Effects of Dietary Supplementation with Sodium Stearoyl Lactylate on Growth Performance, Serum Biochemical Parameters, and Apparent Nutrient Digestibility in Weaned Piglets: Postprint

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Abstract

This study aimed to investigate the effects of sodium stearoyl lactylate (SSL) on growth performance, serum biochemical indices, and nutrient apparent digestibility in weaned piglets. A total of 336 25-day-old weaned piglets were selected and randomly divided into 6 groups based on body weight, with 7 replicates per group and 8 piglets per replicate. SSL supplementation levels were 0, 250, 500, 750, 1,000, and 2,000 mg/kg, and the experiment was conducted in two phases, each lasting 21 days. The experiment measured piglet growth performance, serum biochemical indices such as alanine aminotransferase, aspartate aminotransferase, and total cholesterol, as well as apparent digestibility of energy, dry matter, nitrogen, and crude fat. The results showed that, compared with the control group: 1) dietary supplementation with 500, 750, and 1,000 mg/kg SSL significantly reduced the feed-to-gain ratio of piglets in phase 2 ($P<0.05$), and supplementation with 1,000 mg/kg SSL significantly reduced the overall feed-to-gain ratio ($P<0.05$); 2) dietary SSL supplementation tended to decrease serum aspartate aminotransferase and alanine aminotransferase activities, and increase serum high-density lipoprotein cholesterol content and the high-density lipoprotein cholesterol/low-density lipoprotein cholesterol ratio on day 42 of the experiment, reaching a significant level at the supplementation level of 2,000 mg/kg ($P<0.05$); 3) SSL significantly improved the apparent digestibility of crude fat ($P<0.05$), and tended to increase the apparent digestibility of nitrogen and energy, reaching a significant level at the supplementation level of 2,000 mg/kg ($P<0.05$). The results suggest that dietary SSL supplementation can reduce the feed-to-gain ratio in piglets and improve the apparent digestibility of feed nutrients, especially crude fat.

Full Text

Effects of Dietary Sodium Stearyl Lactate Supplementation on Growth Performance, Serum Biochemical Indices and Nutrient Apparent Digestibility of Weaning Piglets

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Abstract

This study investigated the effects of dietary sodium stearyl lactate (SSL) supplementation on growth performance, serum biochemical indices, and nutrient apparent digestibility in weaning piglets. A total of 336 piglets weaned at 25 days of age were randomly allocated to 6 groups based on body weight, with 7 replicates per group and 8 piglets per replicate. The dietary SSL supplementation levels were 0, 250, 500, 750, 1,000, and 2,000 mg/kg. The experiment consisted of two phases, each lasting 21 days. Measurements included growth performance, serum biochemical indices such as alanine transaminase (ALT), aspartate aminotransferase (AST), and total cholesterol, as well as apparent digestibility of energy, dry matter, nitrogen, and crude fat. The results showed that, compared with the control group: (1) dietary supplementation with 500, 750, and 1,000 mg/kg SSL significantly reduced the feed-to-gain ratio (F/G) during phase 2 ($P<0.05$), and 1,000 mg/kg SSL significantly decreased the overall F/G ($P<0.05$); (2) SSL supplementation tended to reduce serum AST and ALT activities while increasing high-density lipoprotein cholesterol (HDL-C) content and the HDL-C/LDL-C ratio, reaching significance at 2,000 mg/kg ($P<0.05$); (3) SSL significantly improved crude fat apparent digestibility ($P<0.05$) and showed a tendency to enhance nitrogen and energy apparent digestibility, with significant effects observed at 2,000 mg/kg ($P<0.05$). These findings indicate that dietary SSL supplementation can reduce the feed-to-gain ratio and improve nutrient apparent digestibility, particularly for crude fat, in weaning piglets.

Keywords: sodium stearyl lactate; weaning piglet; crude fat; nutrient apparent digestibility; serum biochemical indices

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Energy level is a critical nutritional factor affecting post-weaning growth in piglets, yet conventional diets often fail to meet their energy requirements. In practice, dietary fat is commonly added to increase energy density. However, due to immature gastrointestinal function and insufficient secretion of lipase and bile acids [?], piglets exhibit low utilization efficiency of dietary fats. Emulsifiers are surfactants that emulsify immiscible solutions, enabling uniform distribution within another liquid to form a stable emulsion. Research has demonstrated that dietary emulsifier supplementation in broiler diets promotes the formation of chylomicrons and enhances fat digestion and absorption [?]. Similarly, emulsifiers in swine diets can improve dietary fat and energy digestibility while enhancing feed utilization efficiency [?, ?]. Nevertheless, the effects of emulsifiers on piglet growth performance have been inconsistent [?, ?], and the relationship between supplementation level and efficacy remains unclear.

Sodium stearyl lactate (SSL), with the molecular formula C24H44O6Na, is an anionic surfactant approved by the U.S. Food and Drug Administration for use in bread, where it functions as an emulsifier that interacts with wheat proteins to enhance dough strength, elasticity, and gas retention [?]. Research from the Bangkok Animal Research Center demonstrated that adding 0.05% SSL to broiler diets reduced by 10–13 kg/t of palm oil while maintaining growth performance equivalent to the control diet [?]. This study systematically examined the effects of varying SSL supplementation levels on growth performance, serum biochemical indices, and nutrient apparent digestibility in weaning piglets to provide a scientific basis for its application in piglet nutrition.

1.1 Test Materials

The SSL product contained 98% active ingredient with 6% sodium content, commercially available as SOLMAX®50, provided by Charoen Pokphand Jin Yi (Shanghai) Trading Co., Ltd.

1.2 Experimental Design

A total of 336 "Duroc × Large White × Landrace" piglets weaned at 25 days of age were individually weighed and ear-tagged, then randomly assigned to 6 groups based on body weight and sex, with 7 replicates per group and 8 piglets per replicate. The control group received a basal diet, while the other five groups received the basal diet supplemented with 250, 500, 750, 1,000, or 2,000 mg/kg SSL, respectively. The experiment comprised two phases, each lasting 21 days. The corn-soybean meal-based basal diet composition and nutrient levels are presented in Table 1 .

Table 1 Composition and Nutrient Levels of the Basal Diet (DM Basis), %

Item	Phase 1	Phase 2
Ingredients		
Maize	[Value]	[Value]
Extruded soybean	[Value]	[Value]
Soybean meal	[Value]	[Value]
Whey powder	[Value]	[Value]
Imported fish meal	[Value]	[Value]

Item	Phase 1	Phase 2
Sucrose	[Value]	[Value]
Soybean oil	[Value]	[Value]
Zinc oxide	[Value]	[Value]
CaHPO4	[Value]	[Value]
Limestone	[Value]	[Value]
NaCl	[Value]	[Value]
Premix[1]	[Value]	[Value]
Total	100.00	100.00
Nutrient Levels[2]		
Crude protein	[Value]	[Value]
DE (MJ/kg)	[Value]	[Value]
Total lysine	[Value]	[Value]
Total methionine + cysteine	[Value]	[Value]
Total threonine	[Value]	[Value]
Calcium	[Value]	[Value]
Available phosphorus	[Value]	[Value]

[1]The premix provided the following per kg of diet: Cu (as copper sulfate) 150 mg, Zn (as zinc sulfate) 100 mg, Mn (as manganese sulfate) 20 mg, Fe (as iron sulfate) 120 mg, Se (as sodium selenite) 0.3 mg, I (as calcium iodate) 0.4 mg, VA 7,500 IU, VD3 750 IU, VE 25 IU, VK3 2.0 mg, VB1 1.875 mg, VB2 3.75 mg, VB6 2.19 mg, VB12 0.025 mg, nicotinic acid 25 mg, pantothenic acid 15.6 mg, folic acid 2.0 mg, biotin 0.1875 mg.
[2]Nutrient levels were calculated values.

1.3 Animal Management

The experiment was conducted at the Haining Science and Technology Ranch of the Institute of Animal Husbandry and Veterinary Science, Zhejiang Academy of Agricultural Sciences. Piglets had ad libitum access to feed and water throughout the trial period. Routine management and immunization procedures followed standard protocols.

1.4 Measurements

1.4.1 Growth Performance Following a 3-day adaptation period, the formal experiment lasted 42 days. Individual body weights were recorded at the start, on day 21, and at the end (day 42) of the trial, with feed consumption recorded per replicate. Average daily gain (ADG), average daily feed intake (ADFI), and feed-to-gain ratio (F/G) were calculated for each phase.

1.4.2 Serum Biochemical Indices On day 42, blood samples (10 mL) were collected from two randomly selected piglets per replicate via anterior vena cava puncture. After standing at room temperature for 30 minutes, serum was harvested by centrifugation at 3,000 rpm for 15 minutes and stored at -20°C for subsequent analysis. Serum concentrations of total protein (TP), albumin (ALB), urea nitrogen (UN), total bilirubin (TBIL), creatinine (CREA), total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C), as well as activities of alanine transaminase (ALT), aspartate aminotransferase (AST), and alkaline phosphatase (AKP), were determined using assay kits from Nanjing Jiancheng Bioengineering Institute.

1.4.3 Nutrient Apparent Digestibility During the final three days of the experiment, feces were continuously collected from each replicate and preserved with 10% tartaric acid solution to prevent ammonia volatilization. Diet samples were also collected, dried at 65°C for 12 hours, equilibrated for 24 hours, then ground and sieved. The apparent digestibility of nitrogen, crude fat, dry matter, and energy was determined using the acid-insoluble ash method. Nutrient apparent digestibility was calculated as follows:

$$D = 100 - \left[\left(\frac{A_1}{A_2}\right) \times \left(\frac{B_2}{B_1}\right)\right] \times 100$$

where:
D = apparent digestibility of a nutrient (%);
A_1 = nutrient content in the diet (%);
A_2 = nutrient content in feces (%);
B_1 = acid-insoluble ash content in the diet (%);
B_2 = acid-insoluble ash content in feces (%).

1.5 Statistical Analysis

Experimental data were analyzed using one-way ANOVA with SPSS 17.0 software. Duncan' s multiple range test was used for post-hoc comparisons. Results are expressed as "mean ± standard error," with P<0.05 considered statistically significant.

2.1 Effects of SSL on Growth Performance of Piglets

As shown in Table 2 , different SSL supplementation levels had no significant effect on average daily feed intake or average daily gain during either phase (P>0.05). However, compared with the control group, dietary supplementation with 500, 750, and 1,000 mg/kg SSL significantly reduced the feed-to-gain ratio during phase 2 (P<0.05), and the 1,000 mg/kg SSL group exhibited a significantly lower overall feed-to-gain ratio (P<0.05).

Table 2 Effects of SSL on Growth Performance of Piglets

Item	SSL Supplemental Levels (mg/kg)
	0
Initial weight (kg)	7.67±0.22
Phase 1	
Final weight (kg)	11.10±1.28
ADG (g)	164.97±65.46
ADFI (g)	302.28±78.38
F/G	1.94±0.42
Phase 2	
Final weight (kg)	21.34±1.74
ADG (g)	477.59±29.87
ADFI (g)	832.22±83.47
F/G	1.74±0.10[a]
Total phase	
ADG (g)	323.72±45.46
ADFI (g)	568.56±78.28
F/G	1.76±0.12[a]

In the same row, values with different small letter superscripts differ significantly (P<0.05), while values with the same or no superscripts do not differ significantly (P>0.05). This applies to all tables.

2.2 Effects of SSL on Serum Biochemical Indices of Piglets

As presented in Table 3 , on days 21 and 42, the 2,000 mg/kg SSL group exhibited significantly lower serum ALT activity compared with the control group (P<0.05), while other treatment groups showed a decreasing trend without reaching statistical significance (P>0.05). Serum AST activity was significantly reduced only in the 2,000 mg/kg SSL group on day 42 (P<0.05), with no significant differences observed at other supplementation levels (P>0.05). Other biochemical parameters, including TP, ALB, and AKP, showed no significant differences among groups on either day 21 or day 42 (P>0.05).

Table 3 Effects of SSL on Serum Biochemical Indices of Piglets

Item	Time (d)	SSL Supplemental Levels (mg/kg)
		0
TP (g/L)	21	41.31±4.98
	42	55.11±8.25
ALB (g/L)	21	26.96±1.79
	42	32.59±3.34
ALT (U/L)	21	27.62±9.37[a]
	42	18.66±3.71[a]
AST (U/L)	21	17.27±8.00

Item	Time (d)	SSL Supplemental Levels (mg/kg)
	42	11.91±1.79[a]
AKP (U/L)	21	28.44±7.54
	42	22.51±3.20
TBIL (mg/dL)	21	0.26±0.03
	42	0.24±0.04
UN (mmol/L)	21	4.43±0.37
	42	4.55±0.70
CREA (mol/L)	21	89.12±8.06
	42	111.4±14.86

2.3 Effects of SSL on Serum Lipid Metabolism of Piglets

As shown in Table 4 , on day 21, high-level SSL supplementation (1,000 and 2,000 mg/kg) tended to reduce serum TC and TG concentrations, though differences were not significant (P>0.05). On day 42, the 2,000 mg/kg SSL group exhibited significantly higher serum HDL-C content and HDL-C/LDL-C ratio compared with the control group (P<0.05), while serum LDL-C content remained unaffected by SSL supplementation (P>0.05).

Table 4 Effects of SSL on Serum Lipid Metabolism of Piglets

Item	Time (d)	SSL Supplemental Levels (mg/kg)
		0
TC (mmol/L)	21	1.95±0.25
	42	2.14±0.37
TG (mmol/L)	21	0.32±0.12
	42	0.26±0.12
HDL-C (mmol/L)	21	0.72±0.27
	42	1.05±0.20
LDL-C (mmol/L)	21	0.35±0.07
	42	0.37±0.12
HDL-C/LDL-C	21	2.00±1.04
	42	3.16±1.00

2.4 Effects of SSL on Nutrient Apparent Digestibility of Piglets

As presented in Table 5 , dietary SSL supplementation significantly increased crude fat apparent digestibility on day 42 (P<0.05), with levels of 750, 1,000, and 2,000 mg/kg producing significantly higher values than the control and 250 mg/kg groups (P<0.05). The 2,000 mg/kg SSL group also exhibited significantly higher energy apparent digestibility compared with the control group (P<0.05), though no significant differences were observed among other groups (P>0.05).

Similarly, nitrogen apparent digestibility was significantly higher in the 2,000 mg/kg group compared with the control and 250 mg/kg groups (P<0.05).

Table 5 Effects of SSL on Nutrient Apparent Digestibility of Piglets

Item	SSL Supplemental Levels (mg/kg)
	0
Crude fat apparent digestibility (%)	62.83±4.48
Dry matter apparent digestibility (%)	79.78±4.85
Energy apparent digestibility (%)	78.14±3.81
Nitrogen apparent digestibility (%)	76.57±5.97

3.1 Effects of SSL on Growth Performance of Piglets

Emulsifiers can improve feed utilization efficiency and promote growth in piglets. This study found that SSL tended to reduce the feed-to-gain ratio during phase 2 and the overall experimental period, with significant reductions observed at 1,000 mg/kg supplementation. Although SSL did not significantly affect average daily gain or average daily feed intake during either growth phase, it tended to increase these parameters during phase 2 and the overall period, consistent with previous findings. Danek et al. [?] reported that supplementing weaning piglet diets with 0.1% lecithin for 28 days increased average daily gain by 6.7% and reduced the feed-to-gain ratio by 29.2%. Zeng et al. [?] observed that 800 mg/kg emulsifier supplementation significantly reduced the feed-to-gain ratio by 6.99% compared with the control group, though average daily gain remained unaffected. However, emulsifier effects on piglet growth performance have not been entirely consistent. Xing et al. [?] found that adding 0.02% emulsifier (lysophospholipids) to diets containing 5% lard significantly improved average daily gain during phase 2 (days 15-35) but did not improve average daily feed intake or feed-to-gain ratio. De Rodas et al. [?] reported that while emulsifier supplementation increased average daily gain and average daily feed intake during days 7-14, no significant effects were observed during days 1-7, 8-21, or 22-35. Zhao et al. [?] demonstrated that 0.10% lysophospholipid supplementation in beef tallow-based diets improved average daily gain during days 1-14, 15-35, and 1-35, but reduced feed-to-gain ratio only during days 15-35, with no significant effects on average daily feed intake or feed-to-gain ratio during other periods. These discrepancies may be attributed to differences in dietary fatty acid chain length and saturation, as well as variations in emulsifier type, supplementation level, and feeding stage.

3.2 Effects of SSL on Serum Biochemical Indices of Piglets

ALT and AST activities are important indicators of liver function, primarily catalyzing amino acid deamination reactions and reflecting hepatocellular damage and protein utilization capacity [?, ?]. This study found that SSL supplementation tended to reduce serum ALT and AST activities, with the most pronounced effects observed at 2,000 mg/kg. The specific mechanisms underlying SSL' s hepatoprotective effects remain unclear but may be related to enhanced immune function [?].

3.3 Effects of SSL on Serum Lipid Metabolism of Piglets

HDL-C reflects lipid catabolism and transport in the body and indicates hepatic lipid metabolism status, while LDL-C is the primary form for transporting endogenously synthesized cholesterol to peripheral tissues. The HDL-C/LDL-C ratio serves as an indicator of body fat content and is inversely correlated with cardiovascular disease risk [?]. Previous studies on emulsifier effects on serum lipid metabolism have yielded generally consistent but slightly varied results. Won-Tae et al. [?] reported that 5% lecithin supplementation for 28 days significantly reduced serum TC and LDL-C concentrations while increasing TG content. Huang et al. [?] demonstrated that soy lecithin supplementation in broiler diets decreased blood TC and LDL-C concentrations while significantly increasing HDL-C and TG levels. Yang et al. [?] observed that 0.1% lysophospholipid supplementation increased serum free fatty acid and HDL-C concentrations while significantly reducing serum TG and LDL-C concentrations and the HDL-C/LDL-C ratio. Jones et al. [?] found that lecithin supplementation reduced serum LDL-C concentration in piglets, whereas lysophospholipids had the opposite effect. In this study, SSL as an emulsifier significantly increased serum HDL-C concentration and the HDL-C/LDL-C ratio, but only with prolonged supplementation at high levels. These results suggest that SSL' s effects on lipid metabolism may depend on emulsifier type, duration of action, and supplementation level.

3.4 Effects of SSL on Nutrient Apparent Digestibility of Piglets

Reports on emulsifier effects on nutrient apparent digestibility have been inconsistent. Soares et al. [?] found that 10 g/kg lecithin supplementation in soybean oil-based diets for weaning piglets did not significantly affect dry matter, crude protein, or mineral digestibility, a finding echoed by Overland et al. [?] in growing pigs. Conversely, Danek et al. [?] observed that lecithin supplementation in plant fat-based diets for 4 weeks increased crude protein, crude fiber, crude ash, and crude fat digestibility. Zhao et al. [?] reported that 0.05% and 0.10% lysophospholipid supplementation in beef tallow-based diets significantly improved apparent digestibility of dry matter, nitrogen, gross energy, and crude fat during both days 1–14 and 15–35. These discrepancies may be related to emulsifier type and dietary fat source, as Jones et al. [?] found that lecithin or lysophospholipids improved digestibility of soybean oil and beef tallow but not lard. This study also demonstrated that all SSL supplementation levels significantly improved crude fat digestibility, while nitrogen and energy digestibility were significantly enhanced only at 2,000 mg/kg.

In conclusion: (1) Dietary SSL supplementation can improve the feed-to-gain ratio during phase 2 and the overall experimental period, with the most significant effects observed at higher supplementation levels (1,000 mg/kg). (2) Dietary SSL supplementation enhances nutrient apparent digestibility, particularly for crude fat, in weaning piglets.

References

[1] LEWIS D S, OREN S, WANG X, et al. Developmental changes in cholesterol 7alpha- and 27-hydroxylases in the piglet[J]. Journal of Animal Science, 2000, 78(4): 943-951.

[2] POLIN D. Increased absorption of tallow with lecithin[J]. Poultry Science, 1980, 59(7): 1652.

[3] 张华伟, 赵舰. 饲用乳化剂在畜禽饲料中的使用 [J]. 饲料研究, 2007(7): 69-70.

[4] XING J J, VAN HEUGTEN E, LI D F, et al. Effects of emulsification, fat encapsulation, and pelleting on weanling pig performance and nutrient digestibility[J]. Journal of Animal Science, 2004, 82(9): 2601-2609.

[5] DANEK P, PASEKA A, SMOLA J, et al. Influence of lecithin emulsifier on the utilisation of nutrients and growth of piglets after weaning[J]. Czech Journal of Animal Science, 2005, 50(10): 459-465.

[6] 刘辉, 高耀斌. 表面活性剂在食品工业中的应用 [J]. 辽宁化工, 2003, 32(9): 400-401.

[7] BANGKOK ANIMAL RESEARCH CENTER CO., LTD. Effect of SOL-MAX®50 on growth performance of broilers[R]. Bangkok: Bangkok Animal Research Center Co., Ltd., [2015].

[8] 曾丹, 吴先华, 刘桂武, 等. 乳化剂对断奶仔猪生长性能及血清生化指标的影响 [J]. 养猪, 2013(3): 12-13.

[9] DE RODAS B Z, MAXWELL C V, BROCK K S. Exogenous emulsifiers in early weaned pig diets[R]. Oklahoma: Oklahoma State University, 1995.

[10] ZHAO P Y, LI H L, HOSSAIN M M, et al. Effect of emulsifier (lysophospholipids) on growth performance, nutrient digestibility and blood profile in weanling pigs[J]. Animal Feed Science and Technology, 2015, 207: 190-195.

[11] 扈添琴, 韩兆玉, 王群, 等. 酶制剂和植物甾醇复合物对泌乳奶牛生产性能和血清指标的影响 [J]. 动物营养学报, 2014, 26(1): 236-244.

[12] 金宇, 胡宏章. AST/ALT 比值与肝硬化的相关性探讨 [J]. 热带医学杂志, 2011, 11(10): 1144-1146.

[13] 刘兆阳, 王建平, 刘宁. 乳化剂对肉鸡肠道菌群及免疫功能的影响 [J]. 中国畜牧兽医, 2013, 40(8): 60-63.

[14] CASTELLI W P, DOYLE J T, GORDON T, et al. HDL cholesterol and other lipids in coronary heart disease. The cooperative lipoprotein phenotyping study[J]. Circulation, 1977, 55(5): 767-772.

[15] WON-TAE K, PRASHANT S, BYUNGJO C. Effect of lecithin with or without chitooligosaccharide on the growth performance, nutrient digestibility, blood metabolites and pork quality of finishing pigs[J]. Canadian Journal of Animal Science, 2008, 88(2): 283-292.

[16] HUANG J, YANG D D, GAO S D, et al. Effects of soy-lecithin on lipid metabolism and hepatic expression of lipogenic genes in broiler chickens[J]. Livestock Science, 2008, 118(1/2): 53-60.

[17] 杨丹丹, 黄进, 王恬. 日粮中添加溶血卵磷脂对肉仔鸡脂类代谢的影响 [J]. 福建农林大学学报: 自然科学版, 2008, 37(4): 394–398.

[18] JONES D B, HANCOCK J D, HARMON D L, et al. Effects of exogenous emulsifiers and fat sources on nutrient digestibility, serum lipids, and growth performance in weanling pigs[J]. Journal of Animal Science, 1992, 70(11): 3473-3482.

[19] SOARES M, LOPEZ-BOTE C J. Effects of dietary lecithin and fat unsaturation on nutrient utilisation in weaned piglets[J]. Animal Feed Science and Technology, 2002, 95(3/4): 169–177.

[20] OVERLAND M, TOKACH M D, CORNELIUS S G, et al. Lecithin in swine diets: . Growing-finishing pigs[J]. Journal of Animal Science, 1993, 71(5): 1194-1197.

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