



Evaluation of the productivity of arabian chickens and water spinach plants in an integrated farming system

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Abstract

This study aims to assess the productivity of arabian chickens through the inclusion of mealworm-based feed and evaluate the impact of organic chicken fertilizer on water spinach plant productivity. The initial phase involves descriptive analysis, followed by the implementation of a Completely Randomized Design (CRD) with a single factor and four replications. The treatments include compost application at rates of 0 ton/ha control (K0), compost 1 kg/m² (K1), compost 2 kg/m² (K2), and compost 3 kg/m² (K3). The variables under examination include production performance, egg quality, compost quality, and the growth and production of water spinach plants. Incorporating 4% *tenebrio molitor* meal in the ratio sustains both ratio consumption and egg production. The Haugh value of the egg unit falls within the category of good quality. The application of compost fertilizer increases plant height and fresh production. This implies that substituting 4% *tenebrio molitor* meal in the ration effectively maintains both ration consumption and egg production in arabian chickens aged 29-34 weeks. Furthermore, the utilization of compost fertilizer proves instrumental in elevating the growth and production of water spinach.

Key words : compost chicken, egg quality, performace, *tenebrio molitor*, vegetable

Introduction

The poultry farming sector, particularly free-range chicken farming, is a widely cultivated livestock commodity in Indonesia. In 2020, the population of free-range chickens reached approximately 304.5 million, reflecting a 1.22% increase from 2019. This sector contributed significantly to egg production, accounting for 6.11% of the national egg production, amounting to 358.9 thousand tons (Ditjenpkh 2022). Arabian chickens, a subtype of free-range laying hens, exhibit an average egg production of around 190-250 eggs/year and have a production age of 25 weeks (Yumna et al 2011).

To optimize the productivity of arabian chickens, it is crucial to provide sufficient feed in terms of both quantity and quality. However, the chicken farming industry faces a challenge with the current reliance on imported raw materials for energy and protein ratios, such as soybean meal, corn, and meat bone meal. In 2020, approximately 84% of raw material imports were reported, indicating a 26.7% increase over the last 5 years. To mitigate this dependency, alternative feed sources, such as *tenebrio molitor* meal, are essential. Mealworms boast a crude protein content of approximately 46-56% and fat content of 25-35% (Jeong et al 2021). Previous studies have demonstrated that incorporating mealworms into broiler chicken diets can enhance growth

performance, feed efficiency, and the immune system (Bovera et al 2018; Benzertiha et al 2020; Bellezza et al 2021). *Tenebrio molitor* larvae are rich in omega-3, with a content of around 33.64%, and their inclusion in laying hen diets results in omega-3-enriched eggs (Rahmawati et al 2022).

Environmental concerns in chicken farming extend beyond feed ingredient availability. Waste generated in chicken farms, including excreta and leftover feed, poses challenges such as unpleasant odors and the attraction of flies, impacting human health and livestock productivity (8). Processing methods, such as composting, are essential to mitigate and prevent these adverse effects. As noted by (9) waste from arabian chicken farming can be repurposed as organic plant fertilizer, reducing environmental issues and decreasing reliance on chemical fertilizers. Organic fertilizer, rich in nitrogen, plays a significant role in enhancing soil's physical, chemical, and biological properties, providing essential nutrition to both soil and plants. Utilizing chicken compost has demonstrated positive effects on the growth and yield of crops like black soybeans, pakchoy, and Chinese cabbage(10,11).

Farmers' management of livestock and crops tends to be sub-sectoral, resulting in less than optimal income (12). Additionally, agricultural land faces increasing limitations due to ongoing land conversion. The average landholding of farmers in Indonesia is less than 0.5 ha, presenting a significant challenge in ensuring sustainable food production for future human welfare (13). Sustainable livestock development must align with and complement other commodities, such as vegetable crops. Therefore, this research aims to evaluate: (i) the productivity of arabian chickens through the incorporation of *tenebrio molitor* based food; and (ii) the productivity of vegetable crops utilizing arabian chicken compost.

Research Methods

Time and place

The study was conducted from January to June 2023 at the Harapan Non-Ruminant and Animal Field Laboratory, Department of Animal Production Science and Technology, Faculty of Animal Husbandry, IPB University. The research comprised two stages: the initial stage involved raising livestock and producing compost, while the second stage focused on assessing the application of compost fertilizer on vegetable plants. Feed and egg quality analyses were conducted at the Poultry Nutrition Laboratory, Department of Nutrition Science and Feed Technology. Additionally, compost and soil quality analyses were performed at the Testing Laboratory, Department of Soil Science and Land Resources, Faculty of Agriculture, IPB University.

Materials and equipment

Tenebrio molitor in this study were produced by PT Sugeng Jaya Group. *Tenebrio molitor* used were the larval phase of the insect *Tenebrio molitor* aged 60-80 days. The media used in the rearing of the caterpillars were pollard, onggok and palm kernel cake. *Tenebrio molitor* are mixed in the ration in the form of flour. This study used 100 laying chickens, aged 28 weeks. The ration used was produced by PT Sugeng Jaya based on the needs of layer phase chickens according to the Indonesian National Standard SNI 7783-3: 2022. The ration was given in the form of mash, which is a ration containing 4% *tenebrio molitor*.

The materials employed for assessing livestock production performance comprised 100 arabian chickens aged 28 weeks, the bodyweight 1170.1 ± 160.4 g head. The feed utilized was composed of *tenebrio molitor* meal produced by PT Sugeng Jaya Group on the needs of layer chickens based on the Indonesia National Standard (2023), and the nutritional composition of rations containing 4% *tenebrio molitor* is outlined in Table 1. The creation of compost fertilizer involved Arabic chicken manure, husk ash, bran, molasses, and the use of an EM4 activator. Materials for evaluating vegetable productivity included Arabic chicken compost, vegetable seeds (red arrow stamp), urea fertilizer, and the land designated for vegetable cultivation.

Table 1 Nutrient content of feed made from *tenebrio molitor*

Komponen	Kandungan Nutrien	
	Ransum penelitian	SNI 7783-3: 2022 quality I (layer buras feed)
Dry matter (%)	89,96	87
Ash (%)	12,72	Max. 14
Crude protein (%)	17,58	Min. 16
Crude Fiber (%)	4,05	Max. 8
Crude Fat (%)	3,32	Min. 2,50
Calcium (%)	3,64	2,50 – 4
Fosfor (%)	0,48	Min. 0,50
Lisin (%)**	0,97	Min. 0,75
Metionin + sistin (%)*	0,82	Min. 0,35
Linolenat acid (%)*	0,057	-
Linoleat acid (%)*	1,154	-
EM (kkal/kg ⁻¹)**	2.818,50	Min 2500

Feed analysis was conducted at the Feed Science and Technology Laboratory, Department of Production Science and Feed Technology ;* Feed analysis at the Laboratory of PT. Saraswanti Indo Genetech; **Calculated results

A wide array of equipment was employed in this research. For assessing production performance and egg quality, tools such as battery cages, nipple system feeding and drinking containers, thermohygrometers, digital scales, and various plastic items including trash bags, clips, spoons, sacks, and paper labels were utilized. On the other hand, for composting and vegetable production, the equipment included plastic drums, digital scales, trash bags, poly bags, meters, rulers, buckets, knives, pH meters, hoes, and plant waterers. This diverse set of tools allowed for a comprehensive examination of both livestock and vegetable aspects in the study.

Research procedure

Preparation of *tenebrio molitor* meal

The preparation of hongkong caterpillar flour includes drying with a 600-watt microwave for 10 minutes, then drying again with an oven at 150° C for 5 minutes. After drying, the larvae shrink in the ratio of 3 kg fresh to 1 kg dry weight. The final stage is the process of grinding dried *tenebrio molitor* into flour using a chopper.

Maintain program

Chickens are housed in cages measuring 30 cm in length, 35 cm in width, and 35 cm in height, with each unit accommodating a single chicken. The provided ration consists of food made from *tenebrio molitor* meal. Individual chicken weights are recorded to determine their initial weight, and a 7 days adaptation period is implemented for both rations and cage conditions. The daily ration, totaling 100 g head⁻¹ day⁻¹, is given twice a day at 07:00 and 16:00 WIB (Western Indonesian Time), with ad libitum access to drinking water. Additional vitamins (Vitachick) are administered to the chickens during the research period. Daily cage cleaning is carried out, and the resulting excreta are collected for composting. The composting materials include arabian chicken excreta (50%), husk ash (45%), bran (3%), EM4, and molasses (1% each). The composting process spans 60 days, and after achieving maturity, a fertilizer quality test is conducted.

Following the completion of the composting process, the next step involves testing water spinach plants with a planting distance of 15 x 20 cm. The experimental design utilized was a Completely Randomized Design (CRD). Various doses of compost were applied as treatments, including treatment without compost (K0), 1 kg/m² (K1), 2 kg/m² (K2), and 3 kg/m² (K3). In the first week after planting, each treatment received 200 kg/ha of urea fertilizer. The experiment was replicated four times, resulting in a total of 16 experimental units. Land preparation involved creating beds measuring 1 x 1 m before planting. One week prior to planting, compost was

distributed across the land based on the treatment, and additional urea fertilizer was applied after the plants reached 7 days old. Initial maintenance included removing dead plants. In addition to replanting, weeding was conducted, and watering occurred twice a day at 07:00 WIB and 16:00 WIB. Harvesting was scheduled for when the plants reached 28 days after planting.

Observed variables

The variables monitored for the production performance of arabian chickens included feed consumption ($\text{g head}^{-1} \text{ day}^{-1}$), hen-day production (%), feed conversion, and egg mass (g head^{-1}); egg quality, encompassing egg weight (g item^{-1}), shell thickness (mm), egg yolk color, shell percentage (%), egg white and yolk percentage (%), and Haugh units (14,15); and the growth and production of water spinach, including crown height (cm), number of leaves (strands), and fresh weight (g/m^2) (16).

Data analysis

Performance data, egg quality, and compost quality data were subjected to descriptive analysis. Analysis of variance (ANOVA) was employed for vegetable growth and production data. To identify differences between treatments, the Duncan advanced test was applied (Steel et al 1997). Microsoft Excel 2010 was utilized for data tabulation, and the analysis process was carried out using the IBM SPSS Statistics 25 software.

Results and Discussion

General conditions of research

The research was conducted at the NRSH Field Laboratory, Faculty of Animal Husbandry, IPB University, Dramaga, Bogor Regency, West Java, with coordinates $60^{\circ}32'$ South Latitude and $106^{\circ}42'$ East Longitude, at an altitude of 131.9 meters above sea level. The research location experiences a wet tropical climate (Af) with two main seasons, the rainy season and the dry season.

The soil at the research location is characterized as reddish-brown latosol soil, displaying a reddish-brown color, clay texture, crumbly structure, and low organic matter content. Soil quality testing revealed a pH of 6.13, organic C content of 0.79%, total N of 0.14%, and phosphorus and potassium concentrations of 1.07 and 345 ppm, respectively. While the soil pH falls within the neutral category, ideal for vegetable plants, the C-organic content is relatively low, emphasizing the need for additional organic material.

The average cage temperature during the study was 27.42°C , surpassing the thermoneutral zone limit (21°C - 24°C). High environmental temperatures influence livestock production, particularly feed consumption behavior. However, studies suggest that the cage temperature tolerance for poultry comfort and production maintenance is around 28 - 31°C (Cornescu et al 2023). The average humidity observed was 83.29%, falling into the high humidity category. The recommended humidity range for laying hens is ideally between 60-70%. High humidity affects chicken comfort, potentially leading to decreased egg production, influenced by factors such as livestock body evaporation, evaporation of liquid materials like drinking water, and poor waste management (Amijaya et al 2018).

The production performance of arabian chickens

The production performance of arabian chickens when provided with feed made from *Tenebrio molitor* is outlined in Table 2. The arabian chicken feed consumption in this study falls within the normal range, suggesting comfortable cage conditions and adequate nutritional intake for the chickens. Previous research has reported consumption levels ranging from 50 to $89 \text{ g per day}^{-1}$ for arabian chickens (Alwi et al 2019; Kususiayah et al 2020).

Table 2 the production performance of arabian chickens when provided with feed made from *tenebrio molitor*.

Production Performance	Chicken Age (weeks)#					
	29	30	31	32	33	34
Feed Consumption (g head ⁻¹ day ⁻¹)	79.83	82	86.79	88.1	87.86	87.64
Feed Conversion	3.67	3.54	3.98	3.47	3.86	3.41
Hen day production (%)	61.00	66.29	62.86	66.43	62.57	66.71
Egg Weight (g egg ⁻¹)	35.72	35.03	34.83	38.75	37.30	39.30
Egg mass (g head ⁻¹)	21.79	23.22	21.89	25.74	23.34	26.22

n : 100 heads

Discrepancies in consumption could be attributed to variations in feed nutritional content, palatability, age, and environmental conditions. The observed average feed conversion stands at approximately 4.08, indicating relatively high conversion rates. While this value surpasses the optimal range of 2.0 – 3.0 for laying hens, factors such as body weight, ration composition, stress, and gender play a role in feed conversion. A higher conversion rate suggests less economical use of feed, emphasizing the importance of efficient feed utilization in successful livestock operations (Setiawati et al 2016).

Providing 4% of *tenebrio molitor* in the feed yields favorable results for egg production, indicating high palatability and preference by chickens. This outcome highlights the positive impact of incorporating *tenebrio molitor* based feed on feed consumption levels in arabian chickens. According to Islam dan Yang (2017) supplementing mealworms in broiler chicken feed enhances palatability due to their distinctive odor. Research suggests that up to 8% inclusion of mealworms in the ration increases PBBH without affecting feed consumption and livestock mortality (Elahi et al 2020; Sedgh-Gooya et al 2021).

Daily egg production reached 64.31%, surpassing Suci et al (2020) research results of 50.12% but falling short of Sahara et al (2020) 71.23%. Indra et al (2013) note that arabian chickens commence egg-laying at 20 weeks, peak at 32 weeks, and experience a decline from 82 weeks, with an annual production of 250-300 eggs. Kustiningsih dan Retnawati (2020) emphasize the influence of protein and phosphorus in feed on egg

production; higher protein enhances egg output due to richer amino acid content. Amino acid deficiencies can impact egg size and elevate feed conversion. The feed used in this study, incorporating 4% mealworms, meets the quality requirements for free-range laying chicken feed, categorized as quality I under SNI 7783-3:2022.

Quality of arabian chicken eggs

The egg quality analysis of arabian chickens fed with a diet made from *tenebrio molitor* is detailed in Table 3. The egg weight obtained in this study falls within the small size category, as defined by the National Standardization Agency (BSN) in SNI 3926:2023, classifying chicken eggs based on weight into small (<50 g), medium (50-60 g), and large (>60 g). This aligns with the findings of Herni *et al.* (2022) reporting that the average egg weight of arabian chickens belongs to the small size category (<50 g). Egg weight is influenced by genetic factors, body size, and nutritional aspects, particularly protein content, specifically methionine concentration (Leeson dan Summers 2005; Hartono et al 2014).

The shell thickness of arabian chicken eggs in this study fell within the medium category, with a recorded thickness of 0.36 mm. The standards outlined in SNI 3926:2023 categorize eggshell thickness as thick (0.39-0.41 mm), medium (0.30-0.36 mm), and thin (0.28-0.30 mm). Rahmawati et al (2022) observed eggshells in the range of 0.33 – 0.38 mm for chickens fed mealworms. Calcium and phosphorus are key factors influencing shell thickness; calcium contributes to shell brittleness and strength, while phosphorus affects shell flexibility (Herni et al 2022). Optimal calcium absorption enhances eggshell quality, increasing both thickness and weight (Rahmawati et al 2022).

Table 3: Quality of arabian chicken eggs fed with a diet made from *tenebrio molitor*

Variable	Result (n)	Ref
Egg weight (g item ⁻¹)	40.96	38-45 ¹
Shell Thickness (mm)	0.36	0.28-0.41 ¹
Egg Yolk Color	8.37	7.6-9 ²
Shell percentage (%)	11.88	10-12 ³
Egg white percentage (%)	54.28	58 ³
Egg yolk percentage (%)	33.83	31 ³
Haugh Unit	91.53	>79 (AA), 31-54 (B), <31 (C) ³

*n :90 eggs. Ref = refernces. ¹National Standardization Agency, ²Hartono(2014);Suci (2020), ³USDA (2002)

The requirements for calcium and phosphorus content in free-range chicken feed, as stipulated by SNI 3926:2023, are 2.50-4.00% and 0.50%, respectively. Laying hens require high levels of calcium for increased egg production and quality. Calcium plays a crucial role in shell thickness, color, and the egg yolk index. Insufficient calcium and phosphorus can lead to eggs with thin shells, more pores, and susceptibility to cracking and bacterial contamination (Świątkiewicz et al 2010; Hanusová et al 2015).

Egg yolk color is a significant aspect for consumers and is influenced by carotenoids in the feed and their absorption in the intestine. The egg yolk color obtained in this study scored 8.37. Previous research has reported an average egg yolk color in free-range chickens ranging from 7.6 to 9 (Hartono et al 2014; Suci et al 2020). Highlighted that the ration affects the egg yolk color due to the pigments present, including xanthophyll pigment (28). A higher egg yolk score indicates more xanthophyll pigment. Generally, egg yolk contains pigments from the carotenoid group, such as xanthophyll, lutein, zeaxanthin, beta-carotene, and cryptoxanthin (Yumna et al 2011). Haugh unit is an indicator used to determine egg quality. The higher the haugh unit value, the better the egg quality (34). Haugh Unit (HU) is an indicator describing egg quality (Lv et al 2019). A higher Haugh Unit value reflects better egg quality. Factors influencing Haugh Unit values include chicken age, season, feed nutritional content, storage time, and temperature. According to the United States Department of Agriculture Standard, haugh unit values are categorized as AA for quality eggs (>79), A (55-78), B (31-54), and C (<31) (USDA 2000).

Quality of arabian chicken compost

The nutrient content of chicken compost is outlined in Table 4. The comprehensive nutrient analysis of arabian chicken compost confirms compliance with the standards set for solid organic fertilizer per SNI 7763:2018. The C/N content value of the compost signifies its high quality. The C/N ratio serves as an indicator to evaluate compost maturity. Microbes utilize carbon and nitrogen levels in compost for energy and protein synthesis. A lower C/N ratio indicates greater compost maturity, attributed to the accelerated carbon decomposition by microorganisms (37). An optimal C/N ratio denotes mature compost suitable for application. Mature compost is characterized by an absence of odor, a blackish-brown hue, and a smooth texture (38).

Table 4 Chemical composition of arabian chicken compost fertilizer

Description	chicken compost	SNI 7763:2018 (solid fertilizer)
pH	8.42	4-9
C-organic (%)	14.64	Min 15%
C/N	9.63	Max 25
N-total (%)	1.52	
P ₂ O ₅ (%)	2.76	Min 2
K ₂ O (%)	3.46	

Test results from the Department of Soil Science and Land Resources Laboratory, Faculty of Agriculture, IPB University

The compost pH analysis revealed a range of 8.42. Veronika et al (2019) caution that excessively high pH during composting can convert nitrogen into ammonia (NH₃), while excessively low pH can lead to the death of microorganisms crucial for the composting process. After the ripening process at the end of composting, the pH value stabilizes around 6-8 (40). The NPK content in arabian chicken compost is deemed satisfactory, meeting the SNI standard for solid fertilizer at a minimum of 2%. Nitrogen (N), potassium (K), and phosphorus (P), highlighted by (McGrath et al 2014) are essential macronutrients for plants. They play pivotal roles in fostering vegetative growth, initiating flowering and fruiting, enhancing disease resistance, fortifying roots, and amplifying crop production.

Growth and production of water spinach plants

Table 5 illustrates the growth and production of water spinach, with compost treatments displaying a significant impact ($P < 0.05$) on the number of leaves at 14 DAP, plant height, and fresh weight. The influence of compost fertilizer on the number of water spinach leaves is also depicted in Table 5, revealing a significant effect at 14 DAP ($P < 0.05$). The variation in the number of leaves at 14 DAP is attributed to enhanced nutrient availability when applying chicken compost during initial planting, contrasting with the control treatment relying solely on existing soil nutrients. The infusion of nutrients at the onset facilitates superior growth and development, even though subsequent phases show no discernible difference. Notably, chicken compost, rich in nitrogen, proves beneficial for plant growth and development (Utomo et al 2017).

Table 5 Effect of treatment on growth and production of water spinach

Variable	P0	P1	P2	P3	SEM	<i>p</i>
Number of leaves						
14 DAP	5.4 ^b	5.75 ^{ab}	5.86 ^{ab}	6.11 ^a	0.3	<0.04
21 DAP	9	9.5	9.47	9.63	0.17	0.19
28 DAP	12.14	12.5	13	12	0.11	0.16
Plant Height (cm)						
14 DAP	10.71 ^c	13.89 ^b	13.9 ^b	15.32 ^a	1.44	<0.01
21 DAP	21.02 ^b	25.69 ^a	26.32 ^a	28.59 ^a	3.62	<0.01
28 DAP	31.63 ^c	40.28 ^b	41.62 ^b	47.08 ^a	4.45	<0.01
Fresh Weight	539 ^c	1150.25 ^b	1550.58 ^a	1721.5 ^a	136.85	<0.02

(g/m²)
^{abc} The mean with different superscripts in the row is significant (P<0.05). K0 control (without compost); K1 compost 1 kg/m²; K2 compost 2 kg/m²; K3 compost 3 kg/m². DAP = days after planting

Treatment significantly influenced plant height at all stages (P<0.05). The application of chicken compost showcased superior vegetable production compared to the non-compost treatment, emphasizing the ability of chicken compost to enrich the planting medium, thereby enhancing overall production. Chicken manure has demonstrated positive effects on plant height and leaf count in caisin, water spinach, and lettuce, yielding the highest stem and root production in caisin, kale, and pakchoi (Maryam et al 2015). The increased soil nutrient content can be attributed to the nutrient release from chicken compost during the decomposition process (42). Statistical analysis results revealed a significant effect of compost treatment on the fresh weight of water spinach plants (P<0.05). Compost, being an organic fertilizer rich in nutrients and beneficial organisms, promotes plant growth. Chicken compost, specifically, contains essential nutrients such as organic C, N, P, K, Ca, and Mg, contributing to improved chemical and biological soil properties, thereby fostering enhanced plant growth (43). Incorporating compost into the soil serves to increase organic matter content, ameliorate soil structure, and boost plant productivity (Luo et al 2017). The continual use of agricultural land can deplete soil organic matter; hence, the application of organic fertilizer becomes crucial for restoring soil fertility (45). Adekiya dan Agbede (2017) research results underscored that applying chicken fertilizer three weeks before planting led to increased organic matter and higher NPK, Ca, Mg levels in the soil, positively impacting tomato production.

Conclusion

The use of 4% *tenebrio molitor* meal effectively substitutes protein source feed ingredients in the ration, sustaining both ration consumption and egg production for arab chickens aged 29-34 weeks. The arab chicken compost, complying with the SNI 7763:2018 standard for solid organic fertilizer regarding NPK content, demonstrates quality. Furthermore, its application with a dose of 3 kg/m² resulted in higher growth and production of water spinach.

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