Effects of Alfalfa Meal on Growth Performance, Serum Biochemical Indices, Carcass Quality, and Economic Benefits in Fattening Pigs: Postprint

Authors: Lü Xianzhao, Wang Chengzhang, Qiu Xiaodong, Yao Guolei, Xiao Junnan, Shi Yinghua, Zhu Xiaoyan

Date: 2018-12-24T00:00:00+00:00

Abstract

This experiment aimed to investigate the effects of alfalfa meal on growth performance, serum biochemical indices, carcass quality, and economic benefits in finishing pigs. A total of 130 healthy crossbred (Landrace × Large White or Large White × Landrace) finishing pigs with an average body weight of (60.28±0.73) kg were selected and randomly divided into 5 groups, with 26 replicates per group and 1 pig per replicate. Each group was fed experimental diets supplemented with 0 (control group), 5%, 10%, 20%, and 30% alfalfa meal in the basal diet, respectively. The pre-trial period was 10 days, and the formal trial period was 72 days. The results showed that: 1) During the 60–100 kg stage, the 5% alfalfa meal group had the highest average daily gain and the lowest cost of weight gain. 2) There were no significant differences among groups in serum total protein, albumin, globulin, total cholesterol, and low-density lipoprotein cholesterol contents ($P > 0.05$). Compared with the control group, serum urea nitrogen content was significantly decreased in the 5% and 30% alfalfa meal groups ($P < 0.05$), serum glucose content was significantly increased in the 5% and 10% alfalfa meal groups ($P < 0.05$), serum triglyceride content was extremely significantly decreased in the 30% alfalfa meal group ($P < 0.01$), and serum high-density lipoprotein cholesterol content was significantly increased in the 10% and 30% alfalfa meal groups ($P < 0.05$). Serum alanine aminotransferase and aspartate aminotransferase activities in the 10% and 20% alfalfa meal groups were extremely significantly and significantly lower than those in the control and 5% alfalfa meal groups, respectively ($P < 0.01$, $P < 0.05$), with no significant difference between the control and 5% alfalfa meal groups ($P > 0.05$). 3) The lean meat percentage in the 20% alfalfa meal group was significantly increased by 7.99% compared with the control group ($P < 0.05$). There were no significant differences among groups in carcass weight, dressing percentage, backfat thickness, loin eye area, carcass oblique length, or

carcass straight length (P > 0.05). 4) Muscle protein content in the 20% alfalfa meal group was significantly higher than that in the control group (P < 0.05). In conclusion, dietary supplementation with 5% alfalfa meal can reduce weight gain cost and improve economic benefits; dietary supplementation with 20% alfalfa meal can increase lean meat percentage and muscle protein content, thereby improving pork quality.

Full Text

Effects of Alfalfa Meal on Growth Performance, Serum Biochemical Indexes, Carcass Quality and Economic Benefit of Finishing Pigs

Lyu Xianzhao[1], Wang Chengzhang[1], Qiu Xiaodong[2], Yao Guolei[1], Xiao Junnan[1], Shi Yinghua[1], Zhu Xiaoyan[1]*

(1. College of Animal Science and Veterinary Medicine, Henan Agricultural University, Zhengzhou 450002, China; 2. Henan Xinda Animal Husbandry Co., Ltd., Zhengzhou 450000, China)

Abstract: This experiment was conducted to investigate the effects of alfalfa meal on growth performance, serum biochemical indexes, carcass quality, and economic benefit of finishing pigs. One hundred and thirty healthy Landrace × Large White or Large White × Landrace crossbred finishing pigs with an average body weight of (60.28±0.73) kg were randomly allocated into five groups with 26 replicates per group and one pig per replicate. The pigs were fed experimental diets supplemented with 0 (control group), 5%, 10%, 20%, and 30% alfalfa meal, respectively. The pre-trial period lasted for 10 days, followed by a 72-day formal experimental period.

The results showed: 1) During the 60–100 kg stage, the 5% alfalfa meal group achieved the highest average daily gain and the lowest weight gain cost. 2) No significant differences were observed among groups in serum total protein, albumin, globulin, total cholesterol, and low-density lipoprotein cholesterol contents (P>0.05). Compared with the control group, serum urea nitrogen content was significantly reduced in the 5% and 30% alfalfa meal groups (P<0.05), serum glucose content was significantly elevated in the 5% and 10% alfalfa meal groups (P<0.05), serum triglyceride content was extremely significantly decreased in the 30% alfalfa meal group (P<0.01), and serum high-density lipoprotein cholesterol content was significantly increased in the 10% and 30% alfalfa meal groups (P<0.05). Serum alanine aminotransferase and aspartate aminotransferase activities in the 10% and 20% alfalfa meal groups were extremely significantly and significantly lower than those in the control and 5% alfalfa meal groups, respectively (P<0.01, P<0.05), while no significant differences were found between the control and 5% alfalfa meal groups (P>0.05). 3) The lean meat percentage in the 20% alfalfa meal group was significantly increased by 7.99% compared with the control group (P<0.05). No significant differences were detected among

groups in carcass weight, dressing percentage, backfat thickness, loin-eye area, carcass oblique length, or carcass straight length (P>0.05). 4) Muscle protein content in the 20% alfalfa meal group was significantly higher than that in the control group (P<0.05). In conclusion, dietary supplementation with 5% alfalfa meal can reduce weight gain cost and improve economic benefit, while supplementation with 20% alfalfa meal can increase lean meat percentage and muscle protein content, thereby improving pork quality.

Keywords: alfalfa meal; finishing pigs; serum biochemical indexes; carcass quality; muscle protein

---

Introduction

China is a major pig-producing country, ranking first in the world in pork production. In recent years, the rapid development of grain-consuming animal husbandry has intensified the competition between humans and pigs for grain resources. Feed resource scarcity and low feed utilization efficiency have become primary constraints on the development of China' s pig industry. Additionally, with rising living standards and heightened health awareness, consumers increasingly emphasize the safety and sensory quality of animal products. As pork is the most important meat product in China, its quality receives considerable attention from consumers. Therefore, to meet consumer demand for high-quality pork, the development and utilization of green, safe, and efficient forage feed ingredients in pig production has become an industry trend, holding significant importance for the sustainable development of China' s pig industry.

Alfalfa is a high-quality feed ingredient rich in protein, vitamins, amino acids, and minerals, while also containing various bioactive compounds such as saponins, polysaccharides, and flavonoids. Dietary supplementation with appropriate proportions of alfalfa hay or meal can improve animal growth performance, reproductive performance, immune function, and product quality to varying degrees. Currently, many pig enterprises in China have begun adding alfalfa meal to pig diets to improve pork quality. Previous studies have shown that supplementing finishing pig diets with different proportions of alfalfa meal can increase daily gain and feed intake, improve lean meat percentage and loin-eye area, and enhance meat color and blood biochemical parameters. However, recommended supplementation levels vary across studies. Based on this background, the present study investigated the effects of alfalfa meal on growth performance, serum biochemical indexes, carcass quality, and economic benefit of finishing pigs through feeding and slaughter trials, aiming to enrich the theoretical basis for alfalfa application and provide scientific support for its rational use in finishing pig production and the development of grain-saving animal husbandry.

Materials and Methods

1.1 Experimental Materials The alfalfa meal used in this experiment was provided by Zhenping Minxia Animal Husbandry Co., Ltd., Henan Province, derived from a single batch of alfalfa harvested at the early flowering stage and naturally dried. Analysis revealed the following nutritional composition: dry matter (DM) 89.66%, crude protein (CP) 19.81%, crude fiber (CF) 23.6%, ether extract (EE) 2.12%, crude ash 8.11%, calcium (Ca) 1.59%, and phosphorus (P) 0.30%.

1.2 Experimental Design The feeding trial was conducted from July 10 to September 26, 2015, at Yiyang Xinda Animal Husbandry Co., Ltd., Henan Province, with a 7-day pre-trial period and a 72-day formal trial period. The slaughter trial was performed on September 27, 2015, at Qinyang Food Co., Ltd., Henan Province.

One hundred and thirty healthy Landrace × Large White or Large White × Landrace crossbred finishing pigs with an average body weight of (60.28±0.73) kg were selected and randomly assigned to five groups using a single-factor completely randomized block design, with 26 replicates per group and one pig per replicate. The groups were fed experimental diets supplemented with 0 (control group), 5%, 10%, 20%, and 30% alfalfa meal, respectively. Dietary formulations were designed according to NRC (2012) nutrient requirements for swine and the actual feeding levels of the farm. The composition and nutrient levels of the experimental diets are presented in Table 1 .

1.3 Feeding Management Prior to the experiment, all pig houses were thoroughly cleaned and disinfected. After drying, experimental pigs were weighed, numbered, and grouped, followed by deworming and vaccination. During the pre-trial period, all groups were fed the same basal diet while their health status was monitored and adjusted as needed. At the end of the pre-trial period, pigs were weighed again, and the formal trial commenced when no significant differences in body weight were observed among groups ($P>0.05$). Pigs were fed twice daily at 08:00 and 17:00, with feed provided ad libitum and free access to water. Houses were maintained in sanitary condition with regular disinfection. Body weight and daily feed consumption were recorded throughout the trial, and health status was monitored. At the end of the experiment, slaughter trials and muscle protein content determinations were conducted, with proper records and sampling.

1.4 Measurement Indicators and Methods

1.4.1 Growth Performance The Osborne swine performance testing system (USA) was used to record daily feed intake time, feeding frequency, feed consumption, initial and final body weights at different stages, and days required to

reach target weights. Based on these data, average daily gain (ADG), average daily feed intake (ADFI), and feed-to-gain ratio (F/G) were calculated.

1.4.2 Serum Biochemical Indexes At the end of the feeding trial, five pigs were randomly selected from each group (25 pigs total) for blood collection. Blood samples (10 mL) were collected from the anterior vena cava and centrifuged at 3,000 r/min for 15 minutes. Serum was stored at -20°C for subsequent analysis. Serum biochemical indexes were determined at the Second Affiliated Hospital of Zhengzhou University using a Siemens automatic biochemical analyzer to measure serum urea nitrogen (BUN), glucose (GLU), total protein (TP), albumin (ALB), globulin (GLO), triglyceride (TG), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), alanine aminotransferase (ALT), and aspartate transaminase (AST) activities.

1.4.3 Carcass Traits The 25 pigs from which blood samples were collected were fasted for 24 hours with free access to water before being weighed and slaughtered. Carcass splitting was performed according to the Agricultural Industry Standard of the People' s Republic of China NY/T 825—2004 "Technical Specification for Performance Testing of Lean-type Pig Carcasses." After removing the head, feet, tail, and internal organs (except kidneys and leaf fat), the carcass was split in half and the left side was retained for weighing and measurement of carcass weight, carcass straight length, carcass oblique length, backfat thickness, dressing percentage, lean meat percentage, and loin-eye area.

1.4.4 Muscle Protein Content Determination A 10-g sample of the longissimus dorsi muscle was collected from the region between the 4th and 6th lumbar vertebrae after slaughter. Muscle protein content was determined using the Kjeldahl method (refer to GB 5009.5—1985).

1.5 Statistical Analysis Experimental data were initially processed using Excel 2010 and then subjected to analysis of variance using SPSS 20.0 software. Duncan' s multiple range test was used for inter-group comparisons, with $P<0.05$ as the criterion for significant difference. Results are expressed as mean±standard deviation (mean±SD).

Results

2.1 Effects of Alfalfa Meal on Growth Performance of Finishing Pigs As shown in Table 2 , during the 60-80 kg stage, no significant differences were observed among groups in ADG or F/G ($P>0.05$). However, the ADG of the 5% alfalfa meal group was 0.92% higher than that of the control group and 2.71%, 2.39%, and 12.26% higher than those of the 10%, 20%, and 30% alfalfa meal groups, respectively. The ADFI of the 30% alfalfa meal group was significantly lower than that of other groups ($P<0.05$), and the days required to reach the

60–80 kg stage were significantly longer (P<0.05). However, the F/G of the 30% alfalfa meal group was lower than other groups (P>0.05), and its weight gain cost was lower than other groups, being significantly lower than that of the 10% alfalfa meal group (P<0.05).

During the 81–100 kg stage, ADFI of finishing pigs showed a gradual decreasing trend with increasing alfalfa meal supplementation, while ADG exhibited an initial increase followed by a decrease. The ADFI of the control and 5% alfalfa meal groups was extremely significantly higher than that of the 20% and 30% alfalfa meal groups (P<0.01), and their ADG was significantly higher (P<0.05). The F/G of the control and 10% alfalfa meal groups was significantly higher than that of the 20% and 30% alfalfa meal groups (P<0.05). No significant differences were found in ADFI, ADG, or F/G among the control, 5%, and 10% alfalfa meal groups (P>0.05). The 5% alfalfa meal group required the fewest days to reach the 81–100 kg stage, with ADG 2.46%, 6.91%, 12.43%, and 13.90% higher than the other four groups, respectively, and the lowest weight gain cost.

During the entire 60–100 kg stage, the ADG of the 5% alfalfa meal group was 2.24% higher than that of the control group, though the difference was not significant (P>0.05). Compared with the control group, the ADFI and F/G of the 5%, 10%, 20%, and 30% alfalfa meal groups were all reduced, but no significant differences were observed among groups (P>0.05). The weight gain costs of the 10%, 20%, and 30% alfalfa meal groups increased, with the 30% alfalfa meal group showing a significant increase compared with the control group (P<0.05), while no significant differences were found among the control, 5%, 10%, and 20% alfalfa meal groups (P>0.05).

2.2 Effects of Alfalfa Meal on Serum Biochemical Indexes of Finishing Pigs As shown in Table 3 , serum TP, ALB, and GLO contents showed decreasing trends with increasing alfalfa meal supplementation. Serum UN content in the control and 20% alfalfa meal groups was significantly higher than that in the 5% and 30% alfalfa meal groups (P<0.05). Serum GLU content in the 5% and 10% alfalfa meal groups was significantly higher than that in the control and 30% alfalfa meal groups (P<0.05), with no significant differences among the 5%, 10%, and 20% alfalfa meal groups (P>0.05).

Serum ALT activity in the 10% and 20% alfalfa meal groups was extremely significantly lower than that in the control and 5% alfalfa meal groups (P<0.01) and significantly lower than that in the 30% alfalfa meal group (P<0.05). No significant differences were observed among the control, 5%, and 30% alfalfa meal groups (P>0.05), and no significant difference was found between the 10% and 20% alfalfa meal groups (P>0.05). Serum AST activity in the control and 5% alfalfa meal groups was significantly higher than that in the 10%, 20%, and 30% alfalfa meal groups (P<0.05), with no significant difference between the control and 5% alfalfa meal groups (P>0.05) or among the 10%, 20%, and 30% alfalfa meal groups (P>0.05).

No significant differences were detected among groups in serum TC and LDL-C contents (P>0.05). Serum TG content in the 30% alfalfa meal group was extremely significantly lower than that in the control, 5%, 10%, and 20% alfalfa meal groups (P<0.01), with no significant differences among the latter four groups (P>0.05). Serum HDL-C content in the 30% alfalfa meal group was significantly higher than that in the control and 5% alfalfa meal groups (P<0.05), and the 10% alfalfa meal group was significantly higher than the control group (P<0.05), with no significant differences among the 10%, 20%, and 30% alfalfa meal groups (P>0.05).

2.3 Effects of Alfalfa Meal on Carcass Quality of Finishing Pigs As shown in Table 4 , no significant differences were observed among groups in carcass weight, dressing percentage, backfat thickness, loin-eye area, carcass oblique length, or carcass straight length (P>0.05). Compared with the control group, lean meat percentage in alfalfa meal groups showed an initial increase followed by a decreasing trend, with the 20% alfalfa meal group showing a significant increase of 7.99% (P<0.05). No significant differences were found among the 5%, 10%, and 30% alfalfa meal groups and the control group (P>0.05).

2.4 Effects of Alfalfa Meal on Muscle Protein Content of Finishing Pigs As shown in Table 5 , muscle protein content in all alfalfa meal groups was higher than that in the control group, with the 20% alfalfa meal group being significantly higher (P<0.05). No significant differences were observed among the control, 5%, 10%, and 30% alfalfa meal groups (P>0.05).

2.5 Economic Benefit Analysis As shown in Table 6 , the feed costs per kilogram of weight gain were 7.16, 7.08, 7.54, 7.56, and 8.08 yuan for the control, 5%, 10%, 20%, and 30% alfalfa meal groups, respectively. During the finishing period from 60 to 100 kg, without considering premium pricing and using a uniform market price of 17 yuan/kg for live pigs, the gross profits were calculated as 393.31, 395.68, 377.18, 375.48, and 359.35 yuan for the control, 5%, 10%, 20%, and 30% alfalfa meal groups, respectively, indicating that 5% alfalfa meal supplementation could improve economic benefit.

Discussion

3.1 Effects of Alfalfa Meal on Growth Performance and Economic Benefit of Finishing Pigs The large intestine microbiota of finishing pigs contains highly active fiber-degrading bacterial populations. The volatile fatty acids produced through fiber degradation can provide 3%–5% of the energy requirements for finishing pigs. Therefore, adding appropriate amounts of alfalfa meal to finishing pig diets is feasible, as it not only meets energy needs but also improves feed utilization. Studies on the effects of alfalfa on finishing pig production performance have been reported both domestically and internationally, though results have not been entirely consistent. Some foreign researchers found

that adding 5%–10% high-quality alfalfa meal to finishing pig diets resulted in good growth performance and carcass quality. Wang et al. reported that 15% and 20% alfalfa meal groups showed significantly improved ADG and ADFI compared with the control group when feeding Duroc × Landrace × Large White crossbred pigs weighing 50 kg, with the 15% alfalfa meal group being beneficial for improving body weight and feed conversion rate. Wang et al. found that alfalfa meal supplementation had no significant effect on finishing pig growth performance, but ADFI and F/G decreased gradually with increasing alfalfa meal levels, with 7% and 14% alfalfa meal groups showing trends toward better weight gain and F/G than the control group. Zhao reported that 10% and 15% alfalfa meal supplementation significantly increased ADG and significantly decreased F/G in finishing pigs. In the present study, results from different finishing stages indicated that 5% alfalfa meal supplementation improved ADG and reduced weight gain cost while increasing economic benefit. However, when alfalfa meal supplementation increased to 20%–30%, ADFI and ADG decreased. These findings are similar to those of Xu et al., who reported that 5% and 10% alfalfa meal supplementation improved weight gain and feed conversion rate in growing pigs, while supplementation at 15%–20% reduced these parameters compared with the control group. In this experiment, 30% alfalfa meal supplementation led to decreased ADG and F/G and increased weight gain cost, possibly because the limited capacity of the animal digestive tract was exceeded by the dietary fiber level, which surpassed the pig' s ability to utilize fiber, thereby affecting nutrient digestion and absorption and consequently growth performance.

3.2 Effects of Alfalfa Meal on Serum Biochemical Indexes of Finishing Pigs Serum UN and TP are important indicators reflecting protein metabolism and amino acid balance in animals, with serum UN content directly reflecting protein absorption and utilization status and liver and kidney function. Elevated serum UN content indicates enhanced protein catabolism and reduced nitrogen deposition, leading to decreased serum TP content. In this study, serum UN content was significantly reduced in alfalfa meal groups compared with the control group, while changes in serum TP, ALB, and GLO contents were not significantly different, suggesting that alfalfa meal supplementation could improve protein utilization efficiency and increase nitrogen deposition in blood, possibly related to the bioactive nutrients in alfalfa meal and requiring further verification.

Within the normal physiological range, serum GLU content reflects the efficiency of nutrient digestion and absorption in the intestine. In this study, serum GLU content in alfalfa meal groups showed an initial increase followed by a decreasing trend, with significant increases observed in the 5% and 10% alfalfa meal groups, indicating that appropriate alfalfa meal supplementation could improve nutrient digestibility and consequently increase serum GLU content. The significant decrease in serum GLU content in the 30% alfalfa meal group suggests that excessive alfalfa meal supplementation weakened intestinal absorption of

glucose, consistent with medical research showing that dietary fiber can prevent intestinal absorption of carbohydrates. Therefore, appropriate alfalfa meal supplementation can improve digestibility in finishing pigs, indirectly increasing serum GLU content and affecting animal performance.

Serum ALT and AST activities are sensitive indicators of animal stress levels, protein synthesis and degradation status, and liver and heart damage. Under normal conditions, ALT and AST activities are high in liver and myocardial cells but low in serum; however, when tissue cells are damaged or diseased, large amounts of ALT and AST are released into the blood, increasing their activities. In this study, serum ALT and AST activities decreased markedly with increasing alfalfa meal supplementation, particularly in the 20% alfalfa meal group, indicating that alfalfa meal supplementation could enhance anti-stress capacity and reduce cell membrane damage, possibly related to the antioxidant-active saponins and other bioactive compounds in alfalfa meal.

Triglyceride and total cholesterol are important indicators for evaluating lipid metabolism in animals. High-density lipoprotein cholesterol acts as a "scavenger" of cholesterol in the body, and its increased content can reduce cholesterol deposition and protect blood vessels, whereas excessive low-density lipoprotein cholesterol accumulation leads to cardiovascular disease. Numerous studies have demonstrated that alfalfa saponins can reduce serum TC, TG, and LDL-C contents while increasing serum HDL-C content. In this study, compared with the control group, alfalfa meal groups showed decreasing trends in serum TC and LDL-C contents, though differences were not significant; serum HDL-C content increased gradually, with significant elevation in the 30% alfalfa meal group, and serum TG content was extremely significantly reduced in the 30% alfalfa meal group. These results indicate that alfalfa meal supplementation can improve fat deposition and metabolism, possibly related to the involvement of certain bioactive components (such as alfalfa saponins) in cholesterol metabolism and transport functions.

3.3 Effects of Alfalfa Meal on Carcass Traits of Finishing Pigs In this study, different alfalfa meal supplementation levels had no significant effects on carcass weight, dressing percentage, backfat thickness, loin-eye area, carcass oblique length, or carcass straight length, though average backfat thickness showed a decreasing trend with increasing alfalfa meal supplementation. These findings are consistent with several studies and may be related to increased fiber content in alfalfa, suggesting that alfalfa meal supplementation can be used in practice to reduce backfat thickness in finishing pigs.

The ability of alfalfa meal supplementation to increase lean meat percentage in finishing pigs has been confirmed in many studies. Kass et al. suggested that when dietary fiber levels exceed 7%–10% in finishing pig diets, pig growth is inhibited while carcass fat percentage decreases and lean meat percentage increases. Wang et al. confirmed that appropriate alfalfa meal supplementation can reduce body fat and cholesterol content while increasing lean meat per-

centage. In this study, compared with the control group, alfalfa meal groups showed increasing trends in lean meat percentage, with the 20% alfalfa meal group achieving a significant 7.99% increase, consistent with the above conclusions and indicating that increased dietary fiber content reduces fat synthesis and deposition, thereby improving carcass lean meat percentage. However, the lean meat percentage in the 30% alfalfa meal group was lower than that in the 20% alfalfa meal group, possibly because the large amount of oil added to this group' s diet supplied energy to compensate for the deficiency in digestible energy, ensuring adequate effective energy supply and consequently reducing lean meat percentage. Therefore, appropriate alfalfa meal supplementation can improve carcass traits in finishing pigs, with 20% supplementation showing the best effect.

3.4 Effects of Alfalfa Meal on Muscle Protein in Finishing Pigs Pork is an excellent source of high-quality protein for humans, and high protein content in pork increases its nutritional value and helps meet consumer demand for lean meat. This study found that alfalfa meal supplementation increased muscle protein content, with the 20% alfalfa meal group being significantly higher than the control group ($P<0.05$), demonstrating the best improvement effect on pork protein content.

Conclusion

1. Dietary supplementation with 5% alfalfa meal can reduce weight gain cost and improve economic benefit.
2. Dietary supplementation with 20% alfalfa meal can improve serum biochemical indexes, increase lean meat percentage and muscle protein content, and enhance pork quality.

References

[1] Hu Xiangdong. Research on China' s pork supply and demand based on market models [D]. PhD Thesis. Beijing: Chinese Academy of Agricultural Sciences, 2011.

[2] Wang Chengzhang, Li Defeng, Yan Xuebing, et al. Effects of alfalfa meal supplementation on production performance, digestibility, and serum indexes of finishing pigs [J]. Acta Prataculturae Sinica, 2008, 17(6): 71–77.

[3] Han Chunmei, Zhang Xinquan, Yang Chunhua, et al. Current status of alfalfa leaf protein development and utilization [J]. Pratacultural Science, 2005, 22(9): 23–27.

[4] Spillman A. Nutrient boost alfalfa silage [J]. Agricultural Research, 2003, 51(12): 20–21.

[5] Liu Yanna, Shi Yinghua, Yan Xuebing, et al. Effects of alfalfa hay replacing part of concentrate on production performance and economic benefit of dairy

cows [J]. Acta Prataculturae Sinica, 2013, 22(6): 190-197.

[6] Zhu Xiaoyan, Zhao Cheng, Shi Yinghua, et al. Effects of alfalfa silage replacing alfalfa hay on production performance and milk quality of dairy cows [J]. Acta Prataculturae Sinica, 2016, 25(5): 156-164.

[7] Liu Quanwei, Wang Chengzhang, Yan Xuebing, et al. Effects of fresh alfalfa feeding on slaughter traits and meat quality of Boer goats [J]. Acta Prataculturae Sinica, 2010, 19(1): 158-165.

[8] Xu Hong, Yu Ying, Liang Xinping, et al. Effects of alfalfa hay on rumen fermentation parameters and duodenal chyme amino acid content in Dorper × Small-tailed Han crossbred sheep [J]. Chinese Journal of Animal Nutrition, 2014, 26(6): 1689-1697.

[9] Xia Suyin, Wang Chengzhang, Zhan Fabo, et al. Effects of cellulase supplementation to alfalfa meal diets on performance, egg quality, and nutrient utilization in laying hens [J]. Acta Prataculturae Sinica, 2011, 20(5): 183-191.

[10] Laudado V, Ceci E, Lastella N M B, et al. Low fiber alfalfa (Medicago sativa L.) in the laying hen diet: effects on productive traits and egg quality [J]. Poultry Science, 2014, 93(7): 1868-1874.

[11] Shi Yinghua, Wang Chengzhang, Chen Mingliang, et al. Effects of alfalfa meal on growth performance, antioxidant, and immune indexes of Sichuan White geese [J]. Pratacultural Science, 2011, 28(5): 841-847.

[12] Chen Jihong, Sun Yu, Wang Yanhua, et al. Effects of alfalfa meal on lipid metabolism and antioxidant capacity of meat rabbits [J]. China Animal Husbandry & Veterinary Medicine, 2013, 40(10): 101-105.

[13] Mustafa A F, McKinnon J J, Christensen D A, et al. Effects of micronization of flaxseed on nutrient disappearance in the gastrointestinal tract of steers [J]. Animal Feed Science and Technology, 2002, 95(3/4): 123-132.

[14] Xu Xiangyang, Wang Chengzhang, Yang Yuxin, et al. Effects of alfalfa meal on growth performance and serum indexes of growing pigs [J]. Journal of Huazhong Agricultural University, 2006, 25(2): 164-169.

[15] Wang Chengzhang, Xu Xiangyang, Yang Yuxin, et al. Effects of alfalfa meal on carcass quality and serum indexes of finishing pigs [J]. Scientia Agricultura Sinica, 2008, 41(5): 1554-1559.

[16] Wang Yanhua, Cheng Ningning, Zheng Airong, et al. Effects of alfalfa meal and alfalfa saponins on growth performance and antioxidant capacity of finishing pigs [J]. Chinese Journal of Animal Nutrition, 2013, 25(12): 2981-2988.

[17] National Research Committee. Nutrient requirements of swine [S]. Washington D.C.: National Academy of Sciences Press, 2012.

[18] Ministry of Agriculture of the People' s Republic of China. NY/T 825—2004 Technical specification for performance testing of lean-type pig carcasses

[S]. Beijing: China Agriculture Press, 2004.

[19] Li Defa. Swine nutrition [M]. 2nd ed. Beijing: China Agricultural Science and Technology Press, 2003.

[20] Kass M L, Van Soest P J, Pond W G. Utilization of dietary fiber from alfalfa by growing swine. II. Volatile fatty acid concentrations in and disappearance from the gastrointestinal tract [J]. Journal of Animal Science, 1980, 50(1): 192-197.

[21] Varel V H. Activity of fiber-degrading microorganisms in the large intestine [J]. Journal of Animal Science, 1987, 65(2): 488-496.

[22] Varel V H, Yen J T. Microbial perspective on fiber utilization by swine [J]. Journal of Animal Science, 1997, 75(10): 2715-2722.

[23] Seerley R W, Wahlstrom R C. Dehydrated alfalfa meal in rations for pigs and brood sows in confinement [J]. Dehydrated Alfalfa Meal in Rations for Pigs & Brood Sows in Confinement, 1968, 32(5): 809-815.

[24] Stangroom K E, Smith T K. Effect of whole and fractionated dietary alfalfa meal on zearalenone toxicosis and metabolism in rats and swine [J]. Canadian Journal of Physiology and Pharmacology, 1984, 62(9): 1219-1224.

[25] Zhao Jing. Effects of alfalfa meal supplementation on production performance and meat quality of finishing pigs [J]. Pratacultural Science, 2015, 32(5): 809-815.

[26] Xu Zirong, Lu Jianjun, Yang Ying. Growth-promoting effect of hemicellulase supplementation in diets for growing pigs and its endocrine mechanism [J]. Chinese Journal of Veterinary Science, 2002, 22(2): 201-202.

[27] Yang Yufen, Ge Dejun, Wang Changkang. Effects of dietary fiber level on fecal indices, serum hormones, and biochemical indexes of pregnant sows [J]. Chinese Journal of Animal Nutrition, 2010, 22(6): 1529-1535.

[28] Guan Lihui, Li Honglong, Wu Zhanfu, et al. Effects of Chinese herbal medicine feed additives on immune function of growing-finishing pigs [J]. Feed Industry, 2006, 27(22): 58-59.

[29] Yin Qingqiang, Li Xiaofei, Chang Juan, et al. Effects of microecological preparation on performance of suckling and weaned piglets and its mechanism of action [J]. Chinese Journal of Animal Nutrition, 2011, 23(4): 622-630.

[30] He Shishan, Jin Xiaojun. Effects of high temperature on blood biochemical indexes of broilers [J]. Journal of Zhejiang University: Agriculture and Life Sciences, 2003, 29(3): 311-314.

[31] Ning Yuchang, Zhao Xuyong, Wang Jing. Effects of gynostemma on growth performance, blood biochemical indexes, and immune function of weaned piglets [J]. Chinese Journal of Animal Science, 2014, 50(7): 74-78.

[32] Ruan Hongling, Zhao Jia, Bai Man, et al. Determination and analysis of blood biochemical indexes of Qianhua mutton Merino sheep [J]. China Herbivore Science, 2016, 36(1): 22-25.

[33] Wang Chengzhang, Wang Yanhua, Shi Yinghua, et al. Effects of alfalfa saponins on lipid metabolism, antioxidant capacity, and immunity of weaned piglets [J]. Acta Prataculturae Sinica, 2011, 20(4): 210-218.

[34] Liu Boshuai, Wang Wenjing, Chen Yanyan, et al. Effects of alfalfa saponins on mRNA expression of low-density lipoprotein receptor and ATP-binding cassette transporter in rat liver and liver cells [J]. Chinese Journal of Animal Nutrition, 2017, 29(4): 1437-1445.

[35] Chen Yanyan, Liu Boshuai, Chen Yuepeng, et al. Effects of alfalfa saponins on mRNA expression of reverse cholesterol transport genes ATP-binding cassette transporter A1 and scavenger receptor B [J]. Chinese Journal of Animal Nutrition, 2017, 29(4): 1446-1454.

[36] Hu Xiangqian. Effects of alfalfa meal and dietary crude protein level on carcass quality and meat quality of pigs [D]. Master' s Thesis. Chongqing: Southwest University, 2006.

[37] Yang Feng. Animal nutrition [M]. 2nd ed. Beijing: China Agriculture Press, 2001: 75.

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