OPEN ACCESS Advances in Animal and Veterinary Sciences

Research Article

Development of a Turmeric-Ginger-Teak Delivery Form to Improve Egg Quality and Promote Liver Health in Commercial Layers

Lukman Hakim Ahmad Suwito[1], Muhammad Halim Natsir[2*], Osfar Sjofjan[2], Yuli Frita Nuningtyas[2,3], Feri Eko Hermanto[3], Rizal Rinaldi[2]

[1]Department of Animal Production, Faculty of Animal Science, Universitas Brawijaya, Malang 65145, East Java, Indonesia; [2]Department of Animal Nutrition and Feed Science, Faculty of Animal Science, Universitas Brawijaya, Malang 65145, East Java, Indonesia; [3]Department of Intelligent Livestock Industry, Faculty of Animal Science, Universitas Brawijaya, Malang 65145, East Java, Indonesia.

Abstract | The purpose of this study was to evaluate the effects of mash and encapsulated Turmeric-Ginger-Teak extracts on liver enzyme activity and the internal quality of eggs. An *in vivo* experiment was conducted using a completely randomized design (CRD) with a nested pattern, involving two feed forms: mash and encapsulated. Each factor included five levels of additive: T0 (basal feed without additive), T1 (basal feed + 0.2% additive), T2 (basal feed + 0.4% additive), T3 (basal feed + 0.6% additive), and T4 (basal feed + 0.8% additive). Each treatment level was replicated four times. The measured variables included enzyme activities, i.e., Alkaline Phosphatase (ALP), Alanine Aminotransferase (ALT), and Aspartate Aminotransferase (AST), as well as internal egg quality traits such as egg white weight (EWW), egg yolk weight (EYW), yolk color (YC), egg white viscosity (EWV), Haugh unit (HU), and egg mass (EM). Data were analyzed using Analysis of Variance (ANOVA), followed by Duncan's Multiple Range Test for post-hoc comparisons. The results showed that the additive form had no effect on enzyme levels and layer performance, except for ALT that had lower level in encapsulated than mash form ($p < 0.01$). At level-wise point of view, ALT levels significantly decreased in T3 and T4 with the encapsulated form ($p < 0.05$), but not with the mash form. Both forms increased EYW and EYC, while EM was improved only by the encapsulated form. It is concluded that the encapsulated herbal extract can serve as a potential alternative to natural antibiotics as a feed additive.

Keywords | Liver Enzyme, Egg Internal Quality, Feed Additives, Laying Hens, Mash, Encapsulated

Received | May 21, 2025; **Accepted** | July 17, 2025; **Published** | August 26, 2025
***Correspondence** | Muhammad Halim Natsir, Department of Animal Nutrition and Feed Science, Faculty of Animal Science, Universitas Brawijaya, Malang 65145, East Java, Indonesia; **Email:** emhanatsir@ub.ac.id
Citation | Suwito LHA, Natsir MH, Sjofjan O, Nuningtyas YF, Hermanto FE, Rinaldi R (2025). Development of a turmeric-ginger-teak delivery form to improve egg quality and promote liver health in commercial layers. Adv. Anim. Vet. Sci., 13(9):1922-1929.
DOI | https://dx.doi.org/10.17582/journal.aavs/2025/13.9.1922.1929
ISSN (Online) | 2307-8316

Copyright: 2025 by the authors. Licensee ResearchersLinks Ltd, England, UK.
This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

INTRODUCTION

The global implementation of restrictions on antibiotic growth promoter (AGP) usage in poultry production, driven by concerns over antibiotic resistance and food safety (Ma *et al.*, 2021a), presents significant challenges for maintaining productivity, particularly concerning high-quality egg output (Foroutankhah *et al.*, 2019). Laying hens are inherently susceptible to metabolic burdens, including liver oxidative stress, which negatively impacts liver function and consequently egg quality and production efficiency. This susceptibility persists irrespective of prior AGP use (Yu *et al.*, 2023). Hepatic oxidative stress, often triggered by environmental or nutritional factors, leads to hepatocellular damage, reflected in elevated serum biomarkers such as alkaline phosphatase (ALP), alanine aminotransferase (ALT), and aspartate aminotransferase (AST). These elevations indicate compromised liver health, metabolic disruption, and are associated with conditions like non-alcoholic fatty liver disease (NAFLD), ultimately reducing peak production performance and egg quality (Tang *et al*., 2022; Chu *et al*., 2024; Guo *et al*., 2024).

Phytobiotics, such as extracts from turmeric (*Curcuma longa*), ginger (*Zingiber officinale*), and teak leaves (*Tectona grandis*), represent promising AGP alternatives due to their broad spectrum of bioactivity, including antioxidant, antimicrobial, anti-inflammatory, and hepatoprotective properties (Arslan *et al*., 2017; An *et al*., 2019; Liu *et al*., 2020; Charoensit *et al*., 2021). Synergistic combinations of these botanicals have demonstrated efficacy in improving gut health, modulating immunity, enhancing carcass quality, and boosting performance in broilers (Ardiansyah *et al*., 2024; Hermanto *et al*., 2024; Nuningtyas *et al*., 2024). However, their bioactivity and impact on mitigating liver oxidative stress and improving egg quality in laying hens remain underexplored. Furthermore, the efficacy of phytogenic compounds is critically dependent on their delivery system, as conventional liquid formulations are susceptible to environmental degradation, reducing bioactive compound integrity and bioavailability (Utami *et al*., 2023).

Consequently, developing advanced delivery systems is essential to enhance the stability, controlled release, and bioavailability of these phytobiotics (Marcon *et al*., 2021). Encapsulation using protective carriers offers a viable solution. Maltodextrin has emerged as a particularly effective and economically feasible encapsulating agent, demonstrating high encapsulation efficiency, superior protection for bioactive compounds, and improved bioavailability compared to non-encapsulated or other delivery forms like liposomes alone (Gurturk *et al*., 2017; Wardhana *et al*., 2022; Todorović *et al*., 2022; Cardero *et al*., 2024). Additionally, cassava starch shows significant potential as a functional filler in nano-liquid extract formulations, contributing to the stability and targeted delivery necessary to achieve desired physiological effects (Zalfa *et al*., 2023).

Based on this rationale, we hypothesize that dietary supplementation with a combination of turmeric, ginger, and teak leaves phytobiotics will improve internal egg quality and reduce serum hepatic enzyme concentrations (ALP, ALT, AST) in laying hens by mitigating oxidative stress. Furthermore, we hypothesize that a maltodextrin-encapsulated nano-extract (B2) will better preserve bioactive compounds than a non-encapsulated mash extract (B1), leading to superior efficacy in lowering hepatic enzyme levels and enhancing egg quality parameters. This study therefore aims to evaluate the effects of nano-liquid herbal extracts (formulated as mash (B1) and stabilized via maltodextrin encapsulation (B2)) on laying hen production performance, key serum metabolic enzyme activity (ALP, ALT, AST), and internal egg quality. The goal is to contribute to the optimization of phytogenic compounds and delivery systems for sustainable poultry productivity.

MATERIALS AND METHODS

Preparation of feed additive

The first step in preparing feed additives was the extraction of ginger (*Zingiber officinale*), turmeric (*Curcuma longa*), and teak leaves (*Tectona grandis*). The extraction was performed by following to the previous protocol (Ardiansyah *et al*., 2024). Equal amounts of each herb powder (1:1:1) are weighed and mixed with ethanol at a ratio of 1:5 (w/v). The mixture is then macerated in a closed jar for 24 hours. After maceration, the sample is transferred to a Kjeldahl flask and extracted using Microwave-Assisted Extraction (MAE) at a controlled medium power with temperature of 50–60 °C for 10 minutes. The extract is cooled to room temperature and filtered through a filter paper to obtain the filtrate. This filtrate is then subjected to ethanol evaporation at 50–60°C for 15 minutes on a medium-low setting. After ethanol removal, the process continues with the preparation of the mash and encapsulation formulation from the resulting extract.

The mash form was prepared following the protocol by (Suwito *et al*., 2025), by mixing the liquid herbal extract with cassava starch at a 1:1 ratio (v/w), thoroughly homogenizing the mixture, oven-drying it at 60°C, and milling it into a fine powder. In contrast, the encapsulated feed additive was prepared by combining 700 mL of the herbal extract with 300 g of maltodextrin as the encapsulating agent, then freeze-dried to form microcapsules (Sjofjan *et al*., 2023). The detail of the preparation procedures as illustrated in Figure 1.

In vivo experimental design

A total of 400 birds (aged 68-72 weeks) were employed for *in vivo* experiment with a completely randomized design (CRD) with a nested arrangement to evaluate herbal-extract feed additives. The design comprised two main factors: (i) extract form, i.e., mash (B1) versus encapsulated (B2), and (ii) five inclusion levels (T0 = basal feed only; T1 = basal + 0.2 % additive; T2 = basal + 0.4 %; T3 = basal + 0.6 %; T4 = basal + 0.8 %), which were nested within extract form. Four replicates were allotted per treatment, giving 40 experimental units (2 forms × 5 levels × 4 replicates). Each replicate consisted of ten hens, totalling 400 birds. Birds received mash basal feed and water *ad libitum* under a 16 h light: 8 h dark cycle at 27 ± 2 °C. Experiment was conducted for 5 weeks. Egg and blood sample were collected in the fifth week of the experiment. The detail of the experimental design as displayed in Figure 2.

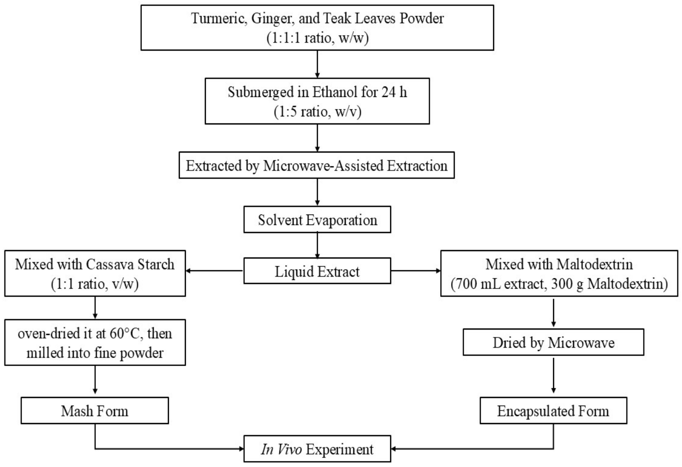

Figure 1: Preparation workflow of herbal feed additive extracts in mash and encapsulated forms. A mixture of turmeric, ginger, and teak leaves powder (1:1:1, w/w) was submerged in ethanol (1:5, w/v) for 24 hours and extracted using Microwave-Assisted Extraction (MAE). After solvent evaporation, the resulting liquid extract was processed into two forms: (1) Mash form, by mixing with cassava starch (1:1, v/w), oven-drying at 60 °C, and milling into fine powder; and (2) Encapsulated form, by mixing with maltodextrin (700 mL extract: 300 g maltodextrin) and drying via microwave. Both forms were used in the *in vivo* experiment.

Egg internal quality analysis

Egg samples collected from the farm were analyzed approximately six hours after collection for internal quality assessment. Egg mass (EM), egg white weight (EWW), and egg yolk weight (EYW) were measured using a digital scale. Egg yolk color (EYC) was evaluated using an egg yolk color scale, egg white viscosity (EWV) was determined with a viscometer, and Haugh unit (HU) was measured using a Haugh micrometer.

Blood sample collection and serum enzymatic assay

Blood samples were collected from the wing vein of chickens using sterile syringes (three samples per replicate per group, totaling 120 samples). The samples were immediately centrifuged at 3000 rpm for 10 minutes to separate the serum. The serum was stored at –20°C until biochemical analysis. Levels of Alkaline Phosphatase (ALP), Alanine Aminotransferase (ALT), and Aspartate Aminotransferase (AST) were measured using commercial biochemical kits (ELK Biotechnology), following the manufacturer's protocols. In general, serum samples and standards were added to pre-coated wells, incubated at 60°C, and washed repeatedly to remove unbound substances. Detection antibodies specific to ALP, ALT, and AST were then added, inducing colorimetric reactions. The absorbance was measured at 450 nm using a microplate reader, and enzyme concentrations (ng/mL) were calculated based on a standard regression curve.

Statistical analysis

The data were analyzed using a CRD with a nested structure, where the feed additive levels were nested within the delivery form (Mash or Encapsulated). The data results in the study were analyzed using a CRD nesting pattern using Microsoft Excel, if the results showed significant ($P<0.05$), it would be followed by Duncan's Multiple Range Test.

Ethical considerations

This study was conducted in accordance with the institutional ethical guidelines for animal research (No. 91/EC/KEPK/04/2025), ensuring that all experimental procedures adhered to animal welfare standards and minimized stress and discomfort. Each chicken was housed individually in a cage measuring 26 cm in width, 35 cm in height, and 35 cm in length. Blood collection was performed under the supervision of a veterinarian, drawing 3 mL of blood from the intramuscular area of the left wing to minimize pain. The experiment was approved by the Ethical Committee of Universitas Brawijaya and complied with all applicable animal welfare regulations.

RESULTS

Influence of delivery form (Mash vs Encapsulation) on enzyme levels and egg quality

The serum ALP activity was significantly lower in the encapsulated form (0.41 ± 0.66 ng mL^{-1}) compared to the mash form (1.04 ± 1.44 ng mL^{-1}; $p < 0.01$). ALT and AST showed no form-related differences ($p = 0.67$ and $p = 0.88$, respectively; Table 1). Delivery form did not influence egg-white weight, yolk weight, yolk-colour score, egg-white viscosity, or Haugh unit ($p > 0.05$, Table 1). Mean Haugh units were 84.01 ± 4.32 % in B1 and 84.47 ± 2.02 % in B2 (Table 1).

Optimal inclusion level within each delivery form

Across graded inclusion levels (T0–T4), ALP and AST did not vary significantly within either form ($p = 0.12$ and $p = 0.21$), whereas ALT differed by level in encapsulated form. Serum level of ALT significantly decreased in T3 and T4, while other level unchanged compared to control (Table 2). However, no difference of ALT level was observed across different inclusion of mash form, despite a lower level of ALT enzyme was observed in T4 (Table 2).

Links Researchers

Table 1: Effects of herbal extract treatment in mash (B1) and encapsulated (B2) forms on enzyme activity and internal egg quality.

a	B1	B2	p-value
ALP. ng/ml	1.04 ± 1.44	0.41 ± 0.66	0.00
ALT. ng/ml	0.42 ± 0.71	0.36 ± 1.01	0.67
AST. ng/ml	0.20 ± 0.21	0.19 ± 0.36	0.88
EWW. g	39.43 ± 5.45	39.98 ± 6.32	0.41
EYW. g	16.06 ± 3.48	16.07 ± 3.62	0.96
EYC	11.49 ± 4.53	11.71 ± 4.05	0.12
EWV. mPa.s	38.79 ± 4.52	39.40 ± 7.3	0.36
HU. %	84.01 ± 4.32	84.47 ± 2.02	0.21

Notes: B1 = mash form; B2 = encapsulated form; ALP = alkaline phosphatase; ALT = alanine aminotransferase; AST = aspartate aminotransferase; EWW = egg white weight; EYW = egg yolk weight; EYC = egg yolk color; EWV = egg white viscosity; HU = Haugh unit. All values are presented as mean ± standard deviation.

On the egg quality perspective, yolk weight increased progressively with inclusion level at both formulation form ($p = 0.01$), rising from 15.15 ± 0.60 g (T0) to 16.85 ± 0.70 g (T4) in mash form and from 15.10 ± 1.31 g to 17.25 ± 0.96 g in encapsulation form. Yolk-colour score likewise rose ($p < 0.05$), ranging from 9.65 ± 0.10 to 12.47 ± 0.38 in B1 and from 9.95 ± 0.53 to 12.47 ± 0.38 in B2. Egg mass also increased with level ($p < 0.01$), from 46.19 ± 1.20 g (T0) to 50.62 ± 0.61 g (T4) in B1 and from 46.94 ± 1.69 g to 52.65 ± 1.28 g in B2. Nevertheless, parameters associated with the egg white were unaffected by the treatment (Table 2).

Association of enzyme levels with egg-quality traits

Canonical Correlation Analysis (CCA) revealed negative associations between the combined enzyme index and both Haugh unit and egg mass (Tables 3 and 4). Canonical correlation analysis produced three functions; the first displayed a canonical correlation of 0.43 (eigenvalue = 0.19) explaining 74.97 % of shared variance but was not significant (Wilks' $\lambda = 0.76$, $p = 0.95$; Tables 3 and 4). ALP and AST loaded 0.85 and 0.67, respectively, on the enzyme variate, whereas egg mass and Haugh unit loaded −0.65 and 0.24 on the production variate (Tables 3 and 4). These data were supported by bivariate scatterplot, which was illustrated a broad dispersion with a shallow negative slope. The scatterplot showed a visible trend in which higher enzyme activity, particularly AST, may be linked to changes in certain egg quality parameters (Figure 3).

Table 2: Treatment of mash-level nested and protected against enzyme activity and the internal quality of the eggs.

Parameter	Form	Level					p-values
		T0	T1	T2	T3	T4	
ALP	B1	0.85 ± 0.32	0.89 ± 0.11	1.32 ± 0.70	0.63 ± 0.40	1.51 ± 0.61	0.12
	B2	0.59 ± 0.67	0.31 ± 0.29	0.40 ± 0.08	0.57 ± 0.29	0.20 ± 0.13	
ALT	B1	0.39±0.28	0.34±0.21	0.62±0.36	0.56±0.34	0.17±0.07	0.03
	B2	0.19±0.13^{b}	0.30±0.16^{b}	0.14±0.09^{b}	1.095±1.09^{a}	0.093±0.028^{a}	
AST	B1	0.20 ± 0.15	0.12 ± 0.04	0.20 ± 0.17	0.21 ± 0.15	0.27 ± 0.07	0.21
	B2	0.29 ± 0.13	0.19 ± 0.17	0.24 ± 0.13	0.19 ± 0.04	0.052 ± 0.01	
EWW	B1	37.15±1.75	39.5±3.08	39.62±1.1	40.2±2.02	40.7±2.33	0.08
	B2	37.7±1.92	39.05±2.31	40.6±0.43	40.95±1.39	41.6±2.99	
EYW	B1	15.15±0.6^{b}	15.1±0.5^{b}	16.4±1.23^{ab}	16.8±1.12^{a}	16.85±0.7^{a}	0.01
	B2	15.1±1.31^{c}	15.4±1.62^{bc}	15.87±0.63^{abc}	16.75±0.96^{ab}	17.25±0.96^{a}	
EYC	B1	9.65±0.1^{c}	11.4±0.71^{b}	11.55±0.44^{ab}	12.4±0.37^{a}	12.45±0.34^{a}	0.00
	B2	9.95±0.53^{b}	11.85±0.3^{a}	12.05±0.68^{a}	12.25±0.34^{a}	12.47±0.38^{a}	
EWV	B1	37.35±0.6	38.25±0.66	38.75±0.19	39.2±2.53	40.4±3.3	0.06
	B2	37.25±2.78	37.75±0.43	39.85±1.79	40.93±0.21	41.25±1.97	
HU	B1	82.36±2.04	83.73±1.12	84.03±1.17	84.8±1.26	85.09±0.44	0.05
	B2	84.42±0.56	84.10±1.09	83.97±0.61	84.63±0.75	85.25±1.69	
EM	B1	46.19±1.2^{a}	47.97±1.78^{a}	48.14±3.75^{a}	51.1±4.06^{a}	50.62±0.61^{a}	0.00
	B2	46.94±1.69^{b}	50.68±1.04^{ab}	50.67±3.23^{ab}	52.43±1.97^{a}	52.65±1.28^{a}	

Notes: B1 = mash form; B2 = encapsulated (protected) form; ALP = alkaline phosphatase; ALT = alanine aminotransferase; AST = aspartate aminotransferase; EWW = egg white weight; EYW = egg yolk weight; EYC = egg yolk color; EWV = egg white viscosity; HU = Haugh unit. All values are presented as mean ± standard deviation.

Links Researchers

Table 3: Results of variant analysis Canonical and variable correlations.

Canonical function	Canonical correlations	Eigen values	Variance percentages	Wilks. Lambda	p value
Canonic 1	0.43	0.19	74.97	0.76	0.95
Canonic 2	0.22	0.05	19.56	0.94	0.99
Canonic 3	0.12	0.01	5.47	0.99	0.98

Table 4: Results of a canonical analysis between liver enzymes and the internal quality of eggs.

Variable	Enzyme activity		Variable	Egg quality	
	Canonical variates	Canonical loadings		Canonical variates	Canonical loadings
ALP	0.22	0.85	EWW	-0.03	-0.32
ALT	0.01	0.10	EYW	0.08	0.34
AST	0.66	0.67	EYC	-0.01	-0.32
			EWV	0.00	-0.10
			HU	0.07	0.24
			EM	-0.04	-0.65

Notes: B1 = mash form; B2 = encapsulated (protected) form; ALP = alkaline phosphatase; ALT = alanine aminotransferase; AST = aspartate aminotransferase; EWW = egg white weight; EYW = egg yolk weight; EYC = egg yolk color; EWV = egg white viscosity; HU = Haugh unit.

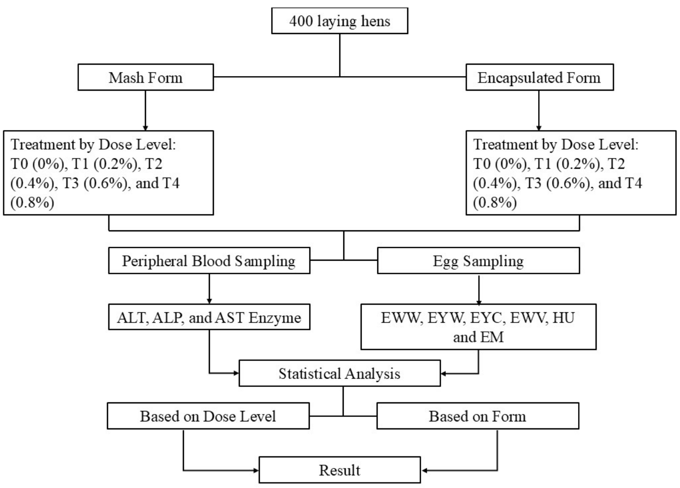

Figure 2: Experimental workflow of the study evaluating mash and encapsulated herbal extract supplementation in laying hens. A total of 400 laying hens were divided into two feed form groups (mash and encapsulated), each receiving five levels of additive dosage: 0 to 0.8% of additive levels. Blood samples were collected to assess ALT, ALP, and AST enzyme activity, while egg samples were analyzed for egg white weight (EWW), egg yolk weight (EYW), yolk color (EYC), egg white viscosity (EWV), Haugh unit (HU), and egg mass (EM). Data were analyzed statistically based on dose level and feed form.

DISCUSSION

The significantly lower serum ALP levels in birds fed the encapsulated blend (B2), compared to the mash form (Table 1), indicate a potential for hepatoprotective activity. The absence of significant differences between forms for ALT, AST, albumin, or yolk traits confirms that encapsulation mitigates oxidative burden without compromising internal egg quality.

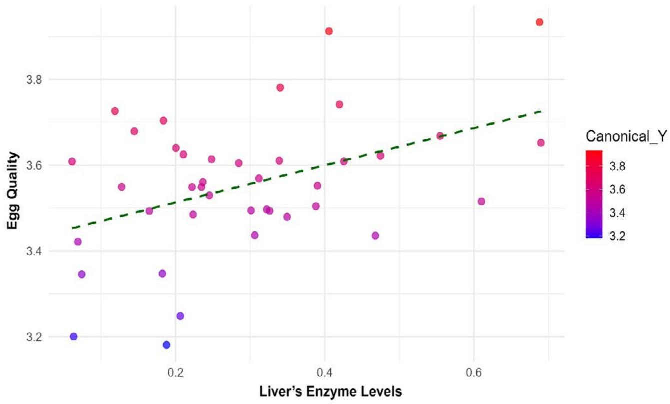

Figure 3: Canonical correlation between liver enzyme activity and internal egg quality parameters in laying hens supplemented with turmeric-ginger-teak extracts in both mash and encapsulated form. Scatterplot illustrating the relationship between the canonical variate of serum liver enzymes, i.e., Alkaline Phosphatase (ALP), Alanine Aminotransferase (ALT), and Aspartate Aminotransferase (AST) and the canonical variate of egg quality traits such as egg mass (EM), Haugh unit (HU), egg yolk weight (EYW), egg yolk color (EYC), egg white weight (EWW), and egg white volume (EWV). Data represent all experimental groups.

Dose-response analysis identified the T4 inclusion level as optimal, evidenced by minimal ALT, maximal yolk weight (EYW), deepest yolk pigmentation (EYC), and the greatest egg-mass gains (EM) (Table 2). The encapsulated format yielded slightly greater absolute improvements in these parameters than the mash form, suggesting superior release kinetics and gastrointestinal stability of the phytogenic payload. The increasing yolk color intensity and weight with higher inclusion levels reflect greater carotenoid and curcuminoid deposition (Phuong and Nguyen, 2021), enhancing nutritional value and functional benefits for consumers (Patil *et al*., 2022; Zurak *et al*., 2022).

These findings suggest maltodextrin encapsulation yielded better effects on specific enzyme levels and egg quality parameters. While ALP was significantly lower in encapsulated groups overall compared to the mash group (Table 1), level-wise analysis (across doses) did not show a significant form effect for ALP (Table 2). However, ALT levels and egg quality parameters (EYW, EYC, EM) showed more pronounced improvements in the encapsulated group compared to mash at specific doses (Table 2). This difference in activity may be attributed

Links Researchers

to the distinct chemical structures of cassava starch and maltodextrin. Cassava starch contains more complex sugar structures (such as amylose), while maltodextrin has simpler sugars. The complex sugars in cassava starch may affect the release and availability of phytobiotic compounds (Sunarti *et al*., 2020). In contrast, the simpler sugars in maltodextrin may enhance bioavailability and promote the delivery of a greater number of bioactive compounds with more desired gradual bioactive compounds release due to its solubility profile and hydrophilic nature (Toraya-Avilés *et al*., 2017; Barthold *et al*., 2019; Xiao *et al*., 2022). Maltodextrin also provide a better compounds stability with retained bioactivity to obtain the looked-for outcome (Postružnik *et al*., 2024). These properties explain the better activity of the encapsulated form in modulating enzyme profiles and egg quality parameters.

Since liver stress enzymes (ALP, ALT, AST) are associated with egg quality of laying hen (Ma *et al*., 2021b; Yin *et al*., 2023), canonical correlation analysis was performed to assess the relationship between liver enzyme activity and internal egg quality traits. The results suggest a weak and statistically non-significant association between the two variable sets. The first canonical function explained approximately 74.97% of the total shared variance and exhibited a moderate canonical correlation coefficient of 0.43. However, the Wilks' Lambda (0.76) and high p-value (0.95) indicate this relationship is not statistically significant (Table 3). Among the liver enzymes, ALP and AST showed the highest canonical loadings (0.85 and 0.67, respectively), indicating they contributed most to the canonical variate representing enzyme activity (Table 4). Elevated ALP and AST levels are established markers of liver damage, released into the bloodstream upon hepatocellular damage (Liu *et al*., 2022). Liver health is crucial for optimal egg production, as damage can impair metabolic functions, reducing egg mass and quality (Ma *et al*., 2021b; Wu *et al*., 2022). Alleviation of these enzymes, including ALT, was observed across almost all treatment levels, particularly in the encapsulated form (Table 2).

On the egg quality side, egg mass (EM) displayed the strongest (negative) canonical loading (-0.65), suggesting it was the primary trait associated with the enzyme activity variate. Although these results imply a potential inverse relationship between liver enzyme activity and egg mass, the lack of statistical significance suggests this relationship should be interpreted cautiously and may not reflect a consistent biological effect under the conditions studied (Table 4, Figure 3). This data supports previous studies indicating that increasing liver damage, reflected by rising levels of enzymes like ALT, ALP, and AST, would induce a lighter egg mass (Ma *et al*., 2021b; Wu *et al*., 2022; Liu *et al*., 2022), a key characteristic for profitability. Further studies with larger sample sizes or different physiological conditions may be needed to clarify this potential link.

CONCLUSIONS

Encapsulating turmeric–ginger–teak extracts in maltodextrin microcapsules significantly lowered serum alkaline phosphatase and, at higher doses, alanine aminotransferase, while simultaneously increasing yolk weight, yolk pigmentation and overall egg mass without affecting albumen characteristics. Mash preparations elicited similar but less consistent responses and never improved egg mass, confirming that protected delivery optimises bioavailability and hepatoprotection. These results support encapsulated phytobiotics as a viable, antibiotic-free strategy for sustaining productivity in late-laying hens. Future work should lengthen the feeding period, track antioxidant and gut-microbiota shifts, test alternative encapsulants and conduct cost-benefit analyses under commercial conditions.

ACKNOWLEDGEMENT

The researchers thank the Ministry of Higher Education, Scince, and Technology, Republic of Indonesia, for funding this research through Applied Research Scheme Grant.

NOVELTY STATEMENT

This study is the first to prove that a triple-herb (turmeric, ginger, teak) nano-encapsulate, stabilised in a low-cost maltodextrin matrix, delivers dose-dependent hepatoprotective effects and egg-quality enhancements that surpass unprotected mash, positioning it as a practical antibiotic growth-promoter substitute for aged laying hens.

AUTHOR'S CONTRIBUTION

Lukman Hakim Ahmad Suwito: Investigation, formal analysis, visualization, writing original draft. Muhammad Halim Natsir: Conceptualization, supervision, funding acquisition. Osfar Sjofjan, Yuli Frita Nuningtyas: Methodology, supervision, writing review and editing. Feri Eko Hermanto, Rizal Rinaldi: Formal analysis, writing review and editing. All authors review and approve the final manuscript.

Conflict of interest

The author has stated that there is no conflict of interest.

REFERENCES

An S, Liu G, Guo X, An Y, Wang R (2019). Ginger extract enhances antioxidant ability and immunity of layers. Anim. Nutr., 5: 407–409. https://doi.org/10.1016/j.

Links Researchers

aninu.2019.05.003

Ardiansyah DT, Nuningtyas YF, Marwi F, Natsir MH (2024). The effect of turmeric, ginger, and teak leaf nanoparticles extraction as feed additives on the microbial of broiler chickens. Bio Web. Conf., 88: 00040. https://doi.org/10.1051/bioconf/20248800040

Arslan M, Haq A, Ashraf M, Iqbal J, Mund M (2017). Effect of turmeric (*Curcuma longa*) supplementation on growth performance, immune response, carcass characteristics and cholesterol profile in broilers. Veterinaria, 66: 16–20.

Barthold S, Hittinger M, Primavessy D, Zapp A, Groß H, Schneider M (2019). Preparation of maltodextrin nanoparticles and encapsulation of bovine serum albumin Influence of formulation parameters. Eur. J. Pharm. Biopharm., 142: 405–410. https://doi.org/10.1016/j.ejpb.2019.07.003

Cardero Y, Aguirre-Calvo TR, Valenzuela LM, Matiacevich S, Santagapita PR (2024). Design of an antioxidant powder additive based on carvacrol encapsulated into a multilayer chitosan-alginate-maltodextrin emulsion. Int. J. Biol. Macromol., 274: 133039. https://doi.org/10.1016/j.ijbiomac.2024.133039

Charoensit P, Sawasdipol F, Tibkawin N, Suphrom N, Khorana N (2021). Development of natural pigments from *Tectona grandis* (teak) leaves: Agricultural waste material from teak plantations. Sustain. Chem. Pharm., 19: 100365. https://doi.org/10.1016/j.scp.2020.100365

Chu Y, Zheng Y, Li Y, Gui S, Zhao J, Zhao Y, Chen X (2024). Dietary supplementation of magnolol alleviates fatty liver hemorrhage syndrome in postpeak Xinhua laying hens via regulation of liver lipid metabolism. Poult. Sci., 103: 103378. https://doi.org/10.1016/j.psj.2023.103378

Foroutankhah M, Toghyani M, Landy N (2019). Evaluation of *Calendula officinalis* L. (marigold) flower as a natural growth promoter in comparison with an antibiotic growth promoter on growth performance, carcass traits and humoral immune responses of broilers. Anim. Nutr., 5: 314–318. https://doi.org/10.1016/j.aninu.2019.04.002

Guo Y, Xu Y, Wang D, Yang S, Song Z, Li R, He X (2024). Dietary silymarin improves performance by altering hepatic lipid metabolism and cecal microbiota function and its metabolites in late laying hens. J. Anim. Sci. Biotechnol., 15: 100. https://doi.org/10.1186/s40104-024-01057-w

Gurturk Z, Tezcaner A, Dalgic AD, Korkmaz S, Keskin D (2017). Maltodextrin modified liposomes for drug delivery through the blood–brain barrier. Med. Chem. Comm., 8: 1337–1345. https://doi.org/10.1039/C7MD00045F

Hermanto FE, Nuningtyas YF, Marwi F, Permata FS, Susilo A, Natsir MH (2024). Discovering the potential of teak, turmeric, and ginger in broiler chicken gut health: A network biology perspective on IL-6 inhibition. Adv. Anim. Vet. Sci., 12: 749–757. https://doi.org/10.17582/journal.aavs/2024/12.4.749.757

Liu T, Zhou J, Li W, Rong X, Gao Y, Zhao L, Fan Y, Zhang J, Ji C, Ma Q (2020). Effects of sporoderm-broken spores of *Ganoderma lucidum* on growth performance, antioxidant function and immune response of broilers. Anim. Nutr., 6: 39–46. https://doi.org/10.1016/j.aninu.2019.11.005

Liu Z, Suo C, Jiang Y, Zhao R, Zhang T, Jin L, Chen X (2022). Phenome-wide association analysis reveals novel links between genetically determined levels of liver enzymes and disease phenotypes. Phenomics, 2: 295–311. https://doi.org/10.1007/s43657-021-00033-y

Ma J, Piao X, Shang Q, Long S, Liu S, Mahfuz S (2021). Mixed organic acids as an alternative to antibiotics improve serum biochemical parameters and intestinal health of weaned piglets. Anim. Nutr., 7: 737–749. https://doi.org/10.1016/j.aninu.2020.11.018

Ma Y, Shi Y, Wu, Q, Ma W (2021). Dietary arsenic supplementation induces oxidative stress by suppressing nuclear factor erythroid 2-related factor 2 in the livers and kidneys of laying hens. Poult. Sci., 100: 982–992. https://doi.org/10.1016/j.psj.2020.11.061

Marcon H, Griss LG, Molosse VL, Cecere BGO, Alba DF, Leal KW, Galli GM, Souza CF, Baldissera MD, Gundel S, de A. Bassotto V, Ourique AF, Vedovatto M, Da Silva AS (2021). Dietary supplementation with curcumin-loaded nanocapsules in lambs: Nanotechnology as a new tool for nutrition. Anim. Nutr., 7: 521–529. https://doi.org/10.1016/j.aninu.2020.06.014

Nuningtyas Y, Natsir H, Hermanto F, Marwi F, Fionita R (2024). Pengaruh Pemberian Feed Additive Ekstrak Nano Cair Jahe, Kunyit, Daun Jati dan Probiotik Terhadap Persentase Karkas dan Kualitas Fisik Daging Ayam Broiler. Ternak. Trop. J. Trop. Anim. Prod., 25: 84–97. https://doi.org/10.21776/ub.jtapro.2024.025.01.10

Patil S, Rao B, Matondkar M, Bhushette P, Sonawane SK (2022). Review on understanding of egg yolk as functional ingredients. J. Microbiol. Biotechnol. Food Sci., 11: e4627. https://doi.org/10.55251/jmbfs.4627

Phuong LT, Nguyen TT (2021). Effect of herbal powder supplementations in feed on egg performances and intestinal microflora of small size local hens in the south of Vietnam. Livest. Res. Rural Dev., 33: 1–5.

Postružnik V, Stajčić S, Borjan D, Ćetković G, Knez Ž, Knez Marevci M, Vulić J (2024). Impact of storage conditions on stability of bioactive compounds and bioactivity of beetroot extract and encapsulates. Processes, 12: 1345. https://doi.org/10.3390/pr12071345

Sjofjan O, Adli DN, Natsir MH, Nuningtyas YF (2023). The interactive influence of nano-structured encapsulation of Moringa oleifera leave particle size and liquid: Growth performance, and gut morphometric of Lohmann broiler. In: Developing Modern Livestock Production in Tropical Countries. CRC Press, https://doi.org/10.1201/9781003370048-7

Sunarti TC, Pasaribu FJ, Winarti C (2020). Encapsulation of temulawak extract by using nanocrystalline cassava and sago starches and maltodextrin. Pharm. Sci. Res., 7: 75–80. https://doi.org/10.7454/psr.v7i1.1068

Suwito LHA, Nuningtyas YF, Hermanto FE, Marwi F, Natsir MH (2025). Evaluation of feed additive liquid nano herbal extract in mash form and protected as a feed supplement to the appearance of laying hen production. Atlantis Press, pp. 499–504. https://doi.org/10.2991/978-94-6463-670-3_54

Tang L-P, Liu Y-L, Zhang J-X, Ding K-N, Lu M-H, He Y-M (2022). Heat stress in broilers of liver injury effects of heat stress on oxidative stress and autophagy in liver of broilers. Poult. Sci., 101: 102085. https://doi.org/10.1016/j.psj.2022.102085

Todorović A, Šturm L, Salević-Jelić A, Lević S, Osojnik Črnivec IG, Prislan I, Skrt M, Bjeković A, Poklar Ulrih N, Nedović V (2022). Encapsulation of bilberry extract with maltodextrin and gum arabic by freeze-drying: Formulation, characterisation, and storage stability. Processes, 10: 1991. https://doi.org/10.3390/pr10101991

Toraya-Avilés R, Segura-Campos M, Chel-Guerrero L, Betancur-Ancona D (2017). Effects of pyroconversion and enzymatic hydrolysis on indigestible starch content and physicochemical properties of cassava (*Manihot esculenta*) starch: Pyroconversion and enzymatic hydrolysis of cassava (*Manihot esculenta*) starch. Starch – Stärke., 69: 1600267. https://doi.org/10.1002/star.201600267

Utami CMP, Sjofjan O, Natsir MH (2023). Effects of Bioherbal compounds on performance and intestinal characteristics of laying chickens. J. Worlds Poult. Res., 13(2): 199-205. https://doi.org/10.36380/jwpr.2023.22

Wardhana YW, Budiati W, Oktavia RD, Widyanti KT, Kurniawansyah IS, Herdiana Y (2022). Ophthalmic release of in situ gel Ciprofloxacin HCl based on combination of Hypromellose and HPC. Indones. J. Pharm., 3: 128–138. https://doi.org/10.24198/idjp.v3i3.36140

Wu C, Song J, Li L, Jiang Y, Applegate TJ, Wu B, Liu G, Wang J, Lin Y, Zhang K, Li H, Wu F, Bai S (2022). Protective effects of selenized yeast on the combination of cadmium-, lead-, mercury-, and chromium-induced toxicity in laying hens. Front. Vet. Sci., 9: 958056. https://doi.org/10.3389/fvets.2022.958056

Xiao Z, Xia J, Zhao Q, Niu Y, Zhao D (2022). Maltodextrin as wall material for microcapsules: A review. Carbohydr. Polym., 298: 120113. https://doi.org/10.1016/j.carbpol.2022.120113

Yin C, Zhou C, Shi Y, Ge Y, Gao X, Wu C, Xu Z, Huang C, Hu G, Liu P, Guo X (2023). Effects and potential mechanism of dietary vitamin C supplementation on hepatic lipid metabolism in growing laying hens under chronic heat stress. J. Anim. Sci., 101: 308. https://doi.org/10.1093/jas/skad308

Yu Z, Cheng M, Luo S, Wei J, Song T, Gong Y, Zhou Z (2023). Comparative lipidomics and metabolomics reveal the underlying mechanisms of taurine in the alleviation of nonalcoholic fatty liver disease using the aged laying hen model. Mol. Nutr. Food Res., 67: 2200525. https://doi.org/10.1002/mnfr.202200525

Zalfa NA, Nuningtyas YF, Hermanto FE, Permata FS, Natsir MH (2023). The effectiveness of cassava waste and skim milk as a filler of phytogenic and probiotic blends to inhibit the pathogenic bacteria and aflatoxin. BIO Web Conf., 81: 00041. https://doi.org/10.1051/bioconf/20238100041

Zurak D, Slovenec P, Janječić Z, Bedeković X D, Pintar J, Kljak K (2022). Overview on recent findings of nutritional and non-nutritional factors affecting egg yolk pigmentation. Worlds Poult. Sci. J., 78: 531–560. https://doi.org/10.1080/00439339.2022.2046447