Research Article

Probiotic Potential of Cabbage Sauerkraut in Drinking Water: Impacts on Growth Performance and Meat Quality in Peking Ducks

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Abstract | Sauerkraut is a source of lactic acid bacteria from fermented cabbage that is inexpensive, easy to produce, and has potential as a natural probiotic for livestock. This study aimed to determine the effect of adding cabbage sauerkraut liquid (*Brassica oleracea* L.) to drinking water on the growth performance and meat quality of Peking ducks. This study used a completely randomized design with four treatments and five replications. The treatments consisted of sauerkraut liquid supplementation in drinking water at the following levels: P1: 0 mL sauerkraut liquid/L drinking water; P2: 1 mL sauerkraut liquid/L drinking water; P3: 2 mL sauerkraut liquid/L drinking water; and P4: 3 mL sauerkraut liquid/L drinking water. The observed variables were growth performance, including body weight gain, feed consumption, and feed conversion ratio (FCR), and meat quality, including water-holding capacity, cooking loss, and meat pH. The results showed that sauerkraut liquid supplementation through drinking water had a significant effect ($P < 0.05$) on growth performance but had no significant effect ($P > 0.05$) on meat quality parameters. The addition of sauerkraut liquid up to 3 mL/L in drinking water improved the growth performance of Peking ducks, particularly body weight gain and FCR, but did not significantly affect meat quality. The best growth performance was observed in P4, with body weight gain of 1714.44 g, feed consumption of 3841.52 g, and FCR of 2.25. In the same treatment, water-holding capacity, cooking loss, and meat pH were 33.84%, 34.52%, and 6.05, respectively, although these meat quality parameters were not significantly affected by treatment. The results showed that supplementation of sauerkraut liquid through drinking water significantly affected growth performance ($P < 0.05$), but had no significant effect on meat quality parameters ($P > 0.05$). Supplementation at up to 3 mL/L improved the growth performance of Peking ducks, particularly body weight gain and feed conversion ratio (FCR), without significantly affecting meat quality. The best growth performance was observed in P4, which recorded a body weight gain of 1714.44 g, feed consumption of 3841.52 g, and an FCR of 2.25. In P4, water-holding capacity, cooking loss, and meat pH were 33.84%, 34.52%, and 6.05, respectively; however, these parameters did not differ significantly among treatments. Sauerkraut liquid supplementation at 3 mL/L may therefore serve as a simple and practical natural probiotic approach for improving the growth performance of Peking ducks without compromising meat quality.

Keywords | Sauerkraut, Probiotics, Fermented cabbage, Peking duck, Growth performance, Meat quality

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INTRODUCTION

Meat is widely consumed because of its palatability and high nutritional value. Besides chicken, duck meat is one of the animal protein sources with potential for further development in Indonesia. Ducks play an important role in producing both eggs and meat, although their contribution as meat-producing poultry remains

lower than that of chickens (Nuningtyas *et al*., 2026). However, duck meat production has continued to increase over time. Duck farming is promising because ducks have good adaptability, relatively high disease resistance, and the ability to efficiently convert feed into meat. Among meat-type ducks, Peking ducks are increasingly popular due to their rapid growth rate and superior carcass characteristics compared with local ducks. Under intensive management, Peking ducks can reach approximately 3 kg body weight at 8 weeks of age (Do *et al*., 2023).

Feed is one of the most important factors affecting poultry production, as feed costs may account for 60–70% of total production costs (Trisna *et al*., 2026). Several strategies have been applied to improve feed efficiency and reduce the feed conversion ratio (FCR), including improving feed quality and using feed additives such as antibiotics (Ipçak and Denli, 2024). Antibiotics have been widely used in the poultry industry to suppress pathogenic microbes and improve meat and egg production. However, inappropriate and long-term use of antibiotics may increase bacterial resistance, leave antibiotic residues in poultry products, and disturb the balance of normal intestinal microflora (Gomaa *et al*., 2025; Abou-Jaoudeh *et al*., 2024). Therefore, alternative natural additives, particularly probiotics, are increasingly being explored as substitutes for antibiotic growth promoters in poultry production.

Probiotics are live microorganisms that, when administered in adequate amounts, provide beneficial effects to the host by supporting gut health, improving resistance to intestinal pathogens, and enhancing nutrient utilization (Ismael *et al*., 2023; Naeem and Bourassa, 2025). Probiotics can be produced through the fermentation of plant or vegetable materials such as cabbage. Cabbage is a vegetable from the genus Brassica, belonging to the species *Brassica oleracea* L. (Stelmach *et al*., 2024). Cabbage is nutritionally valuable but highly perishable; therefore, fermentation can be used to extend its shelf life and produce a distinctive fermented product known as sauerkraut. Sauerkraut fermentation is associated with the development of lactic acid bacteria (LAB), which may have probiotic potential (Zabat *et al*., 2018). The sauerkraut liquid used in the present study contained 5.9×10^9 CFU/mL of LAB, while *E. coli* and *Salmonella* spp. were not detected, indicating its potential as a natural source of probiotics (Laboratory Analysis of Nutrition and Feed Technology, 2024).

Lactic acid bacteria are among the microorganisms that can act as probiotics by improving livestock health, supporting intestinal microbial balance, increasing productive performance, and reducing pathogenic microorganisms in poultry (Liu *et al*., 2025). The use of LAB-based probiotics in ducks has also been reported to improve feed efficiency and carcass-related parameters when administered through drinking water (Chandra *et al*., 2022). In addition, sauerkraut liquid has been reported to improve broiler chicken performance. Hasanah and Sopandi (2017) reported that administering sauerkraut liquid in broiler drinking water at a concentration of 1.5 mL/L increased body weight by 17.3%, reduced feed consumption, and decreased FCR by 23.5%. The reduction in feed consumption and FCR, as well as the increase in feed efficiency, may be related to the role of LAB in increasing beneficial bacteria in the poultry intestine. Probiotics from sauerkraut liquid are expected to suppress pathogenic bacteria in poultry. According to Abdurrahman and Yanti (2018), reducing pathogenic bacteria can improve nutrient absorption in livestock and may contribute to better growth performance and meat quality.

Although probiotic supplementation has been widely studied in poultry, the specific use of cabbage sauerkraut-derived probiotics in drinking water for Peking ducks remains limited. Most previous studies have focused on commercial probiotic preparations, broiler chickens, or general LAB-based probiotics, while information on locally produced sauerkraut liquid as a natural LAB source for Peking duck production is still scarce. Therefore, the novelty of this study lies in evaluating sauerkraut liquid derived from fermented cabbage as an inexpensive natural probiotic supplement in drinking water and assessing its effects on both growth performance and meat quality of Peking ducks. Based on this gap, this study was conducted to determine the effect of adding sauerkraut liquid to drinking water on the performance and meat quality of Peking ducks.

MATERIALS AND METHODS

Animal ethics

The animal-use protocol for this study was reviewed and approved by the Animal Research Ethics Committee of the Faculty of Mathematics and Natural Sciences, Universitas Sumatera Utara (AREC), under approval number 0870/KEPH-FMIPA/2025.

Research materials

The materials used in this study included sauerkraut liquid supplemented into the drinking water of Peking ducks. A total of 100 one-day-old male Peking ducks were used in this experiment. The feed ingredients used were commercial CP 511, rice bran, and coconut oil.

The cages used in this study consisted of 20 units, each measuring 60 × 70 × 40 cm and housing five ducks. Other equipment used included digital scales for weighing ducks and feed residues, excreta collection containers, electric

lamps for lighting and brooding, a thermometer, feed troughs, and drinking water containers.

Experimental design

This study was conducted using an experimental method with a Completely Randomized Design (CRD), consisting of four treatments and five replications. Each experimental unit consisted of five ducks. The treatments were four levels of sauerkraut liquid administration through drinking water, as follows:

- P1: 0 mL sauerkraut liquid/L drinking water
- P2: 1 mL sauerkraut liquid/L drinking water
- P3: 2 mL sauerkraut liquid/L drinking water
- P4: 3 mL sauerkraut liquid/L drinking water

The experimental period lasted from one-day-old ducklings (DOD) to 8 weeks of age. Sauerkraut liquid was administered daily through drinking water according to the treatment levels. Feed and drinking water were provided *ad libitum* throughout the experimental period. The sauerkraut drinking solution was prepared fresh daily to maintain the quality of the drinking water and probiotic preparation.

Research procedure

1. Sauerkraut liquid production

Sauerkraut liquid was prepared using cabbage as the raw material. The cabbage was wilted overnight, and the outer leaves, damaged parts, and core were removed. The cabbage was then washed thoroughly and sliced thinly to approximately 2–3 mm, while avoiding the leaf veins as much as possible. The sliced cabbage was mixed with salt at 2.5% of cabbage weight, followed by the addition of sugar at 3.5% of cabbage weight. The mixture was stirred until homogeneous and then transferred into a jar while being pressed firmly to create compact conditions. The jar was covered with plastic and sealed tightly with a lid to prevent air entry. The mixture was fermented for 7 days at room temperature. After fermentation, the sauerkraut liquid was collected, stored under refrigerated conditions, and administered to Peking ducks through drinking water according to the treatment levels (Ari at al., 2024).

A microbiological analysis of the sauerkraut liquid showed that it contained 5.9×10^9 CFU/ml of LAB, while pathogenic bacteria such as *E. coli* and *Salmonella* sp. were not detected (Laboratory Analysis of Nutrition and Feed Technology, 2024). However, strain-level identification of LAB and repeated viability testing during the administration period were not performed in this study.

Research ration formulation

The ration formulation was calculated based on the feed ingredient composition and nutrient content presented in Tables 1 and 2 to meet the nutritional requirements of Peking ducks. The research rations are presented in Table 3.

Table 1: Nutrient composition and metabolizable energy of feed ingredients used in the ration.

Feed ingredients	Nutritional content					
	Crude protein (%)	Crude fat (%)	Crude fiber (%)	Calcium (%)	Phosphorus (%)	Metabolizable energy (kcal/kg)
CP 511*	21.50	5.00	5.00	0.90	0.60	3,025.00
Rice Bran	9.50	5.09	14.50	0.69	0.26	1,630.00
Vegetable oil	0.00	100.00	0.00	0.00	0.00	8,600.00

* CP 511 (commercial feed).

Table 2: Composition of feed ingredients (%).

Feed ingredients	Percentage
CP 511*	80.85
Rice Bran	17.10
Coconut Oil	2.05

* CP 511 (commercial feed).

Table 3: Nutrient content and metabolizable energy of the research ration*.

Nutrients	Content
Crude Protein	19.01 %
Crude Fat	6.96 %
Crude Fiber	6.52 %
Calcium	0.85 %
Phosphorus	0.53 %
Metabolizable Energy	2900.00 kcal/kg

*Calculation from **Tables 1** and **2**.

Duck placement and treatment randomization

The cages were numbered from 1 to 20, and the treatments were randomly assigned to the cage units. Before placement, ducklings were weighed to obtain the initial body weight. The ducklings were then distributed into numbered cage units, with each unit containing five birds.

Housing, environmental management and sanitation

All ducks were reared under the same management conditions during the experimental period. The cages were equipped with feeding and drinking facilities, electric lamps for lighting and brooding, and adequate ventilation. During the brooding period, supplemental heating was provided using electric lamps, and the temperature was monitored using a thermometer. Before the arrival of ducklings, the barn was cleaned and fumigated, and the feeding and drinking equipment were sterilized. During the experiment, cages, feed troughs, and drinking water

containers were cleaned regularly. Manure was removed daily to reduce ammonia accumulation and maintain bird health.

Mortality and probiotic intake recording

Mortality was recorded daily throughout the experimental period. However, the actual intake of sauerkraut liquid per bird was not directly measured because drinking water was provided *ad libitum* at the cage level. Therefore, the probiotic dose was expressed as the concentration of sauerkraut liquid in drinking water (mL/L).

Research variables

Peking duck performance

Peking duck performance was observed to evaluate the effect of sauerkraut liquid as a probiotic supplement in drinking water. The observed performance variables were: (a) body weight gain, calculated by subtracting the initial body weight from the final body weight; (b) feed consumption, calculated by subtracting the remaining feed from the amount of feed offered; and (c) feed conversion ratio (FCR), calculated by dividing feed consumption by body weight gain.

Quality of peking duck meat

The meat quality variables observed in this study were meat pH, water-holding capacity, and cooking loss. Meat pH was measured using an electronic pH meter. Cooking loss was calculated by subtracting the final weight of meat after cooking from its initial weight, dividing the result by the initial weight, and multiplying by 100%.

Data analysis

Data were analyzed using analysis of variance (ANOVA) according to the Completely Randomized Design (CRD) as described by Steel and Torrie (1995). When significant differences among treatments were detected, treatment means were further compared using Duncan's Multiple Range Test (DMRT). Data are presented as mean ± standard deviation (SD), and exact P-values are shown in the tables. Differences were considered statistically significant at $P < 0.05$.

RESULTS

Effect of treatment on peking duck performance

The growth performance of Peking ducks supplemented with sauerkraut liquid through drinking water is presented in Table 4. Sauerkraut liquid supplementation had a significant effect on body weight gain ($P = 0.0024$), feed consumption ($P = 0.0003$), and FCR ($P = 0.0011$). Ducks receiving 3 mL/L sauerkraut liquid (P4) showed the highest body weight gain and the lowest FCR compared with the other treatments. These results indicate that sauerkraut liquid supplementation through drinking water improved growth performance and feed utilization efficiency in Peking ducks.

Effect of treatment on the quality of peking duck meat

The effect of sauerkraut liquid supplementation through drinking water on the meat quality of Peking ducks is presented in Table 5. Sauerkraut liquid supplementation had no significant effect on meat pH ($P= 0.0534$), water-holding capacity ($P= 0.2687$), and cooking loss ($P= 0.1608$). These results indicate that sauerkraut liquid supplementation up to 3 mL/L did not significantly alter the physical quality of Peking duck meat.

DISCUSSION

The body weight gain of Peking ducks supplemented with sauerkraut liquid through drinking water is presented in Table 4. Body weight gain ranged from 1,532.68 to 1,714.44 g, with the highest value observed in P4 (3 mL/L sauerkraut liquid). This result suggests that sauerkraut liquid supplementation may improve the growth performance of Peking ducks. This improvement may also indicate that the active components in sauerkraut liquid, particularly LAB and fermentation metabolites, contributed to a more favorable intestinal environment. A healthier intestinal condition may increase the efficiency of nutrient digestion and absorption, allowing ducks to achieve better growth even with relatively lower feed consumption. Probiotics administered through feed or drinking water have been reported to improve growth performance by enhancing digestive efficiency and nutrient absorption (Mangisah and Suthama, 2022; Rodríguez *et al.*, 2024). In addition, probiotics may survive in the digestive tract, adhere to intestinal epithelial cells, and help suppress pathogenic microorganisms, thereby supporting intestinal health and feed utilization (Melara *et al.*, 2022; Aleman and Yadav, 2023; Karimi and Hosseinzadeh, 2024).

Feed consumption of Peking ducks supplemented with sauerkraut liquid through drinking water is presented in Table 4. Feed consumption ranged from 3,841.52 to 3,863.12 g, with lower feed consumption observed in P4 compared with the control treatment. This reduction may indicate improved nutrient utilization rather than reduced nutrient availability, because ducks in P4 consumed less feed but achieved higher body weight gain. In poultry production, lower feed consumption is beneficial only when it is accompanied by maintained or improved body weight gain. In the present study, the lower feed consumption in P4 was accompanied by the highest body weight gain, suggesting that sauerkraut liquid supplementation may improve the efficiency of nutrient use rather than

Table 4: Effect of sauerkraut liquid supplementation through drinking water on the growth performance of Peking ducks.

Variabels	Treatment				P value
	P1 (0 mL/L)	P2 (1 mL/L)	P3 (2 mL/L)	P4 (3 mL/L)	
Body weight Gain (g)	1532.68 ± 57.90^{c}	1601.80 ± 59.64^{b}	1617.60 ± 15.94^{b}	1714.44 ± 88.65^{a}	0.0024
Feed consumption (g)	3863.12 ± 1.47^{a}	3853.56 ± 4.32^{b}	3851.80 ± 3.90^{b}	3841.52 ± 10.17^{c}	0.0003
Feed conversion ratio (FCR)	2.52 ± 0.10^{a}	2.41 ± 0.09^{b}	2.38 ± 0.03^{b}	2.25 ± 0.11^{c}	0.0011

Note: Values are presented as mean ± SD (n = 5). Different superscript letters within the same row indicate significant differences among treatments based on Duncan's Multiple Range Test (DMRT) at $P < 0.05$. P1 = 0 mL sauerkraut liquid/L drinking water; P2 = 1 mL sauerkraut liquid/L drinking water; P3 = 2 mL sauerkraut liquid/L drinking water; P4 = 3 mL sauerkraut liquid/L drinking water. FCR = feed conversion ratio.

Table 5: Effect of sauerkraut liquid supplementation through drinking water on the meat quality of Peking ducks

Variabels	Treatment				P-value
	P1 (0 mL/L)	P2 (1 mL/L)	P3 (2 mL/L)	P4 (3 mL/L)	
Meat pH	6.00 ± 0.05	6.07 ± 0.04	6.06 ± 0.02	6.05 ± 0.05	0.0534
Water-holding capacity (%)	32.56 ± 1.19	33.06 ± 1.23	33.64 ± 0.62	33.84 ± 1.16	0.2687
Cooking loss (%)	32.34 ± 0.18	34.48 ± 1.32	34.08 ± 2.89	34.52 ± 0.82	0.1608

Note: Values are presented as mean ± SD (n = 5). The treatments showed no significant effect on meat pH, water-holding capacity, and cooking loss ($P > 0.05$). P1 = 0 mL sauerkraut liquid/L drinking water; P2 = 1 mL sauerkraut liquid/L drinking water; P3 = 2 mL sauerkraut liquid/L drinking water; P4 = 3 mL sauerkraut liquid/L drinking water.

suppressing feed intake in a negative manner. Sauerkraut liquid contains LAB, which may produce metabolites and enzymes that help optimize digestion in the small intestine. The enzymes produced by probiotics can aid in nutrient digestion and absorption, thereby minimizing nutrient loss through feces and improving feed efficiency (Mahesh *et al.*, 2021). Similar findings were reported by Purwati *et al.* (2019), who stated that probiotic dosage may influence feed consumption and feed efficiency in male ducks.

The FCR of Peking ducks supplemented with sauerkraut liquid through drinking water is presented in Table 4. The FCR values ranged from 2.25 to 2.52, with the lowest FCR observed in P4 (3 mL/L sauerkraut liquid). A lower FCR indicates that ducks were more efficient in converting feed into body weight gain. This finding is important because FCR is one of the main indicators of production efficiency in poultry. A lower FCR means that less feed is required to produce the same or greater body weight gain, which may contribute to more efficient duck production. This improvement may be related to better digestibility and nutrient utilization due to probiotic supplementation. Probiotics added to duck feed or drinking water can improve digestive function, increase feed utilization efficiency, and ultimately reduce FCR (Ahmed *et al.*, 2018; Subekti and Hastuti, 2015). The FCR values in this study were comparable to those reported by Subekti and Hastuti (2015), who found FCR values of 2.04–2.40 in ducks supplemented with herbal probiotics for 6 weeks.

The meat pH of Peking ducks supplemented with sauerkraut liquid through drinking water is presented in Table 5. Meat pH values ranged from 6.00 to 6.07 and were not significantly different among treatments. This indicates that sauerkraut liquid supplementation up to 3 mL/L did not significantly alter meat pH compared with P1 (0 mL/L), and all pH values remained within the normal range for meat. The similarity in meat pH among treatments may be related to similar slaughter age, pre-slaughter handling, and muscle glycogen conditions among ducks. Meat pH is an important indicator of postmortem muscle metabolism and is closely related to meat quality attributes such as tenderness, flavor, water-holding capacity, and cooking loss (Khatri and Huff-Lonergan, 2023). The average meat pH in this study was also comparable to the results of Dyah *et al.* (2016) and Huda and Ahmad (2011), who reported normal pH values in duck meat.

The water-holding capacity of Peking duck meat after sauerkraut liquid supplementation through drinking water is presented in Table 5. Water-holding capacity ranged from 32.56 to 33.84% and was not significantly different among treatments. This result may be explained by the relatively stable meat pH values observed in this study, because water-holding capacity is strongly influenced by the rate and extent of postmortem pH decline. When pH values remain within a normal range, major differences in water retention may not occur. Previous studies have also reported that water-holding capacity is closely associated with meat pH and protein-water interactions in muscle tissue (Zhang *et al.*, 2020; Tan *et al.*, 2021; Igarashi and Muramoto, 2023; Ji *et al.*, 2024).

Cooking loss of Peking duck meat after sauerkraut liquid supplementation through drinking water is presented in Table 5. Cooking loss ranged from 32.34 to 34.52% and was not significantly affected by the treatment. The absence of significant changes in cooking loss may be related to the stable meat pH and water-holding capacity values among treatments. Cooking loss is influenced by several factors, including pH, water-holding capacity, sarcomere length, muscle fiber characteristics, sample size, cooking temperature, and cooking duration (Vaskoska, 2024). According to Barbut (2024), higher water-holding capacity can reduce fluid loss during cooking. Rodrigues *et al*. (2024) also stated that cooking loss is an important meat quality indicator because it reflects the amount of water and nutrients lost during heating. The absence of significant changes in meat quality parameters may also indicate that sauerkraut liquid primarily influenced digestive efficiency and growth performance rather than postmortem physical characteristics of meat. This suggests that the supplementation level used in this study was still within a safe range for maintaining normal meat quality. Therefore, the present findings indicate that sauerkraut liquid supplementation improved growth performance without negatively affecting the physical quality of Peking duck meat.

However, this study has limitations regarding the microbiological characterization of the sauerkraut liquid and probiotic intake estimation. Although the LAB count and the absence of pathogenic bacteria were reported, the LAB were not identified at the strain level, and repeated viability testing during the administration period was not conducted. In addition, the actual intake of sauerkraut liquid per bird was not directly measured because drinking water was provided *ad libitum* at the cage level. Therefore, further studies are needed to identify the dominant LAB strains, evaluate probiotic viability during storage and administration, determine the consistency of sauerkraut liquid as a probiotic preparation, and estimate the exact probiotic intake per bird.

CONCLUSION

The addition of sauerkraut liquid up to 3 mL/L in drinking water improved the growth performance of Peking ducks, as indicated by increased body weight gain, reduced feed consumption, and improved FCR. However, sauerkraut liquid supplementation did not significantly affect meat quality parameters, including water-holding capacity, cooking loss, and meat pH. The best growth performance was observed in P4 (3 mL/L), with body weight gain of 1714.44 g, feed consumption of 3841.52 g, and FCR of 2.25. These findings suggest that sauerkraut liquid has potential as a probiotic alternative to antibiotic growth promoters in supporting Peking duck performance.

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NOVELTY STATEMENT

This study provides new evidence on the use of cabbage sauerkraut liquid as a natural lactic acid bacteria-based probiotic administered through drinking water in Peking ducks. Unlike previous studies that primarily focused on commercial probiotics, broiler chickens, or general LAB preparations, this study simultaneously evaluates its effects on growth performance and meat quality. Supplementation at up to 3 mL/L improved body weight gain and feed conversion ratio without adversely affecting the physical quality of Peking duck meat.

AUTHOR'S CONTRIBUTION

AT, AN, EJ, and MA conceived and designed the experiment. MA conducted the study and performed statistical analyses of the experimental data. AT, EJ, and AN supervised and coordinated the experiments, providing guidance on experimental activities. MA prepared the initial draft of the manuscript. All authors critically revised the manuscript and approved the final version.

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Data availability

Data are available upon request.

Ethical statement

All experimental animals were housed at the Faculty of Animal Science farm, Universitas Sumatera Utara. Furthermore, all procedures were carried out in accordance with the guidelines established by the Animal Research Ethics Committee of the Faculty of Mathematics and Natural Sciences, Universitas Sumatera Utara, under approval number 0870/KEPH-FMIPA/2025.

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Conflict of interest

The authors have declared no conflict of interest.

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