Effects of Dietary Fat Source on Production Performance, Nutrient Digestibility, Serum Lipid Metabolism, and Antioxidant Indices in Meat Rabbits under Heat Stress Conditions: Postprint

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Abstract

The present study aimed to investigate the effects of fat sources on growth performance, nutrient digestibility, serum lipid metabolism, and antioxidant indices of meat rabbits under heat stress conditions. Six hundred 30-day-old weaned New Zealand rabbits were randomly allocated into 5 groups with 6 replicates per group and 20 rabbits per replicate. The control group was fed a basal diet, while the fat-supplemented groups were fed diets containing 2% tallow, lard, corn oil, or soybean oil, respectively. All experimental rabbits were housed in heat-stress rabbit barns (temperature-humidity index of 29.5$±$0.5). The experimental period lasted 7 weeks. The results showed that, compared with the control group, dietary supplementation with different fat sources under heat stress conditions significantly increased the average daily gain of meat rabbits ($P<0.05$) and significantly decreased the feed conversion ratio ($P<0.05$), with corn oil showing the best effect. Compared with the control group, dietary supplementation with different fat sources under heat stress conditions significantly increased the dry matter and crude protein digestibility of meat rabbits ($P<0.05$), significantly decreased the crude fat digestibility ($P<0.05$), but had no significant effect on crude ash and crude fiber digestibility ($P>0.05$), with the corn oil group showing the highest dry matter digestibility and the soybean oil group showing the highest crude protein digestibility. Compared with the control group, dietary supplementation with tallow or lard under heat stress conditions significantly increased serum triglyceride and total cholesterol contents in meat rabbits ($P<0.05$); serum triglyceride and total cholesterol contents in the corn oil and soybean oil groups did not differ significantly from the control group ($P>0.05$). Compared with the control group, dietary supplementation with soybean oil and corn oil under heat stress conditions significantly increased

serum superoxide dismutase activity and total antioxidant capacity in meat rabbits (P<0.05) and decreased serum malondialdehyde content (P<0.05); serum superoxide dismutase activity, total antioxidant capacity, and malondialdehyde content in the tallow and lard groups did not differ significantly from the control group (P>0.05). In conclusion, under heat stress conditions, dietary supplementation with different fat sources can improve growth performance and dry matter and crude protein digestibility in meat rabbits, with the overall effectiveness ranking as corn oil > soybean oil > lard > tallow; dietary supplementation with tallow or lard can increase serum triglyceride and total cholesterol contents in meat rabbits, with no significant effect on antioxidant capacity; dietary supplementation with soybean oil or corn oil has no significant effect on serum triglyceride and total cholesterol contents in meat rabbits, but can significantly improve antioxidant capacity.

Full Text

Effects of Fat Source on Performance, Nutrient Digestibility, and Serum Lipid Metabolism and Antioxidant Indices of Meat Rabbits under Heat Stress

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Abstract

This experiment was conducted to investigate the effects of dietary fat source on performance, nutrient digestibility, and serum lipid metabolism and antioxidant indices of meat rabbits under heat stress conditions. Six hundred 30-day-old weaned New Zealand rabbits were randomly allocated to five groups, each consisting of six replicates with 20 rabbits per replicate. The control group received a basal diet, while the fat-supplemented groups received diets containing 2% butter, lard, corn oil, or soybean oil, respectively. All rabbits were housed in a heat-stress environment with a temperature-humidity index of 29.5$±$0.5 for a 7-week experimental period. The results demonstrated that, compared with the control group, dietary supplementation with various fat sources significantly improved average daily gain (P<0.05) and reduced feed-to-gain ratio (P<0.05), with corn oil showing the most pronounced effect. All fat-supplemented diets significantly enhanced dry matter and crude protein digestibility (P<0.05) while decreasing ether extract digestibility (P<0.05), though they had no significant effect on ash or crude fiber digestibility (P>0.05). Corn oil yielded the highest dry matter digestibility, whereas soybean oil produced the highest crude protein digestibility. Butter and lard supplementation significantly elevated serum

triglyceride and total cholesterol concentrations (P<0.05), whereas corn oil and soybean oil had no significant effect on these parameters compared with the control group (P>0.05). Additionally, corn oil and soybean oil significantly increased serum superoxide dismutase activity and total antioxidant capacity (P<0.05) while reducing malondialdehyde content (P<0.05); however, butter and lard showed no significant effect on these antioxidant indices (P>0.05). In conclusion, dietary fat supplementation under heat stress improved meat rabbit performance and the digestibility of dry matter and crude protein, with the overall efficacy ranking as follows: corn oil > soybean oil > lard > butter. Butter or lard increased serum triglyceride and total cholesterol levels without significantly affecting antioxidant capacity, whereas corn oil or soybean oil enhanced antioxidant capacity without significantly altering serum lipid profiles.

Keywords: heat stress; meat rabbits; fat source; performance; serum indices

Introduction

Heat stress represents one of the primary environmental factors impairing normal rabbit production during summer, particularly in southern China where high temperature and humidity persist for extended periods. As fur-bearing animals with underdeveloped sweat glands, rabbits exhibit low tolerance to hot and humid conditions. Under severe heat stress, rabbits experience reduced feed intake and increased incidence of intestinal diseases, causing substantial economic losses to the rabbit industry. Dietary fats have demonstrated efficacy in alleviating heat stress due to their low heat increment and additional energy effects, though the effectiveness varies among fat sources. Therefore, investigating the effects of different dietary fats on mitigating heat stress in meat rabbits provides crucial guidance for scientifically formulating diets under such conditions.

Previous research has shown that while low-fat and high-fat diets produced similar weight gains in rabbits housed at comfortable temperatures (12 and 18°C), high-fat diets significantly improved weight gain at elevated temperatures (24, 30, and 33°C). Similarly, studies have demonstrated that dietary oil supplementation can effectively alleviate heat stress and improve performance in meat rabbits. Research in weaned piglets has indicated that coconut oil promotes growth more effectively than fish oil and lard. However, few studies have examined the effects of fat source on rabbit performance and nutrient metabolism, and no investigations have been conducted under strictly controlled environmental conditions. The present study was designed to evaluate the effects of different fat sources on performance, serum lipid metabolism, and antioxidant indices in meat rabbits under precisely controlled heat stress conditions, thereby providing scientific reference for precise diet formulation.

1.1 Experimental Design

Six hundred 30-day-old weaned New Zealand rabbits were randomly assigned to five groups, each comprising six replicates of 20 rabbits. The control group received a basal diet, while the treatment groups received diets supplemented with 2% butter, lard, corn oil, or soybean oil, respectively. All diets were formulated to be nutritionally equivalent. Rabbits were housed in an environmentally controlled facility under heat stress conditions. Following a 5-day adaptation period, a 7-week feeding trial was conducted. During the final two weeks, six rabbits per group (half male and half female) with body weights approximating the group mean were selected for a total fecal collection digestion trial. At the conclusion of the feeding trial, production performance was assessed, and after a 12-hour fast (with water provided), 10 mL of blood was collected via cardiac puncture for serum biochemical analysis.

1.2 Management and Diets

The experimental rabbits were maintained in an environmentally controlled facility with a temperature-humidity index (THI) of 29.5$±$0.5, representing heat stress conditions. The THI was calculated using the formula: THI = db - [(0.31 - 0.31RH)(db - 14.4)], where db represents dry bulb temperature (°C) and RH represents relative humidity. According to established criteria, heat stress conditions correspond to THI values of 28.9-30.0, while comfortable conditions range from 22.2-23.3. Prior to the experiment, the facility was thoroughly cleaned and disinfected. Rabbits were managed according to conventional protocols with free access to feed and water.

Diets were formulated based on recommended nutrient requirements for rabbits and local feed resources, and processed into pelleted form. The composition and nutrient levels of experimental diets are presented in Table 1 .

1.3 Measurements

1.3.1 Performance

Rabbits were weighed at 08:00 on days 35 and 84 to determine initial and final body weights. Feed consumption was recorded throughout the experimental period to calculate average daily feed intake, average daily gain, and feed-to-gain ratio.

1.3.2 Nutrient Digestibility

A total fecal collection method was employed for the digestion trial. Dry matter (DM), crude protein (CP), ether extract (EE), ash, and crude fiber (CF) contents in diet and fecal samples were determined according to established methods.

1.3.3 Serum Lipid Metabolism Indices

Serum triglyceride (TG), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) concentrations

were measured using commercial assay kits from Nanjing Jiancheng Bioengineering Institute, following the manufacturer' s instructions.

1.3.4 Serum Antioxidant Indices

Serum superoxide dismutase (SOD) activity, malondialdehyde (MDA) content, and total antioxidant capacity (T-AOC) were determined using assay kits purchased from Nanjing Jiancheng Bioengineering Institute, according to the manufacturer' s protocols.

1.4 Data Analysis

Experimental data were processed using Excel 2010 and analyzed statistically with SPSS 18.0 software. Duncan' s multiple comparison test was used to detect significant differences among treatment means, with $P<0.05$ as the criterion for statistical significance. Results are expressed as mean $\pm$ standard deviation.

Results

2.1 Effects of Fat Source on Performance

As shown in Table 2 , dietary fat source significantly affected average daily feed intake, average daily gain, and feed-to-gain ratio ($P<0.05$). The butter group exhibited the lowest average daily feed intake, which was significantly lower than that of the corn oil and soybean oil groups ($P<0.05$) and numerically lower than the control and lard groups, though not significantly ($P>0.05$). The control group showed the lowest average daily gain, with all fat-supplemented groups demonstrating significantly higher values ($P<0.05$). The corn oil and soybean oil groups further exceeded the butter group ($P<0.05$) and were numerically superior to the lard group without reaching statistical significance ($P>0.05$). The control group had the highest feed-to-gain ratio, which was significantly reduced in all fat-supplemented groups ($P<0.05$). The corn oil group achieved the lowest feed-to-gain ratio, significantly better than the butter group ($P<0.05$) and numerically superior to the lard and soybean oil groups ($P>0.05$).

2.2 Effects of Fat Source on Nutrient Digestibility

Table 3 presents the effects of fat source on nutrient digestibility. Dietary fat source significantly influenced dry matter and crude protein digestibility ($P<0.05$) but had no significant effect on ash or crude fiber digestibility ($P>0.05$). The control group exhibited significantly lower dry matter and crude protein digestibility compared with all fat-supplemented groups ($P<0.05$), with corn oil achieving the highest dry matter digestibility and soybean oil attaining the highest crude protein digestibility. Conversely, the control group showed significantly higher ether extract digestibility than the fat-supplemented groups ($P<0.05$), though no significant differences were observed among the fat-supplemented treatments ($P>0.05$). Ash and crude fiber digestibility did not differ significantly among all groups ($P>0.05$).

2.3 Effects of Fat Source on Serum Lipid Metabolism

As illustrated in Table 4 , dietary fat source significantly affected serum triglyceride and total cholesterol concentrations ($P<0.05$) but had no significant impact on HDL-C or LDL-C levels ($P>0.05$). The control, corn oil, and soybean oil groups showed similar triglyceride and total cholesterol concentrations ($P>0.05$), all of which were significantly lower than those observed in the butter and lard groups ($P<0.05$). The butter group exhibited significantly higher values than the lard group ($P<0.05$). No significant differences were detected among any groups for HDL-C and LDL-C concentrations ($P>0.05$).

2.4 Effects of Fat Source on Serum Antioxidant Indices

Table 5 reveals that dietary fat source significantly influenced serum SOD activity, T-AOC, and MDA content ($P<0.05$). The control, lard, and butter groups displayed similar SOD activity and T-AOC ($P>0.05$), all of which were significantly lower than those of the corn oil and soybean oil groups ($P<0.05$). Similarly, the control, lard, and butter groups showed comparable MDA content ($P>0.05$), which was significantly higher than that observed in the corn oil and soybean oil groups ($P<0.05$).

Discussion

3.1 Effects on Performance and Nutrient Digestibility

The present results demonstrate that dietary fat source affects rabbit performance under heat stress, with corn oil being most effective, followed by soybean oil, lard, and butter. The superior performance of fat-supplemented groups can be attributed to the low heat increment and additional energy effects of dietary fats under heat stress conditions. Ether extract digestibility is primarily determined by fat source and is highly correlated with fatty acid chain length and saturation degree. Medium- and short-chain fatty acids exhibit higher utilization efficiency and rate than long-chain fatty acids, and unsaturated fatty acids are more readily digested and absorbed than saturated fatty acids. Medium- and short-chain fatty acids have low esterification rates, with most being absorbed directly without lipase hydrolysis and entering circulation through intestinal epithelial cells. In contrast, long-chain fatty acids must undergo enzymatic hydrolysis to form micelles before cellular absorption and re-synthesis into triglycerides for systemic circulation, resulting in lower absorption efficiency. The significantly higher ether extract digestibility observed in corn oil and soybean oil groups compared with lard and butter groups corroborates this mechanism. Corn oil and soybean oil are rich in medium- and short-chain fatty acids and unsaturated fatty acids, whereas lard and butter contain predominantly long-chain and saturated fatty acids, particularly butter.

3.2 Effects on Serum Lipid Metabolism

In this study, butter and lard supplementation significantly increased serum triglyceride and total cholesterol concentrations compared with the control group, whereas corn oil and soybean oil showed no such effects. Previous research indicates that dietary fat type and content influence blood lipid levels, with saturated fatty acid-rich fats increasing blood lipids and cholesterol, while unsaturated fatty acid-rich fats may reduce these parameters. Studies have demonstrated that under stress conditions, polyunsaturated fatty acids (n-3 and n-6 families) inhibit gene transcription encoding hepatic lipogenic and glycolytic enzymes. Specifically, n-3 fatty acids suppress triglyceride synthesis and very low-density lipoprotein secretion, thereby maintaining low serum triglyceride levels. Conversely, saturated fatty acids directly elevate serum LDL and cholesterol concentrations and may impede cholesterol metabolism by downregulating cholesterol 7α-hydroxylase expression. The elevated serum lipids and cholesterol deposition observed with animal fats like butter and lard align with findings from previous studies. The lack of hypolipidemic effects with plant oils in this experiment may be attributed to the relatively low ether extract content in the control diet compared with the higher fat inclusion in treatment diets, which is consistent with previous reports in broiler chickens.

3.3 Effects on Serum Antioxidant Capacity

The present findings indicate that plant oils (soybean and corn oil) significantly enhanced serum SOD activity and T-AOC while reducing MDA content, whereas animal oils (butter and lard) did not significantly affect these indices compared with the control group, despite showing some numerical improvements. This demonstrates that plant oils possess superior antioxidant capacity, with corn oil being most effective. T-AOC reflects the antioxidant defense capacity of the organism, while MDA represents lipid peroxidation products; both serve as comprehensive indicators of antioxidant system function. Under heat stress, the significant decline in T-AOC and increase in MDA content indicate impaired compensatory capacity of both enzymatic and non-enzymatic antioxidant systems. Research has shown that unsaturated fatty acids exhibit strong antioxidant capacity, whereas saturated fatty acids demonstrate greater resistance to reduction. The content and degree of unsaturation of polyunsaturated fatty acids in tissues directly determine the potential for lipid peroxidation. Therefore, when endogenous antioxidant capacity is compromised, dietary supplementation with unsaturated fatty acid-rich plant oils can effectively scavenge free radicals, protect tissue cells from oxidative damage, and maintain antioxidant capacity. SOD is a metalloenzyme that plays a critical role in maintaining redox balance by scavenging superoxide anion radicals and exerting anti-inflammatory effects, thereby reflecting the capacity to eliminate oxygen free radicals. The increased serum SOD activity observed with plant oil supplementation may be attributed to the heat stress-induced decline in antioxidant capacity, which triggers enhanced SOD synthesis to counteract oxidative

stress. Rabbits consuming plant oils likely experienced lower total free radical production compared with those consuming animal oils, resulting in elevated serum SOD activity.

Conclusion

Under heat stress conditions, dietary supplementation with various fat sources improved meat rabbit performance and the digestibility of dry matter and crude protein, with overall efficacy ranking as: corn oil > soybean oil > lard > butter. Butter or lard supplementation increased serum triglyceride and total cholesterol concentrations without significantly affecting antioxidant capacity. In contrast, corn oil or soybean oil supplementation enhanced antioxidant capacity without significantly altering serum lipid profiles.

References

[1] GUO Zhiqiang, XIE Xiaohong, LEI Min, et al. Effects of dietary oil supplementation on performance of meat rabbits under heat stress [J]. Chinese Journal of Rabbit Farming, 2012(8): 7-9.
[2] LEI Min, XIE Xiaohong, YI Jun, et al. Effects of dietary digestible energy level on performance and nutrient digestibility of meat rabbits under heat stress [J]. China Feed, 2012(7): 20-22.
[3] WANG Zili, ZHANG Zhu, TANG Qi, et al. Effects of Chinese herbal compound on intestinal histology and hepatic antioxidant function of meat rabbits under heat stress [J]. Chinese Journal of Veterinary Medicine, 2014, 50(6): 48-51, 54.
[4] YANG Fengzhu, GUO Zhiqiang, XIE Xiaohong, et al. Research progress on nutritional regulation of heat stress in rabbits [J]. Herbivore Science in China, 2011, 31(4): 68-71.
[5] CHEN Ping, LI Fuchang. Effects of dietary fat supplementation on performance and physiological indices of meat rabbits from weaning to 2 months of age [J]. Chinese Journal of Animal Nutrition, 2006, 18(3): 179-185.
[6] CERVERA C, BLAS E, FERNÁNDEZ-CARMONA J. Growth of rabbits under different environmental temperatures using high fat diets [J]. World Rabbit Science, 1997, 5(2): 71-75.
[7] LIU Zhongchen, CHEN Daiwen, YU Bing, et al. Effects of different fat sources on growth performance and lipid metabolism of weaned piglets [J]. Chinese Journal of Animal Nutrition, 2011, 23(9): 1466-1474.
[8] MARAI I F M, HABEEB A A M, GAD A E. Rabbits' productive, reproductive and physiological performance traits as affected by heat stress: a review [J]. Livestock Production Science, 2002, 78(2): 71-90.
[9] GU Zilin, QIN Yinghe, REN Keling. Rabbit Science in China [M]. Beijing: China Agriculture Press, 2013.
[10] ZHANG Liying. Feed Analysis and Feed Quality Detection Technology [M]. 3rd ed. Beijing: China Agricultural University Press, 2007.
[11] LI Fuchang. Rabbit Nutrition [M]. Beijing: China Agriculture Press, 2009.

[12] BLAS. Rabbit Nutrition [M]. Translated by TANG Liangmei. 2nd ed. Beijing: China Agriculture Press, 2015.
[13] PIAO Xiangshu, LI Defa, DAI Jianguo, et al. Effects of different fat sources on performance of early-weaned piglets [J]. Chinese Journal of Animal Nutrition, 2001, 13(4): 34-39.
[14] YUAN L, LIN H, JIANG K J, et al. Corticosterone administration and high-energy feed results in enhanced fat accumulation and insulin resistance in broiler chickens [J]. British Poultry Science, 2008, 49(4): 487-495.
[15] HAO Jingyu, LU Qingping, ZHANG Hongfu, et al. Effects of chronic high temperature on fat metabolism and serum adipocytokine levels in male and female Beijing fatty chickens [J]. Chinese Journal of Animal Nutrition, 2012, 24(6): 1038-1043.
[16] FERNÁNDEZ C, COBOS A, FRAGA M J. The effect of fat inclusion on diet digestibility in growing rabbits [J]. Journal of Animal Science, 1994, 72(6): 1508-1515.
[17] LI Juanjuan, TONG Jianming, DONG Xiaofang, et al. Effects of oil type and dietary energy level on growth performance and fat deposition in broiler chickens [J]. Chinese Journal of Animal Nutrition, 2008, 20(5): 501-508.
[18] PAN Yu, MAO Shuhong, GUAN Yong, et al. Effects of different dietary fat sources on growth performance, lipid metabolism and antioxidant capacity of common carp [J]. Chinese Journal of Animal Nutrition, 2012, 24(7): 1368-1375.

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