RESEARCH PAPER

The Combination of Herbal Phytobiotics and Moringa Leaves on Growth Performance, Feed Digestibility and H/L Ratio of Stress Indicators in Male Alabio Ducks

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Abstract.
Objective: This study aimed to analyze the combination of herbal phytobiotics and Moringa leaves on the growth performance, feed digestibility and leukogram profiles (H/L ratio) of male Alabio ducks. The research method used a 5 x 3 factorial design with three replications, each consisting of 4 ducks, totaling 180 ducks. The first factor was the herbal phytobiotic dosage, consisting of J0 (0%); J1 (1.0%); J2 (2.0%); J3 (3.0%), and J4 (4.0%). The second factor was the level of moringa leaf powder, consisting of K1 (2%; K2 (4%), and K3 (6%). The variables observed included body weight, weight gain, feed consumption, feed conversion ratio (FCR), feed digestibility, and leukogram profiles (H/L ratio). The results showed that the combination of herbal phytobiotic doses and the level of moringa leaf administration significantly affected growth performance, including body weight, feed consumption and conversion ratio (FCR), protein digestibility, crude fiber digestibility ($p<0.05$) and heterophyle/limphosit (H/L) ratio. The best combination was a combination of 1% phytobiotic dose with 6% moringa leaf powder (J1K3), with a body weight of 1140 g/head, the achievement of body weight gain of 916,67 g/head, consumption of 2.750 g/head, feed conversion ratio (FCR) of 2,98, the protein digestibility obtained is 73,87 %, the crude fiber digestibility is 48,93%. Meanwhile, achieving a leukogram profile with 186.80 thousand/µl leukocytes, 69.81% heterophils, 89.9% lymphocytes, and an H/L ratio (heterophils/lymphocytes) of 0.647. The conclusion showed an improvement in the health status of ducks, indicated by reduced stress through a decrease in the H/L ratio with the combination of phytobiotics and moringa leaf flour.
Keywords: Alabio ducks; growth performance; moringa; phytobiotics; H/L rasio
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Introduction

The use of antibiotic growth promoters (AGPs) has long supported growth performance, feed efficiency, and health in intensive poultry systems; however, their prolonged use has raised concerns regarding antibiotic residues and the accelerating emergence of antimicrobial resistance (AMR). Consequently, many countries have restricted or banned AGPs, including Indonesia, which formally prohibited their use in livestock feed in 2017 following earlier regulations in the European Union [1]. Despite these measures being necessary, AGP withdrawal has challenged poultry production by increasing disease susceptibility and reducing growth and feed efficiency under antibiotic-free conditions.

These challenges are more pronounced in tropical systems, where poultry are exposed to heat stress, high humidity, and variable feed quality. Indigenous ducks such as male Alabio ducks are particularly affected, as suboptimal nutrition and environmental stress often limit their productivity. Thus, sustainable nutritional strategies that enhance growth, digestive efficiency, and physiological resilience are urgently needed in duck production systems.

Herbal phytobiotics have emerged as promising natural alternatives to AGPs. Derived from plant sources, phytobiotics contain bioactive compounds such as essential oils, phenolics, flavonoids, alkaloids, and terpenoids that exhibit antimicrobial, antioxidant, and immunomodulatory activities. These compounds can suppress pathogenic bacteria, improve gut microbiota balance, stimulate digestive enzymes, and enhance intestinal morphology, thereby supporting nutrient absorption and growth performance in poultry [2].

Multi-herbal phytobiotic formulations containing turmeric, ginger, garlic, kencur, galangal, cinnamon, and betel leaf have shown particular potential. In male Alabio ducks, supplementation with 2% herbal phytobiotics increased final body weight to 1,118 g at eight weeks, improved average daily gain to 209.37 g/bird/week, and reduced feed conversion ratio to 2.71 [3]. However, improvements in fiber digestibility remained limited, indicating that phytobiotics alone may not fully meet the nutritional requirements for optimal growth.

Nutritional synergy using phytobiotics combined with nutrient-dense plant ingredients has therefore gained attention. *Moringa oleifera* leaf meal is a functional feed resource in tropical regions, characterized by high crude

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protein content (30–55%) and essential amino acids, including methionine (0.3%), lysine (1.63%), and tryptophan (0.49%) [1]. Its vitamins, minerals, and antioxidant compounds support metabolic regulation, immune function, and tissue growth in poultry.

Previous studies indicate that inclusion of moringa leaf meal up to 3% does not adversely affect duck performance and may enhance growth and health parameters, demonstrating its safety and feasibility as a feed ingredient [4]. The antimicrobial and antioxidant properties of moringa may complement the bioactivity of phytobiotics, suggesting potential synergistic effects when both additives are combined.

Managing physiological stress is also critical in AGP-free poultry production, particularly under tropical conditions. Heat stress disrupts thermoregulation, reduces feed intake, impairs nutrient utilization, and suppresses immunity. The heterophil-to-lymphocyte (H/L) ratio is a widely used hematological indicator of stress, with lower values reflecting improved immune balance and stress tolerance [5]. Nutritional interventions that reduce stress indicators are therefore essential for sustaining duck productivity.

Herbal phytobiotics can alleviate stress through antioxidant and anti-inflammatory mechanisms, while moringa leaf flour provides additional antioxidants and essential nutrients that strengthen immune function. Together, these additives may enhance gut integrity, nutrient absorption, and physiological resilience, leading to improved leukogram profiles and reduced H/L ratios [6].

Accordingly, this study evaluated the combined effects of herbal phytobiotics and *Moringa oleifera* leaf flour on growth performance, nutrient digestibility, and physiological stress indicators in male Alabio ducks under AGP-free conditions. It was hypothesized that this synergistic combination would improve body weight gain, feed conversion, nutrient utilization, and stress-related hematological responses more effectively than single supplementation or control diets [7]. This approach aims to propose a sustainable nutritional strategy to replace AGPs while maintaining productivity, health, and welfare in indigenous duck production systems [8].

Materials and Methods

Experimental Design and Animals

The experiment was conducted using a Completely Randomized Design (CRD) with a 5 × 3 factorial arrangement to evaluate the combined effects of herbal phytobiotic dosage and *Moringa oleifera* leaf flour level on male Alabio ducks. The first factor consisted of five levels of herbal phytobiotics, while the second factor comprised three levels of moringa leaf flour inclusion. A total of 180 healthy male Alabio ducks of uniform age and body weight were used in the study. The birds were randomly allocated to 15 dietary treatment combinations, with three replications per treatment and four ducks per replication, ensuring adequate statistical power for detecting treatment effects.

Dietary Treatments and Ration Formulation

The herbal phytobiotic factor consisted of five inclusion levels: J0 (0%), J1 (1.0%), J2 (2.0%), J3 (3.0%), and J4 (4.0%) of the ration. The second factor was the inclusion level of moringa leaf flour, namely K1 (2%), K2 (4%), and K3 (6%). All experimental diets were formulated to be iso-protein and iso-energetic, containing 16% crude protein and approximately 3,000 kcal/kg metabolizable energy, in accordance with the nutrient requirements for meat-type ducks as recommended by the National Research Council in 1994. This formulation ensured that any observed differences in performance and physiological responses were attributable to dietary treatments rather than nutrient imbalances.

Table 1. Nutritional Composition of the Basal Ration for Male Alabio Ducks

Feed Ingredients	Crude Protein (%)	Metabolizable Energy (kcal/kg)	Crude Fiber (%)	Composition (%)
Concentrate	40,00	3.000	4,10	10,00
BR I	20,00	2.900	3,25	36,00
Yellow Corn	9,00	3.400	3,37	20,00
Rice Bran	10,5	1.890	11,60	29,00
Vegetable Oil	0,00	8.800	0,00	5,00
Total				100,00

Note: Results from the Nutrition and Animal Feed Lab, Faculty of Agriculture, ULM, 2025

Feeding Management and Experimental Period

The experimental period covered the finisher phase from 3 to 8 weeks of age. Prior to treatment application, all ducks were reared under identical management conditions during the starter phase (0–2 weeks) and were fed a commercial BR-1 diet. From the beginning of the finisher phase, the experimental diets were introduced according to their respective treatment groups. Feed and drinking water were provided ad libitum throughout the study. The basal ration consisted of concentrate (10%), BR-1 (36%), yellow corn (20%), rice bran (29%), and vegetable oil (5%), which served as the carrier for incorporating the phytobiotic and moringa leaf flour treatments.

Preparation of Herbal Phytobiotics

The herbal phytobiotic used in this study was prepared from a mixture of eight medicinal plants, namely turmeric (*Curcuma longa*), ginger (*Zingiber officinale*), garlic (*Allium sativum*), kencur (*Kaempferia galanga*), galangal (*Alpinia galanga*), ginger rhizome, cinnamon (*Cinnamomum* sp.), and betel leaf (*Piper betle*). Each plant material weighed 250 g, resulting in a total mixture of 2,000 g combined in a 1:1 proportion. The herbal mixture was dissolved in 150 L of clean water and subjected to anaerobic fermentation by adding 5% sugar and 150 mL of effective microorganism solution (EM-4). Fermentation was carried out for seven days, with manual stirring for approximately 30 seconds once daily from day two to day seven to ensure homogeneity and optimal microbial activity.

Preparation of Moringa Leaf Flour and Observed Variables

Fresh moringa leaves were separated from stems, thoroughly washed, and oven-dried at 60°C for 2 × 24 h to preserve nutrient quality and bioactive compounds. The dried leaves were then ground into a fine powder to produce moringa leaf flour. Proximate analysis indicated that the moringa leaf flour contained crude protein ranging from 32.26% to 32.30%, metabolizable energy of approximately 4,196 kcal/kg, and crude fiber of 5.54%. The observed variables in this study included growth performance parameters (final body weight, body weight gain, feed consumption, and feed conversion ratio), nutrient digestibility (protein and crude fiber digestibility), and physiological stress indicators based on the leukogram profile, particularly the heterophil-to-lymphocyte (H/L) ratio.

Data Collection Procedures

Growth performance data were recorded throughout the finisher phase (3–8 weeks). Feed intake was measured weekly by subtracting feed refusal from feed offered, while body weight was measured at the beginning and end of the experimental period to calculate body weight gain and feed conversion ratio. Protein and crude fiber digestibility were determined using the total collection approach, where nutrient intake and nutrient excretion were quantified over a defined collection period. Apparent digestibility coefficients were calculated as the difference between nutrient intake and excretion divided by nutrient intake, expressed as a percentage.

Blood samples were collected at the end of the experimental period to evaluate physiological stress indicators. Samples were obtained via venipuncture and used to prepare blood smears, which were subsequently stained using Wright's stain. Leukocyte differentiation was conducted under a light microscope to determine heterophil and lymphocyte counts, and the H/L ratio was calculated as the number of heterophils divided by the number of lymphocytes.

Statistical Analysis

All data were subjected to analysis of variance (ANOVA) appropriate for a factorial CRD using an F-test to evaluate the main effects of herbal phytobiotic dosage, moringa leaf flour level, and their interaction. When significant differences were detected at $p < 0.05$, means were separated using Duncan's Multiple Range Test (DMRT). Statistical analyses were performed to ensure rigorous interpretation of treatment effects on growth performance, nutrient digestibility, and stress-related physiological responses.

Results and Discussion

Final Body Weight and Body Weight Gain

The growth performance of ducks receiving combinations of phytobiotic doses and moringa leaf powder including final body weight, feed intake, average daily gain (ADG), and feed conversion ratio (FCR) is presented in Table 1.

Table 1. Final body weight and body weight gain of Male Alabio Ducks

Treatment	Final Weight ($g.bird^{-1}$) at 8 weeks	Body Weight Gain ($g.bird^{-1}.6\ weeks^{-1}$)	Feed Consumption ($g.bird^{-1}.6\ weeks^{-1}$)	FCR
J0K1	1.060,00±7,3^{cd}	805,67 ±7,3^{d}	2.529,54 ±29,1^{a}	3,14 ±0,04^{ab}
J0K2	1.053,33±7,3 ^{cd}	758,83 ±6,2^{bc}	2.591,00 ±26,2^{a}	3,41 ±0,03^{cd}
J0K3	986,66±7,3^{bc}	724,83 ±5,9^{bc}	2.654,84 ±31,3^{ab}	3,66 ±0,03^{cd}
J1K1	977,70±7,3^{bc}	713,03 ±5,2^{bc}	2.446,50 ±27,7^{a}	3,43 ±0,05^{cd}
JIK2	1.085,00±7,3^{e}	813,00 ±6,6^{cd}	2.563,55 ±29,2^{a}	3,15 ±0,04 ^{ab}
JIK3	1.140,00±7,3^{f}	916,67 ±4,1^{e}	2.730,00 ±23,1^{bc}	2,98 ±0,02^{a}
J2K1	945,00±7,3^{ab}	675,00 ± 5,6^{ab}	2.597,40 ±26,4^{a}	3,85 ± 0,03^{cd}
J2K2	990,00±7,3^{bc}	745,00 ± 5,5^{bc}	2.694,00 ±24,5^{ab}	3,62 ±0,03^{cd}
J2K3	1.016,67±7,3^{cd}	636,67 ± 6,7^{ab}	2.723,40 ±28,3^{bc}	4,28 ±0,05^{cd}
J3K1	810,00±7,3^{a}	510,00 ± 4,7^{a}	2.730,00 ±28,6^{bc}	5,35 ±0,06^{e}
J3K2	902,50±7,3^{ab}	647,50 ± 5,8^{ab}	2.730,00 ±28,3^{bc}	4,22 ±0,03^{cd}
J3K3	1.007,50±7,3^{cd}	727,50 ± 6,6^{bc}	2.519,65 ±29,6^{a}	3,46 ±0,03^{bc}
J4K1	1.095,00±7,3^{e}	797,00 ± 6,9^{bc}	2.661,40 ±27,4^{ab}	3,34 ±0,04^{bc}
J4K2	1.085,00±7,3^{cd}	805,00 ± 7,1^{d}	2.695,91 ±28,7^{ab}	3,35 ±0,03^{bc}
J4K3	1.090,00±7,3^{e}	764,33 ± 6,4^{bc}	2.730,00 ±29,2^{bc}	3,57 ±0,03^{bc}

Note: Numbers followed by different superscripts in the same column are significantly different ($p < 0.05$).

Final body weight differed significantly among treatments ($p < 0.05$). Ducks fed the optimal combination (J1K3) achieved a final body weight of 1,140 g per bird, whereas ducks in the control groups without phytobiotic supplementation (J0) exhibited lower final body weights ranging from 986.66 to

1,060.00 g per bird. The corresponding body weight gain during the finisher period (3–8 weeks) was also highest in J1K3, reaching 916.67 g per bird over the 6-week period, and this value was significantly higher than most other treatment groups.

The interaction between herbal phytobiotic dose and *Moringa oleifera* leaf flour level significantly affected growth performance variables, including final body weight, body weight gain, feed consumption, and feed conversion ratio (FCR) ($p < 0.05$). Across all treatment combinations, the best growth performance was observed in J1K3 (1% phytobiotic + 6% moringa leaf flour), which produced the highest final body weight of 1,140 g per bird at 8 weeks of age.

This study demonstrates that combining herbal phytobiotics with *Moringa oleifera* leaf flour produces measurable improvements in growth performance, nutrient digestibility, and physiological stress indicators in male Alabio ducks under AGP-free feeding. The significant interaction effects ($p < 0.05$) on final body weight, body weight gain, feed intake, feed conversion ratio (FCR), protein digestibility, crude fiber digestibility, and leukogram variables indicate that the response to phytobiotics depends on moringa inclusion level and vice versa, supporting the concept of nutritional synergy between bioactive phytogenic compounds and a nutrient-dense leaf meal.

A consistent pattern across outcomes was that the most favorable responses occurred at moderate phytobiotic dosage combined with the highest moringa level. Specifically, J1K3 (1% phytobiotic + 6% moringa) produced the highest final body weight (1,140 g/bird at 8 weeks) and body weight gain (916.67 g/bird over the 6-week finisher phase), while also yielding the lowest FCR (2.98). By contrast, control diets without phytobiotics (J0) resulted in lower final body weights (986.66–1,060.00 g/bird), illustrating the production advantage of phytobiotic–moringa integration. These results align with evidence that *Moringa oleifera* inclusion can stimulate growth performance in ducks; Ibrahim et al. (2017) [9] reported that 1% moringa inclusion increased final body weight by 9.5%, daily weight gain by 9.4%, and daily feed intake by 6.14% relative to controls. The present findings extend that evidence by showing that moringa-associated gains can be further strengthened when paired with phytobiotics, likely through additive or synergistic effects on gut function, microbiome stability, and immune competence [10; 11].

Feed Consumption and Feed Conversion Ratio

Feed consumption over the 6-week finisher period was significantly influenced by dietary treatments ($p < 0.05$) and ranged from 2,446.50 to 2,730.00 g per bird. Feed conversion ratio (FCR) was likewise significantly affected ($p < 0.05$), indicating differences in feed utilization efficiency across dietary combinations. The lowest (best) FCR was recorded in J1K3 at 2.98, whereas the highest FCR was observed in J3K1 at 5.35, suggesting that higher phytobiotic inclusion combined with low moringa level resulted in inefficient conversion of feed into body mass.

The observed range of feed consumption (2,446.50–2,730.00 g/bird over 6 weeks) suggests that treatments influenced appetite and feeding behavior, which is plausible given the sensory and functional roles of phytobiotics. Plant-derived essential oils, phenolics, and pungent compounds are known to affect palatability and stimulate digestive secretions, potentially increasing feed intake when inclusion is optimal. Importantly, the improvement in FCR under J1K3 indicates that enhanced intake was not merely compensatory but translated into more efficient conversion of feed into body mass. This pattern supports the mechanistic framework that phytobiotics can improve nutrient absorption by promoting favorable gut microbial balance and stimulating enzymatic activity, while moringa provides a superior amino acid supply that supports protein accretion and tissue growth.

A key outcome is the dose-dependent response to phytobiotic inclusion. While 1% phytobiotic (J1) combined with 6% moringa (K3) was optimal, higher phytobiotic levels were not consistently beneficial. The poorest feed efficiency occurred at J3K1, with an FCR of 5.35, indicating that phytobiotic inclusion at ≥3% can impair feed utilization under certain nutritional contexts. Dose-dependent responses to phytobiotics have been widely reported, where low-to-moderate inclusion (often 1–2%) improves performance, whereas higher inclusion may reduce palatability, alter gut motility unfavorably, or introduce excessive bioactive load that disrupts metabolic homeostasis [12, 13, 14]. In the present study, the negative responses at higher phytobiotic doses were also accompanied by weaker fiber digestibility trends, suggesting that excessive phytobiotic concentrations may not uniformly support microbial fermentation or digestive physiology, particularly when moringa inclusion is low.

Protein Digestibility (Nitrogen Retention)

The results of the variance analysis on nutrient digestibility, including crude protein digestibility (Ret-N) and crude fiber digestibility, are presented in Table 2 below.

Table 2. Crude Protein Digestibility (Ret-N) in the Treatment Ration

Treatment	Consumption (g/day)	N in Ration (%)	NI	Excreta (g/day)	N in Excreta (%)	NE	Nitrogen Retention (%)
J0K1	61,75	16,05	9,919	38,0	8,600	3,268	67,026±4,34^{ab}
JOK2	61,69	16,05	9,901	31,7	9,930	3,147	68,207±5,35^{ab}

JOK3	63,21	16,05	10,145	39,5	7,530	2,974	70,682±4,21[ab]
J1K1	58,25	16,05	9,349	53,6	6,240	3,344	64,225±6,03[ab]
J1K2	61,04	16,05	9,796	59,4	5,120	3,041	68,956±5,11[ab]
J1K3	65,00	16,05	10,432	44,1	6,180	2,725	73,876±4,45[ab]
J2K1	61,84	16,05	9,925	86,0	4,040	3,474	64,994±6,22[ab]
J2K2	64,14	16,05	10,294	52,0	7,080	3,681	64,237±5,06[ab]
J2K3	64,84	16,05	10,406	80,0	7,420	5,936	42,960±7,04[ab]
J3K1	65,00	16,05	10,432	90,0	7,560	6,804	34,780±4,01[ab]
J3K2	65,00	16,05	10,432	40,7	8,080	3,288	68,477±5,33[ab]
J3K3	59,99	16,05	9,628	69,0	8,980	6,196	35,646±6,15[ab]
J4K1	63,37	16,05	10,170	54,0	6,900	3,726	63,366±6,44[ab]
J4K2	64,19	16,05	10,302	74,60	6,480	4,834	53,078±5,42[ab]
J4K3	65,00	16,05	10,432	52,00	8,880	4,617	55,738±4,19[ab]

Note: Numbers followed by different superscripts in the same column are significantly different ($p < 0.05$)

Nitrogen intake across treatments ranged from 9.349 to 10.432 g per day, whereas nitrogen excretion ranged from 2.725 to 6.804 g per day. The superior protein digestibility observed in J1K3 corresponded with relatively lower nitrogen excretion, supporting the interpretation that the optimal treatment improved nitrogen retention and reduced nutrient losses through excreta.

Protein digestibility, expressed as nitrogen retention, was significantly affected by the interaction between phytobiotic and moringa supplementation ($p < 0.05$). Protein digestibility values varied widely across treatments, ranging from 34.78% to 73.88%. The highest nitrogen retention was observed in J1K3 at 73.876%, indicating the most efficient utilization of dietary protein among all treatment combinations.

Improvements in protein digestibility provide mechanistic support for the superior growth observed in J1K3. Protein digestibility (nitrogen retention) varied widely (34.78% to 73.88%), with the highest value recorded for J1K3 at 73.876%. This improvement coincided with relatively lower nitrogen excretion in the same treatment, consistent with more efficient protein utilization and reduced nutrient wastage. Nitrogen intake ranged narrowly (9.349–10.432 g/day), suggesting that differences in retention were primarily driven by digestive and metabolic efficiency rather than intake alone. The literature indicates that moringa's favorable amino acid profile and digestibility can enhance crude protein utilization when included at appropriate levels and when anti-nutritional factors are effectively managed by moderate inclusion [15, 16]. Further, phytobiotics can support protein digestion through stimulation of digestive enzymes and suppression of proteolytic pathogenic bacteria, thereby preserving intestinal integrity and absorptive capacity [17]. Reports that moringa-based diets can increase protein utilization by up to 10% over standard diets [18] (Safwat et al., 2024) are consistent with the present observation that the best treatment combination markedly increased nitrogen retention relative to low-performing groups.

Crude Fiber Digestibility

The results of the variance analysis on crude fiber digestibility is presented in Table 2 below.

Table 2. Crude Fiber Digestibility

Treatment	Dry Matter of Ration (g/day) (a)	Crude Fiber in Ration (%) (b)	(a x b)	Dry Matter of Excreta (g/day) (c)	Crude Fiber in Excreta (%) (d)	(c x d)	Crude Fiber Digestibility (%)
J0K1	61,75	5,62	3,470	38,0	5,230	1,987	42,732±4,42[ab]
JOK2	61,69	5,62	3,467	31,7	6,035	1,913	44,819±5,11[ab]
JOK3	63,21	5,62	3,552	39,5	6,090	2,405	32,283±6,44[ab]
J1K1	58,25	5,62	3,273	53,6	3,523	1,888	42,317±5,25[ab]
J1K2	61,04	5,62	3,430	59,4	3,235	1,921	43,984±5,62[ab]
J1K3	65,00	5,62	3,653	44,1	4,230	1,865	48,934±4,42[ab]
J2K1	61,84	5,62	3,475	86,0	3,230	2,777	20,072±3,22[ab]
J2K2	64,14	5,62	3,604	52,0	5,035	2,618	27,366±3,55[ab]
J2K3	64,84	5,62	3,644	80,0	4,090	3,272	10,208±2,54[ab]
J3K1	65,00	5,62	3,653	90,0	3,230	2,907	20,421±3,42[ab]

J3K2	65,00	5,62	3,653	40,7	5,035	2,049	43,902±5,12^{ab}
J3K3	59,99	5,62	3,371	69,0	4,230	2,918	13,428±2,52^{ab}
J4K1	63,37	5,62	3,561	54,0	4,230	2,284	35,862±5,62^{ab}
J4K2	64,19	5,62	3,607	74,6	4,230	3,155	12,526±0,33^{ab}
J4K3	65,00	5,62	3,653	52,0	6,090	3,166	13,309±0,98^{ab}

Note: Numbers followed by different superscripts in the same column are significantly different ($p < 0.05$)

Crude fiber digestibility was significantly influenced by dietary treatments ($p < 0.05$) and ranged from 10.21% to 48.93%. The highest crude fiber digestibility was recorded in J1K3 at 48.934%, demonstrating that the combined supplementation at this level improved the utilization of fibrous fractions in the ration.

Crude fiber intake ranged from 3.27 to 3.65 g per day across treatments, while crude fiber excretion ranged from 1.86 to 3.27 g per day. Treatments receiving higher phytobiotic doses (≥3%) tended to show reduced crude fiber digestibility, consistent with the lower efficiency observed at these inclusion levels.

Crude fiber digestibility also responded strongly to the combined supplementation, ranging from 10.21% to 48.93%. The highest value occurred again in J1K3 (48.934%), indicating that an optimal phytobiotic–moringa balance can enhance the utilization of structural carbohydrates. Fiber intake varied modestly (3.27–3.65 g/day), whereas fiber excretion varied more widely (1.86–3.27 g/day), implying that treatment effects primarily influenced breakdown and absorption. Phytobiotics may improve fiber digestibility indirectly by enhancing gut morphology (e.g., villus height and absorptive surface), supporting microbial ecology in the lower gut, and modulating digesta viscosity and transit time [17]. Moringa inclusion can contribute to a healthier gut environment through anti-inflammatory effects and provision of fermentable substrates and micronutrients, potentially promoting microbial fermentation that supports fiber degradation [18]. However, the tendency for reduced fiber digestibility at higher phytobiotic doses (≥3%) suggests that excessive phytogenic compounds may inhibit certain microbial populations involved in fermentation or alter gut conditions in ways that are unfavorable to fiber breakdown. This again underscores the importance of identifying an optimal dosage window rather than assuming linear benefits with increasing inclusion.

The link between improved digestibility and enhanced growth performance is biologically coherent. Higher protein and fiber digestibility increases nutrient availability, especially amino acids required for muscle accretion and growth, while improved utilization of fiber-associated energy can support maintenance and production needs. In addition, better gut health reduces energy diversion to immune activation and intestinal repair, improving metabolic efficiency and resulting in lower FCR [19]. The present dataset supports this chain of causality, as the treatment producing the highest nitrogen retention and fiber digestibility (J1K3) also produced the best growth and FCR.

Leukogram Profile and H/L Ratio

The results of the variance analysis on the effect of the combination of phytobiotic and moringa leaf flour on the H/L ratio in The Leukogram Profile of Duck Blood in Table 3 below.

Table 3. H/L ratio in The Leukogram Profile of Duck Blood

Treatment	Heterophils (%)	Leukocytes (thousand/µl)	Lymphocytes (%)	H/L Ratio
J0K1	95,08±6,18^{f}	207,16±12,22^{f}	92,30±0,98^{bc}	1,300±0,98^{bc}
J0K2	77,26±7,58^{bc}	195,80±9,82^{e}	67,00±0,98^{a}	1,350±0,98^{cd}
J0K3	89,21±6,49^{e}	159,57±11,22^{ab}	88,73±0,98^{b}	1,280±0,98^{b}
J1K1	70,90±4,28^{b}	176,66±8,55^{bc}	89,90±0,98^{c}	1,180±0,98^{b}
JIK2	81,01±5,26^{cd}	153,71±8,56^{a}	95,20±0,98^{d}	1,220±0,98^{a}
JIK3	69,81±4,75^{c}	186,80±11,11^{d}	89,90±0,98^{b}	0,650±0,08^{a}
J2K1	82,50±6,88^{de}	216,33±1`5,23^{ab}	92,30±0,98^{bc}	1,310±0,98^{cd}
J2K2	79,42±5,66^{cd}	133,18±6,98^{a}	91,60±0,98^{bc}	1,340±0,98^{cd}
J2K3	56,60±6,21^{a}	173,91±10,34^{bc}	64,90±0,98^{a}	1,340±0,98^{cd}
J3K1	56,06±3,64^{a}	209,02±11,34^{f}	66,10±0,98^{a}	1,330±0,98^{cd}
J3K2	64,69±6,12^{b}	183,88±11,24^{bc}	74,20±0,98^{ab}	1,300±0,98^{bc}
J3K3	72,06±5,88^{b}	187,92±8,96^{d}	79,50±0,98^{ab}	1,300±0,98^{b}
J4K1	75,91±7,11^{bc}	142,46±8,82^{a}	90,00±0,98^{bc}	1,290±0,98^{b}
J4K2	71,71±5,68^{b}	169,10±8,87^{ab}	87,10±0,98^{b}	1,330±0,98^{cd}
J4K3	58,99±6,62^{a}	194,49±11,21^{e}	67,30±0,98^{a}	1,290±0,98^{b}

Note: Numbers followed by different superscripts in the same column are significantly different ($p < 0.05$)

Leukogram variables, including total leukocyte count, heterophil percentage, lymphocyte percentage, and heterophil-to-lymphocyte (H/L) ratio, were significantly affected by the interaction of phytobiotic dose and moringa leaf flour level (p

< 0.05). The lowest H/L ratio was observed in J1K3 at 0.65, indicating reduced physiological stress relative to other treatments.

Leukocyte, Heterophil, Lymphocyte Responses and H/L ratio

Total leukocyte counts ranged from 133.18 to 216.33 thousand/µL across treatment groups, showing significant variation in hematological responses to dietary supplementation. In the J1K3 treatment, heterophils reached 69.81% and lymphocytes reached 89.90%, reflecting a more favorable immune cell profile consistent with improved physiological status in ducks receiving the optimal dietary combination.

Beyond productivity and digestion, the present findings highlight the relevance of hematological stress indicators in evaluating functional feed additives. The H/L ratio is widely used as an integrative biomarker reflecting chronic stress and immune balance, where elevated ratios indicate increased heterophil recruitment and reduced lymphocyte proportion, commonly associated with stressors such as heat, disease, or nutritional challenges. In this study, dietary treatments significantly affected leukocyte profiles and H/L ratio ($p < 0.05$), and the lowest H/L ratio was observed in J1K3 (0.65). This suggests that the optimal combined supplementation not only improved growth but also enhanced physiological resilience.

The leukocyte count range (133.18–216.33 thousand/µL) indicates meaningful variation in systemic immune activity across treatments. In J1K3, heterophils were reported at 69.81% and lymphocytes at 89.90%, reflecting a shift toward a more favorable immune balance. Although leukocyte differentials can vary with sampling time and environmental conditions, the consistent reduction of H/L ratio under the best-performing diet supports the interpretation that phytobiotics and moringa acted as immunomodulatory and antioxidant agents, reducing stress-related immune dysregulation. This is consistent with reports that moringa and phytobiotic supplementation can decrease H/L ratio by improving antioxidant capacity, increasing lymphocyte counts, and mitigating excessive heterophil-driven inflammation [20, 21, 22]. Phytobiotics may additionally prevent stress-associated dysbiosis by modulating gut microbiota and reducing pathogen load, which can lower systemic inflammatory signaling and stabilize leukocyte dynamics [15, 23].

The H/L ratio of 0.65 recorded in J1K3 falls within commonly cited “low stress” or “balanced” ranges (often ≤1.0), whereas higher ratios are interpreted as moderate-to-high stress depending on threshold definitions [24, 25]. From a production perspective, this reduction in physiological stress is important because chronic stress is known to decrease feed intake, impair nutrient utilization, and suppress immune responsiveness, ultimately compromising growth performance. Therefore, the concurrent improvements in FCR, digestibility, and H/L ratio under the same treatment provide strong evidence that the combined supplementation improves both productivity and welfare-related physiological status.

Mechanistically, several complementary pathways likely explain the synergy observed in J1K3. First, moringa supplies high-quality protein and micronutrients that directly support growth and immune function, while phytobiotics enhance digestive secretions and nutrient absorption capacity. Second, both components have antioxidant and anti-inflammatory properties that can mitigate oxidative stress, particularly relevant under tropical conditions where heat stress elevates reactive oxygen species and disrupts endocrine and immune regulation. Third, both components influence gut health and microbiome composition: phytobiotics provide antimicrobial selectivity and may promote beneficial bacteria, while moringa provides substrates and bioactive molecules that support gut barrier integrity and reduce inflammatory damage [26, 27, 28, 29]. Together, these mechanisms can shift energy allocation away from stress responses and toward growth.

Comparatively, phytobiotic effectiveness has been reported across poultry species, though the magnitude of response can differ between ducks and broilers due to physiological and digestive differences. Broilers often show strong improvements in FCR and growth in response to phytobiotics (sometimes reported at 10–15% improvements), whereas ducks may show moderate improvements (often 5–10%), potentially due to differences in baseline digestive capacity and adaptation to fibrous ingredients. Nevertheless, ducks under tropical stressors may display pronounced benefits from immunomodulatory feed additives, making combined phytobiotic–moringa strategies particularly relevant for indigenous duck production systems [30, 31, 32, 33].

From an applied standpoint, these findings support the development of antibiotic-free feeding programs that improve both production efficiency and physiological resilience. The optimal treatment identified here (1% phytobiotic with 6% moringa leaf flour) provides a practical inclusion window that can be adopted by producers, particularly in regions where moringa is locally available and herbal ingredients are accessible. Importantly, the decline in performance at higher phytobiotic inclusion emphasizes that “more is not always better,” and that formulation must balance bioactive intensity with palatability, nutrient density, and gut microbial stability.

Overall, the present study provides evidence that a moderate phytobiotic dose combined with a higher inclusion of moringa leaf flour enhances growth performance, increases protein and crude fiber digestibility, and reduces the H/L ratio in male Alabio ducks. These outcomes collectively indicate improved nutrient utilization, gut functionality, and stress tolerance—three critical targets for sustainable duck production under AGP-free and tropical conditions. Future work may strengthen mechanistic inference by evaluating intestinal morphology, digestive enzyme activity, and microbiome composition, and by validating the observed benefits across different seasons or environmental stress intensities.

Conclusion

The best combination treatment of herbal phytobiotics with moringa leaf flour is the combination of a 1% phytobiotic dose with 6% moringa leaf flour (J1K3), achieving the best growth performance including a final body weight of 1140 g/bird, average daily gain (ADG) of 916.67 g/bird, feed intake of 2,750 g/bird, feed conversion ratio (FCR) of 2.98, the best nutrient digestibility achievements namely protein digestibility (Ret-N) of 73.87% and crude fiber digestibility of 48.93%, as well as the best leukogram achievement, particularly the heterophil-to-lymphocyte ratio (H/L) of 0.65 (<0.8), which indicates the lowest stress level in livestock and the best overall health status.

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