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Research Article

Effect of Feeding a Combination of Fish Waste and *Indigofera zollingeriana* Leaves as Diet for Laying Quails (*Coturnix coturnix japonica*): Impact on Production Performance

Heppy Setya Prima[1], Fajri Maulana[2], Rusfidra[3], Satri Yusasra Agasi[2], Malikil Kudus Susalam[4], Mia Ayu Agusti[5]*

[1]*Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan;* [2]*Department of Agricultural Industrial Technology, Study Program of Animal Feed Technology, Politeknik Negeri Tanah Laut, Tanah Laut, South Kalimantan 70815, Indonesia;* [3]*Department of Technology and Livestock Production, Faculty of Animal Science, Unversitas Andalas, Padang, Indonesia;* [4]*Department of Agroindustry, Animal Science Study Program, Faculty of Mathematics and Natural Sciences, Universitas Negeri Padang, Sijunjung, Indonesia;* [5]*Department of Management, Faculty of Economics and Business, Universitas Negeri Padang, Padang City, Indonesia.*

Abstract | Fish waste and *Indigofera zollingeriana* leaves have potential as alternative protein sources for poultry feed. The utilization of these ingredients is expected to reduce dependence on conventional feed materials while improving the rearing efficiency of laying quails. This study aimed to evaluate the effect of feeding a combination of fish waste and *Indigofera zollingeriana* leaves on the production performance of laying quails (*Coturnix coturnix japonica*). The experimental birds were 10 weeks old laying quails reared for 6 weeks. A completely randomized design was used with five treatments: A = 0% fish waste and 0% *Indigofera zollingeriana* leaves, B = 5% fish waste and 5% *Indigofera zollingeriana* leaves, C = 10% fish waste and 5% *Indigofera zollingeriana* leaves, D = 5% fish waste and 10% *Indigofera zollingeriana* leaves and E = 10% fish waste and 10% *Indigofera zollingeriana* leaves, each with four replications. The results showed that the combination of fish waste and *Indigofera zollingeriana* leaves had no significant effect ($p > 0.05$) on the performance of laying quails. The inclusion of fish waste and *Indigofera zollingeriana* leaves at a ratio of 10% : 10% in the diet of laying quails resulted in a feed intake of 20.90 ± 0.13 g/bird/day, egg production rate of 89.17 ± 0.64%, egg weight of 12.15 ± 0.05 g, feed conversion ratio (FCR) of 1.93 ± 0.02, and yolk color score of 7.50 ± 0.58. These results indicate that the combined inclusion of fish waste and *Indigofera zollingeriana* leaves at these levels can be effectively used in quail diets without negatively affecting their performance.

Keywords | Laying quail, Fish waste, *Indigofera zollingeriana*, Production performance, Egg yolk color, Alternative feed

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***Correspondence** | Mia Ayu Gusti, Department of Management, Faculty of Economics and Business, Universitas Negeri Padang, Padang City, Indonesia; **Email:** ayugustimia@gmail.com
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INTRODUCTION

Laying quail (*Coturnix coturnix japonica*) is one of the most preferred poultry commodities in the livestock industry due to its rapid production cycle, low price, small body size requiring less feed and the ability to be reared in limited spaces such as household yards (Maulana *et al*., 2025). The development of laying quail farming faces several major challenges, particularly in feed supply, where issues related to availability, price and quality have become significant constraints. Feed costs account for the largest portion of production expenses, reaching 60–70% of the total rearing costs (Agasi and Maulana, 2025).

Conventional feed ingredients like soybean meal, meat and bone meal serve as protein sources in poultry diets (Nuraini *et al*., 2019). One solution is to search for locally available, non-conventional feed ingredients around farming areas (Febrina *et al*. 2022). Soybean meal can be substituted with fish waste (Idris *et al*., 2025), highlighting the need to explore alternative feed sources that are locally available, affordable and sustainable.

Previous studies on the use of agricultural or industrial by products and non-conventional feed ingredients in poultry diets include pineapple peel (Adrizal *et al*., 2021), hotel and restaurant organic waste (Wizna *et al*., 2023), palm kernel cake (Maulana *et al*., 2025), kitchen organic waste (Hidayat *et al*., 2024), Pangasius fish waste (Abun *et al*., 2025) and skipjack tuna waste meal (Rasa *et al*., 2025). Among potential alternatives, fish waste and *Indigofera zollingeriana* leaves are promising options to reduce the use of conventional feed ingredients.

Fish waste is a by-product of fish processing activities, generally consisting of heads, bones, fins and residual meat. Laboratory analysis in this study showed that fish waste from traditional markets contains 25.00% crude protein, 6.30% crude fat, 1.10% crude fiber, 5.30% calcium, 2.60% phosphorus and 2400 kcal/kg metabolizable energy. Skipjack tuna waste contains 29.70% crude protein, 18.83% fat, 1.94% carbohydrates and 1.07% crude fiber (Rasa *et al*., 2025). However, the unbalanced amino acid profile of fish waste can affect poultry performance if not properly adjusted to nutritional requirements (NRC, 1994; Tacon *et al*., 2013). Another limitation is its relatively high fat content, which may lead to rancidity if storage is inadequate (Hardi, 2010).

A potential strategy to address these limitations is to combine fish waste with other feed ingredients that contain high quality protein and bioactive compounds. *Indigofera zollingeriana* is a tropical legume known for its high nutritional value, containing 28.98% crude protein, 8.49% crude fiber and a complete amino acid profile, including histidine (0.67%), threonine (1.14%), arginine (1.67%), tyrosine (1.05%), methionine (0.43%), valine (1.56%), phenylalanine (1.60%), isoleucine (1.35%), leucine (2.26%) and lysine (1.57%) (Tirajoh *et al*., 2022).

The combination of fish waste meal as an animal protein source and *Indigofera zollingeriana* leaves as a plant protein source is expected to produce a nutritionally balanced ration. This synergy can improve the availability of essential amino acids, enabling non-conventional feed ingredients to be optimally utilized in laying quail diets. A balanced diet is expected to maximize quail production performance (Djulardi *et al*., 2024).

Based on this potential, this study was conducted to evaluate the effect of combining fish waste meal from traditional markets and *Indigofera zollingeriana* leaves in the diet on the production performance of laying quails (*Coturnix coturnix japonica*). The findings are expected to provide practical recommendations for farmers to utilize locally sourced alternative feed ingredients without compromising production performance, while supporting the sustainability of poultry farming. The urgency of this research lies in reducing the use of conventional feed ingredients by substituting them with locally available resources such as fish waste and *Indigofera zollingeriana* leaves, thereby promoting a sustainable laying quail farming system through waste utilization and contributing to sustainable agriculture.

MATERIALS AND METHODS

Experimental animals

This study used 10 weeks old laying quails (*Coturnix coturnix japonica*) as experimental animals. The laying quails were reared individually in cages during the 6 weeks experimental period. They were housed in compartments within a specially designed experimental cage unit consisting of five tiers. Each tier was divided into four compartments measuring 45 × 20 × 30 cm. Each compartment contained 10 laying quails, making a total of 200 laying quails used in this study.

The diet provided was a formulated feed consisting of ground corn, fish waste, *Indigofera zollingeriana* leaves, meat and bone meal, soybean meal, rice bran, coconut oil, bone meal, calcium carbonate ($CaCO_3$) and top mix.

Experimental design and feed

The experiment used a completely randomized design (CRD) with dietary treatments containing five different inclusion levels of a combination of fish waste and *Indigofera zollingeriana* leaves: Treatment A = 0% fish waste and 0% *Indigofera zollingeriana* leaves, Treatment B = 5% fish waste and 5% *Indigofera zollingeriana* leaves, Treatment C = 10% fish waste and 5% *Indigofera zollingeriana* leaves, Treatment D = 5% fish waste and 10% *Indigofera zollingeriana* leaves and Treatment E = 10% fish waste and 10% *Indigofera zollingeriana* leaves, each with four replications. The control diet (Treatment A) contained 0% fish waste and 0% *Indigofera zollingeriana* leaves, whereas the treatment diets were represented by Treatments B, C, D and E. Each replicate consisted of 10 laying quails, with each treatment having four replicates. A total of 200 laying quails aged 10 weeks were used in this study and the experimental period lasted for six weeks.

The diets were formulated using ground corn, fish waste, *Indigofera zollingeriana* leaves, meat and bone meal, soybean meal, rice bran, coconut oil, bone meal, calcium carbonate ($CaCO_3$) and top mix, as shown in Table 1. The diets were formulated to be iso-protein (20%) and iso-energy (2800 kcal/kg). The ingredient composition and nutrient content of the experimental diets are presented in Table 2.

Fish waste

Fish waste was obtained from a traditional market located in Tanah Laut Regency, South Kalimantan, Indonesia. The fish waste consisted of heads, bones, viscera and residual flesh not utilized for human consumption. The waste was washed thoroughly with clean water to remove dirt, sand and foreign materials, then cut into small pieces or ground to facilitate the drying process. Drying was carried out either under direct sunlight or in an oven at a temperature of approximately 50–60°C until the moisture content was below 14% to prevent microbial growth. The dried fish waste was ground into a fine meal and stored in airtight containers in a dry, cool place protected from pests.

Table 1: Nutritional composition of experimental feed ingredients.

Feed ingredients	Crude protein (%)	Crude fat (%)	Crude fiber (%)	Ca (%)	P (%)	Metabolizable energy (kcal/kg)
Ground Corn[a]	8.67	2.76	2.78	0.41	0.21	3300
Fish Waste[a]	25.00	6.30	1.10	5.30	2.60	2400
Indigofera zollingeriana Leaves[a]	29.45	15.50	17.89	0.18	0.14	3100
Meat and Bone Meal[b]	50.00	12.00	3.00	11.00	3.00	2800
Soybean Meal[a]	46.00	2.50	3.00	0.80	0.45	2240
Rice Bran[a]	6.00	5.70	16.64	0.69	0.26	1700
Coconut Oil[a]	0.00	100.00	0.00	0.00	0.00	8500
Bone Meal[a]	0.00	0.00	0.00	24.00	12.00	0.00
Calcium Carbonate ($CaCO_3$)[a]	0.00	0.00	0.00	40.00	0.00	0.00
Top mix[c]	0.00	0.00	0.00	0.06	0.00	0.00

[a]Laboratory test results. [b]Indonesia National Standard (INS), 2014. [c]Packaging label from PT Medion Indonesia.

Table 2: Composition of feed ingredients and nutritional content of experimental diets.

Feed ingredients	Composition of treatment feed (%)				
	A	B	C	D	E
Ground Corn	58.00	53.00	50.00	50.00	48.00
Fish waste	0.00	5.00	10.00	5.00	10.00
Indigofera zollingeriana Leaves	0.00	5.00	5.00	10.00	10.00
Meat and Bone Meal	15.00	14.00	14.00	13.00	11.00
Soybean Meal	16.00	12.00	10.00	11.00	10.00
Rice Bran	7.00	7.00	7.00	7.00	7.00
Coconut Oil	0.50	0.50	0.50	0.50	0.50
Bone Meal	1.00	1.00	1.00	1.00	1.00
Calcium Carbonate ($CaCO_3$)	1.50	1.50	1.50	1.50	1.50
Top mix	1.00	1.00	1.00	1.00	1.00
Nutritional composition of treatment diets *	A	B	C	D	E
Crude protein (%)	20.31	20.26	20.33	20.51	20.13
Crude fat (%)	4.70	5.43	5.61	5.98	5.97
Crude fiber (%)	3.71	4.37	4.28	5.12	5.03
Ca (%)	2.90	3.02	3.25	2.89	2.92
P (%)	0.78	0.86	0.98	0.83	0.89
Metabolizable energy (kcal/kg)	2853.90	2846.30	2822.50	2851.90	2827.50

*Calculated based on the nutritional contents of the composition and feed ingredients used in the experimental diet. Preparation of fish waste and *Indigofera zollingeriana* leaves as feed for laying quails.

Indigofera zollingeriana leaves

Indigofera zollingeriana leaves were collected from the area surrounding the Politeknik Negeri Tanah Laut, South Kalimantan, Indonesia. The leaves were cleaned by washing with clean water to remove dust, soil and other debris, then drained. The leaves were chopped into small pieces of approximately 1–2 cm to facilitate the drying process. Drying was carried out under direct sunlight until the moisture content reached approximately 14%. The dried *Indigofera zollingeriana* leaves were ground into a fine powder and stored in airtight containers in a dry, cool place to maintain their nutritional quality.

Performance parameters

The performance parameters measured in this study included feed consumption, quail day egg production, egg weight, feed conversion ratio (FCR), and egg yolk color. The calculation methods for each parameter are described below.

Feed consumption

Feed consumption (g/head/day) was determined by subtracting the amount of feed leftover from the total feed offered and dividing the result by the number of birds and experimental days. This value represented the average daily feed intake per bird throughout the study period.

Quail day egg production

Quail day egg production (%) was calculated by dividing the total number of eggs collected by the product of the number of birds and the number of experimental days, then multiplying by 100. This percentage indicated the daily laying performance of the birds.

Egg weight

The average egg weight (g) was obtained by weighing all eggs produced during the collection period and dividing the total egg weight by the total number of eggs. The result was expressed in grams per egg.

Feed conversion ratio (FCR)

The feed conversion ratio was calculated by dividing the feed consumption by the total egg mass produced. It was expressed as grams of feed required to produce one gram of egg. A lower FCR indicated better feed efficiency.

Egg yolk color

Egg yolk color was evaluated using the Roche Yolk Color Fan (RYCF) and expressed as a numerical score ranging from 1 (light yellow) to 15 (dark orange). The assessment was performed on freshly laid eggs to ensure color accuracy.

Data analysis

All collected data were analyzed using analysis of variance (ANOVA). If significant differences among treatments were detected, Duncan's multiple range test ($P<0.05$) was applied for further comparison (Steel and Torrie 1995).

RESULTS AND DISCUSSION

The effects of feeding a combination of fish waste and *Indigofera zollingeriana* leaves on the performance parameters of laying quails are summarized in Table 3. Feed consumption of laying quails aged 10–16 weeks fed diets containing a combination of fish waste and *Indigofera zollingeriana* leaves ranged from 20.90 ± 0.13 to 21.09 ± 0.05 g/head/day. Feed consumption in treatment A (0% fish waste and 0% *Indigofera zollingeriana* leaves) was 21.09 ± 0.05 g/head/day; treatment B (5% fish waste and 5% *Indigofera zollingeriana* leaves) was 21.07 ± 0.11 g/head/day; treatment C (10% fish waste and 5% *Indigofera zollingeriana* leaves) was 21.03 ± 0.16 g/head/day; treatment D (5% fish waste and 10% *Indigofera zollingeriana* leaves) was 20.89 ± 0.05 g/head/day; and treatment E (10% fish waste and 10% *Indigofera zollingeriana* leaves) was 20.90 ± 0.13 g/head/day. Statistical analysis showed that the inclusion of fish waste and *Indigofera zollingeriana* leaves in the diet had no significant effect ($p > 0.05$) on feed consumption.

Table 3: Effect of feeding a combination of fish waste and *Indigofera zollingeriana* leaves on feed consumption, quail day egg production, feed conversion ratio and egg yolk color in laying quails.

Treatment	Feed consumption (g/head/day)	Quail day egg production (%)	Egg weight (g)	Feed conversion ratio	Egg yolk color
A	21.09 ± 0.05	90.92 ± 1.10	12.28± 0.13	1.89 ± 0.04	8.25 ± 0.50
B	21.07 ± 0.11	90.67 ± 1.05	12.29± 0.08	1.89 ± 0.04	8.25 ± 0.50
C	21.03 ± 0.16	90.58 ± 0.50	12.27± 0.11	1.89 ± 0.04	7.75 ± 0.50
D	20.89 ± 0.05	89.67 ± 0.86	12.17± 0.04	1.91 ± 0.03	7.25 ± 0.50
E	20.90 ± 0.13	89.17 ± 0.64	12.15± 0.05	1.93 ± 0.02	7.50 ± 0.50
SEM	0.06	0.43	0.05	0.02	0.26
P-value	NS	NS	NS	NS	NS

SEM: Standard error of the mean; NS: Non-significant. A: 0% fish waste and 0% *Indigofera zollingeriana* leaves; B: 5% fish waste and 5% *Indigofera zollingeriana* leaves; C: 10% fish waste and 5% *Indigofera zollingeriana* leaves; D: 5% fish waste and 10% *Indigofera zollingeriana* leaves; E: 10% fish waste and 10% *Indigofera zollingeriana* leaves.

The absence of significant differences in feed consumption among treatments indicates that the combination of fish waste and *Indigofera zollingeriana* leaves did not alter feed palatability or physical characteristics to the extent that it affected voluntary intake. This suggests that both feed ingredients were well accepted by the quails, possibly due to processing methods such as drying and fine grinding, which could minimize undesirable odors and textures (Irine *et al.*, 2021).

Partial substitution of conventional protein sources with fish waste does not affect poultry feed intake, provided that nutrient balance and feed formulation still meet the animal's requirements (Rasa *et al.*, 2025). In the present study, the diets were formulated to be iso-protein (20%) and iso-energy (2800 kcal/kg), which likely contributed to the stable feed intake observed across all treatments.

The inclusion of *Indigofera zollingeriana* leaves, despite their fiber content, did not reduce feed intake because their inclusion level remained within the tolerance limit for quails (Li *et al.*, 2019). These findings confirm that fish waste and *Indigofera zollingeriana* leaves can be used in laying quail diets without adversely affecting feed intake, thereby supporting their potential as alternative feed ingredients in laying quail production systems.

Quail day egg production of laying quails aged 10–16 weeks fed diets containing a combination of fish waste and *Indigofera zollingeriana* leaves ranged from 89.17 ± 0.64% to 90.92 ± 1.10%. Quail day egg production in treatment A (0% fish waste and 0% *Indigofera zollingeriana* leaves) was 90.92 ± 1.10%, treatment B (5% fish waste and 5% *Indigofera zollingeriana* leaves) was 90.67 ± 1.05%, treatment C (10% fish waste and 5% *Indigofera zollingeriana* leaves) was 90.58 ± 0.50%, treatment D (5% fish waste and 10% *Indigofera zollingeriana* leaves) was 89.67 ± 0.86% and treatment E (10% fish waste and 10% *Indigofera zollingeriana* leaves) was 89.17 ± 0.64%. Statistical analysis showed that the inclusion of fish waste and *Indigofera zollingeriana* leaves in the diet had no significant effect ($p > 0.05$) on quail day egg production

The absence of significant differences indicates that partial substitution of conventional feed ingredients with a combination of fish waste and *Indigofera zollingeriana* leaves up to a level of 10% was still able to supply nutrients according to the physiological requirements of quails for egg formation. This is because fish waste contains essential amino acids, namely lysine (4.7%), methionine (1.9%) and threonine (1.6%) and when combined with *Indigofera zollingeriana* leaves, which have a crude protein content of 29.45%, the overall nutrient balance of the diet is maintained. The amino acid profile of fish waste contributes to egg protein synthesis, while the plant protein from *Indigofera* supports the nutritional balance of the feed, ensuring that egg production performance is not reduced. Since egg formation requires amino acids, diet formulation must meet the poultry nutritional standards (Hidanah *et al.*, 2018).

Although the higher inclusion levels (treatments D and E) numerically reduced egg production compared to the control, the reductions were not statistically significant. This may be related to the fact that the balance between metabolizable energy and digestible protein was still achieved, allowing ovulation and egg formation to proceed normally. Poultry diets combining both animal and plant protein sources can maintain egg productivity as long as the energy-to-protein ratio and essential amino acid availability are met (Ravindran and Bryden, 1999). The use of alternative feed ingredients with good protein quality, even when slightly higher in fiber than conventional feedstuffs, does not necessarily reduce egg production performance (Nuraini *et al.*, 2022).

The egg weight of laying quails aged 10–16 weeks fed diets containing a combination of fish waste and *Indigofera zollingeriana* leaves ranged from 12.15 ± 0.05 to 12.29 ± 0.08 g. Egg weight in treatment A (0% fish waste and 0% *Indigofera zollingeriana* leaves) was 12.28 ± 0.13 g, treatment B (5% fish waste and 5% *Indigofera zollingeriana* leaves) was 12.29 ± 0.08 g, treatment C (10% fish waste and 5% *Indigofera zollingeriana* leaves) was 12.27 ± 0.11 g, treatment D (5% fish waste and 10% *Indigofera zollingeriana* leaves) was 12.17 ± 0.04 g and treatment E (10% fish waste and 10% *Indigofera zollingeriana* leaves) was 12.15 ± 0.05 g. Statistical analysis showed that the inclusion of fish waste and *Indigofera zollingeriana* leaves in the diet had no significant effect ($p > 0.05$) on quail egg weight.

The range of egg weights in this study (12.15–12.29 g) indicates that using a combination of fish waste and *Indigofera zollingeriana* leaves up to a 10% inclusion level did not reduce product quality compared to the control (treatment A: 0% fish waste and 0% *Indigofera zollingeriana* leaves). Egg weight is strongly influenced by the availability of high-quality protein and the balance of essential amino acids in the diet (Nuraini *et al.*, 2019; Maulana *et al.*, 2025). In this study, fish waste was found to contain essential amino acids, namely lysine (4.7%), methionine (1.9%) and threonine (1.6%). Amino acids play a crucial role in the formation of albumen and yolk, while *Indigofera zollingeriana* leaves, with a protein content of 29.45%, serve as a plant protein source that complements the amino acid profile of the feed. This balance allows the egg protein synthesis process to run optimally even when part of the conventional feed ingredients is replaced (Djulardi *et al.*, 2024).

The combination of animal protein from fish waste and plant protein from *Indigofera zollingeriana* provides a synergistic effect on amino acid availability. Animal protein tends to be rich in limiting amino acids (lysine and methionine), while plant protein from *Indigofera zollingeriana* complements other amino acids, making the non-conventional feed replacement nutritionally complete for laying quail diets. A complete nutrient profile that meets laying quail requirements will maximize their productivity (Agasi and Maulana, 2025).

The potential to reduce the use of imported feed ingredients was observed with the inclusion of a combination of fish waste and *Indigofera zollingeriana* leaves. In treatment E (10% fish waste + 10% *Indigofera zollingeriana* leaves), soybean meal usage could be reduced by up to 37.50%; meat and bone meal by up to 26.67%. Meanwhile, in treatment D (5% fish waste + 10% *Indigofera zollingeriana* leaves), the reduction reached 31.25% for soybean meal and 13.33% for meat and bone meal. This reduction can provide a positive economic impact for farmers by lowering feed formulation costs while reducing dependence on imported ingredients.

The utilization of fish waste and *Indigofera zollingeriana* leaves also offers added value in terms of sustainability. Properly processed fish waste can reduce environmental pollution, while *Indigofera zollingeriana* can be cultivated on marginal land with low input requirements. Both ingredients have the potential to serve as more environmentally friendly poultry feed alternatives and support the principles of circular agriculture.

The feed conversion ratio (FCR) of laying quails aged 10-16 weeks fed diets containing a combination of fish waste and *Indigofera zollingeriana* leaves ranged from 1.89 ± 0.04 to 1.93 ± 0.02. The FCR for treatment A (0% fish waste and 0% *Indigofera zollingeriana* leaves) was 1.89 ± 0.04, treatment B (5% fish waste and 5% *Indigofera zollingeriana* leaves) was 1.89 ± 0.04, treatment C (10% fish waste and 5% *Indigofera zollingeriana* leaves) was 1.89 ± 0.04, treatment D (5% fish waste and 10% *Indigofera zollingeriana* leaves) was 1.91 ± 0.03 and treatment E (10% fish waste and 10% *Indigofera zollingeriana* leaves) was 1.93 ± 0.02. Statistical analysis showed that the inclusion of fish waste and *Indigofera zollingeriana* leaves in the diet had no significant effect ($p > 0.05$) on feed conversion ratio.

The absence of significant differences among treatments ($p > 0.05$) indicates that the combination of fish waste and *Indigofera zollingeriana* leaves up to a 10% inclusion level was still able to provide metabolizable energy and protein in an appropriate ratio to meet the physiological requirements of laying quails for egg production. Feed conversion ration in poultry is influenced by the availability of energy and the balance of essential amino acids (Palupi *et al.*, 2023). Feed conversion ratio efficiency also reflects the digestibility of feed ingredients (Wizna *et al.*, 2025). Although fish waste is a by-product, it has a high protein digestibility value, as evidenced by the comparable performance of laying quails to those fed a control diet (conventional feed).

The consistent feed conversion across all treatments suggests that farmers can reduce the use of conventional feed ingredients (meat and bone meal, soybean meal) without compromising feed conversion efficiency. The combination of 10% fish waste and 10% *Indigofera zollingeriana* leaves can be a cost-effective feed formulation strategy while utilizing cheaper, sustainable local ingredients and supporting organic waste management.

The egg yolk color of laying quail eggs at 10–16 weeks of age fed diets containing a combination of fish waste and *Indigofera zollingeriana* leaves ranged from 7.25 ± 0.50 to 8.25 ± 0.50. The egg yolk color were as follows: treatment A (0% fish waste and 0% *Indigofera zollingeriana* leaves): 8.25 ± 0.50, treatment B (5% fish waste and 5% *Indigofera zollingeriana* leaves): 8.25 ± 0.50, treatment C (10% fish waste and 5% *Indigofera zollingeriana* leaves): 7.75 ± 0.50, treatment D (5% fish waste and 10% *Indigofera zollingeriana* leaves): 7.25 ± 0.50 and treatment E (10% fish waste and 10% *Indigofera zollingeriana* leaves): 7.50 ± 0.58. Statistical analysis showed that the inclusion of fish waste and *Indigofera zollingeriana* leaves in the diet had no significant effect ($p > 0.05$) on egg yolk color in laying quails.

In treatment D (5% fish waste + 10% *Indigofera zollingeriana* leaves), corn usage was reduced by 13.33%, whereas in treatment E (10% fish waste + 10% *Indigofera zollingeriana* leaves), corn usage was reduced by 17.24%. The stable yolk color despite the reduced proportion of corn in the laying quail diet indicates that the carotenoid pigment supply in the ration remained within the standard requirement for pigment deposition in the yolk. Yellow corn is the primary source of xanthophylls (lutein and zeaxanthin) for poultry (Dansou *et al.*, 2023); however, in this formulation, part of its contribution was replaced by *I. zollingeriana* leaves, which contain β-carotene (Palupi *et al.*, 2023). In this study, *Indigofera zollingeriana* leaves were included at 5–10% of the diet, which helped maintain pigment supply when corn was reduced due to their β-carotene content.

The presence of fat from fish waste can improve the solubility and bioavailability of carotenoids, ensuring that pigment absorption from corn and *Indigofera zollingeriana* leaves remained optimal (Kojima *et al.*, 2022). Partial replacement of corn with non-corn feed ingredients that contain sufficient carotenoids can maintain yolk color intensity without affecting production performance (Valentim *et al*., 2025; Moreno *et al*., 2020).

CONCLUSIONS AND RECOMMENDATIONS

This study concludes that the inclusion of a combination of fish waste and *Indigofera zollingeriana* leaves in the diet of laying quails can be applied without compromising their performance. The combination can be included at levels up to 10% : 10%, resulting in feed consumption of 20.90 ± 0.13 g/head/day, egg production of 89.17 ± 0.64%, egg weight of 12.15 ± 0.05 g, a feed conversion ratio of 1.93 ± 0.02, and an egg yolk color score of 7.50 ± 0.58.

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NOVELTY STATEMENTS

1. This study evaluated the use of a combination of fish waste and *Indigofera zollingeriana* leaves as alternative feed ingredients for laying quails (*Coturnix coturnix japonica*).
2. The utilization of these two non-conventional feed ingredients originating from forage (*Indigofera zollingeriana* leaves) and fish waste can maintain production performance without negative effects on laying quail performance, making them a potentially sustainable alternative to replace conventional feed ingredients.
3. This approach supports the concept of circular agriculture by utilizing locally available by-products (fish waste) and exploring forage as feed for laying quails (*Indigofera zollingeriana* leaves) to reduce environmental waste from fish processing or traditional fish markets.

AUTHOR'S CONTRIBUTION

Fajri Maulana designed the study, developed the methodology, curated the data and prepared the original draft; Heppy Setya Prima performed formal analysis, software processing and validation; Rusfidra supervised the research, provided resources and secured funding; Satri Yusasra Agasi conducted the investigation and prepared visualizations; Malikil Kudus Susalam managed the project and contributed to writing, review and editing; and Mia Ayu Gusti* collected data, conducted laboratory analyses and contributed to writing review and editing.

Ethical approval

This study was conducted in accordance with the principles for the use of experimental animals in research, as stipulated in the Decree of the Minister of Agriculture of the Republic of Indonesia No. 306/KPTS/TN.330/4/1994 and Law of the Republic of Indonesia No. 18 of 2009 on Animal Husbandry and Animal Health, as amended by Law No. 41 of 2014.

Generative AI and AI-assisted technology statement

The authors declare that generative AI and AI-assisted technologies were used solely for language translation purposes in this manuscript. Specifically, ChatGPT (OpenAI, USA) was employed to translate the text from Indonesian to English to improve linguistic clarity. The authors reviewed and verified all AI-assisted outputs to ensure accuracy and alignment with the scientific content. No part of the data analysis, interpretation, or scientific writing was generated by AI tools.

Conflict of interests

The authors have declared no conflict of interest.

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