Research Article

Effects of Dietary Fermented *Padina australis* Seaweed on Egg Production Performance and Egg Quality of Laying Quails

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Abstract | This study aims to evaluate the effects of fermented *Padina australis* (brown seaweed) on performance, production, and external and internal egg quality in laying quail (*Coturnix coturnix japonica*). This study employed a completely randomised design with four different treatments of fermented *Padina australis* brown seaweed (0, 15, 20, and 25%) in the quail diet, and each treatment was replicated five times. Measurements in this experiment are daily feed intake, quail day egg production (QDEP), egg weight, egg mass, feed conversion, egg length, egg width, egg index, eggshell thickness, eggshell strength, yolk colour, egg yolk fat, egg yolk weight, albumen weight, albumen height and haugh unit. The results showed fermented *Padina australis* had no significant effect ($p>0.05$) on daily feed intake, egg weight, egg length, egg width, eggshell thickness, eggshell strength, egg index, egg yolk colour, egg yolk weight, albumen weight, and albumen height. However, it significantly affected ($p<0.05$) QDEP, egg mass, feed conversion ratio, yolk fat content, and Haugh unit. In conclusion, fermented *Padina australis* could be used up to 15% in the diet without disrupting production performance, external egg quality, and internal egg quality of laying quail.

Keywords | *Coturnix coturnix japonica*, Fermentation, Egg quality, *Padina australis*, Performance production

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INTRODUCTION

Indonesia still relies on imported feed ingredients. Corn imports are 7.92% (Komalasari, 2024), soybean meal 810 MT (Rahmanulloh, 2023), and fish meal 112.567 MT (Siahaan, 2024). Diversification of feed ingredients is necessary to reduce this dependence. The government's blue economy program, which has been in place since 2012 and utilises marine resources, presents an excellent opportunity to obtain new local feed ingredients, thereby achieving national feed security. Brown seaweed (*Phaeophyceae*) is found in almost all Indonesian marine waters. Basyunia *et al.* (2024) stated that 325 seaweed species have been identified in Indonesia, consisting of 103 species of green seaweed (*Chlorophyceae*), 167 species of red seaweed (*Rhodophyceae*), and 55 species of brown seaweed (*Phaeophyceae*).

Brown seaweed has been reported to contain bioactive compounds, including alginate, fucoidan, fucoxanthin and tannin (Reski *et al.*, 2025). Alginate, a polysaccharide composed of mannuronate and guluronic acid, can inhibit lipase activity, suppress triglyceride absorption, reduce blood triglycerides, and prevent fat accumulation in the liver and throughout the body (Kasahara *et al.*, 2019). 0.2% sodium alginate is very effective in reducing *Salmonella*

colonisation and increasing lactic acid bacteria in the ceca of broilers infected with *Salmonella Enteritidis* (Yan *et al*., 2011). Fucoidan also occurs in brown seaweed, and it is a sulfated polysaccharide with L-fucose that has anti-atherosclerotic, anti-dyslipidemic properties, induces lipoprotein lipase (LPL), reduces HMG-CoA reductase activity in cholesterol synthesis, and increases lecithin cholesterol acyltransferase (LCAT) activity for cholesterol esterification (Yang *et al*., 2019; Yakota *et al*., 2016; Braga *et al*., 2023). Fucoidan extract reduces interleukin-22 expression, thereby protecting against pathogenic bacteria (Venardou *et al*., 2022). Fucoxanthin compounds in brown seaweed are carotenoids that can reduce cholesterol, lipids and the composition of the intestinal microbiota of obese mice (Zhou *et al*., 2025). In brown seaweed, tannin compounds are reported to damage the structure of microbial cell membranes (Wahid *et al*., 2023). Additionally, brown seaweed contains flavonoids, including quercetin and epigallocatechin gallate (EGCG), which are reported to disrupt the structure and function of microbial cell membranes (Górniak *et al*., 2019). Phenol compounds in brown seaweed can damage the structure of microbial cell membranes and exhibit antibacterial activity against *Escherichia coli* and *Staphylococcus aureus* (Septiani *et al*., 2017). All bioactive compounds in brown seaweed are beneficial for poultry health.

P. australis brown seaweed has a high content of salt and crude fibre, which limits its use in poultry diets. Immersion of *P. australis* brown seaweed in running water for four hours reduced its salt content from 10.70% to 0.27%. Additionally, fermentation with local microorganisms (LMo) effectively decreased the crude fibre content from 10.79% to 2.20% (Mahata *et al*., 2023a). After fermentation, the *P. australis* product has a water content of 7.21%, dry matter of 92.79%, organic matter of 76.16%, crude fat of 4.40%, crude protein of 17.12%, calcium of 6.49%, phosphorus of 0.54%, alginate of 39.88%, and fucoidan of 0.33%. It provides 1,374 Kcal/kg of metabolic energy (Mahata *et al*., 2023b).

Previous experiments showed that after fermentation, *P. australis* can be used up to 15% in broiler diets, reducing the fat and cholesterol content of broiler meat, as well as the lipoprotein content in broiler blood serum. Besides its antimicrobial properties, it also reduces the utilisation of corn and soybean meal, replacing 100% of the rice bran in broiler diets (Mahata *et al*., 2025).

Quail eggs are popular as a source of animal protein due to their affordability and widespread availability. However, their fat and cholesterol content is the highest among poultry eggs, and if consumed regularly, it can contribute to the development of metabolic syndrome, which is detrimental to health. *P. australis* brown seaweed is a promising natural resource for poultry nutrition due to its rich content of nutrients and bioactive compounds. Among these, alginate stands out as a key bioactive polysaccharide that positively influences gut health by modulating the intestinal environment and enhancing nutrient absorption. Additionally, *P. australis* is characterised by a high calcium content, which plays a crucial role in improving both the production performance of laying Quail and the external and internal quality of eggs. There are not many research reports on the effect of giving brown seaweed *P. australis*, after reducing its salt and crude fibre content through fermentation with LMo on production performance and egg quality of laying quail (*Cortunix cortunix japonica*). Thus, we investigated the effects of *P. australis* on quail laying performance and egg quality, particularly in terms of lower salt and crude fibre content.

MATERIALS AND METHODS

Materials

This study utilised 200 laying quails (*Coturnix coturnix japonica*) at 28 weeks, with an average egg production of 80 %. The diet is composed of corn, rice bran, soybean meal, fish meal, stone flour, *P. australis* seaweed flour, and LMo. Diets were manually prepared and mixed with isoproteic (20% protein) and isoenergetic (2,900 kcal/kg). The feed nutrient composition, metabolizable energy, and diet formulation are presented in Table 1.

Methods

This study employed a completely randomised design (CRD) with four treatments, incorporating varying levels of fermented *P. australis* seaweed (0, 15, 20, and 25%) in the diet, and each treatment was replicated five times. Data were subjected to analysis of variance (ANOVA), followed by Duncan's Multiple Range Test (DMRT) when significant differences were detected (Steel and Torrie, 1991).

Experimental procedure

Brown seaweed *P.australis* was collected using simple random sampling along the Painan Selatan coastline in Painan, District IV Jurai, Pesisir Selatan Regency, West Sumatra Province, Indonesia. The sampling area was systematically divided into five sections to ensure representative coverage, with samples harvested from each section (Mahata *et al*., 2023b). Fresh *P. australis* from the Nipah River coast were immediately placed in nylon nets and immersed in running freshwater for four h to remove epibiota and excess salts, he seaweed was then drained to reduce moisture content, chopped into small pieces (approximately 1-2 cm), and fermented using a local rice microorganism (LRM) solution at a 1:2 ratio (seaweed: LRM, w/v), and fermentation proceeded under anaerobic conditions at ambient temperature (28-32˚C) for 14

days (Mahata *et al*., 2023b). The fermented product was subsequently dried under sunlight until constant weight, milled into fine powder (passing through a 1 mm sieve), and incorporated into iso-nitrogenous (isoprotein) layer quail diets formulated to contain 20% crude protein and 2,900 kcal/kg metabolizable energy with different levels of fermented *P. australis* seaweed flour and these diets were fed to quails over eight-week experimental period (56 days).

Table 1: Feed composition, nutrient and metabolizable energy content of diet formulation.

Feed composition (%) and metabolizable energy (Kcal/Kg)	Diet formulation (%)			
	A	B	C	D
Ground maize	48.05	47.80	46.95	42.76
Rice bran	15.00	3.00	0.00	0.00
Soybean meal	11.00	8.25	7.50	6.35
Fish meal	20.00	20.00	20.00	20.00
Padina australis flour	0.00	15.00	20.00	25.00
Coconut oil	2.00	3.21	3.60	4.74
A Mineral	2.00	1.50	0.70	0.00
L-Lysine	0.19	0.27	0.29	0.32
L-Methionine	0.01	0.05	0.06	0.07
CaCO3 and CaO	1.75	0.92	0.90	0.76
Total	100	100	100	100
Crude protein	20.17	20.01	20.08	20.01
Crude fat	5.04	6.19	6.59	7.77
Crude fiber	5.59	4.40	4.08	3.92
Ca	3.00	3.00	3.04	3.00
P available	0.62	0.54	0.51	0.51
L-Methionine	0.45	0.45	0.45	0.45
L-Lysine	1.00	1.00	1.00	1.00
Triptophan	0.22	0.21	0.20	0.20
Linoleic Acid	1.62	1.24	1.14	1.09
Alginate	0.00	5.98	7.98	9.97
Flavonoid	0.06	0.63	0.83	1.01
Phenol	0.35	0.40	0.40	0.39
Tannin	0.20	0.20	0.19	0.18
Metabolizable energy (Kcal/kg)	2,901	2,905	2,903	2,900

Note: A: Diet with 0% Padina australis flour; B: Diet with 15% Padina australis flour; C: Diet with 20% Padina australis flour; D: Diet with 25% Padina australis flour.

Parameters measured

Production performance of laying quail *Coturnix coturnix japonica*

1. Daily Feed Intake (g/bird/day): Calculated as total feed offered minus total feed refusal, divided by the number of quails and the duration of the observation period (56 days).
2. Quail Egg Production (QEP, %): Calculated as: (number of eggs produced / number of quails / number of production days) × 100.
3. Egg Weight (g/egg): Determined by dividing total egg weight by the total number of eggs.
4. Egg Mass per Quail per Day (g/bird/day): Calculated as Quail Egg Production (%) × average egg weight.
5. Feed Conversion Ratio (FCR): Calculated as total feed intake (kg) divided by total egg mass (kg).

External egg quality of laying quail *Coturnix coturnix japonica*

1. Egg length and width (mm): Measured using a digital vernier caliper.
2. Shell thickness (mm): Determined using a vernier caliper.
3. Egg shape index (%): Calculated as: (egg width / egg length) × 100.
4. Eggshell strength (N): Measured using an eggshell strength meter.

Internal egg quality of quail *Coturnix coturnix japonica*

1. Yolk color: Assessed using a Roche yolk color fan with a scale ranging from 1 to 15.
2. Yolk fat content (%): Determined using the Soxhlet extraction method according to the Association of Official Analytical Chemists (AOAC, 2005).
3. Yolk weight (g): Measured after separating the yolk from albumen and shell, using a digital balance (±0.001 g accuracy).
4. Albumen height (mm): Measured using a vernier caliper.
5. Haugh unit (HU): Calculated using the formula: HU = 100 × log10(h + 7.57 – 1.7W^0.37) where *h* = albumen height (mm) and W = egg weight (g).
6. Albumen weight (g): Determined after separating albumen from yolk and shell and weighing it using a digital balance (±0.001 g accuracy).

Data analysis

The collected data were statistically evaluated using analysis of variance (ANOVA) under a completely randomised design (CRD) to determine the effects of the treatments. When significant differences were detected, comparisons among treatment means were further analysed using Duncan's Multiple Range Test following the procedures described by Steel and Torrie (1991).

RESULTS AND DISCUSSION

The production performance of laying Quail *Coturnix coturnix japonica* is presented in Table 2. The provision of brown seaweed. *P. australis* up to 25% in the diet did not have a significant effect (p>0.05) on daily feed intake, and

egg weight, but it decreased Quail Egg Day Production (QEDP), egg mass, and increased feed conversion significantly ($p<0.05$). This indicates that *P. australis* reaches 25% in laying diet palatability due to seaweed, which produces a fishy odour from ammonia compounds (Damayanti *et al*., 2021). The fishy smell in seaweed is interesting to Quail when *P. australis* is up to 25% in the diet, and it equals the daily feed intake of Quail that consumes a control diet (0% *P. australis*). Therefore, the nutrients for egg synthesis are sufficient, so that the egg weight is not disrupted. However, QEDP, egg mass decreased, and feed conversion increased when *P. australis* was up to 25 % in the diet. The bioactive compounds tannins and flavonoids are associated with this condition in the diet, and their levels increase with increasing *P. australis* in the diet (Table 1). These compounds bind to dietary protein in the digestive tract, thereby impairing the absorption of the protein needed for egg production. Ojo (2021) stated, tannins decrease protein absorption by binding to proteins, forming indigestible complexes that make them unavailable for digestion and absorption, and flavonoid also bind the protein (Swieca *et al*., 2013), therefore the egg mass found in this experiment decreased because the QDEP decreased, and inefficiency of converting of diet to egg production occured, so that feed conversion increased in line with *P. australis* increased in the diet.

In this study, it was found that the external quality of eggs related to length, width, index and strength of eggshells was not affected ($p>0.05$) by the provision of *P. australis* seaweed up to 25 % in the quail diet. The external quality of the eggs was equivalent to the external quality of quail eggs that were not given seaweed (Table 3). This indicates that the need for minerals needed for eggshell formation and eggshell strength in quails that consumed *P. australis* seaweed can be met, especially Ca and P minerals (Table 1). The results of the proximate analysis indicate that *P. australis* brown seaweed contains high ash, which suggests that this seaweed is rich in minerals. Sallosao *et al*. (2020) stated that the highest mineral content of *P. australis* was calcium (10.22% w/w), followed by potassium (1.48% w/w), and the lowest was iron (0.125% w/w). Calcium and phosphorus compounds in poultry diets significantly influence the external quality of eggs, particularly eggshell characteristics such as thickness, strength, and resistance to breakage. Higher dietary calcium reduces cracked eggs and enhances shell strength and thickness, as hens mobilise calcium from bones and diet for shell deposition. Imbalances, such as low calcium or high phosphorus levels, weaken shells and reduce overall external quality (Sasongko *et al*., 2012). These findings indicate that *P. australis* seaweed can also be relied upon as a feed source of minerals needed for eggshell formation.

The internal quality of quail eggs is shown in Table 4. The administration of *P. australis* seaweed in the diet up to 25 % has no significant effect ($p>0.05$) on egg yolk colour, egg yolk weight, albumen height, and albumen weight. However, it has a significant effect ($p<0.05$) on reducing egg yolk fat and increasing HU. The internal quality of quail eggs is closely related to their external quality, as it affects the protection of internal egg quality. If the external quality of eggs is poor, it will lead to a decline in internal

Table 2: The average of production performance of laying quail *Coturnix coturnix japonica.*

P. australis level in diet formulation (%)	Average daily feed intake (g/bird/day)	Average quail egg day production (QEDP %)	Average egg weight (g/egg)	Average egg mass (g/bird)	Average feed conversion
A (0)	22.73	85.74[a]	8.70	7.46[a]	3.05[b]
B (15)	23.00	84.40[a]	8.47	7.15[a]	3.22[b]
C (20)	22.21	75.79[b]	8.38	6.36[b]	3.53[b]
D (25)	22.95	64.07[c]	8.83	5.64[c]	4.08[a]
SE	0.45	1.89	0.13	0.16	0.13

Note: SE: Standard error. Different superscripts in the same column indicate a statistically significant effect ($p<0.05$) among the treatments.

Table 3: External egg quality of laying quail *Coturnix coturnix japonica.*

P. australis level in diet formulation (%)	Average egg length (mm)	Average egg width (mm)	Average egg index (%)	Average eggshell strength (Newton)	Average shell thickness (mm)
A (0)	31.72	24.02	75.82	10.24	0.23
B (15)	31.29	23.76	75.98	9.95	0.23
C (20)	30.98	23.85	77.07	9.86	0.23
D (25)	31.57	23.91	75.79	10.28	0.23
SE	0.28	0.23	0.55	0.56	0.23

Note: SE: Standard error

Table 4: Internal egg quality of laying quail *Coturnix coturnix japonica.*

P. australis level in diet formulation (%)	Average egg yolk colour	Average egg yolk fat content on a dry matter basis (%)	Average egg yolk weight (g)	Average albumen height (mm)	Average haugh unit (HU%)	Average albumen weight (g)
A (0)	5.14	52.00[a]	3.11	4.74	69.52[b]	4.64
B (15)	5.56	51.00[a]	3.13	4.74	93.26[a]	4.57
C (20)	5.68	49.00[a]	3.19	4.49	91.97[a]	4.39
D (25)	5.81	48.00[b]	3.34	4.88	93.64[a]	4.29
SE	0.16	0.01	0.08	0.14	3.19	0.10

Note: SE: Standard error. Different superscripts in the same column indicate a statistically significant effect ($p<0.05$) among the treatments.

egg quality. In this study, the external quality of quail eggs fed a diet containing *P. australis* seaweed up to 25% of their internal egg quality, such as average egg yolk colour, egg yolk weight, high egg weight and egg white weight, can be maintained equivalent to the control diet. We predicted that the bioactive fucoxanthin, as a carotenoid compound in *P australis* in this experiment, could increase the Quail's egg yolk colour. However, it did not, and we predict that the dosage of fucoxanthin for all levels of *P. australis* in the diet remains lower to increase egg yolk colour. According to Reski *et al.* (2023), the use of fermented *Turbinaria murayana* seaweed meal at levels up to 20% in the diet of laying quail did not affect egg yolk colour. According to Kojima *et al.* (2022), carotenoids are effective feed additives for laying hens to improve egg yolk colour. Egg yolk fat content decreased when *P. australis* was included at 25 % in the diet, which was related to the increase of alginate in the diet (Table 1). Alginate has been reported to inhibit lipase activity, suppress triglyceride absorption, reduce blood triglyceride levels, and prevent fat accumulation in the liver and throughout the body (Kasahara *et al.*, 2019). The lower alginate content in the diet with 15 and 20 % *P. australis* was not enough to reduce egg yolk fat content. The HU value increases with increasing levels of *P. australis* in the diet. HU is a value that indicates the freshness of an egg from the viscosity of the egg white; the higher the HU percentage, the fresher the egg. In this study, the highest HU was observed in treatment 25% seaweed in the diet, which was attributed to the increased levels of alginate, tannin, and flavonoid in the diet (Table 1). All of these active compounds possess antimicrobial properties in the gastrointestinal tract of Quail, promoting a healthy digestive tract and optimal nutrient absorption, particularly protein, which is crucial for albumen synthesis. According to Yan *et al.* (2011), alginate compounds possess antimicrobial properties that can suppress intestinal microbial growth, thereby creating a healthy intestinal environment that optimises protein absorption for egg white formation. Zhou *et al.* (2025) stated that brown seaweed tannin compounds reported damage to the structure of microbial cell membranes, and Górniak *et al.* (2019) stated that brown seaweed also contains flavonoids quercetin and epigallocatechin gallate (EGCG), which are reported to disrupt the structure and function of microbial cell membranes. Obianwuna *et al.* (2022) stated that the supplementation of *Clostridium* and *Brevibacillus* spores as probiotics in the diet of laying hens might be a promising, safe feed additive and enhancer for intestinal health, egg production rate, feed efficiency, and albumen quality.

CONCLUSION

In conclusion, fermented *Padina australis* could be used up to 15 % in diet without disrupting production performance, external egg quality, and internal egg quality of laying quail *Coturnix coturnix japonica*, and utilization of *Padina australis* reached 15 % in laying quail diet decreased utilization of ground maize 0.52%, rice bran 80%, soybean meal 25 % in diet, and could be an alternative as rice bran replacement in diet.

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NOVELTY STATEMENT

The novelty of this study lies in the use of the brown seaweed Padina australis, fermented with local microorganisms, as an alternative feed ingredient to reduce the inclusion of ground maize and replace rice bran in laying quail diets, without compromising production performance or egg quality.

AUTHOR'S CONTRIBUTION

All authors contributed to the research activities. MEM conceptualised the study, and together with YR, Z, and SR, analysed the data, wrote the manuscript, and revised it from drafting through to finalisation. MSA, MI, and PNA

collected and tabulated the research data.

Ethical statement

This research was conducted in accordance with the ethical guidelines for animal experimentation and has been approved by the research ethics commission of the Faculty of Medicine, Universitas Andalas, to protect animal welfare and health. The ethical approval number is 631/UN.16.2/KEP-FK/2025.

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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