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Effects of Replacing Duckweed with Red Corn Meal and Rice Bran on Growth Performance of Local Chicken in Semi-Confined and Confined Systems

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ABSTRACT

Incorporating duckweed into poultry diets can improve feed efficiency and growth rate. However, its effectiveness as a replacement for traditional feeds such as red corn meal or rice bran remains less explored. The present study aimed to evaluate the feed intake, average daily gain (ADG), and feed conversion ratio (FCR) in local chickens reared under confined and semi-confined systems. The experiment was conducted at the campus of Svay Rieng University, Svay Rieng Province, Cambodia, from June to August 2024. The present study consisted of two factors. The first factor was the rearing system, including semi-confined and confined systems, and the second factor was the diet, with four treatments. A total of 120 local chickens, 35 days old, with an average initial body weight of 300 grams, were arranged in a 2 × 4 factorial layout using a completely randomized design within eight treatments and three replications. The first group included 5% duckweed, 22% commercial feed, 20% red corn meal, 52.5% rice bran, and 0.5% premix/salt (T1). The second group consisted of 10% duckweed, 19% commercial feed, 20% red corn meal, 50.5% rice bran, and 0.5% premix/salt (T2). The third group had 15% duckweed, 16% commercial feed, 20% red corn meal, 48.5% rice bran, and 0.5% premix/salt (T3), and the fourth group included 20% duckweed, 13% commercial feed, 20% red corn meal, 46.5% rice bran, and 0.5% premix/salt (T4). There were no significant interactions between four diets and two raising systems for feed intake, ADG, and FCR in the chickens, except for the crude fiber intake. However, significant differences were observed in T1 and T2 compared to T4 regarding feed intake and ADG, with a tendency toward improved FCR for chickens fed T3 compared to T4 and those raised under the confined system. The growth performance in chickens raised under the confined system was higher than that of chickens raised under the semi-confined system. The present results indicated that using duckweed at 15% mixed with other ingredients led to higher feed intake, higher ADG, and improved FCR, even when chickens were raised in a confined or semi-confined system.

Keywords: Commercial feed, Confined system, Duckweed, Performance, Red corn

INTRODUCTION

Poultry production plays an important role in the agricultural sector across Cambodia, particularly backyard chicken rearing, a common practice among rural households. Approximately 32.4%-67.6% of rural farmers rear local chickens, with flock sizes ranging from 31 to 42 chickens per household (Yitayih et al., 2023). Backyard or village chickens contribute significantly to poverty reduction and food security in developing countries such as Vietnam, Laos, and Cambodia (Saroeun et al., 2010). However, improving poultry growth performance requires providing nutritionally balanced feeds that supply the essential nutrients for growth, egg production, and meat development (Saroeun et al., 2010). The free-range production system alone often fails to meet these nutritional requirements. Therefore, it is recommended to supplement the diet of the free-range chickens with protein-rich feeds to provide affordable, sustainable sources of protein and vitamins (Saroeun et al., 2010). The forages can partially replace conventional protein ingredients such as fish meal or soybean meal, making them useful feed alternatives for smallholder and household-level poultry production (Vlaicu et al., 2024). Duckweed is a rich protein source, especially a superior source of the essential amino acids compared to most vegetable proteins, and is very useful as a protein source for animal feed (Demann et al., 2022). Duckweed represents a valuable source of high-quality protein, suitable for utilization in household backyard animals, particularly for the cultivation of pigs and poultry production (Hang, 1998; Samnang, 1999; Khang and Brian, 2004a), and is a suitable source of vitamins and minerals for growing ducks (Men et al., 1995). To date, only a limited number of studies have examined the protein requirements in local chicken breeds raised under confined or semi-confined systems in Cambodia, even though numerous investigations have focused on the nutrient needs of hybrid or exotic chickens. Johnson (1998) reported that the crude protein (CP) content of duckweed varied widely from 7% to 40%, depending on its growth medium, with experimentally measured values ranging from 8.7% to 24.9%. Additionally, the lysine content of duckweed ranges from 0.40% to 1.13%. In a duckweed feed containing 29%-31.82% of CP, the methionine content is 0.18%, and the lysine content is 10.9% (Yilmaz et al., 2004).

Corn is considered the principal energy source in poultry diets and is an important cereal grain for human consumption (Ojediran and Olorunlowu, 2025). Recently, scientists have been exploring alternative feedstuffs that could partially or fully replace corn in poultry diets due to its increasing cost and competition with human food needs (Agwunobi, 1999). Corn is regarded as an excellent grain for poultry feed because it is low in fiber and provides a well-balanced nutrient profile. Its chemical composition includes 86% of dry matter (DM), metabolizable energy at 3373 kcal/kg, CP at 7.5%, methionine at 0.18%, cysteine at 0.18%, tryptophan at 0.07%, tannin at 0.29%, crude fat at 3.5%, crude fiber (CF) at 1.9%, ash at 1.1%, calcium at 0.01%, and phosphorus at 0.12% (Jacob, 2016).

Rice bran is a rich source of nutrients and is currently used in animal diets (Tahira and Butt, 2007). According to Sivala et al. (1991), rice bran is high in energy and fat and contains essential vitamins, particularly vitamins B and E, as well as important minerals. Jacob (2016) reported that the nutrient composition of rice bran includes 91% of DM, digestible energy at 2040 kcal/kg, 13.5% of CP, methionine at 0.17%, cysteine at 0.10%, lysine at 0.50%, tryptophan at 0.10%, threonine at 0.40%, crude fat at 5.9%, 13.0% of CF, ash at 11.0%, calcium at 0.10%, and phosphorus at 1.70%.

The present study aimed to evaluate the effects of replacing duckweed with a commercial feed containing red corn meal and rice bran on feed intake, growth rate, and feed conversion ratio (FCR) in local chickens reared under confined and semi-confined systems.

MATERIALS AND METHODS

Ethical approval

The chickens were treated in accordance with the animal welfare guidelines of the Animal Health and Production Office in Svay Rieng province, Cambodia. The experiment received ethical approval from Svay Rieng University, as documented in the reference letter dated September 9, 2024.

Study area

The experiment was conducted from June 1, 2024, to August 31, 2024, at the research station of Svay Rieng University on National Road 1, in Sangkat Chek, Svay Rieng City, Svay Rieng Province, Cambodia. The temperature of the environmental house during the experimental period was maintained at 27°C ± 2.

Experimental design

A total of 120 local chickens (60 males and 60 females), aged 35 days, with an average initial body weight of 300 g, were selected and arranged in a 2 × 4 factorial arrangement using a completely randomized design with eight treatments and three replications. The chickens were weighed at the beginning of the experiment (June 1) and every 10 days thereafter until the end of the experiment on August 31, 2024.

Experimental factors

The present study included two factors. The first was the rearing system, which consisted of semi-confined (SC) and confined (C) systems, and the second was the diet, with four treatments. The dietary treatments were formulated based on the book Animal Nutrition (McDonald et al., 2011) and the nutrient requirements of poultry (NRC, 1994). The first group contained 5% duckweed, 22% commercial feed, 20% red corn meal, 52.5% rice bran, and 0.5% premix/salt (T1), the second group contained 10% duckweed, 19% commercial feed, 20% red corn meal, 50.5% rice bran, and 0.5% premix/salt (T2), the third group contained 15% duckweed, 16% commercial feed, 20% red corn meal, 48.5% rice bran, and 0.5% premix/salt (T3), and the fourth group contained 20% duckweed, 13% commercial feed, 20% red corn meal, 46.5% rice bran, and 0.5% premix/salt (T4; Table 1).

Table 1. Ingredients and chemical composition of the experimental diets for local chickens during the experiment period

Diet ingredients / Group	T1	T2	T3	T4
Ingredients (%)				
Commercial feed	22	19	16	13
Duckweed	5	10	15	20
Red corn meal	20	20	20	20
Rice bran	52.5	50.5	48.5	46.5
Premix/salt	0.5	0.5	0.5	0.5
Chemical composition (% on dry weight basis)				
Dry matter[1]	85.1	81.1	77.1	73.1
Crude protein[2]	19.9	20.0	20.2	20.3
Crude fibre[2]	4.50	4.81	5.13	5.44
Organic matter[2]	88.2	88.6	89.1	89.6

[1]: Analysis results of the animal feed laboratory of Svay Rieng University, Cambodia, [2]: Analysis of results of the Laboratory at the Center for Livestock and Agriculture Development, Cambodia.

Housing

There were a total of 24 pens, each measuring 2 meters in length, 1 meter in width, and 1.5 meters in height. The pens were constructed from steel frames and plastic netting and housed in an open-sided shed with a roof made of a steel structure and zinc sheets. Each pen had a drinker and a feeder individually. A total of 120 local chickens were housed, five heads per pen. A routine preventive vaccination program was implemented. Chickens were vaccinated at three, six, and eight weeks of age against Newcastle disease, Fowl Pox, and Fowl Cholera. This approach aligns with standard poultry health management principles, where vaccination is customized to local disease risks and administered on a sequential schedule to develop effective immunity (Marangon and Busani, 2006; Cserep, 2009). The vaccines used were produced in Vietnam and imported by the Green Feed company, Cambodia (Islam et al., 2008; Hossain et al, 2025). The chickens were acclimated to the feed and pen conditions for seven days before the experiment. The housing temperature was maintained at 27°C ± 2, while the relative humidity ranged from 70% to 80% during the experiment.

Experimental feeds

Duckweeds were grown in the big pond in the research station of Svay Rieng University, Cambodia, and were collected from the pond daily in the morning. For the commercial feed, red corn and rice bran were purchased from the local market and from Green Feed Company, Cambodia.

The feed amounts provided were based on a dry-matter intake equivalent to 10% of each chicken's body weight, as determined during the adaptation period. Feed offered during the collection period was adjusted according to the actual intake recorded during adaptation. Water was available *ad libitum* through a drinker placed in each pen (Dukhta et al., 2018).

Duckweeds were dried under a shaded roof for one hour before mixing with relevant ingredients. The duckweed, commercial feed, red corn, rice barn, and premix were weighed and well mixed, and then fed to local chickens three times per day at 7 am, 11 am, and 4 pm according to the advice by the Green Feed and CP companies, Cambodia. There were no refusals of any feed during the experimental period.

Sample collection

The chickens were weighed in the morning before feeding, at the beginning of the experiment, and every 10 days thereafter. Feed offered was collected and weighed daily. Both the offered feed and the feed residues were placed in plastic bags and stored at -20 °C until further analysis. At the end of each 10-day experimental period, the collected feed offered and the residues were thoroughly mixed by hand, then homogenized in a coffee grinder before laboratory analysis (Phiny et al., 2008).

Chemical analysis

Chemical analysis of the feed ingredients, diets, and feed offers was carried out according to the procedures of AOAC (1990) for determining ash, nitrogen, and CF. Dry matter content was determined using the microwave method described by Undersander et al. (1993). All analyses of the samples were conducted in duplicate in order to avoid different errors.

Statistical analysis

The data for feed intake, FCR, growth rate, and standard error of the mean (SEM) were analyzed using Analysis of Variance (ANOVA) via the General Linear Model (GLM) procedure in Minitab version 16.

Significant differences among treatment means were compared using Tukey's Honestly Significant Difference (HSD) test at a significance level of p value less than 5% ($p < 0.05$). The source of variation in the data was attributed to the effects of diet, raising system, their interaction, and the residual error.

RESULTS

Chemical characteristics

The feed ingredients, such as red corn meal, commercial feed, and rice bran, had relatively high DM contents of 92.1%, 89.7%, and 87.6%, respectively, compared to duckweed, which had a DM content of 9.12%. However, duckweed had a higher CP content of 34.5% on a dry-matter basis than red corn meal (12.2%) and rice bran (10.8%), which were primarily used as energy sources. Additionally, red corn meal had a higher CF content (28.7%) and a higher organic matter (OM) content (98.7%) on a dry-matter basis (Table 2).

Feed intake

Notable effects on the chicken's consumption were that DM intake in T1 (80.7 g/day) and T2 (80.3 g/day) were significantly higher than the DM intake in T4 (73.5 g/day; $p < 0.05$). However, DM intake in T1 was not significantly different compared to T2 (80.3 g/day) and T3 (78.1 g/day; $p > 0.05$; Table 3; Figure 1). The DM intake in the chickens reared under the confined system was significantly higher than in the semi-confined system ($p < 0.05$; Table 3). The dietary consumption in chickens indicated that CF (61.1 g/day) and OM (181 g/day) intakes in T4 were significantly higher than thoes in T1 (6.95 g/day of CF, 107 g/day of OM), T2 (10.4 g/day of CF, 136 g/day of OM), and T3 (13.5 g/day of CF, 162 g/day of OM; $p < 0.05$). Additionally, CP intake in T3 and T4 was not significant ($p > 0.05$). There were no significant interactions between diet and rearing system for CP (Figure 2) and OM intakes ($p > 0.05$; Figure 3). However, a significant interaction between diet and rearing system was observed for CF intake ($p < 0.01$; Figure 4). The dietary intake curves illustrating the relationship between feed intake and days of the experiment demonstrated that as the experiment duration increased, feed intake of the chickens rose across both dietary regimens and rearing systems. There was a significant increase in feed intake in T1 and T2 compared to T3 and T4 ($p < 0.05$; Figure 5). Moreover, chickens reared under the confined system demonstrated a greater increase in DM intake than those reared under the semi-confined system ($p < 0.05$). This was likely because the DM intake in chickens between days 20 and 60 of the experiment increased in a mostly linear pattern (Figure 6).

Table 2. Chemical composition of different feed ingredients for local chickens before starting the experiment

Ingredients / As a percentage of DM[2]	DM (%)[1]	CP (%)	CF (%)	OM (%)
Commercial feed	89.7%	45.7%	3.1%	76.7%
Duckweed	9.12%	34.5%	10.2%	91.2%
Red corn meal	92.1%	12.2%	28.7%	98.2%
Rice bran	87.6%	10.8%	5.21%	89.7%
Premix/salt	98.3%	0%	0%	0%

DM: Dry matter, CP: Crude protein, CF: Crude fiber, and OM: Organic matter. [1]: Analysis results of the animal feed laboratory of Svay Rieng University, Cambodia. [2]: Analysis of results of the Laboratory at the Center for Livestock and Agriculture Development, Cambodia.

Table 3. Feed intake in local chickens using duckweed to replace commercial feed mixed with red corn meal and rice bran

Parameters	System (S)			Diet (D)					
	Confined	Semi-confined	SEM	T1	T2	T3	T4	SEM	S*D
DM intake (g/d)	86.7[a]	69.6[b]	0.97	80.7[a]	80.3[a]	78.1[ab]	73.5[b]	1.37	ns
CP intake (g/d)	52.1[a]	41.5[b]	0.54	32.4[d]	43.1[c]	52.3[ab]	59.6[a]	0.76	ns
CF intake (g/d)	13.1[a]	10.4[b]	0.13	6.95[d]	10.4[c]	13.5[b]	16.1[a]	0.19	S
OM intake (g/d)	163[a]	130[b]	1.67	107[d]	136[c]	162[b]	181[a]	2.36	ns

DM: Dry matter, CP: Crude protein, CF: Crude fiber, and OM: Organic matter. T1: 5 % duckweed + 22% commercial feed + 20% red corn meal + 52% rice bran + 0.5% premix/salt, T2: 10% duckweed + 19% commercial feed + 20% red corn meal + 50.5% rice bran + 0.5% premix/salt, T3: 15% duckweed + 16% commercial feed + 20% red corn meal + 48.5% rice bran + 0.5% premix/salt, T4: 20% duckweed + 13% commercial feed + 20% red corn meal + 46.5% rice bran + 0.5% premix/salt. [a, b, c, and d] Means within rows with different superscript letters are significantly different at $p < 0.05$. ns: not significant. S: significant

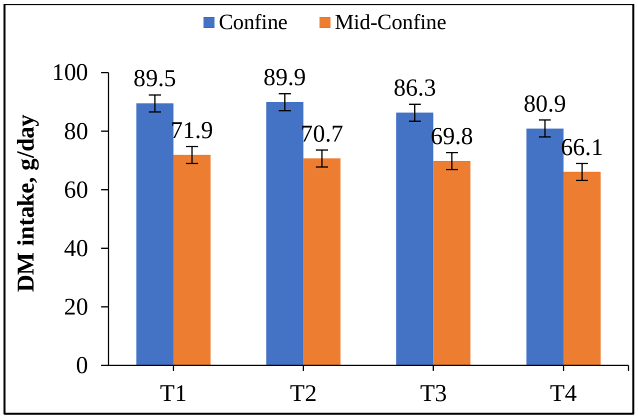

Figure 1. Interaction between dry matter intake and raising systems in 18-week-old local chickens fed duckweed to replace commercial feed mixed with red corn meal and rice bran

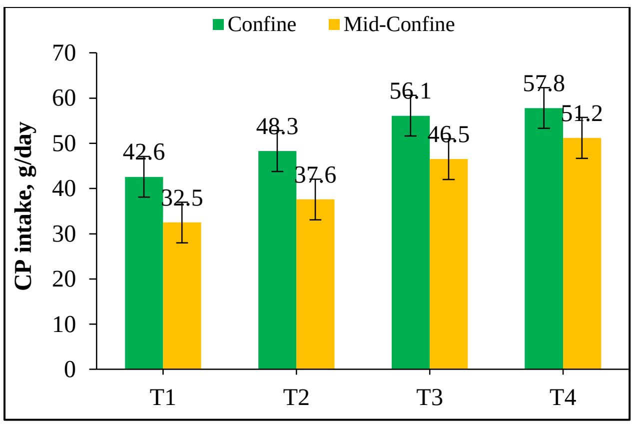

Figure 2. Interaction between crude protein intake and raising systems in 18-week-old local chickens fed duckweed to replace commercial feed mixed with red corn meal and rice bran

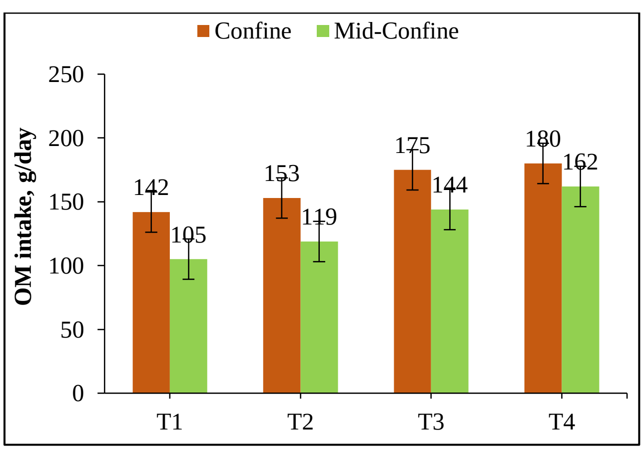

Figure 3. Interaction between organic matter intake and raising systems in 18-week-old local chickens fed duckweed to replace commercial feed mixed with red corn meal and rice bran

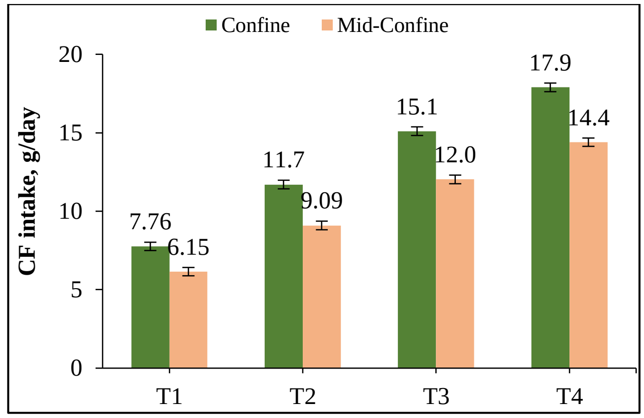

Figure 4. Interaction between crude fiber intake and raising systems in 18-week-old local chickens fed duckweed to replace commercial feed mixed with red corn meal and rice bran

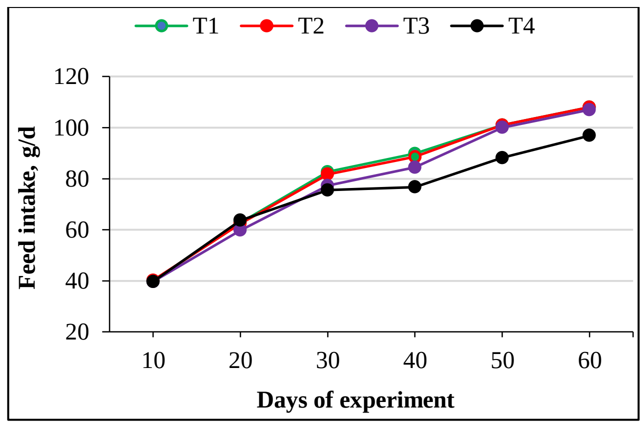

Figure 5. Feed intake curves in 18-week-old local chickens with different diets fed duckweed to replace commercial feed mixed with red corn meal and rice bran

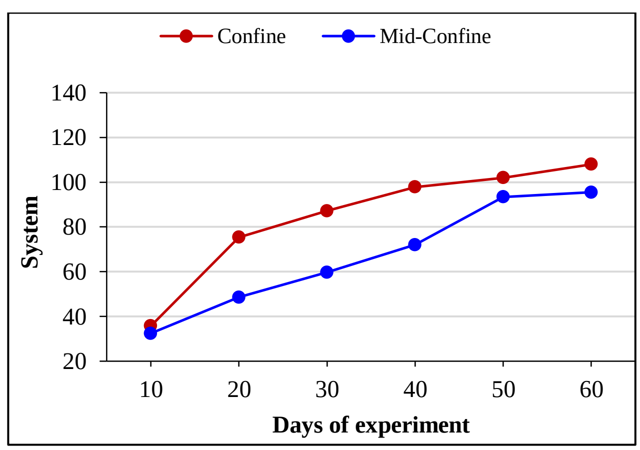

Figure 6. Feed intake curves for 60 days in local chickens with different rearing systems fed duckweed to replace commercial feed mixed with red corn meal and rice bran

Growth performance and feed conversion ratio

Considerable changes in average daily gain (ADG) and FCR were observed in the chickens' performance. Group T3 indicated the highest ADG (18.1 g/day; Figure 7). Additionally, T3 had the most improved FCR (4.29), compared to T4 (4.58), under both rearing systems. However, no significant differences in FCR were observed between T3 (4.29) and T1 (4.64) or T2 (4.50; $p > 0.05$; Table 4; Figure 8). The ADG and FCR of the chickens reared under the confined system were significantly higher than those reared under the semi-confined system ($p < 0.05$; Table 4). There were no significant interactions between diet and rearing system for ADG and FCR ($p > 0.05$). The best performance, including feed intake, ADG, and FRC, was observed in chickens reared under the confined system (Table 4). The growth curves illustrating the relationship between the ADG and the days of experiment indicated that the ADG of the chickens increased as the experimental period progressed. The increase of ADG was more pronounced in T3 compared to those in T1, T2, and T4 ($p < 0.05$; Figure 9). The growth curves in chickens reared under the confined system demonstrated a greater increase in ADG from 40 days onward compared to the chickens raised under the semi-confined system ($p < 0.05$; Figure 10).

Table 4. Average daily gain and feed conversion ratio in 18-week-old local chickens using duckweed to replace commercial feed mixed with red corn meal and rice bran

Parameters	System (S)			Diet (D)					
	Confined	Semi-Confined	SEM	T1	T2	T3	T4	SEM	S*D
Initial weight (g)	364	360	9.49	361	362	361	363	13.4	ns
Final weight (g)	1422	1362	25.3	1396	1412	1444	1316	35.8	ns
ADG (g/d)	17.6[a]	16.7[b]	0.32	17.3[ab]	17.5[ab]	18.1[a]	15.9[b]	0.45	ns
FCR	4.72[a]	4.29[b]	0.07	4.64	4.50	4.29	4.58	0.09	ns

ADG: Average daily gain, FRC: Feed conversion ratio. T1: 5 % duckweed + 22% commercial feed + 20% red corn meal + 52% rice bran + 0.5% premix/salt, T2: 10% duckweed + 19% commercial feed + 20% red corn meal + 50.5% rice bran + 0.5% premix/salt, T3: 15% duckweed + 16% commercial feed + 20% red corn meal + 48.5% rice bran + 0.5% premix/salt, T4: 20% duckweed + 13% commercial feed + 20% red corn meal + 46.5% rice bran + 0.5% premix/salt. [a, b] Means within rows with different superscript letters are significantly different at $p < 0.05$. ns: Not significant.

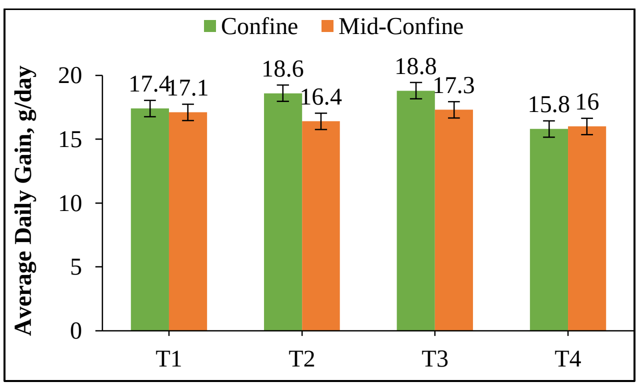

Figure 7. Mean values of live weight gain in 18-week-old local chickens fed duckweed to replace commercial feed mixed with red corn meal and rice bran

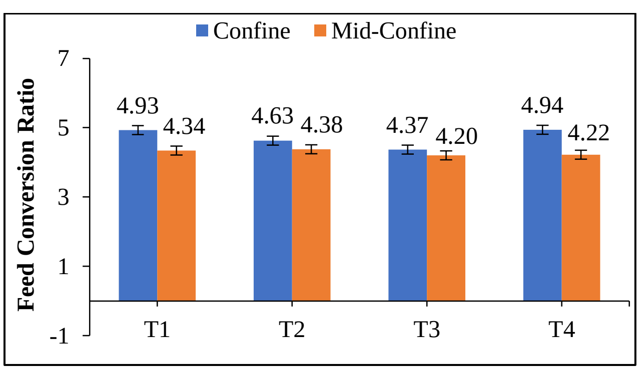

Figure 8. Feed conversion ratio in 18-week-old local chickens fed duckweed to replace commercial feed mixed with red corn meal and rice bran.

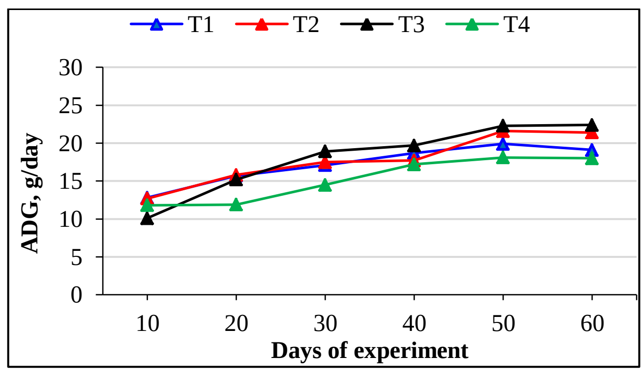

Figure 9. Growth curves for 60 days in local chickens with different diets included duckweed to replace commercial feed mixed with red corn meal and rice bran.

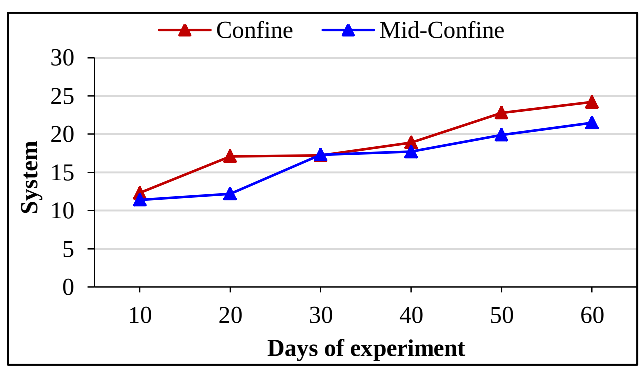

Figure 10. Growth curves in 60 days in local chickens with different rearing systems fed duckweed to replace commercial feed mixed with red corn meal and rice bran.

DISCUSSION

The present study exhibited higher DM, CF, and OM contents but lower CP levels, in contrast to the findings of Mwale and Gwaze (2013). The red corn meal byproduct analyzed in the present study had a DM content of 92.1%, aligned with the DM content (92%) reported for corn bran by Beck et al. (2024); however, its CP content was in contrast to that of the present study. The CF content of red corn meal (28.7%) in the present study was similar to the CF content (26.8%) reported for corn and cob meal (26.8%) by Ojediran and Olorunlowu (2025). However, the observed variation might be attributed to differences in red corn meal varieties and production locations in Cambodia. Similarly, the DM (87.6%) and OM (89.7%) contents of rice bran in the present study aligned with the findings of Shin et al. (2004).

The DM intake observed in the present study contrasted with the findings of Samnang (1999), who reported substantially lower DM intakes (30-40 g/day) in native chickens fed duckweed combined with broken rice under scavenging systems. Similarly, the present results were in contrast to those of Rodriguez and Preston (1999), who reported DM intakes ranging from 30 to 36 g/day when chickens were fed duckweed mixed with rice bran or duckweed alone as a supplement. Furthermore, the DM intake recorded in the present study was in contrast to the findings of Khang and Ogle (2004a), who reported a substantially lower DM intake of 38.3 g/day in chickens fed a concentrate diet supplemented with fresh duckweed in the confined system. This discrepancy in the results might be due to the *ad libitum* inclusion of fresh duckweed, which led to nutrient imbalances and potentially resulted in nutrient deficiencies and reduced feed intake. The CP and CF intakes in the present study were consistent with those reported by Khanum et al. (2005), who indicated that growing ducks were supplemented with duckweed mixed with other ingredients, including concentrate feed, soybean meal, maize, and wheat bran.

In the present study, the ADG of chickens fed a diet containing 15% duckweed mixed with red corn meal and rice bran was 18.1 g/day, higher than that of other diets. The current results were higher than those reported by Kingori et al. (2003), who fed a balanced diet containing 18% CP, maize, maize gluten meal, fish meal, and limestone, resulting in ADG of 12.2 g/day. This discrepancy might be attributed to the utilization of duckweed at different inclusion levels as a substitute for commercial feed within the diet. This substitution potentially has influenced the chickens' preference for the experimental feed diet. Additionally, the ADG observed in the present study was in contrast to the higher ADG (20.4 g/day) reported by Thuy and Ogle (2005) for Loung Phuong chickens fed a nutritionally balanced mixed diet containing duckweed. Thuy and Ogle (2005) reported a superior performance, possibly due to a more balanced diet. Their diet included fish meal, soybean meal, broken rice, rice bran, and *ad libitum* duckweed, which probably led to higher feed intake and greater nitrogen retention than the mixed diet used in the present study. The lower growth performance observed in the present study contrasts with the findings of Khang and Ogle (2004a), who supplemented the chickens with duckweed *ad libitum*. The FCR measures the efficiency of chicken performance by comparing feed utilization to live weight gain. In the present study, local chickens fed the diet containing 15% duckweed exhibited an FCR of 4.29, representing the greatest improvement among the dietary treatments. This result was in alignment with the findings of Nakkazi et al. (2015), who reported FCR values ranging from 2.7 to 4.9 in local chickens fed diets containing maize, fish meal, and sunflower (formulated to 20-23% CP) under an intensive feeding system during the 1-6-week growing period. The present findings were also in line with the results of Putra and Ritonga (2018), who fed native chickens conventional starter and finisher diets containing 5-20% duckweed meal and reported FCR values ranging from 3.96 to 4.18 over a 13-week growing period. Additionally, the present results are consistent with those of Khang and Ogle (2004b), who reported a slight improvement in daily weight gain and FCR when fresh duckweed was provided *ad libitum* alongside a concentrate diet. These differences in results might be attributed to duckweed nutrient content, especially its carotenoid content, as well as differences in species, feeding system, and rearing conditions. The FCR observed in the present study was in contrast to that reported by Ma et al. (2021), who recorded an FCR of 5.23 in chickens fed diets containing yellow corn, fish meal, rice bran, molasses, and limestone with 15% duckweed. The difference in FCR may be attributed to the inclusion of 5% molasses as an energy source in their formulated diets, which likely reduced DM and CP intake during the experimental period.

CONCLUSION

Based on the present findings, duckweed can be included at 15% and mixed with other feed ingredients. Local chickens consumed high amounts of DM content, exhibited increased live weight of 18.1 g/day, and demonstrated a greater FCR of 4.29. Moreover, the local chickens raised under the confined system had an enhanced ADG of 17.6 g/day compared to those raised under the semi-confined system. Future studies should investigate the nutritional digestibility, carcass quality, and economic efficiency of diets containing duckweed under different management systems.

DECLARATIONS

Availability of data and materials

The datasets produced and examined in the present study can be obtained from the corresponding author upon reasonable request.

Funding

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Authors' contributions

Chiv Phiny conceived, developed, and designed the present experiment. All data collection was carried out by Srey Lida, Lay Sophin, and Phuon Phou. Data analysis and the initial draft of the manuscript were completed by Chiv Phiny. Tum Saravuth and Sin Putheasath provided critical input and assistance in improving the English language and overall quality of the paper. All authors have read and approved the manuscript before its submission to the JWPR journal.

Ethical considerations

The authors conducted a comprehensive review of the manuscript to ensure adherence to ethical guidelines, including the prevention of plagiarism, proper attribution of authorship and consent to publish, avoidance of research misconduct, data fabrication, duplicate publication, and/or submission redundancy. All data presented in this study were collected and analyzed with integrity and transparency. The authors confirmed that the manuscript is original, has not been published elsewhere, and is not currently under consideration by other journal. The authors confirmed that they have not used AI tools in conducting the present study.

Competing interests

The authors declared that they have no known financial, personal, or professional conflicts of interest.

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