difference (P<0.05), and different uppercase letters indicate extremely significant difference (P<0.01). The same applies below.

2.2 Effects of Different Feed-to-Water Ratios on Nutrient Digestibility of Growing Silver Foxes

As shown in Table 3 , during the digestion and metabolism trial, Group I' s dry matter digestibility was significantly higher than Group III' s ($P<0.05$). Protein digestibility showed no significant differences among groups ($P>0.05$), but was 4.62% higher in Group I than Group II, and 5.42% higher in Group II than Group III. Fat digestibility also showed no significant differences ($P>0.05$), but was 4.03% higher in Group I than Group III, and 4.46% higher in Group II than Group III.

Table 3 Effects of Different Feed-to-Water Ratios of Wet Mash on Nutrient Digestibility of Growing Silver Foxes, %

2.3 Effects of Different Feed-to-Water Ratios on Nitrogen Metabolism of Growing Silver Foxes

As shown in Table 4 , Group III' s nitrogen intake was extremely significantly higher than Groups I and II ($P<0.01$), while Group II showed a higher trend than Group I ($P>0.05$). Fecal nitrogen output increased with higher water ratios (Group III > Group II > Group I), though differences were not significant ($P>0.05$). Urine volume in Group III was extremely significantly higher than Group I ($P<0.01$) and significantly higher than Group II ($P<0.05$), with Group II also significantly higher than Group I ($P<0.05$). Urinary nitrogen output showed no significant differences among groups ($P>0.05$), but numerically followed Group I < Group II < Group III. Nitrogen retention did not differ signifi-

cantly among groups (P>0.05). Net protein utilization tended to decrease with higher water ratios, though differences were not significant (P>0.05). Group I' s protein biological value was significantly higher than Groups II and III (P<0.05).

Table 4 Effects of Different Feed-to-Water Ratios of Wet Mash on Nitrogen Metabolism of Growing Silver Foxes

2.4 Effects of Different Feed-to-Water Ratios on Body Weight of Growing Silver Foxes

As shown in Table 5 , average body weight increased markedly with age across all three groups. No significant differences were observed among groups for average body weight at different weeks, ADG at various stages, total weight gain, or feed-to-gain ratio (P>0.05). However, feed-to-gain ratio tended to decrease with lower water ratios, being 4.30% lower in Group II than Group III, and 1.21% lower in Group I than Group II.

Table 5 Effects of Different Feed-to-Water Ratios of Wet Mash on Average Body Weight, Average Daily Gain, Total Weight Gain, and Feed-to-Gain Ratio of Growing Silver Foxes

3.1 Effects on Feed Intake

Silver foxes are canids characterized by stress susceptibility, cold tolerance, and poorly developed sweat glands. The growing period (July–September) coincides with hot summer weather in the Northern Hemisphere, when this experiment was conducted. Results demonstrated that both weekly ADFI and total dry matter intake increased with higher water proportions in wet mash. Low-moisture wet mash dries and hardens quickly after mixing, reducing palatability and intake. Additionally, in hot weather, high-moisture diets effectively replenish rapidly lost body water and reduce heat stress when drinking water is not continuously available, as reported in dairy cattle studies. High temperatures cause heat stress, reducing feed intake and activity. During the trial, silver foxes regulated body temperature through panting and rapid breathing like dogs, requiring substantial water evaporation for heat dissipation. Therefore, farmers should monitor environmental temperature, especially in summer, by increasing water provision frequency, adding anti-heat stress additives, and improving shelter conditions to prevent direct sunlight, thereby avoiding heat stress, preventing heatstroke, and improving animal welfare.

3.2 Effects on Nutrient Digestibility

Silver foxes are typically weaned at approximately 7 weeks of age. By 12 weeks, they have largely overcome weaning stress and developed intestinal adaptation to diets. However, excessively high water proportions accelerate feed passage through the digestive tract, shorten intestinal residence time, and dilute digestive enzymes, reducing saliva and gastric juice secretion and impairing nutrient

digestion and absorption. This trial showed that dry matter digestibility decreased significantly with higher water ratios, while protein and fat digestibility also showed declining trends. These results differ from studies on growing Ussuri raccoon dogs, which showed no significant effects of water ratio on nutrient digestibility, and from studies on growing blue foxes, which showed no significant effects on dry matter and fat digestibility but significantly increased protein digestibility with higher water ratios. These discrepancies suggest species-specific tolerance to diluted feed among fur-bearing animals, warranting further investigation into underlying mechanisms.

3.3 Effects on Nitrogen Metabolism

Urine volume increased extremely significantly with higher water ratios, indicating that silver foxes can dissipate heat through enhanced water metabolism to alleviate heat stress. Although urinary nitrogen excretion did not differ significantly among groups, it tended to increase with higher water ratios, consistent with findings in blue foxes, raccoon dogs, and pigs. After ingesting dietary nitrogen, animals metabolize it through digestion; a portion is synthesized into body protein or utilized, while the remainder is excreted via feces and urine. Nitrogen retention reflects protein utilization efficiency. This trial showed that while nitrogen intake increased with higher water ratios, fecal and urinary nitrogen excretion also increased, resulting in non-significant differences in nitrogen retention among groups. Net protein utilization and protein biological value, both indicators of protein utilization efficiency, decreased with higher water ratios, indicating reduced effective protein utilization and increased excretion. This elevates environmental nitrogen emissions, a major pollutant from livestock waste. Therefore, improving feed resource utilization efficiency, particularly protein ingredients, and reducing nitrogen emissions are critical for sustainable animal production.

3.4 Effects on Body Weight

Different feed-to-water ratios had no significant effects on average body weight at various weeks, ADG, total weight gain, or feed-to-gain ratio. This aligns with findings in pigs. Two factors may explain this: First, silver foxes are typically fed with cold water, but excrete urine above 35°C; excessive water ratios increase passive water metabolism energy costs, wasting energy. Second, although high water ratios increased feed intake and total energy consumption, nutrient digestibility decreased, reducing dietary efficiency, increasing feed-to-gain ratio, and raising production costs without meaningful benefit.

Conclusion

Under these experimental conditions, increasing the water ratio in wet mash enhanced feed intake but reduced nutrient digestibility, failed to improve body weight, increased feed-to-gain ratio, and elevated fecal and urinary nitrogen excretion, causing environmental pollution and reducing feed efficiency. Therefore,

a feed-to-water ratio of 1.0:2.5 is recommended for growing silver foxes. Raccoon dogs, blue foxes, and silver foxes are the three main canid fur-bearing animals in China and are often raised together due to similar habits, fur growth cycles, reproductive timing, and nutritional requirements. However, this recommendation differs from optimal ratios of 1.0:(2.5–3.5) for raccoon dogs and 1.0:(3.5–4.5) for blue foxes, indicating that species-specific feeding strategies should be implemented.

In conclusion, although silver foxes prefer diluted feed, comprehensive evaluation of all indices indicates that a feed-to-water ratio of 1.0:2.5 is optimal for growing silver foxes to minimize environmental pollution and feed costs while ensuring adequate weight gain.

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