Effects of Dietary Zinc Levels on Growth Performance, Cashmere Production Performance, and Cashmere Growth-Related Hormone Content in Shaanbei White Cashmere Goats during the Cashmere Growth Period (Postprint)

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Abstract

This experiment was conducted to investigate the effects of dietary zinc levels on growth performance, cashmere production performance, and cashmere growth-related hormone contents in Shaanbei white cashmere goats during the cashmere growth period, aiming to determine the appropriate dietary zinc level for Shaanbei white cashmere goats during this period. A single-factor randomized block design was adopted. Thirty-two healthy 8-month-old Shaanbei white cashmere goats with similar body weight were randomly divided into 4 groups, with 4 replicates per group and 2 goats per replicate. The control group (Group I) was fed a basal diet (zinc level of 28.57 mg/kg DM), while the three experimental groups (Groups II, III, and IV) were fed experimental diets supplemented with feed-grade zinc sulfate based on the basal diet, with dietary zinc levels of 50, 70, and 100 mg/kg DM, respectively. The preliminary period lasted for 15 days, and the formal experimental period lasted for 45 days. The results showed: 1) Dietary zinc level had no significant effect on dry matter intake (DMI) and feed to gain ratio (F/G) in Shaanbei white cashmere goats ($P>0.05$). Group III had the highest average daily gain (ADG), which was significantly different from Group I ($P<0.05$), but not significantly different from the other two groups ($P>0.05$). 2) Dietary zinc level had no significant effect on cashmere fineness and cashmere yield at the initial and final stages of the experiment ($P>0.05$). At the final stage, cashmere length in Group IV was significantly greater than that in Group III ($P<0.05$), while Group III was extremely significantly greater than Group I ($P<0.01$) and significantly greater than Group II ($P<0.05$). Cashmere growth amount and cashmere growth rate in Group III were significantly higher than those in Groups I and IV ($P<0.05$), with no significant difference from

Group II (P>0.05). 3) As the cashmere growth period progressed in Shaanbei white cashmere goats, serum melatonin (MT), insulin-like growth factor-1 (IGF-1), and growth hormone (GH) contents showed an increasing trend, while serum prolactin (PRL) content showed a decreasing trend. Dietary zinc level had no significant effect on serum MT and PRL during the experimental period, and GH at the mid-stage (P>0.05). At the mid-stage, serum IGF-1 content in Group III was significantly higher than that in Group IV (P<0.05). At the final stage, serum IGF-1 content in Group III was significantly higher than that in Groups I and IV (P<0.05). At the final stage, serum GH content in Group III was significantly higher than that in Group I (P<0.05). In conclusion, the appropriate dietary zinc level for Shaanbei white cashmere goats during the cashmere growth period is 70 mg/kg DM.

Full Text

Effects of Dietary Zinc Level on Growth Performance, Cashmere Performance and Cashmere Growth-Related Hormone Contents of Shanbei White Cashmere Goats during the Cashmere Growing Period

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Abstract

This experiment investigated the effects of dietary zinc level on growth performance, cashmere performance, and cashmere growth-related hormone contents in Shanbei white cashmere goats during the cashmere growing period to determine the optimal dietary zinc level. Using a single-factor randomized block design, 32 healthy 8-month-old Shanbei white cashmere goats with similar body weight were randomly divided into 4 groups, with 4 replicates per group and 2 goats per replicate. The control group (Group I) received a basal diet containing 28.57 mg/kg DM zinc, while the three experimental groups (Groups II, III, and IV) received the basal diet supplemented with feed-grade zinc sulfate at dietary zinc levels of 50, 70, and 100 mg/kg DM, respectively. The pre-trial period lasted 15 days, followed by a 45-day formal experimental period. The results showed: (1) Dietary zinc level had no significant effect on dry matter intake (DMI) or feed-to-gain ratio (F/G) (P>0.05). Group III exhibited the highest average daily gain (ADG), which differed significantly from Group I (P<0.05)

but not from the other two groups (P>0.05). (2) Dietary zinc level had no significant effect on cashmere diameter at either the initial or final stages, nor on cashmere yield (P>0.05). At the end of the experiment, cashmere length in Group IV was significantly greater than in Group III (P<0.05), while Group III was extremely significantly greater than Group I (P<0.01) and significantly greater than Group II (P<0.05). Cashmere growth amount and growth rate in Group III were significantly higher than in Groups I and IV (P<0.05), with no significant difference from Group II (P>0.05). (3) As the cashmere growing period progressed, serum melatonin (MT), insulin-like growth factor-1 (IGF-1), and growth hormone (GH) contents showed an increasing trend, while serum prolactin (PRL) content showed a decreasing trend. Dietary zinc level had no significant effect on serum MT or PRL contents throughout the experiment or on GH content at the mid-term (P>0.05). At mid-term, serum IGF-1 content in Group III was significantly higher than in Group IV (P<0.05). At the end of the experiment, serum IGF-1 content in Group III was significantly higher than in Groups I and IV (P<0.05), and serum GH content in Group III was significantly higher than in Group I (P<0.05). In summary, the optimal dietary zinc level for Shanbei white cashmere goats during the cashmere growing period is 70 mg/kg DM.

Keywords: dietary zinc level; Shanbei white cashmere goats; cashmere performance; hormone

Introduction

Cashmere is a fine and soft animal fiber, and its textile products are often praised as "soft gold."The Shanbei white cashmere goat is a new breed developed through hybridization using Liaoning white cashmere goats as the paternal line and Shanbei black goats as the maternal line [1]. As one of three nationally certified breeds, it leads China in cashmere yield, fiber length, and fineness. Cashmere growth is a complex physiological process influenced by nutrition, environment, and genetics. Among nutritional factors, the trace element zinc is essential for cashmere production. Therefore, determining the appropriate dietary zinc level during the cashmere growing period is crucial for improving cashmere performance.

Zinc deficiency severely affects sulfur and nitrogen absorption, thereby significantly impairing normal wool growth, manifested as incomplete keratinization, reduced wool growth rate, hair loss, and even skin damage [2]. Suo [3] reported that during the cashmere growing period, cashmere goats deposit 98.04 mg of zinc per kg of body weight gain and 110.87 mg of zinc per kg of hair growth. Research suggests that the dietary zinc requirement for Liaoning cashmere goats during the cashmere growing period is 86 mg/kg DM [4-5]. These findings underscore the importance of zinc supplementation in cashmere goat diets. However, the zinc requirement for Shanbei white cashmere goats under intensive feeding conditions remains undetermined. Therefore, this study investigated the effects of dietary zinc level on growth performance, cashmere performance, and

cashmere growth-related hormone contents to provide a scientific basis for establishing zinc requirement standards and improving nutritional regulation theories for cashmere growth in Shanbei white cashmere goats.

1.1 Experimental Design

The experiment was conducted at the experimental goat farm of the Shaanxi Province Cashmere Goat Engineering Technology Research Center at Yulin University from November 2015 to May 2016. Growth performance, cashmere performance (except cashmere yield), and cashmere growth-related hormone contents were measured from November to December 2015, while cashmere yield was determined in May 2016. Thirty-two healthy 8-month-old female Shanbei white cashmere goats with similar body weight were selected and randomly allocated to 4 groups using a single-factor randomized block design, with 4 replicates per group and 2 goats per replicate. The control group (Group I) received a basal diet containing 28.57 mg/kg DM zinc, while the experimental groups (Groups II, III, and IV) received the basal diet supplemented with feed-grade zinc sulfate at dietary zinc levels of 50, 70, and 100 mg/kg DM, respectively. The pre-trial period lasted 15 days, followed by a 45-day formal experimental period. The composition and nutrient levels of the basal diet are presented in Table 1 .

1.2 Feeding Management

The experimental goats were fed twice daily at 08:00 and 16:00, with roughage offered before concentrate. Water was provided ad libitum (no zinc was detected in the drinking water).

1.3 Sample Collection and Preprocessing

One day before the formal experimental period, a 10 cm × 10 cm area behind the scapula of each goat was dyed with hair dye. At the end of the experiment, the dyed wool and cashmere were clipped to determine cashmere performance indicators. Blood samples (20 mL) were collected via jugular venipuncture at the initial, mid-term, and final stages of the experiment (with 15-day intervals between stages). Serum was harvested by centrifugation at 3,500 r/min for 10 minutes and stored at -20 °C.

1.4.1 Growth Performance

Growth performance parameters included dry matter intake (DMI), average daily gain (ADG), and feed-to-gain ratio (F/G). Body weight was measured at the beginning and end of the experiment using a goat cage and scale to calculate ADG. Feed offered and refusals were recorded accurately before each feeding during the formal period to calculate DMI. The formulas were as follows:

ADG = (final body weight - initial body weight) / number of experimental days

F/G = amount of standard diet consumed during feeding period / weight gain during the same period

1.4.2 Cashmere Performance

Cashmere performance indicators included cashmere diameter, cashmere length, cashmere growth amount, cashmere growth rate, and cashmere yield. Cashmere length was measured using a steel ruler on 100 fibers. Cashmere diameter was measured using a fiber fineness analyzer. Cashmere yield was determined by combing in early May. Cashmere growth amount and growth rate were calculated using the following formulas:

Cashmere growth amount (mm) = cashmere length at final experiment - cashmere length at initial experiment
Cashmere growth rate (mm/d) = (cashmere length at final experiment - cashmere length at initial experiment) / time interval between samplings

1.4.3 Cashmere Growth-Related Hormone Contents

Serum insulin-like growth factor-1 (IGF-1), melatonin (MT), prolactin (PRL), and growth hormone (GH) contents were determined by radioimmunoassay according to the kit instructions. The kits were purchased from Beijing Yinghua Biotechnology Research Institute.

1.5 Data Processing and Analysis

Experimental data were initially processed using Excel 2010 and analyzed by one-way ANOVA using SPSS 17.0 statistical software. Duncan' s multiple range test was used for post-hoc comparisons. Due to significant differences in cashmere length among groups at the initial stage, analysis of covariance was used for final cashmere length. The significance level was set at $P<0.05$, and the extremely significant level at $P<0.01$. Results are expressed as mean ± standard deviation.

2.1 Effects of Dietary Zinc Level on Growth Performance

As shown in Table 2 , dietary zinc level had no significant effect on DMI or F/G ($P>0.05$). Group III exhibited the highest ADG, which was significantly different from Group I ($P<0.05$) but not from Groups II or IV ($P>0.05$).

2.2 Effects of Dietary Zinc Level on Cashmere Performance

As shown in Table 3 , dietary zinc level had no significant effect on cashmere diameter (at initial and final stages) or cashmere yield ($P>0.05$). At the end of the experiment, cashmere length in Group IV was significantly greater than in Group III ($P<0.05$), while Group III was extremely significantly greater than Group I ($P<0.01$) and significantly greater than Group II ($P<0.05$). Cashmere growth amount and growth rate in Group III were significantly higher than

in Groups I and IV ($P<0.05$), with no significant difference from Group II ($P>0.05$).

2.3 Effects of Dietary Zinc Level on Cashmere Growth-Related Hormone Contents

As shown in Table 4 , serum MT, IGF-1, and GH contents increased as the cashmere growing period progressed, while serum PRL content decreased. Throughout the experiment, serum MT and PRL contents were highest in Group III, but differences among groups were not significant ($P>0.05$). Serum IGF-1 content did not differ significantly among groups at the initial stage ($P>0.05$). At midterm, serum IGF-1 content in Group III was significantly higher than in Group IV ($P<0.05$). At the end of the experiment, serum IGF-1 content in Group III was significantly higher than in Groups I and IV ($P<0.05$), and serum GH content in Group III was significantly higher than in Group I ($P<0.05$).

3.1 Effects of Dietary Zinc Level on Growth Performance

Zinc, known as a "life element," is a trace element with multiple physiological functions [6]. It promotes rapid regeneration of taste bud cells, enhances appetite, and improves digestive enzyme activity in intestinal epithelial cells while increasing intestinal retention time, thereby improving digestibility and feed intake [7]. The NRC (2001) reported that zinc deficiency reduces feed intake and growth rate. Since animals cannot store zinc, they must obtain it from the diet to maintain health and nutrient balance [6]. Studies have shown that dietary zinc level significantly affects daily gain and feed conversion rate in Inner Mongolian white cashmere goats [3] and Liaoning cashmere goats [8]. However, Aditia et al. [9] found no significant effects of dietary zinc level on ADG, DMI, or feed conversion rate in goats. In this experiment, dietary zinc level did not significantly affect DMI or F/G but significantly influenced ADG, with Group III showing the highest ADG and lowest F/G. This suggests that the zinc level in Group III improved diet utilization efficiency and growth performance. Therefore, from a growth performance perspective, a dietary zinc level of 70 mg/kg DM is recommended for Shanbei white cashmere goats during the cashmere growing period.

3.2 Effects of Dietary Zinc Level on Cashmere Performance

Research on dietary zinc effects on cashmere performance is limited. Studies found that adding 45 mg/kg DM zinc to a basal diet (22.30 mg/kg DM) did not significantly affect cashmere length, growth rate, or diameter in Liaoning cashmere goats [4,8]. Liu et al. [5] reported no significant effects on cashmere growth rate or diameter when adding 0, 20, 40, or 80 mg/kg DM zinc to a basal diet (45.9 mg/kg DM). However, Wei et al. [10] found that dietary zinc methionine increased fiber density and diameter, thereby improving cashmere yield. Similar results have been reported for zinc' s effect on wool growth and yield in goats [11-12]. In this experiment, dietary zinc level did not significantly affect

cashmere diameter or yield, though Group III had the highest cashmere yield. Additionally, dietary zinc level significantly affected final cashmere length, with Group III showing significantly greater cashmere growth amount and rate than Groups I and IV, demonstrating a nutritional regulatory role of zinc on cashmere growth. These results indicate that a dietary zinc level of 50-70 mg/kg DM is appropriate for Shanbei white cashmere goats during the cashmere growing period. Considering that this period coincides with the breeding season, a dietary zinc level of 70 mg/kg DM is recommended to meet both cashmere growth and reproductive nutritional needs.

3.3 Effects of Dietary Zinc Level on Cashmere Growth-Related Hormone Contents

Zinc interacts with hormones by affecting hormone receptor efficacy, target organ responsiveness, and hormone production, storage, secretion, and metabolism, while hormones also influence zinc absorption and metabolism [13]. Cashmere growth follows photoperiodic cycles, with hair follicles undergoing growth, regression, and resting phases. Studies have shown that MT, PRL, GH, and IGF-I play important roles in regulating cashmere goat hair follicle growth and cycling [14-16]. Zinc-related hormones include GH, PRL, insulin, and IGF-1 [17-18]. Zinc deficiency reduces serum insulin and IGF-1 contents, while zinc supplementation increases serum GH and insulin [17,19]. In this experiment, serum MT, IGF-1, and GH contents increased while PRL decreased as the cashmere growing period progressed. No significant differences in serum MT or PRL contents were observed among groups, indicating that dietary zinc level did not significantly affect these hormones. However, dietary zinc level significantly affected serum IGF-1 and GH contents, with Group III showing higher IGF-1 at mid-term and final stages, and higher GH at the final stage compared to other groups. Concurrently, cashmere growth amount and rate were significantly higher in Group III than in Groups I and IV, suggesting that dietary zinc may regulate cashmere growth by promoting IGF-1 and GH secretion. Therefore, the optimal dietary zinc level for Shanbei white cashmere goats during the cashmere growing period is 70 mg/kg DM.

References

[1] 屈雷, 雷安民, 闫海龙, 等. 陕北白绒山羊种公羊的体细胞克隆 [J]. 西北农林科技大学学报 (自然科学版), 2012, 40(9): 29-34, 40.
[2] KRAMETTER-FROETSCHER R, HAUSER S, BAUMGARTNER W. Zinc-responsive dermatosis in goats suggestive of hereditary malabsorption: two field cases[J]. Veterinary Dermatology, 2005, 16(4): 269-275.
[3] 索宝. 内蒙古白绒山羊生长羯羊锌需要量的研究 [D]. 硕士学位论文. 呼和浩特: 内蒙古农业大学, 2006: 43-49.
[4] JIA W B, JIA Z H, ZHANG W, et al. Effects of dietary zinc on performance, nutrient digestibility and plasma zinc status in cashmere goats[J]. Small Ruminant Research, 2008, 80(1/2/3): 68-72.

[5] LIU H Y, SUN M H, YANG G Q, et al. Influence of different dietary zinc levels on cashmere growth, plasma testosterone level and zinc status in male Liaoning cashmere goats[J]. Journal of Animal Physiology and Animal Nutrition, 2015, 99(5): 880-886.
[6] 朱雯, 刘建新, 叶均安. 微量元素锌在奶牛中的应用研究进展 [J]. 中国畜牧杂志, 2014, 50(15): 83-86.
[7] 于倩楠. 微量元素和抗氧化剂对奶牛生产性能和营养代谢的影响 [D]. 硕士学位论文. 武汉: 华中农业大学, 2013: 8-9.
[8] JIA W B, ZHU X P, ZHANG W, et al. Effects of source of supplemental zinc on performance, nutrient digestibility and plasma mineral profile in cashmere goats[J]. Asian-Australasian Journal of Animal Sciences, 2009, 22(12): 1648-1653.
[9] ADITIA M, SUNARSO S, SEVILLA C C, et al. Growth performance and mineral status on goats (Capra hircus Linn.) supplemented with zinc proteinate and selenium yeast[J]. Scientific Research & Essays, 2014, 7(2): 1741-1751.
[10] 韦月平, 王鹏. 不同锌源对舍饲辽宁绒山羊产绒性能的影响 [J]. 湖北农业科学, 2008, 47(9): 1056-1058.
[11] SALAMA A A, CAJA G, ALBANELL E, et al. Effects of dietary supplements of zinc-methionine on milk production, udder health and zinc metabolism in dairy goats[J]. Journal of Dairy Research, 2003, 70(1): 9-17.
[12] PUCHALA R, SAHLU T, DAVIS J J. Effects of zinc-methionine on performance of Angora goats[J]. Small Ruminant Research, 1999, 33(1): 1-8.
[13] 高建伟. 不同锌源和水平在奶山羊肠道的消化吸收及对相关内分泌的影响 [D]. 硕士学位论文. 郑州: 河南农业大学, 2010: 18-20.
[14] 魏云霞, 肖玉萍, 杨保平, 等. 河西绒山羊绒毛生长的季节性变化规律及其与生长激素关系的研究 [J]. 中国草食动物科学, 2012, 32(6): 10-13.
[15] BAI W L, YIN R H, YIN R L, et al. IGF-1 mRNA splicing variants in Liaoning cashmere goat: identification, characterization, and transcriptional patterns visceral organs[J]. Animal Biotechnology, 2013, 24(2): 81-93.
[16] 胡秀芝, 王永军. 绒山羊毛囊的周期性发育及其分子调控研究进展 [J]. 家畜生态学报, 2012, 33(3): 1-6.
[17] 张春善. 动物必需微量元素营养学 [M]. 北京: 高等教育出版社, 2007: 115.
[18] 李聚才, 张春珍, 庞琪艳, 等. 动物微量元素锌营养研究进展 [J]. 宁夏农林科技, 2007(6): 30-32.
[19] 李利根, 郭振荣, 赵霖, 等. 缺锌和补锌对烫伤大鼠血清和组织锌含量, 含锌酶、激素、蛋白质的影响 [J]. 中华临床营养杂志, 2006, 14(1): 29-32.

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