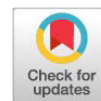


Research Article



Functional Feed Development from a Mixture of Fermented Copra Meal and Soybean Curd Residue Using *Bacillus amyloliquefaciens* to Enhance Peking Duck Performance

WIZNA^{1*}, RUSFIDRA², YULIATY SHAFAN NUR¹, FAJRI MAULANA³, ROMI ANDIKA⁴, SATRI YUSASRA AGASI³, SHINTHIA RAHMI⁵, MUTIA NABILA⁵

¹Department of Animal Feed and Technology, Faculty of Animal Science, Universitas Andalas, Padang 25163, Indonesia; ²Department of Technology and Livestock Production, Faculty of Animal Science, Universitas Andalas, Padang 25163, Indonesia; ³Department of Agricultural Industrial Technology, Study Program of Animal Feed Technology, Politeknik Negeri Tanah Laut, Tanah Laut 70815, Indonesia; ⁴Graduate student Faculty of Animal Science, Universitas Andalas, Padang 25163, Indonesia; ⁵Student Faculty of Animal Science, Universitas Andalas, Padang, Indonesia.

Abstract | This study aimed to evaluate the potential of *Bacillus amyloliquefaciens* in developing a functional feed ingredient produced from a Mixture of Fermented Copra Meal and Soybean Curd Residue (FCM-SCR) and to assess its effects on the growth performance of Peking ducks (*Anas platyrhynchos*). A Completely Randomized Design (CRD) was applied using five dietary treatments containing 0%, 10%, 15%, 20%, and 25% FCM-SCR, each replicated four times. The measured parameters included feed consumption (g/head), body weight gain (g/head), feed conversion ratio (FCR), carcass percentage (%), abdominal fat percentage (%), mortality (%/period), and income over feed cost (IOFC; Rp/head). The results demonstrated that dietary inclusion of FCM-SCR significantly ($P < 0.05$) affected feed consumption, body weight gain, and carcass percentage, while FCR and abdominal fat percentage were not significantly influenced ($P > 0.05$). Mortality remained within normal physiological limits across treatments. Based on overall performance and economic evaluation, FCM-SCR can be effectively included up to 20% in the diet without compromising duck productivity. At this optimal inclusion level, the ducks showed feed consumption of 6471.44 ± 77.91 g/head, body weight gain of 1487.87 ± 20.51 g/head, FCR of 4.35 ± 0.07 , carcass percentage of $62.20 \pm 1.03\%$, abdominal fat percentage of $2.31 \pm 0.07\%$, IOFC of Rp 26,320.06/head, and mortality of $5 \pm 0.58\%$ per period.

Keywords | *Bacillus amyloliquefaciens*, Fermented copra meal, Soybean curd residue, Functional feed, Peking duck, Growth performance

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***Correspondence** | Wizna, Department of Animal Feed and Technology, Faculty of Animal Science, Universitas Andalas, Padang 25163, Indonesia; Email: wizna@ansci.unand.ac.id

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INTRODUCTION

Peking ducks (*Anas platyrhynchos*) are among the most widely cultivated waterfowl due to their rapid growth rate, high production efficiency, and strong environmental

adaptability. The increasing demand for Peking duck meat, driven by the expansion of the poultry-based culinary sector, underscores the need to enhance duck productivity. Feed remains the most influential factor affecting growth performance and carcass quality in ducks (Wizna *et al.*,

2025). As feed costs can account for more than 70% of total production expenses, efforts to improve cost efficiency through innovative use of affordable, locally available alternative feed ingredients are essential. The utilization of agro-industrial by-products is considered a promising strategy to reduce feed costs (Andika *et al.*, 2025).

Copra meal and tofu-processing residues are two agro-industrial by-products with great potential as alternative feed ingredients for Peking ducks due to their abundance and favorable nutrient composition. Copra meal, a by-product of coconut oil and coconut milk production commonly found in coconut-processing centers across Indonesia (Laksono *et al.*, 2023), contains crude protein (5.38%), crude fat (53.49%), crude fiber ($24 \pm 1.53\%$), and nitrogen-free extract (32.90%) (Kurniawan *et al.*, 2016). However, its high crude fiber content remains a major limitation because it reduces nutrient digestibility in poultry.

Tofu-processing residues, which include tofu dregs and soybean hulls, also offer significant nutritional potential. Tofu dregs are the solid residue obtained after grinding, boiling, and pressing soybeans for extract production. According to Bahar and Setyawan (2023), fermented tofu dregs contain 3.23% moisture, 4.46% ash, 20.46% protein, 6.03% crude fiber, and 4.30% fat. Soybean hulls, the outer seed coat removed during soaking, boiling, and filtering, contain relatively high crude fiber and lower protein, with reported nutrient values of 94.41% dry matter, 4.40% ash, 16.23% protein, and 33.41% crude fiber (Auza *et al.*, 2017). Laksono *et al.* (2023) further reported that fermented copra meal contains 92.60% dry matter, 6.08% crude protein, 10.25% crude fiber, and 24.62% crude fat.

Despite their nutritional potential, both copra meal and tofu residues are limited by their high crude fiber content, which restricts their direct use in poultry diets. Therefore, further processing is needed to improve their nutritional quality, enhance digestibility, and reduce anti-nutritional factors. Fermentation is considered one of the most effective processing techniques, as it can increase nutrient availability and reduce crude fiber levels (Hidayat *et al.*, 2024).

One of the key microorganisms used in feed fermentation is *Bacillus amyloliquefaciens*. This bacterium is known to produce protease, amylase, and cellulase, enabling it to degrade proteins, starch, and crude fiber in feed materials (Wizna *et al.*, 2023). *Bacillus amyloliquefaciens* was selected in this study due to its strong probiotic potential, including its ability to improve gut health, enhance nutrient digestibility, produce extracellular hydrolytic enzymes, and suppress pathogenic microorganisms in the gastrointestinal tract of poultry. These multifunctional properties make it particularly suitable for solid-state fermentation of high-

fiber agro-industrial by-products. Fermentation of copra meal and tofu residues using *Bacillus amyloliquefaciens* is expected to produce a functional feed ingredient. Functional feed not only supplies nutrients but also provides additional benefits, such as enhancing immunity, improving metabolic efficiency, and inhibiting pathogenic microbes in the digestive tract (Peng *et al.*, 2022). Thus, supplying functional feed derived from fermented agro-industrial by-products may serve as a sustainable strategy to improve Peking duck productivity.

The combination of copra meal and tofu-processing residues in this study is based on their complementary nutritional characteristics, where copra meal contributes relatively high energy and fat content, while tofu-processing residues provide a better protein source and essential amino acid profile. In addition, both materials are abundantly available agro-industrial by-products in Indonesia, and their combined utilization supports a balanced nutrient formulation while enhancing the feasibility of large-scale feed production within a circular bioeconomy framework. This integration is expected to overcome the individual limitations of each ingredient, particularly their high crude fiber content, through synergistic effects after fermentation.

The urgency of this research lies in the need to identify economically viable and sustainable feed alternatives based on agro-industrial waste. Using copra meal and tofu residues fermented with *Bacillus amyloliquefaciens* can improve feed quality, support the growth performance of Peking ducks, and simultaneously contribute to reducing organic waste that may otherwise cause environmental pollution. This study is crucial for providing scientific evidence on the utilization of local by-products as functional feed ingredients, supporting national food security through cost-efficiency in livestock production, and promoting environmentally friendly poultry systems.

MATERIALS AND METHODS

MATERIALS

This study used 200 male Pekin ducklings (day-old ducks/ DOD) obtained from a local commercial hatchery located in Padang City, West Sumatra, Indonesia. At the beginning of the experiment, all ducklings were one day old with an initial body weight ranging from 50 to 55 g per bird, indicating good uniformity in starting body weight among experimental animals.

The ducks were reared for 8 weeks, with the treatment period applied from week 2 to week 8. Starting from the second week, a mixture of fermented copra meal and soybean curd residue (FCM-SCR) was incorporated into the experimental diets and provided for 7 weeks.

HOUSING AND EXPERIMENTAL UNITS

The ducklings were randomly allocated into 20 experimental units using a Completely Randomized Design (CRD). Each experimental unit consisted of 10 male ducklings with a relatively uniform initial body weight (50–55 g per bird), resulting in a total of 20 pens.

All experimental birds were male to eliminate variation associated with sex differences in growth performance. Each pen measured 120 × 120 × 100 cm, and uniform environmental conditions were maintained across all experimental units. Ventilation, lighting, and temperature were managed consistently throughout the experiment.

FEED, MANAGEMENT, AND HEALTH CARE

The ducks were fed a standard diet consisting of corn,

rice bran, soybean meal, meat and bone meal, fish meal, coconut oil, limestone (CaCO₃), bone meal, and FCM-SCR (Mixture of Fermented Copra Meal and Soybean Curd Residue). Fresh drinking water was provided ad libitum. Feed was offered twice daily.

For health management, the ducks were vaccinated according to standard poultry vaccination protocols, including vaccination against common diseases such as Newcastle disease and avian influenza. Hygiene was maintained by regularly cleaning the pens, feeders, and drinkers. The feed ingredients and their nutrient composition (based on dry matter) are presented in Table 1. The formulation and nutrient composition of the experimental diets are shown in Table 2.

Table 1: The feed ingredients and their nutrient composition (based on dry matter).

Feed ingredients	Crude protein (%)	Crude fat (%)	Crude fiber (%)	Calcium (%)	Phosphorus (%)	Lysine (%)	Methionine (%)	Metabolizable Energy (Kcal/kg)
Corn	8.60	2.71	3.65	0.29	0.15	0.32	0.20	3350
Rice bran	9.34	5.23	13.54	0.55	0.43	3.57	0.25	1870
Soybean meal	43.00	2.35	4.00	0.63	0.36	0.60	0.50	2240
Meat and bone meal	54.00	8.75	0.80	10.50	3.75	3.50	2.89	2750
Fish meal	40.25	6.75	2.50	4.50	2.75	4.94	2.75	2500
Coconut oil	0	100	0	0	0	0	0	8600
Limestone (Caco3)	0	0	0	40.50	0	0	0	0
Bone meal	0	0	0	38.00	19.50	0	0	0
FCM-SCR*	15.89	15.15	12.64	0.32	0.34	0.54	0.33	3550

*Mixture of Fermented Copra Meal and Soybean Curd Residue (FCM-SCR).

Table 2: The formulation and nutrient composition of the experimental diets.

Percentage of feed ingredients	DIET A	DIET B	DIET C	DIET D	DIET E
Corn	54.00	46.00	42.00	38.00	34.00
Rice bran	9.00	9.00	9.00	9.00	9.00
Soybean meal	10.00	9.00	8.00	8.00	8.00
Meat and bone meal	11.00	10.00	10.00	9.00	8.00
Fish meal	13.00	13.00	13.00	13.00	13.00
Coconut oil	2.00	2.00	2.00	2.00	2.00
Limestone (Caco3)	0.50	0.50	0.50	0.50	0.50
Bone meal	0.50	0.50	0.50	0.50	0.50
FCM-SCR*	0.00	10.00	15.00	20.00	25.00
Total	100	100	100	100	100
Feed ingredients					
Crude protein (%)	20.96	20.89	20.91	20.82	20.73
Crude fat (%)	6.01	7.20	7.82	8.38	8.945
Crude fiber (%)	4.00	4.93	5.37	5.85	6.33
Calcium (%)	2.40	2.30	2.30	2.20	2.10
Phosphorus (%)	1.02	1.00	1.01	0.99	0.96
Lysine (%)	1.58	1.57	1.58	1.56	1.54
Methionine (%)	0.86	0.84	0.84	0.82	0.80
Metabolizable energy (Kcal/kg)	3000.8	3037.9	3059	3075	3091

METHODS

The experiment was arranged in a Completely Randomized Design (CRD) with five dietary treatments and four replications per treatment. Each replication consisted of 10 male Pekin ducklings with a uniform initial body weight (50–55 g per bird), resulting in a total of 20 experimental units.

The dietary treatments were based on different inclusion levels of fermented copra meal and soybean curd residue (FCM-SCR) in the diets as follows:

- A: 0% FCM-SCR
- B: 10% FCM-SCR
- C: 15% FCM-SCR
- D: 20% FCM-SCR
- E: 25% FCM-SCR

FERMENTATION PROCESS OF FCM-SCR WITH *BACILLUS AMYLOLIQUEFACIENS*

The fermentation process of the FCM-SCR was carried out in following steps under controlled conditions to improve the nutritional quality of the feed ingredient and ensure microbiological safety.

SUBSTRATE PREPARATION

The raw materials consisted of copra meal, soybean curd residue (tofu dregs), and soybean hulls, at a ratio of 60% copra meal, 20% tofu dregs, and 20% soybean hulls (w/w). All materials were thoroughly mixed until a homogeneous substrate was obtained.

To eliminate undesirable microorganisms, the mixture was sterilized using an autoclave at 121°C for 15 minutes under 1 atm pressure. After sterilization, the substrate was cooled to room temperature ($\pm 27\text{--}30^\circ\text{C}$) prior to inoculation.

INOCULATION

The *Bacillus amyloliquefaciens* inoculum with a concentration of 10^8 CFU/g was applied at a level of 3% (w/w) of the substrate weight. The inoculum was evenly distributed throughout the substrate to ensure uniform microbial colonization.

FERMENTATION PROCESS

Fermentation was conducted under aerobic conditions at 40°C for 4 days. During fermentation, key parameters were monitored, including: pH level, which ranged from 3 to 4, indicating a stable acidic environment throughout fermentation, viable cell count of *B. amyloliquefaciens*, reaching 10^8 CFU/g, moisture content, to maintain optimal conditions for microbial activity.

Microbiological evaluation was also performed to ensure the absence of pathogenic contamination such as coliform

bacteria and molds, confirming the safety of the product as a feed ingredient.

DRYING AND STABILIZATION

After fermentation, the product was sun-dried until the moisture content reached approximately 14%, ensuring product stability during storage and preventing microbial spoilage.

PHYSICOCHEMICAL AND NUTRITIONAL EVALUATION

Proximate analysis was conducted before and after fermentation to evaluate changes in nutrient composition. Before fermentation: crude protein 11.70%, crude fat 16.27%, crude fiber 16.85%, calcium 0.35%, phosphorus 0.39% and metabolizable energy 3,352.10 kcal/kg. After Fermentation: crude protein 15.89%, crude fat 15.15%, crude fiber 12.64%, calcium 0.32%, phosphorus 0.34% and metabolizable energy 3,550 kcal/kg.

These results indicate that fermentation improved the nutritional quality of FCM-SCR by increasing crude protein and metabolizable energy while reducing crude fiber content, thereby enhancing its potential as an alternative poultry feed ingredient.

PREPARATION OF *BACILLUS AMYLOLIQUEFACIENS* INOCULUM

The *Bacillus amyloliquefaciens* inoculum was prepared prior to the fermentation process. A total of 100 g of rice bran was used as a solid substrate, sterilized at 121°C under 1 atm pressure for 15 minutes, and then cooled to room temperature.

A volume of 10 mL of sterile distilled water was added to the culture and gently shaken to release the bacterial cells. This microbial suspension was transferred into 190 mL of sterile distilled water in an Erlenmeyer flask, resulting in 200 mL of suspension.

The suspension was then evenly mixed with the sterilized rice bran and incubated for 24 hours at 40°C. After incubation, the mixture was oven-dried at 60°C to form a powder with a bacterial density of approximately 1×10^8 CFU/g, ready to be used as a fermentation inoculum.

PARAMETERS

- Feed consumption (g/head): Feed consumption was calculated by subtracting the remaining feed from the total feed offered during the experimental period, averaged per duck.
- Body weight gain (g/head): Body weight gain was determined by subtracting the initial body weight from the final body weight at the end of the trial, per duck.
- Feed conversion ratio (FCR): FCR was calculated as

the total feed intake divided by the total weight gain for each duck during the experiment.

- Carcass percentage (%): Carcass percentage was measured by calculating the ratio of carcass weight to live body weight before slaughter, multiplied by 100.
- Abdominal fat percentage (%): Abdominal fat percentage was measured by weighing the abdominal fat and dividing it by live body weight, then multiplying by 100.
- Income over feed cost (IOFC, Rp/head): Income over feed cost was calculated as the difference between revenue from carcass weight and the cost of feed consumed by each duck during the trial.
- Mortality: the percentage of ducks that died during the experimental period relative to the initial number placed at the start of the treatment.

DATA ANALYSIS

All collected data were analyzed using analysis of variance (ANOVA). If significant differences were detected among treatments, Duncan's Multiple Range Test was performed at a significance level of $P < 0.05$ (Steel and Torrie, 1991).

RESULTS AND DISCUSSION

FEED INTAKE

As shown in Table 3, the supplementation of mixture of FCM-SCR in Peking ducks had a significant effect ($P < 0.05$) on feed consumption. Statistical analysis showed that treatment A (0% FCM-SCR) with 6515.88 ± 83.09 g/head was not significantly different ($P > 0.05$) from treatment B (10% FCM-SCR) with 6508.63 ± 90.78 g/head, treatment C (15% FCM-SCR) with 6496.25 ± 86.90 g/head, and treatment D (20% FCM-SCR) with 6471.44 ± 77.91 g/head. However, feed consumption in these treatments differed significantly ($P < 0.05$) from treatment E (25% FCM-SCR) with 6319.56 ± 93.93 g/head.

Feed consumption in treatments A (0% FCM-SCR), B (10% FCM-SCR), C (15% FCM-SCR), and D (20% FCM-SCR) remained statistically similar, with higher intake compared to treatment E (25% FCM-SCR). This trend was attributed to the maintained palatability of the

diet, particularly in terms of aroma, texture, and taste, which greatly influence feed preference in ducks. A decrease in palatability reduces the birds' interest in consuming feed (Nuraini *et al.*, 2022). Fermented products containing *Bacillus amyloliquefaciens* can enhance mild acidic flavor, reduce fiber content, and increase nutrient availability. *Bacillus amyloliquefaciens* is known to produce cellulase enzymes capable of degrading crude fiber (Rusfidra *et al.*, 2025).

The fermentation process may also increase organic acid content and produce a distinctive aroma which, when too strong, may decrease feed intake (Maulana *et al.*, 2021). During fermentation, levels of glutamic acid may increase, which contributes to flavor enhancement (Maslami *et al.*, 2018). Commercial feed can be partially replaced with self-produced mixtures, one of which is fermented feed (Septinova *et al.*, 2019), fermentation technology allows feed ingredients to be supplied in larger quantities for poultry (Mirnawati *et al.*, 2021).

The decline in feed consumption in treatment E (25% FCM-SCR), which was 6319.56 ± 93.93 g/head, was likely associated with physiological stress in the digestive system. Higher levels of fiber and coarser feed particles may increase gizzard workload, causing discomfort and reducing feeding motivation. The crude fiber contents of the formulated diets were 6.33% in E, 5.85% in D, 5.37% in C, 4.93% in B, and 4.00% in A. High crude fiber content can slow digestion and reduce nutrient absorption efficiency, ultimately decreasing feed intake (McDonald *et al.*, 2011). Darker or uneven feed color may also negatively affect visual preference in poultry, which are naturally sensitive to changes in feed appearance (Kusumorini *et al.*, 2021). Other factors that may reduce feed intake include the presence of antinutritional compounds (Supriatman *et al.*, 2017).

BODY WEIGHT GAIN

The inclusion of FCM-SCR significantly affected ($P < 0.05$) body weight gain in Peking ducks. Treatment A (0% FCM-SCR) with 1597.42 ± 76.46 g/head was not significantly different ($P > 0.05$) from treatment B

Table 3: Effects of mixture of fermented copra meal and soybean curd residue (FCM-SCR) on feed consumption, body weight gain, and feed conversion of Peking ducks.

Treatment	Feed consumption (g/head)	Body weight gain (g/head)	Feed conversion ratio
A (0% FCM-SCR)	6515.88 ± 83.09^a	1597.42 ± 76.46^a	4.09 ± 0.21
B (10% FCM-SCR)	6508.63 ± 90.78^a	1581.15 ± 84.32^a	4.12 ± 0.21
C (15% FCM-SCR)	6496.25 ± 86.90^a	1570.21 ± 83.34^a	4.15 ± 0.24
D (20% FCM-SCR)	6471.44 ± 77.91^a	1487.87 ± 20.51^{ab}	4.35 ± 0.07
E (25% FCM-SCR)	6319.56 ± 93.93^b	1429.94 ± 60.85^b	4.43 ± 0.19

^{a-b}Different superscripts in the same column are significantly different ($P < 0.05$). FCM-SCR: Fermented Copra Meal and Soybean Curd Residue.

(10% FCM-SCR) with 1581.15 ± 84.32 g/head, treatment C (15% FCM-SCR) with 1570.21 ± 83.34 g/head, and treatment D (20% FCM-SCR) with 1487.87 ± 20.51 g/head (Table 3). However, body weight gain in these groups differed significantly ($P < 0.05$) from treatment E (25% FCM-SCR): 1429.94 ± 60.85 g/head.

The uniformity of body weight gain among treatments A–D was attributed to improved nutrient quality of FCM-SCR following fermentation by *Bacillus amyloliquefaciens*. Fermentation has been widely reported to increase protein digestibility, reduce crude fiber, and enhance amino acid profiles, enabling alternative feed ingredients to support growth when used at appropriate inclusion levels. Fermentation also produces proteolytic enzymes and bioactive metabolites such as organic acids and bacteriocins that improve gut health and nutrient absorption efficiency (Katu *et al.*, 2025).

The significant reduction observed in treatment E (25% FCM-SCR), 1429.94 ± 60.85 g/head, indicates that excessive use of FCM-SCR may hinder growth. This reduction was likely due to increased crude fiber and decreased effective energy density in the diet at high inclusion levels. Excessive crude fiber reduces nutrient retention, accelerates feed passage rate, and decreases digestive efficiency (Jha and Mishra, 2021). Diets with low energy density require birds to consume more feed to meet their energy needs; however, poultry have limited intake capacity, preventing adequate energy intake for optimal growth (NRC, 1994).

FEED CONVERSION RATIO (FCR)

The supplementation of FCM-SCR in Peking ducks had no significant effect ($P > 0.05$) on feed conversion ratio (Table 3). The FCR values obtained in this study were 4.09 ± 0.21 for A (0% FCM-SCR), 4.12 ± 0.21 for B (10% FCM-SCR), 4.15 ± 0.24 for C (15% FCM-SCR), 4.35 ± 0.07 for D (20% FCM-SCR), and 4.43 ± 0.19 for E (25% FCM-SCR).

The increasing trend in FCR at higher inclusion levels may have been influenced by reduced energy density and increased crude fiber fraction in the FCM-SCR material. Higher crude fiber reduces metabolizable energy utilization and digestive efficiency, requiring more feed to achieve similar body weight gain (Singh and Kim, 2021). Although fermentation improves protein digestibility and reduces antinutritional factors, these benefits diminish when the fermented ingredient is included at excessive levels (Rusfidra *et al.*, 2025).

Overall, the FCR values across treatments were still within the normal range for Peking ducks fed diets containing fibrous or by-product ingredients. Thus, FCM-SCR can

be used up to 25% without significantly impairing feed efficiency. Fermented agro-industrial by-products can be incorporated at moderate levels without negatively affecting poultry FCR (Katu *et al.*, 2025).

Table 4: Effects of mixture of fermented copra meal and soybean curd residue (FCM-SCR) on carcass percentage and abdomen fat percentage.

Treatment	Carcass %	Abdomen fat (%)
A (0% FCM-SCR)	63.61 ± 1.18^a	2.36 ± 0.10
B (10% FCM-SCR)	63.06 ± 0.71^a	2.35 ± 0.12
C (15% FCM-SCR)	62.98 ± 0.78^a	2.36 ± 0.16
D (20% FCM-SCR)	62.20 ± 1.03^a	2.31 ± 0.07
E (25% FCM-SCR)	61.49 ± 0.67^b	2.30 ± 0.12

^{a-b}Different superscripts in the same column are significantly different ($P < 0.05$). FCM-SCR: Fermented Copra Meal and Soybean Curd Residue

CARCASS PERCENTAGE

The inclusion of Mixture of FCM-SCR in the diet of Peking ducks had a significant effect ($P < 0.05$) on carcass percentage (Table 4). Statistical analysis showed that treatment A (0% FCM-SCR), with a carcass percentage of $63.61 \pm 1.18\%$, was not significantly different ($P > 0.05$) from treatment B (10% FCM-SCR; $63.06 \pm 0.71\%$), treatment C (15% FCM-SCR; $62.98 \pm 0.78\%$), and treatment D (20% FCM-SCR; $62.20 \pm 1.03\%$). However, treatment A differed significantly ($P < 0.05$) from treatment E (25% FCM-SCR), which resulted in a carcass percentage of $61.49 \pm 0.67\%$.

The reduction observed in treatment E (25% FCM-SCR) indicates a significant decline in carcass percentage ($61.49 \pm 0.67\%$). This reduction may be associated with the increased crude fiber content and the lower effective energy density at high inclusion levels of FCM-SCR. Excessive crude fiber can decrease digestive efficiency and nutrient absorption, thereby limiting the availability of energy and protein for muscle tissue growth. Consequently, the growth of non-carcass components becomes relatively higher compared with the growth of commercially valuable carcass parts, leading to a reduced carcass percentage. High crude fiber levels accelerate feed passage rate and reduce nutrient retention (Hetland and Svihus, 2001). These findings suggest that FCM-SCR can be utilized in Peking duck diets up to the 20% level without reducing carcass yield, whereas inclusion at 25% begins to exert negative effects on growth efficiency and carcass quality.

ABDOMEN FAT PERCENTAGE

The inclusion of mixture of FCM-SCR in the diet of Peking ducks had no significant effect ($P > 0.05$) on abdomen fat percentage (Table 4). The abdominal fat percentages in this study were $2.36 \pm 0.10\%$ for treatment A (0% FCM-SCR),

Table 5: Income over feed cost (Rp/kg) of peking ducks fed mixture of fermented copra meal and soybean curd residue (FCM-SCR)

Description	Diet				
	A	B	C	D	E
I. Revenue					
1. Final body weight of ducks (kg)	1.57	1.56	1.54	1.57	1.43
2. Selling price (Rp/kg)	60,000	60,000	60,000	60,000	60,000
Total Revenue (Rp)	94,036.80	93,357.45	92,473.95	94,330.35	85,796.25
II. Expenses					
1. Feed intake (kg)	6.52	6.51	6.50	6.47	6.32
2. Feed Cost (Rp)	9,835	9,245	8,945	8,655	8,365
3. Cost of day-old ducklings (DOD) (Rp)	12,000	12,000	12,000	12,000	12,000
Total Expenses (Rp)	76,083.63	72,172.24	70,108.96	68,010.29	64,863.14
III. Income Over Feed Cost	17,953.17	21,185.21	22,364.99	26,320.06	20,933.11

2.35 ± 0.12% for treatment B (10% FCM-SCR), 2.36 ± 0.16% for treatment C (15% FCM-SCR), 2.31 ± 0.07% for treatment D (20% FCM-SCR), and 2.30 ± 0.12% for treatment E (25% FCM-SCR).

The absence of significant differences indicates that the use of FCM-SCR up to the 25% inclusion level did not affect body fat deposition in Pekin ducks. This may be due to the fact that the metabolizable energy content across treatments was formulated to be equivalent, preventing changes in energy allocation toward either growth or fat storage. Fat deposition in poultry is more strongly influenced by dietary energy balance than by the specific feed ingredients used (Wizna *et al.*, 2025; Choo *et al.*, 2025).

INCOME OVER FEED COST (IOFC)

IOFC is an important economic indicator in poultry production, as it represents the net income obtained after subtracting the total feed cost during the production period. IOFC strongly determines the economic feasibility of using alternative feed ingredients such as the mixture of FCM-SCR in poultry rations. IOFC is influenced by two main factors: Income, which depends on the final body weight and market price of the ducks, and feed cost, which is related to feed intake and the price of the feed ingredients. The higher the final body weight and the lower the feed cost, the greater the IOFC value obtained (Pesti *et al.*, 2009).

The results of this study showed that treatment D (20% FCM-SCR) produced the highest IOFC, amounting to Rp 26,320.06 (Table 5). Although the final body weight of ducks in treatment D (1.57 kg) was not significantly different from those in treatments A (1.57 kg) or B (1.56 kg), the IOFC value in treatment D was markedly higher. This condition occurred because treatment D had one of

the lowest feed costs (Rp 68,010.29) compared with the other treatments. The inclusion of FCM-SCR at 20% was able to reduce the ration formulation cost without compromising duck growth performance. Fermented feed ingredients can improve nutrient digestibility and utilization efficiency, allowing feed consumption to be more effectively converted into body mass (Rusfidra *et al.*, 2025). Thus, treatment D represents the optimum point, combining high growth performance with reduced feed cost, resulting in the most favorable income-to-feed-cost ratio.

The IOFC value in treatment E decreased despite having the lowest feed cost, because the reduction in final body weight (1.43 kg) led to lower total revenue. This indicates that the inclusion of FCM-SCR above 20% begins to negatively affect growth, thereby reducing economic efficiency. It can be concluded that the 20% inclusion level of FCM-SCR is the most economically optimal, providing good feed efficiency, lower ration cost, and the highest net income.

MORTALITY

As shown in Table 6, the mortality of Peking ducks fed FCM-SCR in this study was recorded as 7.5 ± 0.5%/period for treatment A (0% FCM-SCR), 7.5 ± 0.5%/period for treatment B (10% FCM-SCR), 5 ± 0.58%/period for treatment C (15% FCM-SCR), 5 ± 0.58%/period for treatment D (20% FCM-SCR), and 5 ± 0.58%/period for treatment E (25% FCM-SCR). The experiment consisted of five treatments with four replications, with 40 Peking ducks in each treatment. The number of ducks that died during the rearing period was 3 birds in treatment A, 3 birds in treatment B, and 2 birds each in treatments C, D, and E.

Mortality is an important parameter in evaluating

poultry performance because it reflects the effectiveness of management practices, feed quality, and overall flock health throughout the experimental period (Chandio *et al.*, 2023). Mortality was calculated by recording the number of ducks that died in each treatment during the rearing period and expressing it as a percentage of the initial population.

Table 6: Mortality of Peking ducks fed mixture of fermented copra meal and soybean curd residue (FCM-SCR).

Treatment	Mortality (%/period)
A (0% FCM-SCR)	7.5 ± 0.5
B (10% FCM-SCR)	7.5 ± 0.5
C (15% FCM-SCR)	5 ± 0.58
D (20% FCM-SCR)	5 ± 0.58
E (25% FCM-SCR)	5 ± 0.58

The low mortality values observed in treatments C (15% FCM-SCR) at 5 ± 0.58%, D (20% FCM-SCR) at 5 ± 0.58%, and E (25% FCM-SCR) at 5 ± 0.58% indicate that the diets did not have adverse effects on duck health, particularly with respect to palatability, nutrient balance, or the presence of potential antinutritional compounds. Mortality can serve as a direct indicator of nutritional stress or dietary imbalance (North and Bell, 1990).

Analyzing mortality is essential to ensure that the use of alternative feed ingredients not only enhances production performance but also remains safe and supports overall animal welfare. The inclusion of alternative feed materials must maintain the physiological safety of poultry to avoid increasing the risk of death (NRC, 1994). Mortality rates can be minimized through proper sanitation, high-quality feed, and good housing management (Singer, 1997).

CONCLUSIONS AND RECOMMENDATIONS

A mixture of fermented copra meal and soybean curd residue processed with *Bacillus amyloliquefaciens* can be used up to 20% in the diet while maintaining the productivity of Peking ducks. The results obtained were: feed consumption of 6471.44 ± 77.91 g/head, body weight gain of 1487.87 ± 20.51 g/head, feed conversion ratio of 4.35 ± 0.07, carcass percentage of 62.20 ± 1.03%, abdominal fat percentage of 2.31 ± 0.07%, income over feed cost of 26,320.06 Rp/head, and mortality of 5 ± 0.58%/period.

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NOVELTY STATEMENT

This study is the first to explore the use of a fermented mixture of copra meal and soybean curd residue (FCM-SCR) as a functional feed ingredient for ducks, focusing on enhancing nutritional value while simultaneously utilizing agro-industrial waste. The application of *Bacillus amyloliquefaciens* fermentation to a combined substrate of copra meal and tofu-processing by-products represents a novel approach for improving fiber degradation and increasing nutrient availability. The synergistic effect of integrating two local agro-industrial wastes into a single formulation offers the potential to enhance the productivity and feed efficiency of Mojosari ducks while reducing feed costs and promoting sustainability.

AUTHOR'S CONTRIBUTION

W contributed to the research conceptualization, supervision, and manuscript preparation. R was responsible for methodology validation, supervision, and final manuscript editing. YSN carried out data analysis and results interpretation. FM was responsible for the initial draft writing, translation, and reference management. RA and SYA performed laboratory analysis and contributed to the methodology writing. SR conducted the research implementation and data collection, while MN was involved in research implementation and results documentation.

ETHICAL APPROVAL

This research was conducted after obtaining ethical approval based on the Decree of the Minister of Agriculture No. 306/KPTS/TN.330/4/1994, in accordance with the provisions of the Animal Research Ethics Committee of Universitas Andalas, Padang, Indonesia, as required for the use of experimental animals in research and teaching.

GENERATIVE AI AND AI ASSISTED TECHNOLOGY STATEMENT

The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

CONFLICT OF INTEREST

The authors have declared no conflict of interest.

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