*Journal of Animal and Feed Sciences, 35, 1, 2026, e4, https://doi.org/10.22358/jafs/205285/2025*
*The Kielanowski Institute of Animal Physiology and Nutrition, Polish Academy of Sciences, Jabłonna*

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ORIGINAL PAPER

# Effects of micelle herbal extract and coenzyme Q10 on growing-finishing pig performance

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**KEY WORDS:** blood profile, coenzyme Q10, growth performance, growing-finishing pigs, micelle herbal extract

Received: 9 January 2025
Revised: 19 May 2025
Accepted: 19 May 2025

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**ABSTRACT.** A 16-week trial on 160 growing-finishing pigs (initial body weight (BW) 25.20 ± 1 kg) evaluated the effects of 0.05% micelle silymarin (MS), micelle piperine (MP), and micelle coenzyme Q10 (MQ10) supplementation compared to a basal control diet. MP supplementation tended to increase BW by week 16 and improved average daily gain throughout the trial ($P < 0.05$). At week 6, MS and MQ10 significantly reduced aspartate transaminase activity and triglyceride levels ($P < 0.05$), with these decreasess sustained by week 16. MS and MQ10 groups also showed a trend towards lower alanine transaminase activity. The results indicate that while 0.05% MP may offer partial growth benefits, MS and/or MQ10 at the same dosage provide a more comprehensive approach for enhancing both growth performance and liver health in growing-finishing pigs.

## Introduction

Researchers have recently shown interest in using natural feed additives, including herbal medicines to improve livestock growth performance because many of them possess antimicrobial, antioxidant, immunostimulant, and antiparasitic properties. Silymarin, a flavonolignan complex from milk thistle has been widely applied as a functional feed additive due to its antimicrobial, antioxidant, and hepatoprotective properties. Rich in flavonoids and polyphenols, it consists mainly (70–80%) of silybin, along with isosilybin, silychristin, and silydianin (El-Garhy et al., 2016; Bijak, 2017). Sylimarin shows particular efficacy in treating liver disorders (Vargas-Mendoza et al., 2014), and recent findings by Zarenezhad et al. (2023) indicate that silymarin supplementation improves nutrient absorption, intestinal health, and immune function by reducing inflammation. Despite these therapeutic benefits, silymarin use as a dietary supplement is hindered by its poor water solubility, limited oral bioavailability and lipophilic nature, which restrict gastrointestinal absorption (Sornsuvit et al., 2018). To address these limitations, researchers have explored micellar technology as an innovative delivery system. Black pepper (*Piper nigrum* L.), one of the oldest spices used by humans (Yang et al., 2019), has gained scientific interest for its bioactive component – piperine, which demonstrates antibacterial, anti-proliferative, and cholesterol-lowering properties (Damanhouri et al., 2014). Previously, Yan et al. (2011) reported increased growth performance in weanling and growing pigs supplemented with black pepper extract, while EI-Hamss et al. (2003) observed reduced diarrhoea incidence in mice. Although black pepper supplementation showed positive results in pig and mice models, the effects of micelle piperine (MP) on growing-finishing pigs remain unexplored. Therefore, the use of micellized black pepper in livestock diets deserves increased attention given its potential for improving animal health and yielding economic benefits.

Coenzyme Q10 (CoQ10), a natural lipophilic antioxidant, is essential for mitochondrial adenosine triphospate (ATP) synthesis (Geng et al. 2004). Previous broiler studies reported that CoQ10 supplementation (20–40 mg/kg) improved weight gain (Geng et al., 2007; Huang et al., 2011) and reduced lipid peroxidation markers like malondialdehyde (MDA) (Geng et al., 2004).

Based on this literature, we hypothesised that micelle herbal extracts and CoQ10 could enhance pig performance. Considering limited research on micelle CoQ10 in swine diets and lack of existing comparisons between micelle herbal extracts and CoQ10 as dietary additives, this study aimed to evaluate their comparative effects on growth performance, nutrient digestibility, gas emissions, and blood profiles in growing-finishing pigs.

**Table 1.** Basal diet composition for growing-finishing pigs (as-fed basis)

| Item | Growing | Finishing | |
|---|---|---|---|
| | | Phase 1 | Phase 2 |
| Ingredients, % | | | |
| maize | 74.40 | 77.84 | 83.27 |
| soybean meal | 20.16 | 17.56 | 12.35 |
| tallow | 2.09 | 1.74 | 1.61 |
| MDCP | 1.50 | 1.25 | 1.10 |
| limestone | 0.73 | 0.62 | 0.60 |
| salt | 0.20 | 0.10 | 0.10 |
| methionine (99%) | 0.05 | 0.06 | 0.09 |
| lysine (78%) | 0.44 | 0.40 | 0.45 |
| mineral mix[1] | 0.20 | 0.20 | 0.20 |
| vitamin mix[2] | 0.20 | 0.20 | 0.20 |
| choline (25%) | 0.03 | 0.03 | 0.03 |
| total | 100.00 | 100.00 | 100.00 |
| Calculated value | | | |
| crude protein, % | 16.00 | 15.00 | 13.00 |
| metabolizable energy, kcal/kg | 3300 | 3300 | 3300 |
| Ca, % | 0.70 | 0.60 | 0.55 |
| P, % | 0.60 | 0.55 | 0.50 |
| ysine, % | 1.10 | 1.00 | 0.90 |
| methionine, % | 0.30 | 0.30 | 0.30 |
| fat, % | 4.94 | 4.68 | 4.66 |

[1] provided per kg of diet: mg: Fe 100 (as ferrous sulphate), Cu 17 (as copper sulphate), Mn 17 (as manganese oxide), Zn 100 (as zinc oxide), I 0.5 (as potassium iodide), Se 0.3 (as sodium selenite); [2] provided per kg of diet: IU: vit. A 10800, vit. $D_3$ 4000, vit. E 40; mg: vit. $K_3$ 4, vit. $B_1$ 6, vit. $B_2$ 12, vit. $B_6$ 6, vit. $B_{12}$ 0.05, biotin 0.2, folic acid 2, niacin 50, D-calcium pantothenate 25; MDCP – mono-dicalcium phosphate

## Material and methods

The experimental procedures and animal care protocols employed in this study were ethically reviewed and approved by the Institutional Animal Use and Care Committee (IAUAC) of Dankook University, Republic of Korea (Approval No. DK-1-2403). All research activities strictly adhered to the ARRIVE (Animal Research: Reporting of In Vivo Experiments) guidelines, ensuring transparent reporting, ethical treatment, and welfare of the animals involved.

### Trial design, animal housing and feeding regime

A total of 160 [Landrace ×Yorkshire) × Duroc] growing-finishing pigs, with an initial body weight (BW) of 25.20 ± 1 kg, were randomly assigned to 1 of 4 treatment groups (8 replicates/group, 3 barrows and 2 gilts/pen) in a 16-week trial. The dietary treatments included a control group (CON) fed a basal diet formulated according to NRC (2012) requirements, and three experimental groups receiving the basal diet supplemented with 0.05% micelle silymarin (MS), 0.05% MP, or 0.05% micelle coenzyme Q10 (MQ10) (Table 1). The additives were obtained from Synergen Co Ltd (Gyeonggi-do, Republic of Korea). All animals were housed in pens with slatted plastic flooring with *ad libitum* access to feed, and were maintained at 24 °C and 50% relative humidity.

### Sampling and clinical analysis

Performance variables were calculated through individual BW measurements taken at the start of the trial and at weeks 6, 11, and 16 using a GL-6000S scale (G-Tech International, Gyeonggi-do, Republic of Korea). This allowed calculation of average daily gain [(ADG (g/day) = daily gain / feeding days]. Simultaneously, feed consumed, and leftovers (per pen) were recorded to determine average daily feed intake [(ADFI (g/day) = daily feed intake / feeding days] and gain-to-feed ratio [G:F = ADFI (g) / ADG (g)].

Chromium oxide was added to the diet one week prior to faecal sample collection. Directly after mixing, feed samples were collected in sterile plastic bags, transported to the laboratory, and refrigerated. On week 6 and 16, fresh faeces were collected from 2 pigs/pen (1 barrow and 1 gilt) and stored at −20 °C. Prior to chemical analysis, faecal samples were dried at 105 °C for 2 days in a WOF-L800 convection oven (Daehan Scientific Co. Ltd, Wonju-si, Republic of Korea), then ground using a Wiley mill (Thomas Scientific, Chadds Ford Township, PA, USA) fitted with a 1-mm screen. Dry matter content was determined by drying 2-g samples at 80 °C for 24 h and reweighing. For chromium analysis, samples were treated with $KOH/K_2HPO_4$ solution, ashed in a muffle furnace for 3–4 h, then processed with acetone and $H_2SO_4$ before measuring chromium concentration using a UV spectrophotometer. Digestible energy was measured via bomb calorimetry, while nitrogen content was determined using a Kjeldahl analyser. Apparent total tract digestibility was calculated using the standard formula comparing chromium and nutrient concentrations between feed and faecal samples. All analytical procedures followed established AOAC (2006) methods. The apparent total tract digestibility (ATTD) was subsequently calculated using the following equation:

$$\text{ATTD} = [1 - \{(\text{Nf} \times \text{Cd}) / (\text{Nd} \times \text{Cf})\}] \times 100,$$

where: ATTD – apparent total tract digestibility, Nf – nutrient concentration in faeces (% DM), Nd – nutrient concentration in diets (% DM), Cf – chromium concentration in faeces (% DM); and Cd – chromium concentration in diets (% DM).

At the end of the experiment, fresh faecal and urine samples were collected from at least two randomly selected pigs (1 barrow and 1 gilt) per pen. Urine samples were collected to a bucket via a funnel placed below the cage. Subsequently, faecal (150 g) and urine samples from each pen were thoroughly mixed to create slurry. The samples were then sealed in 2.6-l plastic boxes at room temperature (25 °C) for 7 days of anaerobic fermentation. After manual shaking to ensure homogeneity, headspace gas was collected at 100 ml/min, approximately 2.0 cm above the sample surface. Concentrations of ammonia ($NH_3$), hydrogen sulphide ($H_2S$), carbon dioxide ($CO_2$), acetic acid, and total mercaptans were measured with GASTEC detector tubes (GASTEC, Ayase, Japan).

At the end of week 6 and 16, blood samples (5 ml) were collected from two pigs per pen (1 barrow and 1 gilt) using sterile needles and syringes via the anterior vena cava. Samples were aliquoted into labelled tubes containing ethylenediaminetetraacetic acid, transported to the laboratory within 20 min, centrifuged at 3000 *g* for 10 min at 4 °C to obtain plasma, and stored at −20 °C further analysis. Total cholesterol (TC), triglycerides, alanine aminotransferase (ALT), and aspartate transaminase (AST), were analysed using an automated Hitachi F-2700, high fluorescence spectrophotometer (Hitachi, Tokyo, Japan) according to the manufacturer's instructions.

### Data analysis

Experimental data were analysed as a completely randomised block design using the General Linear Model (GLM) procedure implemented in SAS software, with each pen as an experimental unit. Significant differences between treatment groups were determined using Duncan's multiple range test. Statistical significance was set at $P < 0.05$, while trends were considered at $P < 0.1$.

## Results and discussion

Feed provides the primary energy source for livestock, and natural spices are increasingly used to improve animal performance. Yan et al. (2011) and Czech et al. (2009) showed that herbal blends containing black pepper improved growth in pigs, while Zhang et al. (2023) reported higher average daily gain (ADG) with 0.1% micelle silymarin, and Huang et al. (2011) observed better weight gain in broilers supplemented 20–40 mg/kg CoQ10. The present study found that growing-finishing pigs fed a diet containing 0.05% micelle herbal extract and micelle MQ10 tended to show improved body weight ($P < 0.1$) by week 16, and increased ADG during week 11, and

**Table 2.** Effects of micelle herbal extract and coenzyme Q10 supplementation on growth performance in growing-finishing pigs

| Items | Diets | | | | SEM | *P*-value |
|---|---|---|---|---|---|---|
| | CON | MS | MP | MQ10 | | |
| Body weight, kg | | | | | | |
| Initial | 25.20 | 25.21 | 25.21 | 25.21 | 0.24 | 1.000 |
| Week 6 | 54.19 | 55.81 | 56.08 | 55.48 | 0.38 | 0.325 |
| Week 11 | 81.16 | 84.61 | 85.17 | 83.78 | 0.65 | 0.131 |
| Week 16 | 111.38 | 117.70 | 118.73 | 116.31 | 1.05 | 0.051 |
| Initial – Week 6 | | | | | | |
| ADG, g | 690 | 729 | 735 | 721 | 7.20 | 0.124 |
| ADFI, g | 1656 | 1709 | 1720 | 1697 | 10.53 | 0.154 |
| G:F | 0.417 | 0.426 | 0.427 | 0.424 | 0.001 | 0.180 |
| Week 6–11 | | | | | | |
| ADG, g | 770 | 823 | 831 | 809 | 8.87 | 0.068 |
| ADFI, g | 2319 | 2381 | 2390 | 2362 | 14.91 | 0.348 |
| G:F | 0.333 | 0.345 | 0.347 | 0.342 | 0.002 | 0.199 |
| Week 11–16 | | | | | | |
| ADG, g | $863^{b}$ | $945^{ab}$ | $959^{a}$ | $929^{ab}$ | 12.03 | 0.017 |
| ADFI, g | 2954 | 3050 | 3046 | 3041 | 21.97 | 0.362 |
| G:F | 0.293 | 0.310 | 0.315 | 0.306 | 0.003 | 0.173 |
| Overall | | | | | | |
| ADG, g | $769^{b}$ | $826^{ab}$ | $835^{a}$ | $813^{ab}$ | 9.19 | 0.049 |
| ADFI, g | 2269 | 2338 | 2344 | 2325 | 12.51 | 0.127 |
| G:F | 0.339 | 0.353 | 0.356 | 0.350 | 0.002 | 0.136 |

CON – control, basal diet, MS – CON diet supplemented with 0.05% micelle silymarin, MP – CON diet supplemented with 0.05% micelle piperine, MQ10 – CON diet supplemented with 0.05% micelle coenzyme Q10; ADG –average daily gain, ADFI – average daily feed intake, G:F – gain-to-feed ratio, SEM – standard error of the mean; $^{ab}$ – means within a row with different superscripts are significantly different at $P < 0.05$

16, as well as over the entire experimental period compared to controls ($P < 0.05$; Table 2). The current findings were consistent with results of Grela et al. (2020) and Dang et al. (2022), who observed significant effects on growth performance in weaning and growing pigs, respectively, following the inclusion of *Silybum marianum* seed extracts. On the other hand, while Sampath et al. (2020) reported linear increases in pig BW, ADG, and G:F with black pepper extract, our study found no significant difference in daily feed intake or gain-to-feed ratio with either micelle herbal extract or MQ10. We speculate that these discrepancies may be due to variations in pig age, breed, sex, additive dosage, or feed formulation.

**Table 3.** Effects of micelle herbal extract and coenzyme Q10 supplementation on nutrient digestibility in growing-finishing pigs

| Items, % | Diets | | | | SEM | *P*-value |
|---|---|---|---|---|---|---|
| | CON | MS | MP | MQ10 | | |
| Week 6 | | | | | | |
| dry matter | 78.70 | 79.32 | 79.67 | 79.22 | 0.19 | 0.380 |
| nitrogen | 75.44 | 76.24 | 76.43 | 76.02 | 0.26 | 0.633 |
| energy | 77.49 | 78.24 | 78.38 | 78.11 | 0.19 | 0.443 |
| Week 16 | | | | | | |
| dry matter | 71.86 | 72.22 | 72.49 | 72.16 | 0.12 | 0.415 |
| nitrogen | 68.85 | 69.97 | 70.24 | 69.69 | 0.20 | 0.074 |
| energy | 70.23 | 71.06 | 71.34 | 70.90 | 0.16 | 0.105 |

CON – control, basal diet, MS – CON diet supplemented with 0.05% micelle silymarin, MP – CON diet supplemented with 0.05% micelle piperine, MQ10 – CON diet supplemented with 0.05% micelle coenzyme Q10, SEM – standard error of the mean; $P > 0.05$ (not statistically significant)

At the end of week 16, pigs fed the MP diet showed no effect on N digestibility compared to CON and MQ10 groups (Table 3). This contrasts with previous findings where 0.1–0.2% micelle silymarin (MS) improved N digestibility in fattening pigs (Zhang et al., 2013) and 0.04–0.06% MS increased nutrient digestibility in broilers (Shanmugam et al., 2022). Sampath et al. (2020) found that black pepper extract supplementation linearly increased only DM digestibility. In the present study, pigs fed diets supplemented with neither 0.05% micelle herbal extract nor MQ10 showed differences in DM and E digestibility, which aligned with findings of Dang et al. (2022), who observed similar results in weanling pigs supplemented with *Silybum* seed extracts. These variations in nutrient utilisation may be attributed to factors such as intestinal microbiota composition, gut barrier function, duration of supplementation, or the health status of individual pigs.

$NH_3$ and $H_2S$ emissions from swine farms represent significant environmental and health concerns, affecting both air quality, as well as farm workers and animal welfare (Zhang et al., 2014; Sampath et al., 2020). Elevated concentrations of these gases are often associated with reduced nutrient digestibility, as undigested nutrients serve as substrates for microbial fermentation in the hindgut (Liu et al., 2020). However, in this study, no significant differences in $NH_3$ and $H_2S$ emissions were observed between experimental groups (Table 4). This outcome may be linked to the physiological effects of the supplements MS may enhance liver function and promote ammonia detoxification, while MQ10 may support nitrogen metabolism and microbial nitrogen retention, lowering urea excretion. Additionally, both additives may have lowered urease activity in manure, thereby limiting $NH_3$ volatilisation. However, the precise mechanism underlying these observations remain unclear and require further research.

**Table 4.** Effects of micelle herbal extract and coenzyme Q10 supplementation on gas emissions in growing-finishing pigs

| Items, ppm | Diets | | | | SEM | *P*-value |
|---|---|---|---|---|---|---|
| | CON | MS | MP | MQ10 | | |
| Week 6 | | | | | | |
| $NH_3$ | 8.75 | 8.38 | 8.25 | 8.50 | 0.11 | 0.510 |
| $H_2S$ | 6.83 | 6.08 | 5.95 | 6.33 | 0.25 | 0.669 |
| methyl mercaptan | 7.38 | 6.88 | 6.75 | 7.00 | 0.28 | 0.905 |
| acetic acid | 8.50 | 7.88 | 8.25 | 8.13 | 0.31 | 0.935 |
| $CO_2$ | 14650 | 13850 | 14125 | 14050 | 257.50 | 0.765 |
| Week 16 | | | | | | |
| $NH_3$ | 11.75 | 10.63 | 10.38 | 10.75 | 0.46 | 0.773 |
| $H_2S$ | 8.23 | 7.28 | 6.98 | 7.63 | 0.31 | 0.590 |
| methyl mercaptan | 9.63 | 8.88 | 8.38 | 8.63 | 0.46 | 0.833 |
| acetic acid | 11.38 | 10.13 | 11.13 | 10.63 | 0.59 | 0.907 |
| $CO_2$ | 16225 | 15425 | 15600 | 15225 | 247.35 | 0.558 |

CON – control, basal diet, MS – CON diet supplemented with 0.05% micelle silymarin, MP – CON diet supplemented with 0.05% micelle piperine, MQ10 – CON diet supplemented with 0.05% micelle coenzyme Q10, SEM – standard error of the mean; $P > 0.05$ (not statistically significant)

Silymarin has been traditionally used in Chinese medicine to treat liver diseases. In this study, MS and CoQ10 supplementation resulted in significant ($P < 0.05$) reductions in triglyceride levels by week 6, indicating early improvement in liver function. The concomitant reduction in AST activity, sensitive marker of hepatocellular damage, indicates preserved hepatic integrity in supplemented animals. The significant triglyceride level reduction is particularly clinically relevant, as hypertriglyceridaemia frequently accompanies hepatic dysfunction and metabolic conditions like fatty liver disease. These findings suggest that MS and MQ10 effectively supported hepatic lipid metabolism, crucial for cholesterol and triglyceride homeostasis. At the end of week 16, both MS and MQ10-treated groups maintained these hepatoprotective benefits, showing sustained reductions ($P < 0.05$) in AST activity and triglyceride concentrations, with a trend toward improved ALT marker values. These findings are consistent with Feher et al. (2007), who recorded reduced serum cholesterol and triglyceride concentrations in supplemented with CoQ10. This compound is known for its antioxidant properties and role in mitochondrial energy production, which may support liver function and lipid metabolism, contributing to reduced lipid levels. However, contrasting results were reported by Hossain et al. (2023), who found no significant effect of MS supplementation on ALT and AST activity in pigs, suggesting species-specific responses or variations due to diet, dosage, or metabolic state. These discrepancies could also stem from differences in study duration or animal models. Additionally, it should be noted that while ALT and AST are reliable indicators of liver health, they represent only partial measures of liver function. Therefore, additional research is needed to clarify the mechanisms involved and to confirm the hepatoprotective potential of MS and CoQ10 in swine.

## Conclusions

The inclusion of 0.05% micelle herbal extract and coenzyme (CoQ10) in pig diets positively affected growth performance, as evidenced by increased body weight and average daily gain. Additionally, pigs receiving micellar silymarin (MS) and micellar CoQ10 (MQ10) showed significant reductions in liver enzyme markers (alanine aminotransferase, aspartate transaminase) and triglyceride levels, indicating a protective effect on liver function. These results suggest that while 0.05% micelle piperine provide moderate benefits for growth, MS and/or MQ10 supplementation at same dosage offers a more comprehensive and effective approach for enhancing both growth performance and liver health in growing-finishing pigs.

## Acknowledgements

This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-RS-2023-00275307) and by the Korea Institute of Planning and Evaluation for Technology in Food, Agriculture and Forestry (IPET) through the Agricultural Microbiome R&D Programme for Advancing Innovative Technology, funded by the Ministry of Agriculture, Food and Rural Affairs (MAFRA) (RS-2024-00403477409821194201 01).

## Conflict of interest

The Authors declare that there is no conflict of interest.

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