Research Article

Herbal Jamu Pulp *Oryza sativa* and *Kaemferia galanga* L Antioxidant and Flavonoid Compound Infuence Performance Production and Intestinal Morphology of Hybrid Ducks

Prihatiningsih[1], **Muhammad Halim Natsir**[2], **Osfar Sjofjan**[2*]

[1]*Postgraduate Program, Faculty of Animal Science, Universitas Brawijaya, Malang 65145, East Java, Indonesia;* [2]*Faculty of Animal Science, Universitas Brawijaya, Malang 65145, East Java, Indonesia.*

Abstract | Herbal pulp from production of *beras kencur* (a traditional Indonesian herbal drink made by using *Oryza sativa* and *Kaempferia galangal* L) is an underutilized by-product containing bioactive compounds. This study aimed to evaluated herbal jamu pulp *Oryza sativa* and *Kaempferia galangal* L as a feed additive to hybrid ducks. in performance production and intestinal morphology. The material used was 192 one-day-old hybrid ducks (unsexing) a Completely Randomized Design: T0(-): basal diet; T1(+): basal diet + antibiotic (*Zinc bacitracin* 0.1%); T2: basal diet + herbal jamu pulp 0.25%; T3: basal diet + herbal jamu pulp 0.50%; T4: basal diet + herbal jamu pulp 0.75%; T5: basal diet + herbal jamu pulp 1%. Variables measured included production performance (feed intake, body weight gain, feed conversion ratio, production index, income over feed cost) and intestinal morphology (number of villus, villus height, villus area, crypt depth, ratio Vh:Cd, pH, and viscosity). Data were analyzed using ANOVA followed by Duncan's test. Phytochemical analysis showed antioxidant activity (IC50=23.81-49.80 ppm) and total flavonoid content (48.53-62.70 mg EQ/100 g). In vivo experiment resulted in no significant effect of treatment ($P>0.05$) on performance production. Significant effect ($P<0.05$) on intestinal morphology (villus area) and highly significant effect ($P<0.01$) on the Crypt Depth, pH and viscosity of digesta. It is concluded the herbal jamu pulp can serve as a potential Natural Growth Promoters as a feed additive can improve intestinal morphology (villus area), Crypt Depth, pH, and viscosity, it increases nutrient absorption in hybrid ducks.

Keywords | Antioxidant, Flavonoid, Herbal Jamu Pulp, Hybrid ducks, Intestinal morphology, Performance production

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***Correspondence** | Osfar Sjofjan, Faculty of Animal Science, Universitas Brawijaya, Malang 65145, East Java, Indonesia; **Email:** osfar@ub.ac.id
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INTRODUCTION

Duck meat production in Indonesia has shown a steady increase, over the last five years (2020-2024) has experienced fluctuations with a tendency to increase by 0.97% per year or an average meat production of 36.672.975 tons per year (Central Statistics Agency of Indonesia, 2024). In the years studied, the cost of feed accounted for 60-70% of the total production cost (Skwirzyńska *et al*., 2025), while antibiotic growth promoters have been banned due to health risks and bacterial resistance (Morgan *et al*., 2023). Antibiotic growth promoters has been banned as feed additives in Indonesia following the circulation of PERMENTAN RI Number.14/PERMENTAN/PK.350/5/2017 concerning the classification of veterinary drugs (Regulation of the Minister of Agriculture of the Republic of Indonesia, 2017). This regulation makes the use of natural growth promoters (NGP) a feed additive in animal feed, such as *Oryza sativa* and *Kaempferia galanga* L. Herbal pulp, a by-product of jamu production, known to enhance immunity, antioxidant status, and feed efficiency (Parkunan *et al*., 2024; Rusny et al., 2021).

Kaempferia galanga L contains essential oils are *ethyl p-methoxy cinnamate* (34.79%), *ethyl cinnamate* (20.72%), 1,8-*cineole* (8.96%), *trans-cinnamaldehyde* (7.03%), and *borneol* (5.64%) (Li *et al*., 2017). Nutritional content of *Oryza sativa* contains several several B vitamins, including thiamine (B1), riboflavin (B2), and folate (B9), which are crucial for energy metabolism and overall health (Mohidem *et al*., 2022). Antioxidants and flavonoids from herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L are important in feed additives in counteracting free radicals to prevent oxidative stress. Antioxidants are compounds or molecules that play a role in stabilizing free radicals through electron donors by inhibiting the significant activity of free radical formation (Alenisan *et al*., 2017). Flavonoids in both act as antioxidants by scavenging free radicals, thus preventing oxidative stress (Xian *et al*., 2021; Hassanpour and Doroudi., 2023).

Hybrid duck is the cross between white pekin and khaki campbell combine fast growth and good egg production (Giri *et al*., 2023a). The body measurements of these crossbreds are generally higher than those of Khaki Campbell but lower than white pekin ducks of the same age (Giri *et al*., 2023b). Active compound in *Oryza sativa* and *Kaempferia galanga* L function as restoring bacterial balance to the digestive tract, antibacterials, and enhancing livestock production. This study aims to assess the impact of giving herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L into hybrid ducks feed on their performance production and intestinal morphology. Although the bioactive properties of *Oryza sativa* and *Kaempferia galanga* L. have been widely reported, their combined use in the form of herbal jamu pulp as a feed additive has not yet been investigated in Indonesia. This study therefore addresses an important research gap by evaluating its potential role in improving growth performance and gut health of hybrid ducks.

MATERIALS AND METHODS

Herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L preparation of feed additive

The herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L were obtained from tradisional homemade jamu in Malang, East Java, Indonesia. Herbal jamu pulp used with the best formulation after selecting the best of two samples, which was: (*Oryza sativa* 35%, *Kaempferia galanga* L 45%, brown sugar and water 20%). The procedure for producing herbal jamu pulp involved by following the previous protocol (Attia *et al*., 2025; Nurhaslina *et al*., 2022). The herbal jamu pulp were cleaned using water, herbal jamu pulp aired for three days, after that, the herbal jamu pulp were dried for 24 hours at 105 °C in the oven, reducing the amount of water to less than 14% then proceed with grinding using a grinder until it had a powder texture. The herbal jamu pulp powder was filtered using a 400μ mesh sieve to form a powder.

In vivo experimental design

Location *in vivo* experimentasl design was conducted at a Sunarko duck farm in Perembangan, Sawahan, Turen, Malang. This research uses a total of 192 days-old ducklings (DOD) hybrid duck with uniformity coefficient 9%. *In vivo* experiment with a completely randomized design (CRD) with six treatments and four replications with total in 24 pens. Each cage housed 8 ducks and they were raised for a period of 5 weeks. All duck were kept in environmentally controlled rooms within pens measuring 100cm (L) x 50cm (W) x 50cm (H), filled with rice hull litter. Hybrid ducks were provided *ad libitum* feed and water with temperature 26°C. Treatment in this research use herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L. The treatment feeds were as follows: T0(-) basal diet, T1(+): basal diet + antibiotic (*Zinc bacitracin* 0.1%), T2 basal diet + herbal jamu pulp 0.25%, T3 basal diet + herbal jamu pulp 0.50%, T4 basal diet + herbal jamu pulp 0.75%, and T5 basal diet + herbal jamu pulp 1%.

Total flavonoid compound

Procedure Flavonoid compound following by (Ássimos *et al*., 2025) with steps analysis will be determined using the UV-Vis Spectrophotometry methods. Samples 2g with addition 10mL methanol, macerated 15 minutes and filter sample, take 1mL filtrate and adding 1mL $AlCl_3$ 2%, acetic acid 5% (incubate for 30 minutes), and read absorbance at 410 nm (nanometers is standard for UV-Vis). Make a standard curve until an equation is formed (the equation is used to calculate the flavonoid content).

Total antioxidant compound

Procedure antioxidant compound following by (Guchu *et al*., 2020) with analysis step will be determined using the DPPH (2,2-*diphenyl*-1-*picrylhydrazyl*) 0.3 mM method in UV-Vis Spectrophotometry methods with procedure. Samples 2g with addition 10ml methanol, macerated 15 minutes and filter sample, take 1mL filtrate and adding 1mL DPPH 0.3mM (incubate for 30 minutes), and read absorbance at 517nm.

Performance production

Ducks were weighed from day-old (DOD) to determine uniformity, then weekly up to 5 weeks. Feed intake was calculated daily from feed offered minus refusals, adjusted for mortality. Feed conversion ratio (FCR) was obtained as total feed intake divided by weight gain (Li *et al*., 2023).

Weight gain was measured as the difference between initial and final body weight, while IOFC represented income over feed cost during the rearing period. The formula for the performance index is poorly formatted (Laili *et al*., 2022). It should be:

$$\text{Performance Index} = \frac{(Final\ Population\ \times Average\ Final\ weight)}{(Feed\ Conversation\ Ratio \times Final\ age)} \times 100$$

Intestinal morphology

Intestinal morphology samples for examination number of villus, villus height, villus area, crypt depth, ratio villus height: crypt depth (Vh:Cd), pH, viscosity were obtained from 5-week- old hybrid ducks. Ducks were fasted for eight hours before blood collection. Intestinal morphology samples were taken to the laboratory in a refrigerated tray containing ice gel in less than two hours from collection. The preparation of small intestine histology following by (Deng *et al*., 2020) slides was carried out following standard histotechnical procedures. The embedded tissue was sectioned at a thickness of 4 µm using a microtome and mounted on glass slides. The sections were then fixed with cold methanol, washed with PBS, and stained with hematoxylin and eosin through a series of dipping and rinsing steps. Preparations were processed through graded alcohols (70%, 80%, 96%, and 100%), cleared with xylene, covered with a cover glass, and finally examined under a light microscope at 4×, 10×, 40×, and 100× magnifications according to the requirements of intestinal histological analysis.

Paraffin embedding procedure by (Sadeghipour and Babaheidarian, 2019), in which the infiltrated tissue is placed into a mold filled with molten paraffin and allowed to solidify, forming a paraffin block. This block is then sectioned into thin slices (approximately 4-6 µm) using a microtome and mounted onto glass slides. The resulting sections are subsequently stained, commonly with Hematoxylin and Eosin (H and E), for histological evaluation. The histomorphology intestinal villus analysis using Microscope Nikon Ei with camera *Optilab* Plus (zoom 4x) and software image processor Optilab Viewer + Image Raster in each treatment.

Statistical analysis

Data were analyzed using R version 4.5.1. An Analysis of Variance (ANOVA) was conducted under the General Linear Model (GLM) framework (Field *et al*., 2012). Significant results (P< 0.05) were further separated using Duncan's Multiple Range Test (DMRT), with (α= 0.05). The findings were reported as standard error mean (SEM), and probability values were determined using least significant difference testing. The model utilized for analysis is outlined below:

$$\gamma_{ij} = \mu + T_i + e_{ij}$$

Where; γ_{ij} parameters observed, μ Overall mean, T_i is the fixed effect of the i-th treatment, and e_{ij} refers to the residual error.

RESULTS

Total flavonoid and antioxidant compound of herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L

Herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L exhibited potential as a feed additive due to its bioactive compound content, particularly flavonoids and antioxidants. The relatively high total flavonoid content in herbal jamu pulp indicated the presence of active phenolic compounds. Phytochemical analysis, as shown in (Table 1), revealed that the herbal jamu pulp contained significant levels of flavonoids, antioxidants, and a moderately acidic pH. The flavonoid content in treatment A2 was 62.70 mg EQ/100 g, which was higher than that in A1 (48.53 mg EQ/100 g). These results indicated that although although it was categorized as waste, it still contained high levels of flavonoids, making it a valuable feed additive candidate. The antioxidant activity, measured by IC50 values, showed that treatment A1 had stronger free radical scavenging ability (IC50= 23.810 ppm) compared to A2 (IC50 = 49.795 ppm). This difference could be attributed to variations in flavonoid structure, particularly the number of hydroxyl groups and the degree of polymerization. Environmental factors such as temperature, light intensity, soil composition, and water availability may also influence the antioxidant levels in plants.

Table 1: Total antioxidant and flavonoid compound of herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L.

Parameters	Treatment Herbal Jamu Pulp	
	A1	A2
Flavonoid (mg/EQ/100 g)	48.53	62.70
Antioxidant IC50 (ppm)	23.810	49.795

Mg: Milligram; EQ: Equivalen Quersetin; g: gram; IC50: Inhibition Concentration 50%; ppm: parts per million.

Effect of herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L on the performance production of the hybrid duck

The results showed that herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L in hybrid ducks did not significant effect (P>0.05) feed intake, body weight gain, feed conversion ratio (FCR), production index, or income over feed cost (IOFC) (Table 2). The greatest feed intake in T2 (2701±314.00g/bird), body weight gain T2 (1722 ±84.5 g/ bird), FCR T2 (1.57), production index T2 (324 ±28), and

Table 2: Effect of herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L on the performance production of the hybrid ducks.

Treatments	Variables				
	Feed intake (g/bird)	Body weight again (g/bird)	Feed conversation ratio	Production index	IOFC (IDR/bird)
T0 (-)	2633±214.00	1672±184.00	1.58±0.12	313±51.00	21,500±3.43
T1 (+)	2664±167.00	1601±62.60	1.67±0.14	285±31.00	19,327±2.19
T2	2701±314.00	1722±84.50	1.57±0.14	324±28.00	22,254±1.82
T3	2749±117.00	1568±182.00	1.76±0.14	264±50.00	17,992±3.94
T4	2543±191.00	1472±124.00	1.73±0.10	251±29.00	17,080±2.58
T5	2744±53.70	1668±68.00	1.65±0.04	298±19.00	20,693±1.36
SEM	88.00	58.82	0.06	17.43	1276.17
P Value	0.67	0.13	0.18	0.09	0.09

NS: Not Significant; g: gram; IOFC: Income Over Feed Cost; IDR: Indonesian rupiah (1US$= Rp. 16.623); T0(-): basal diet; T1(+): basal diet + Zinc bacitracin 0.1%; T2: basal diet + 0.25% herbal jamu pulp; T3: basal diet + 0.50%; herbal jamu pulp; T4: basal diet + 0.75% herbal jamu pulp; T5: basal diet + 1.00% herbal jamu pulp.

IOFC IDR 22,254±1.82. Production performance is influenced by mortality, at the time of the research all ducks survived until the end of the trial the mortality was 0% across treatments. Although no significant differences in production performance, a consistent biological trend indicated that herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L as a feed additive in hybrid ducks at the level of 0.25% could potentially provide higher economic and improved production performance compared to both the antibiotic (*zinc bacitracin*) and the control treatment.

During the experiment, conducted in the Indonesian transitional season (pancaroba), ducks faced fluctuating temperatures and rainfall. These unstable conditions created environmental stressors that influenced the physiological responses of the ducks across different treatments (Figure 1). Ducks in the control group (T0) appeared normal but less active, in antibiotic group (T1) showed panting, frequent drinking, and reduced feed intake, indicating heat stress. In contrast, ducks receiving herbal pulp (T2-T5) exhibited stable clinical conditions, with regular feeding, drinking, and more active behavior. This suggests that bioactive compounds in the pulp, particularly flavonoids and antioxidants, mitigated stress responses and enhanced physiological adaptation under unstable climates. Overall, herbal jamu pulp not only supported gut health but also helped maintain clinical stability under environmental stressors.

Effect of herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L on the intestinal morphology of the hybrid duck

Herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L as a feed additive in hybrid ducks did not significant effect (P>0.05) the number of villi, villus height (Vh), and ratio Vh:Cd. However, significant effect (P<0.05) in villus area and highly significant (P<0.01) in crypt depth (Cd) (Table 3). The greatest villus area in T2 (1577 ± 303 μm²) and crypt depth in T2 (272±37.60), indicating an increased absorptive surface area of the intestine. Crypt depth was also highest in T2 (272 ± 37.6 μm), reflecting crypt hyperplasia and enhanced epithelial cell regeneration. Although VH:CD ratio differences were not statistically significant, the higher value in T2 (483 ± 65.4) suggests improved nutrient absorption capacity. Herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L as a feed additive in hybrid ducks at level of 0.25% exerted the most positive effect on intestinal morphology compared to control and other treatments. T2 indicates potential improvement in nutrient absorption function.

Figure 1: Behavior in hybrid ducks during *in vivo*.

Histological examination of the hybrid duck intestine with Hematoxylin-Eosin staining revealed clear differences among treatments (Figure 2). Control ducks (T0) had short villi with narrow widths and shallow crypts, indicating limited absorption. The antibiotic group (T1) showed thinner, irregular, and fragmented villi with widened crypts, indicating stress effects. In contrast, duck herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L (T2-T5) improved intestinal morphology. T2 showed the most optimal structure, with tall, broad villi and deep, organized

Table 3: Effect of herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L on the intestinal morphology of the hybrid ducks.

Treatment	Variables				
	Number of Villus	Villus Height (Vh) µm	Villus Area µm² *	Crypt Depth (Cd) µm**	Ratio Vh:Cd
T0 (-)	10.00±2.44	659±116.00	1157±208.00^{b}	228±22.30^{ab}	448±51.00
T1 (+)	9.55±2.29	634±61.60	1081±216.00^{b}	186±48.70^{bc}	410±53.70
T2	9.25±1.56	690±95.00	1577±303.00^{a}	272±37.6^{0}a	483±65.40
T3	9.10±1.59	652±160.00	936±296.00^{b}	140±21.60^{c}	396±88.40
T4	12.05±1.59	570±110.00	945±318.00^{b}	173±41.50^{bc}	372±63.40
T5	10.30±1.47	535±102.00	1116±319.00^{b}	187±78.00^{bc}	361±49.90
SEM	0.1	48.62	138.33	20.83	30.97
P Value	0.29	0.39	0.05	0.01	0.11

*: Significant (P<0.05); ** Highly Significant (P<0.01); µm: Micrometer; Vh: Villus Height; Cd: Crypt Depth; T0(-): basal diet; T1(+): basal diet + Zinc bacitracin 0.1%; T2: basal diet + 0.25% herbal jamu pulp; T3: basal diet + 0.50%; herbal jamu pulp; T4: basal diet + 0.75% herbal jamu pulp; T5: basal diet + 1.00% herbal jamu pulp.

crypts, reflecting enhanced absorptive area. T3 displayed branched villi with wider basal and apical structures, potentially enhancing absorptive capacity, T4 maintained stable crypts with moderate villus height, and T5 showed long compact villi with deeper crypts. Herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L improved villus and crypt morphology compared to control and antibiotic groups, indicating enhanced nutrient absorption and intestinal health.

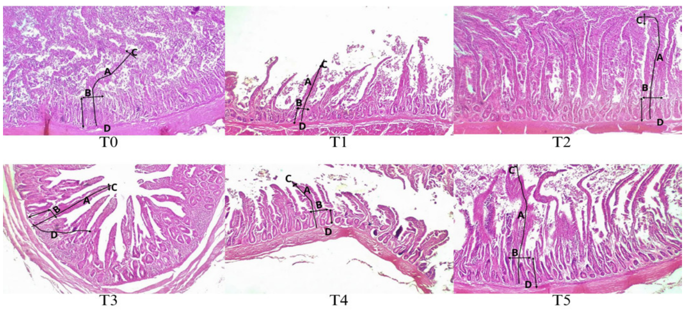

Figure 2: Histological morphology of the ileum in hybrid ducks fed different diets (H and E staining). a (villus height); b (basal width); c (apical width); d (crypt depth); T0(-): basal diet; T1(+): basal diet + Zinc bacitracin 0.1%; T2: basal diet + 0.25% herbal jamu pulp; T3: basal diet + 0.50%; herbal jamu pulp; T4: basal diet + 0.75% herbal jamu pulp; T5: basal diet + 1.00% herbal jamu pulp; Arrows indicate representative villus structures. Scale bar = 100 µm.

Effect of herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L on the pH and viscosity of the hybrid duck

Results of Table 4 at pH and Viscosity impact of herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L as a feed additive in hybrid ducks. Giving herbal jamu pulp in duck feed Treatment T2 (0.25%) had a had a highly significant effect (P<0.01), resulting in a pH of (6.12±0.70) and viscosity (5.22±0.09). This condition indicates an ideal balance in the intestinal pH of the intestinal digesta highly significant effect the (P<0.01), the lowest pH value was observed in the negative control group T0 (5.88 ± 0.37), and highest in T5 (7.88 ± 0.46). Viscosity of the intestinal digesta highly significant effect the (P<0.01). Highest viscosity in T2 (5.22 ± 0.09), T0 (5.02 ± 0.80), and the lowest was in T3 (3.49 ± 0.34).

Table 4: pH and viscosity *Oryza sativa* and *Kaempferia galanga* L on hybrid ducks.

Treatment	Variabels	
	pH**	Viscosity (mPa.s)**
T0 (-)	5.88±0.37^{c}	5.02±0.80^{ab}
T1 (+)	6.77±0.45^{b}	4.40±0.85^{ab}
T2	6.12±0.70^{bc}	5.22±0.09^{a}
T3	6.67±0.64^{bc}	3.49±0.34^{c}
T4	6.24±0.37^{bc}	4.21±0.97^{bc}
T5	7.88±0.46^{a}	4.79±0.43^{ab}
SEM	0.25	0.22
P Value	5E-04	26E-02

**: Highly significant (P<0.01); pH: Potential of Hydrogen; mPa.s: Milipascal-second; T0(-): basal diet; T1(+): basal diet + Zinc bacitracin 0.1%; T2: basal diet + 0.25% herbal jamu pulp; T3: basal diet + 0.50%; herbal jamu pulp; T4: basal diet + 0.75% herbal jamu pulp; T5: basal diet + 1.00% herbal jamu pulp.

DISCUSSION

Total flavonoid and antioxidant compound

Kaempferia galanga L. contains flavonoids (galangin, alpinetin, flavonols) and essential oils (ethyl p-methoxycinnamate, camphor) with strong antioxidant, anti-inflammatory, and antimicrobial effects beneficial for animal health (Szabó et al., 2023). Flavonoid content in *Oryza sativa* varies by variety, with pigmented rice showing higher levels: *Oryza sativa* L indica contains 500 mg QE/100 g, *Oryza nivara* 400 mg QE/100 g, and *Oryza sativa* L 260-270 mg QE/100 g (Nayeem *et al*., 2021). Ethanol extract of *Kaempferia galanga* L rhizome contains flavonoids of 37.72 mg QE/g and total phenolics of 15.40 mg GAE/g (Riastri, 2024). Based on the research results, the flavonoid content of herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L, as shown in (Table 1), ranges from 48.53 to 62.70 mg QE/100 g, this value is relatively low compared to the flavonoid content in fresh *Oryza sativa* and *Kaempferia galanga* L influenced ratios and the types used. Rice bioactives such as *anthocyanins*, *quercetin*, *γ-oryzanol*, and ferulic acid act as antioxidants and immunomodulators (Colombo *et al*., 2024).

Antioxidant activity is classified as very strong (<50 ppm), strong (50-100 ppm), moderate (101-150 ppm), and weak (151-200 ppm) (Nasution et al., 2015). The herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L showed IC_{50} values of 23.810 ppm and 49.795 ppm, indicating strong antioxidant activity consistent (Surai *et al*., 2019). Stating that lower IC_{50} reflects stronger antioxidant capacity. *Oryza sativa* phenolics like *γ-oryzanol* and *tocopherols* react with DPPH radicals and stabilize within the feed matrix (Irakli *et al*., 2016) protecting against oxidative stress, supporting intestinal integrity, and improving nutrient absorption.

Performance production

Kaempferia galanga L contains flavonoids and phenolic compounds with aromatic and pharmacological properties that act as potent antioxidants. The research present herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L as a feed additive improved feed intake, body weight gain, feed conversion ratio (FCR), production index, and income over feed cost (IOFC) in hybrid ducks, particularly in treatment T2 (0.25%). These findings are consistent with the results of (Alem, 2024) that herbal feed additives containing flavonoids enhanced growth performance and feed efficiency in broilers. Ayana and Kamutambuko (2024) showed that flavonoid supplementation reduced oxidative stress and improved nutrient utilization in poultry, supporting our observation that bioactive compounds in herbal pulp contributed to better physiological function.

Jiang *et al*. (2020) in duck demonstrated that enzyme supplementation enhanced nutrient digestibility and growth performance. Cineole compound in *Kaempferia galanga* may stimulate digestive enzyme secretion, leading to improved FCR, Wen *et al*. (2021) emphasized the importance of gut health in poultry productivity, noting that antioxidant compounds stabilize intestinal microbiota and enhance nutrient absorption. This supports the results herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L enhanced intestinal function and feed intake compared to the control and antibiotic groups. Economic perspective the improved Income Over Feed Cost (IOFC) observed in this research aligns with the findings of (North *et al*., 2019) stated that phytogenic feed additives can improve profitability by enhancing feed efficiency and overall animal performance. These findings confirm that herbal jamu pulp as a feed adiitive has comparable or even superior effects to previously reported phytogenic feed additives, highlighting its potential as a natural and economically viable alternative to antibiotics in duck production.

Intestinal morphology

The findings of this study indicated that supplementation with herbal jamu pulp in treatment T2 improved the histological structure of the small intestine, particularly through enhanced villus morphology and deeper crypts. The intestinal villi are essential structures that increase the absorptive surface area, thereby facilitating efficient nutrient uptake. These villi are composed of simple columnar epithelial cells and contain blood vessels, lacteals, enteric nerves, smooth muscle cells, fibroblasts, and immune cells, all of which play a critical role in nutrient absorption and mucosal integrity (Beumer and Clevers, 2016). The improvement observed in villus height and crypt depth in T2 suggests that herbal jamu pulp may stimulate mucosal proliferation, providing both an increased absorptive surface and a more stable regenerative capacity. Flavonoids have been shown to stimulate crypt cell proliferation, thereby accelerating epithelial regeneration and enhancing mucosal integrity (Belote *et al*., 2023).

In broilers, dietary supplementation flavonoid plant extracts increased villus height and ratio Vh:Cd, which translated into improved nutrient utilization (Prihambodo *et al*., 2021). Saponins to interact with the lipid bilayer of intestinal cells, increasing membrane permeability and modulating tight junctions, which can further enhance nutrient absorption efficiency (Moghimipour *et al*., 2016). Villus height: crypt depth (Vh:Cd) a higher ratio reflects greater absorptive capacity and more effective tissue renewal (Belote *et al*., 2023). In the research T2 exhibited an increased villus area and crypt depth compared to the control and antibiotic groups, supporting the bioactive compounds in herbal jamu pulp particularly flavonoids and phenolic compounds enhanced mucosal function (Beumer and Clevers, 2016). This is consistent with previous findings that polyphenol supplementation in poultry diets improves intestinal histomorphology, reduces oxidative stress, and enhances growth performance Wen *et al*. (2021).

pH and viscosity

pH and digesta viscosity as they directly influence nutrient solubility, diffusion, and absorption efficiency. In the present study, supplementation with herbal jamu pulp (T2) contributed to stabilizing intestinal pH and reducing digesta viscosity compared to the control and antibiotic groups. These findings are consistent with (Schop *et al*., 2020) that increased digesta viscosity impairs the separation of solid and liquid fractions, dilutes gastric content, and consequently reduces nutrient absorption. Therefore, the reduction in viscosity observed in the present study may have facilitated improved nutrient utilization. Intestinal pH balance also plays a key role in digestive function. Excessively high pH has been shown to reduce the activity of proteolytic enzymes such as pepsin, whereas excessively low pH may inhibit intestinal enzyme activity, disrupt microbial homeostasis, and impair nutrient absorption (Krogdahl *et al*., 2015). The stabilized intestinal pH in ducks supplemented with herbal pulp indicates that bioactive compounds may have optimized digestive conditions.

The herbal jamu pulp was enriched with bioactive compounds such as flavonoids, tannins, saponins, and soluble fiber, which are known to modulate the intestinal microbial environment and stabilize pH balance. Flavonoids and polyphenols exhibit selective antimicrobial activity, particularly against Gram-negative pathogens such as *Escherichia coli* and *Salmonella*, which are known to produce ammonia and elevate intestinal pH (Babii *et al*., 2016). This aligns with our results, where the T2 group exhibited a more stable intestinal environment than the control. Phytogenic compounds with antioxidant and antimicrobial properties improve gut health by stabilizing microbiota composition, enhancing enzymatic activity, and supporting nutrient absorption (Alenisan *et al*., 2017). The outcomes of this study are consistent with these findings, demonstrating that jamu pulp supplementation effectively enhanced intestinal function and digestive efficiency in ducks. Thus, the present research supports the potential of *jamu* pulp as a natural feed additive capable of improving intestinal physiology and overall production efficiency.

CONCLUSIONS

Herbal jamu pulp herbal *Oryza sativa* and *Kaempferia galanga* L significat effect in villus area and highly significant in crypt depth, pH, and viscosity of digesta. These changes contributed to improved intestinal absorption, resulting in more efficient nutrient utilization. The findings support Herbal jamu pulp herbal *Oryza sativa* and *Kaempferia galanga* L as a viable phytobiotic and antibiotic free strategy to sustain productivity in hybrid ducks. Future research should extend the feeding period, apply fermentation techniques, and evaluate its effectiveness in other poultry species.

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NOVELTY STATEMENT

The novelty of this research is the use of secondary formulation herbal jamu pulp *Oryza sativa* and *Kaempferia galanga* L with different formulation as an alternative feed additive.

AUTHOR'S CONTRIBUTION

P: conceptualization, drafting the original manuscript, collecting data, analyze statistics. MHN: conceptualization, supervision. OS: conceptualization, supervision. Each author has reviewed and approved the manuscript's published form.

Ethical approval

The experimental procedure in this study was approved by the Institutional Animal Care and Use Committee (IACUC) of universitas brawijaya (Number: 208-KEP-UB-2024).

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Generative AI and AI-assisted technology statement

The authors declare that no Generative AI was used in the creation of this manuscript.

Conflict of interest

The authors have declared no conflict of interest.

REFERENCES

Alem WT (2024). Effect of herbal extracts in animal nutrition as feed additives. Heliyon, 10(3): 1-8. https://doi.org/10.1016/j.heliyon.2024.e24973

Alenisan MA, Alqattan HH, Tolbah LS, Shori AB (2017). Antioxidant properties of dairy products fortified with natural additives: A review. J. Assoc. Arab Univ. Basic Appl. Sci., 24(1): 101-106. https://doi.org/10.1016/j.

jaubas.2017.05.001

Ássimos AA, Bernardes CD, Aleme HG, Sanches BPJ (2025). Determination of flavonoid content in brazilian propolis extracts by uv-vis spectroscopy and pls regression. Anal. Chem. J., 21(1).

Attia YA, Addeo NF, Bovera F, Al-Hack MEA, Al-Banoby MA, Alhotan RA (2025). Phytogenic substances as novel feed supplements and their application in livestock nutrition. Phytogenic and phytochemical as alternative feed additives for animal production, Sharjah, Uni Emirat Arab: Bentham Science Publishers: 4-18. https://doi.org/10.2174/9789815322767125010005

Ayana, GU, Kamutambuko R (2024). Probiotics in disease management for sustainable poultry production. Adv. Gut Microbiome Res., 2024(1): 1-9. https://doi.org/10.1155/2024/4326438

Babii C, Bahrin LG, Neagu AN, Gostin I, Mihasan M, Birsa LM (2016). Antibacterial activity and proposed action mechanism of a new class of synthetic tricyclic flavonoids. J. Appl. Microbiol., 120(3): 1-8. https://doi.org/10.1111/jam.13048

Belote BL, Soares I, Sanches AWD, de Souza C, Scott DR, Lahaye L (2023). Applying different morphometric intestinal mucosa methods and the correlation with broilers performance under eimeria challenge. Poult. Sci., 102(9): 1-9. https://doi.org/10.1016/j.psj.2023.102849

Beumer J, Clevers H (2016). Regulation and plasticity of intestinal stem cells during homeostasis and regeneration. Development (Cambridge), 143(20): 3639-3649. https://doi.org/10.1242/dev.133132

Central Statistics Agency of Indonesia (2024). Peternakan dalam Angka 2024. Badan Pusat Statistik. Available at: https://www.bps.go.id/id/publication/2024/12/20/522e07b24c7bbeb1c19b0a4e/peternakan-dalam-angka-2024.html (accessed 21 July 2025).

Colombo R, Moretto G, Barberis M, Frosi I, Papetti A (2024). Rice byproduct compounds: from green extraction to antioxidant properties. Antioxidants, 13(1): 1-26. https://doi.org/10.3390/antiox13010035

Deng F, Miller J, Swanson T (2020). Histology revolution: from inefficient, two dimensional, and low resolution techniques to high throughput, three dimensional and high resolution techniques. Egypt. J. Histol., 43(2): 373-379.

Field An, Miles J, Field Z (2012). Discovering statistics using R. California: SAGE Publication. Available at: https://batrachos.com/sites/default/files/pictures/Books/Field_ea_2012_Discovering%20Statistics%20using%20R.pdf (accessed 22 July 2025).

Giri SC, Padhi MK, Sahoo SK (2023a). Performance of cross bred (white pekin × khaki campbell) ducks under intensive system of rearing. Indian J. Anim. Sci., 93(5): 528-533. https://doi.org/10.56093/ijans.v93i5.130671

Giri SC, Padhi MK, Sahoo SK (2023b). Performance of cross bred (white pekin × khaki campbell) ducks under extensive system of rearing. Indian J. Anim. Sci., 93(5): 646-648. https://doi.org/10.56093/ijans.v93i6.132809

Guchu BM, Machocho AKO, Mwihia SK, Ngugi MP (2020). *In vitro* antioxidant activities of methanolic extracts of *Caesalpinia volkensii harms*, *Vernonia lasiopus, O. hoffm* and *Acacia hockii* de wild. Evid. Based Complement. Altern. Med., 2020(1): 1-10. https://doi.org/10.1155/2020/3586268

Hassanpour, SH, Doroudi, A (2023). Review of the antioxidant potential of flavonoids as a subgroup of polyphenols and partial substitute for synthetic antioxidants. Avicenna Journal of Phytomedicine, 13(4): 354-376. https://doi.org/10.22038/AJP.2023.21774

Irakli, MN, Samanidou, VF, Katsantonis, DN, Biliaderis, CG, Papadoyannis, IN (2016). Phytochemical profiles and antioxidant capacity of pigmented and non-pigmented genotypes of rice (*Oryza sativa* L.). Cereal Res. Commun., 44(1): 98-110. https://doi.org/10.1556/0806.43.2015.033

Jiang J, Wu H, Zhu D, Yang J, Huang J, Gao S (2020). Dietary supplementation with phytase and protease improves growth performance, serum metabolism status, and intestinal digestive enzyme activities in meat ducks. Animals, 10(2): 1-12. https://doi.org/10.3390/ani10020268

Krogdahl A, Sundby A, Holm H (2015). Characteristics of digestive processes in atlantic salmon (*Salmo salar*). enzyme ph optima, chyme ph, and enzyme activities. Aquaculture, 449(1): 27-36. https://doi.org/10.1016/j.aquaculture.2015.02.032

Laili AR, Damayanti R, Setiawan B, Hidanah S (2022). Comparison of broiler performance in closed house and open house systems in trenggalek. J. Appl. Vet. Sci. Technol., 3(1): 6-11. https://doi.org/10.20473/javest.V3.I1.2022.6-11

Li X, Yang B, Dong Z, Geng D, Wang C, Guo Q (2023). Growth performance, carcass traits, meat quality, and blood variables of small-sized meat ducks with different feed efficiency phenotypes. Poult. Sci., 102(8): 1-10. https://doi.org/10.1016/j.psj.2023.102818

Li YC, Ji H, Li XH, Zhang HX, Li HT (2017). Isolation of nematicidal constituents from essential oil of *Kaempferia galanga* l rhizome and their activity against heterodera avenae wollenweber. Trop. J. Pharma. Res., 16(1): 59-65. https://doi.org/10.4314/tjpr.v16i1.8

Ministry of Agriculture of the Republic of Indonesia (2017). Regulation number 14/PERMENTAN/PK.350/5/2017 concerning the classification of veterinary drugs. Jakarta Available at: https://peraturan.bpk.go.id/Details/160953/permentan-no-14permentanpk35052017-tahun-2017 (accessed 15 July 2025)

Moghimipour E, Tabassi SAS, Ramezani M, Handali S, Lobenberg R (2016). Brush border membrane vesicle and caco-2 cell line: two experimental models for evaluation of absorption enhancing effects of saponins, bile salts, and some synthetic surfactants. J. Adv. Pharma. Technol. Res., 7(3): 75-79. https://doi.org/10.4103/2231-4040.184588

Mohidem NA, Hashim N, Shamsudin R, Man HC (2022). Rice for food security: Revisiting its production, diversity, rice milling process and nutrient content. Agriculture (Switzerland), 12(6): 1-28. https://doi.org/10.3390/agriculture12060741

Morgan ALK, Woolhouse MEJ, Wagenaar JA, van Bunnik BAD (2023). Modelling the effects of antibiotic usage in livestock on human salmonellosis. One Health, 17(1): 1-8. https://doi.org/10.1016/j.onehlt.2023.100639

Nasution, PA, Batubara, R, Surjanto, S (2015) Tingkat kekuatan antioksidan dan kesukaan masyarakat terhadap teh daun gaharu (Aquilaria Malaccensis Lamk) berdasarkan pohon induksi dan non-induksi. Peronema Forestry Science Journal, 4(1): 10-21.

Nayeem S, Venkidasamy B, Sundararajan S, Kuppuraj SP, Ramalingam S (2021). Differential expression of flavonoid biosynthesis genes and biochemical composition in different tissues of pigmented and non pigmented rice. J. Food Sci. Technol., 58(3): 884-893. https://doi.org/10.1007/s13197-020-04602-3

North MK, Zotte AD, Hoffman LC (2019). The use of dietary flavonoids in meat production: A review. Anim. Feed Sci. Technol., 257(1): 1-15. https://doi.org/10.1016/j.anifeedsci.2019.114291

Nurhaslina CR, Bacho SA, Mustapa AN (2022). Review on drying methods for herbal plants. Materoals Today Proc., 63(1): 122-139. https://doi.org/10.1016/j.matpr.2022.02.052

Parkunan T, Kumar BM, Kumar M, Govindasamy T, Kumar RD, Mahesh MS (2024). Herbal feed additives and supplements for a sustainable ruminant production. feed additives and supplements for ruminants, Singapore: Springer Nature Singapore: pp. 197-234. https://doi.org/10.1007/978-981-97-0794-2_9

Prihambodo TR, Sholikin MM, Qomariyah N, Jayanegara A, Batubara I, Utomo DB (2021). Effects of dietary flavonoids on performance, blood constituents, carcass composition and small intestinal morphology of broilers: A meta analysis. Anim. Biosci., 34(3): 434-442. https://doi.org/10.5713/ajas.20.0379

Rajput, N, Muhammad, N, Yan, R, Zhong, X, Wang, T (2013). Effect of dietary supplementation of curcumin on growth performance, intestinal morphology and nutrients utilization of broiler chicks. J. Poult. Sci., 50(1): 44-52. https://doi.org/10.2141/jpsa.0120065

Riastri A (2024). *Kaempferia galanga* (L.): An updated overview of *in vitro* and *in vivo* antioxidant properties. J. Food Pharma. Sci., 12(1): 67-79. https://doi.org/10.22146/jfps.9997

Rusny, R, Hidayat, MN, Kalsum, U, Masri, M (2021). The protein digestibility of the broiler chickens fed jamu formula, a local herbal solution. Online J. Anim. Feed Res, 11(2): 63-67. https://dx.doi.org/10.51227/ojafr.2021.11

Sadeghipour A, Babaheidarian P (2019). Making formalin fixed, paraffin embedded blocks. methods in molecular biology, New York: Humana Press Inc: pp. 253-268. https://doi.org/10.1007/978-1-4939-8935-5_22

Szabó, RT, Kovács, WM, Zimborán, Á, Kovács, L, Erdélyi, M (2023). Effects of short-and medium-chain fatty acids on production, meat quality, and microbial attributes- a review. Molecules, 28(13): 1-17. https://doi.org/10.3390/molecules28134956

Schop M, Jansman AJM, De Vries S, Gerrits WJJ (2020). Increased diet viscosity by oat β-glucans decreases the passage rate of liquids in the stomach and affects digesta physicochemical properties in growing pigs. Animal, 14(2): 269-276. https://doi.org/10.1017/S1751731119001824

Skwirzyńska MA, Konieczka P, Bucław M, Majewska D, Pietruszka A (2025). Analysis of the production and economic indicators of broiler chicken rearing in 2020-2023: A case study of a polish farm. Agriculture (Switzerland), 15(2): 1-11. https://doi.org/10.3390/agriculture15020139

Surai PF, Kochish II, Fisinin VI, Kidd MT (2019). Antioxidant defence systems and oxidative stress in poultry biology: An update. Antioxidants, 8(7): 1-36. https://doi.org/10.3390/antiox8070235

Wen C, Yan W, Mai C, Duan Z, Zheng J, Sun C (2021). Joint contributions of the gut microbiota and host genetics to feed efficiency in chickens. Microbiome, 9(1): 1-23. https://doi.org/10.1186/s40168-021-01040-x

Xian D, Guo M, Xu J, Yang Y, Zhao Y, Zhong J (2021). Current evidence to support the therapeutic potential of flavonoids in oxidative stress related dermatoses. Redox Rep., 26(1): 134-146. https://doi.org/10.1080/13510002.2021.1962094