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Research Article

Effects of *Carica papaya* Leaves and Fermented Fish Waste on the Production Performance of Broiler Chickens

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ABSTRACT

Introduction: Poultry feed management requires novel dietary additives to enhance chicken performance and manage feed availability. The present study investigated the effects of dietary supplementation of *Carica papaya* leaf meal (CPL) and fermented fish waste (FFW) in water on different growth indicators, such as body weight, carcass yield, feed intake, and conversion rate of Bovans brown male broiler chickens. **Materials and methods:** A randomized complete block design with a 2x4 factorial arrangement was used to study the effect of the combination supplementation of the 10% CPL with FW at 0%, 5%, 10%, and 15%. Both additives combination treatment was replicated four times with five broiler chicks per replication, a total of 160-day-old male Bovans brown broilers with 39-40g body weight were used in the current study. The duration of the study was 20 days (from the 16th to 35th days of age).

Results: Studies have revealed that CPL negatively impacted the final body weight, whereas FFW positively influenced feed intake, final weight, and weight gain. Moreover, 15% of FFW supplementation resulted in noteworthy increases in drumstick and thigh weights compared to the control group, with significant interactions identified between CPL and FFW for breast, wing, and back weights. However, neither CPL nor FFW had an impact on the weights of edible visceral organs. The palatability of meat quality assessment showed no significant difference among the treatments. Adding CPL and FFW increased weights and profits, with the best rate of intake observed in broilers given the standard diet plus 15% of FFW supplementation.

Conclusion: These results indicated that using CPL and FFW at 10% and 15%, respectively was a financially feasible approach to improve broiler development, carcass quality, and profitability while capitalizing on nutritional advantages and reducing environmental waste.

1. Introduction

The increasing need for animal-based protein sources has led to a significant rise in global poultry production. Nonetheless, the conventional methods used in broiler chicken farming, which rely heavily on resource-intensive feed ingredients and result in substantial waste generation, have raised concerns about environmental impact and limited economic development[1,2]. Therefore, further studies on appropriate diets or feeding practices that enhance the efficiency, profitability, and eco-friendliness of broiler farming are essential.

In recent years, phytogenic feed additives, fermented by-products, and their derivatives have garnered interest as potential substitutes for conventional supplements in poultry diets. *Carica papaya* leaves, a prevalent and found more as agro-waste, poultry farms use it frequently. Studies indicate that incorporating low to moderate levels of *Carica papaya* leaves (below 5–15% of the diet) of the lesser-known Papaya Leaf Meal (PLM) does not significantly impact body weight gain, final weight, or voluntary feed intake in broiler[3-5]. However, a high

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inclusion rate of PLM could disrupt the proteolytic process and decrease nutrient absorption in the gastrointestinal tract due to the presence of phytochemicals such as alkaloids, saponins, tannins, and protease inhibitors[6, 7].

The bitter taste linked to PLM chemicals also reduced the chicken's feed intake and palatability[6]. Although the majority of trials show no discernible effects of low-level PLM on production metrics such as feed conversion ratio (FCR), a few research describe variations in feed efficiency based on inclusion rates and dietary formulations. Therefore, the fermentation of fish processing waste yields fermented fish waste (FFW), which is nutrient-rich and contributes vital elements including protein, amino acids, and bioactive substances. Studies indicate that while fermented fish waste has no detrimental effects on feed consumption, growth performance, or feed conversion ratio, it can be a useful source of protein for broiler chick diets[8]. Up to 20% of soybean meal can be substituted with fish silage without affecting meat quality or development[9,10]. Furthermore, fermented fish waste can improve the nutritional value of feed and the health of hens' digestive systems[11,12].

While previous research has explored the individual effects of *Carica papaya* leaf meal (CPL) and fermented feed waste (FFW) on broiler performance, the potential synergistic benefits of combining these two supplements remain largely unexplored[7]. Additionally, the novel approach of administering FFW through drinking water, as opposed to feed, offers a promising avenue for optimizing nutrient utilization and reducing feed wastage[13]. The combination of CPL and FFW has great value for chicken production from different perspectives such as health improvement, body growth, and egg production[4,10].

This study aimed to measure feed intake and body weight gain, examine the feed conversion ratio and carcass yield, and evaluate the effects of CPL and FFW on meat quality and potential profit margins. The incorporation of CPL and FFW into the diet was conducted with consideration of both agronomic and economic factors, using a holistic approach that integrates the benefits of these ingredients. In essence, leveraging the synergistic capabilities of these sustainable supplements is intended to optimize broiler chicken production, reduce environmental impacts, and maximize economic returns.

2. Materials and Methods

2.1. Ethical approval

The current study has been approved for its ethical soundness by the Institutional Ethical Review Board (IRB) of the College of Veterinary Medicine and Animal Sciences, University of Gondar, Ethiopia. It has been given at reference (Reference No: CVMAS.Sc.16.282030).

2.2. Experimental design

The study was carried out in Gondar, Ethiopia, at the University of Gondar College of Veterinary Medicine and Animal Sciences from November 2023 to March 2024. A control group that was given a standard diet (SD) with has ratio composed of protein: 20-24%, energy: 2900-3000 Kcal/kg, Calcium: 0.9-1.0%, Phosphorus 0.45-0.5%, Methionine: 0.45-0.5% and Lysine: 1.1-1.3% used to assess two levels of dietary supplements designed by Factor A. The experimental design 2x4 factorial structure to test 10% *Carica papaya* leaf meal was added to the treatment group (CPL). Four stages made up Factor B clean tap water, 5% fermented fish waste (FFW), 10% FFW, and 15% FFW. There were 160 male Bovans brown broiler chickens in total after the experiment was repeated four times, with five sample broiler chickens in each treatment combination.

2.3. Management

The chickens were 160-day-old Bovans brown male broiler chicks which are 39-41 grams purchased from Andasa Hatchery Center, a prominent Ethiopian poultry enterprise, located in Bahirdar. The chicks brooded for the first two weeks of the experiment after being purchased and chickens were fed commercial chicken booster feed at this time and were allowed to drink tap water whenever they needed to drink. Each floor of the chicken house measured 4 by 4 square feet. Implement strict biosecurity measures, including controlling access to the facility, disinfecting equipment, and using protective clothing.

Electric light bulbs are used to control the ideal heat, maintaining a constant temperature range of 30-36°C, humidity 60-70%, and light protocol 23-24 hours for first week age, and 16-18 hours in 4 weeks during the brooding phase. Follow a vaccination schedule appropriate for the region and the specific diseases prevalent. NCD BIBI, LaSota Strain vaccine of chicken produced by the national veterinary institute in Ethiopia used to vaccinate the chicks against Newcastle Disease on the tenth day of brooding. Following the brooding stage, the chicks were moved to raised cages and assigned at random to their experimental treatments. The chicken cage was constructed as each floor of the chicken house measured 4 by 4 square feet. The chickens were regularly inspected and supervised on their health status, disease, abnormal behavior, and growth performance. Regularly check the health of the chickens, looking for signs of disease, abnormal behavior, or growth issues. The data on chicken records feed intake, growth rates, health treatments, and environmental conditions. Regularly clean the litter on the chicken house floor and replace the bedding to maintain a dry and healthy environment. Properly dispose of chicken manure and other waste products in compliance with environmental regulations

2.4. Carica papaya leaf meal

Carica papaya (papaya) leaf meal was collecting the mature, healthy papaya leaves. After cleaning and properly drying the leaves, it has chopping and grinding and it stores the papaya leaf meal in airtight containers or bags in a cool, dry place to prevent moisture absorption and spoilage.

2.5. Formulation of Carica papaya leaf meal and fish fermented waste

After being meticulously removed from their stems, fresh *Carica papaya* leaves were thoroughly cleaned and allow drying. The leaves were chopped finely and sun-dried for four to six days to achieve a constant crispness while keeping their distinctive green color. The dried leaves were ground into a fine powder after reaching a steady weight. According to recommendations by Akpolu and Moroye[7], then 10% *Carica papaya* leaf is incorporated into the regular broiler starter and finisher meals.

The preparation of fermented fish waste (FFW) followed established protocols outlined by Adajar and Taer[14], with some modifications. Initially, fish by-products such as internal organs, fins, scales, bones, and heads were collected from the local public market. These components were washed, drained, and then chopped into 1-inch pieces. Next, the chopped fish parts were mixed with crude molasses in a 1:1 ratio. This mixture was then wrapped in Manila paper and left to ferment for 15 days. After the fermentation period, the mixture was processed to extract a liquid rich in fish amino acids[15]. This extract was carefully collected, stored in plastic jars, and kept in a shaded area to preserve its quality.

2.6. Feeding applied to the chicken

Upon completion of the two-week brooding phase, the designated experimental treatments were administered to the broiler chicks from the 16th day until the 35th day of the feeding trial. The chicks were distributed across 32 compartments, with each compartment representing a unique treatment combination and providing a floor space of 3x2 square feet per replication. One subset of chicks received a pure standard diet (SD) and was further divided into four sub-groups, each receiving different water supplements: pure tap water (control), 5% fermented fish waste (FFW), 10% FFW, and 15% FFW. This allocation strategy was based on the optimal FFW inclusion rates recommended by Shabani et al.[10].

Another subset of broiler chickens fed a diet supplemented with 10% *Carica papaya* leaf meal (CPL) and similarly subdivided into four groups, each receiving the same water supplementations as the previous subset. Experimental rations are provided twice daily, at 6:00 AM and 5:00 PM. Feed refusals were carefully weighed each morning to determine the feed intake levels of the chicken.

2.7. Data collection

Feed intake was determined by dividing the total amount of feed given by the number of hens per replication[16] and then deducting the amount of feed rejected from the amount given. After the 35-day feeding study, the ultimate weight of the chickens was noted. The broilers' final weight was subtracted from their initial weight, which was measured at two weeks of age, to calculate weight increase. After the feeding session, the total feed consumed was divided by the total live weight of the hens, yielding the feed conversion ratio (FCR), which was then calculated for each treatment and replication.

2.8. Carcass yield

Carcass yield was assessed by measuring the dressed weight of the chicken at the end of the 35-day feeding trial. The dressed weight represents the weight of the birds after the removal of non-edible parts. The dressing percentage, which indicates the proportion of edible carcass meat relative to the live weight, was calculated using the following formula by Coyne et al[17]: Dressing Percentage (%) = (Dress Weight / Final Live Weight) x 100.

In addition to assessing carcass yield, the study recorded specific cut-up portions to evaluate the various meat characteristics of broiler carcasses across different treatment groups. After the severing or neck-cutting slaughter process, the carcasses are divided into distinct parts: breast, thigh, drumstick, wings, and back. Each of these primal cuts was individually weighed to determine its contribution to the overall carcass composition. Furthermore, the study assessed the impact of different dietary treatments on the development of edible visceral organs in broiler chickens by documenting the weights of key organs, including the liver, gizzard, and heart. After the slaughtering and dressing procedures, these internal organs are carefully isolated and weighed individually to accurately evaluate their growth and development.

2.9. Palatability of feed

The palatability of broiler meat across various treatment groups was evaluated using a panel testing methodology. Following the approach outlined by Rahman et al.[18] a panel of 20 evaluators, including faculty members and students from ASSCAT, assessed the broiler meat samples. They utilized a 5-point hedonic scale to evaluate tenderness, juiciness, taste, aroma, and overall acceptability. For tenderness, juiciness, taste, and aroma, scores ranged from 1 (indicating very tough, dry, poor taste, or weak aroma) to 5 (indicating very tender, juicy, flavorful, or strong aroma). For overall acceptability, scores ranged from 1 (not acceptable) to 5 (very acceptable).

2.10. Statistical analysis

The experimental design employed a 2x4 factorial arrangement within a Randomized Complete Block Design. Data was analyzed with Stata using the Analysis of Variance (ANOVA) technique to assess the main effects and interactions of papaya leaf meal levels and fish amino acid levels on the response variables. Where significant differences were detected, Duncan's Multiple Range Test (DMRT) was applied to distinguish between specific treatments. The statistical significance level was set at 0.05

for all significant differences.

3. Results

3.1. Feed Intake and growth response

Chicken feed intake showed a significant association with the water supplement of fermented fish waste (FFW) ($p < 0.05$), while dietary supplementation with *Carica papaya leaf* (CPL) showed no significant effect ($p > 0.05$) as indicated in Table 1. Broilers receiving 10% FFW in their drinking water demonstrated higher feed intake compared to those receiving 5% or 15% FFW, as well as those receiving only tap water (control). Specifically, feed intake increased numerically from 2166.00 g in control chicken to 2280.75g in the 10% FFW group, slightly decreasing to 2166.00 g in the 15% FFW group, indicating a potential quadratic response to FFW levels.

The final body weight of broilers was significantly influenced by three groups of FFW diet supplementation ($p < 0.05$). However, there was no observed interaction between the effects of water and diet supplementation. Broilers receiving 10% *Carica papaya leaf* (CPL) exhibited a reduced final weight compared to those on the standard diet ($p < 0.05$).

Final body weight displayed a dose-response increase from 1161.00g in control chicken to 1517.00g in those receiving 15% fermented fish waste (FFW). All FFW groups exhibited greater final weights compared to the control ($p < 0.05$), with statistically similar performance observed among the 5%, 10%, and 15% inclusion levels.

The group of chicken that received 10% *Carica papaya* leaf (CPL) showed reduced weight gain compared to those on the standard diet ($p < 0.05$). Regarding water additives, weight gain demonstrated a numerical increase from 735.00g in control chicken to 832.75g in those receiving 15% FFW. All FFW groups gained more weight compared to the control ($p < 0.05$), with statistically similar performance of FFW inclusion level.

The feed conversion ratio (FCR) of broiler chickens fed 10% CPL exhibited a higher FCR of 1.73 compared to those fed the standard diet, which had an FCR of 1.64. Broilers provided with 100% tap water demonstrated the highest FCR of 1.82, while chickens supplemented with varying levels of FFW showed lower FCR values ranging from 1.60 to 1.66.

3.2. Carcass weight

As shown in Table 2, broiler chickens fed a 10% CPL diet had lower dressed weights (1159.81 g) compared to those on a standard diet (1240.87g). However, increasing levels of FFW in the diet led to higher dressed weights, ranging from 1070.00g for broilers on 100% tap water to 1279.00 g for those with 15% FFW substitution. The dressing percentage, which measures the ratio of carcass weight to live weight, varied between 90.0% and 92.75% across the different treatment groups.

Thigh weights increased with higher FFW supplementation in the drinking water, ranging from 109.9 g with 0% FFW to 143.3g with 15% FFW. Additionally, diets supplemented with both CPL and FFW resulted in significantly higher drumstick weights compared to the control group fed only a standard diet (SD) with plain tap water. Specifically, supplementing with 10% CPL led to a 21.3% increase in drumstick weight (138.00g) over the control group (114.00g). Broilers receiving 5% FFW exhibited a notable 48.7% increase in drumstick weight, reaching 169.3g compared to the control.

The study compared the effects of various feed supplements on broiler weight. Broilers fed 5% FFW showed a significant increase in breast weight, reaching 379.00g, compared to those without FFW supplements, which had an average weight of 269 g (Table 3). For broilers fed with 10% CPL, supplementing with 15% FFW resulted in the highest wing yield of 138.05g, in contrast to 88.01 g for those given only tap water. In birds on the SD diet, FFW supplementation led to wing weights between 104.25g and 121.50g additionally, broilers on the CPL diet

Table 1. Effects of dietary papaya leaf meal and water-based fermented fish waste supplementation on the growth performance broiler male chicken

Level of CPL	FFW	Feed intake (g)	Final weight (g)	Weight gain (g)	FCR
Tap water	100% SD	2119.75^{a}	1160.00^{a}	736.00^{a}	1.84^{b}
	10% FFW	2280.75^{c}	1347.00^{b}	897.00^{b}	1.68^{a}
	5% FFW	2169.00^{ab}	1277.75^{b}	843.75^{b}	1.71^{a}
	15% FFW	2166.00^{ab}	1274.75^{b}	833.75^{b}	1.71^{a}
10% CPL	100% SD	2119.50^{a}	1179.25^{a}	744.00^{a}	1.82^{b}
	10% FFW	2291.50^{c}	1420.00^{b}	963.00^{b}	1.64^{a}
	5% FFW	2210.00^{ab}	1370.00^{b}	939.50^{b}	1.62^{a}
	15% FFW	2278.50^{c}	1519.00^{b}	1071.00^{b}	1.51^{a}
P-Value					
Levels of CPL		0.057^{NS}	0.014*	0.025*	0.04*
Levels of FFW		0.001**	0.002*	0.087*	0.006*
Level CPL x Levels of FFW		0.26^{NS}	0.26^{NS}	0.29^{NS}	0.51^{NS}

Column means with different superscripts (a, b, c) are statistically significant at the 0.05 level. *Significant, **Highly significant, NS: Not significant. SD: Standard diet, CPL: *Carica papaya* leaf meal, TW: Tap water, FFW: Fermented fish wastes, and FCR: Feed conversion rate.

Table 2. Effects of dietary papaya leaf meal and water-based fermented fish waste on carcass yields and weights of meat cuts and viscera of broiler male chicken

Type of supplement		Dressing weight	Dressing percentage %	Thigh weight	Drumstick weight	Heart weight	Liver weight	Gizzard weight
Dietary supplement	SD	1240.87[b]	90.56[NS]	129.75[NS]	150.81[b]	12.9[NS]	37.2[NS]	21.6[NS]
	10% CPL	1159.81[a]	91.87[NS]	127.62[NS]	138.00[a]	13.4[NS]	38.25[NS]	22.1[NS]
Water supplement	TW	1070. 00[a]	91.38[NS]	109.89[a]	114.00[a]	12.3[NS]	37.05[NS]	20.55[NS]
	5% FFW	1201.15[b]	90.62[NS]	123.77[b]	169.3[c]	13.4[NS]	37.23[NS]	22.9[NS]
	10% FFW	1260.20[b]	91.25[NS]	135.89[c]	139.3[b]	13.41[NS]	38.3[NS]	21.89[NS]
	15% FFW	1279.00[b]	91.63[NS]	143.28[c]	151.9[b]	13.55[NS]	38.4[NS]	22.04[NS]
P-Value								
Levels of dietary		0.044*	0.27[NS]	0.76[NS]	0.013*	0.25[NS]	0.07[NS]	0.74[NS]
Levels of water		0.002*	0.94[NS]	0.01**	0.001**	0.16[NS]	0.16[NS]	0.74[NS]
Level diet x Levels of water		0.29[NS]	0.65[NS]	0.74[NS]	0.38[NS]	0.75[NS]	0.70[NS]	0.42[NS]

Column means with different superscripts ([a, b, c]) are statistically significant at the 0.05 level. *Significant, **Highly significant, NS: Not significant. SD: Standard diet, CPL: *Carica papaya* leaf meal, TW: Tap water, FFW: Fermented fish wastes.

supplemented with 10% FFW had an increased back weight of 235.00g, compared to 148.00g in those receiving tap water. Among the SD-fed birds, tap water treatment alone led to a back muscle yield of 199.00g. Increases in drumstick weight compared to the control group were observed with both 15% FFW and 10% FFW supplements, leading to weights that were 28.3% and 22.3% heavier, respectively.

Significant interaction effects between diet and water supplementation were noted on the breast, wing, and back weights of broiler chickens. Among chickens fed a 10% CPL diet, those supplemented with 10% FFW exhibited the heaviest breast weight.

Supplementing broiler chicken diets with CPL and drinking water with FFW, either alone or in combination, did not significantly impact the weights of the edible visceral organs - heart, liver, and gizzard (Table 4). Heart weights ranged from 12.79 g to 13.37g between diet groups and 12.25g to 13.050g in water supplements. Liver weights increase of 15% FWW supplementation 38.6g Gizzard weights varied non-significantly from 19.00 g to 24.00 g between groups.

3.3. Quality and palatability of broiler meat

Sensory analysis showed that neither the dietary

Table 3. Interaction effects of dietary papaya leaf meal and water-based fermented fish waste supplementation on breast, wings, and back weights in broiler male chickens

supplementation Levels		Breast weight in grams per kilogram live weight of broiler	Wings weight in grams per kilogram live weight of broiler	Back weight in grams per kilogram live weight of broiler
SD	TW	369.3[b]	115.00[ab]	199.00[ab]
	5% FFW	379.00[c]	116.00[ab]	165.50[a]
	10% FFW	293.76[a]	104.3[a]	175.60[a]
	15% FFW	360.75[b]	121.50[b]	186.77[ab]
10% CPL	100% SD	269.00[a]	88.01[a]	148.01[a]
	5% FFW	307.25[ab]	125.77[c]	204.60[b]
	10% FFW	370.3[c]	123.76[b]	235.01[c]
	15% FFW	362.00[b]	138.05[c]	213.00[b]
P-Value				
Levels of CPL		0.001***	0.046*	0.011*
Levels of FFW		0.001***	0.001**	0.016*
Level CPL x Levels of FFW		0.0018**	0.001**	0.001**

Column means with different superscripts (a, b, c) are statistically significant at the 0.05 level. *Significant, **Highly significant, NS: Not significant. SD: Standard diet, CPL: *Carica papaya* leaf meal, TW: Tap water, FFW: Fermented fish wastes.

Table 4. Effects of dietary papaya leaf meal and water-based fermented fish waste supplementation on breast, wings, and back weights in male broiler chickens

Level of CPL	Levels of FFW	Heart weight	Liver weight	Gizzard weight
100% Tap water	100% SD	12.00[NS]	37.20[NS]	21.3[NS]
	10% FFW	14.000[NS]	38.00[NS]	20.01[NS]
	5% FFW	13.050[NS]	38.01[NS]	24.60[NS]
	15% FFW	13.750[NS]	39.00[NS]	22.50[NS]
10% CPL	100% SD	12.250[NS]	36.75[NS]	19.00[NS]
	10% FFW	12.790[NS]	37.50[NS]	24.00[NS]
	5% FFW	13.250[NS]	36.25[NS]	21.30[NS]
	15% FFW	13.250[NS]	38.60[NS]	21.50[NS]
P-Value				
Levels of CPL		0.25[NS]	0.07[NS]	0.74[NS]
Levels of FFW		0.16[NS]	0.16[NS]	0.74[NS]
Level CPL x Levels of FFW		0.75[NS]	0.70[NS]	0.42[NS]

NS: Not significant. SD: Standard diet, CPL: *Carica papaya* leaf meal, TW: Tap water, FFW: Fermented fish wastes, g/kg LW: Grams per kilogram live weight.

Table 5. Effects of dietary papaya leaf meal and water-based fermented fish waste supplementation on palatability quality attributes of broiler chicken meat

Level of CPL	Levels of FFW	Tenderness	Juiciness	Taste	Aroma	General Acceptability
100% Tap water	100% SD	3.18^{NS}	2.78^{NS}	2.80^{NS}	2.7^{NS}	3.3^{NS}
	10% FFW	3.0^{NS}	2.42^{NS}	2.80^{NS}	2.51^{NS}	2.9^{NS}
	5% FFW	3.2^{NS}	2.51^{NS}	2.76^{NS}	3.05^{NS}	3.01^{NS}
	15% FFW	2.7^{NS}	2.52^{NS}	3.1^{NS}	2.40^{NS}	2.88^{NS}
10% CPL	100% SD	2.7^{NS}	2.51^{NS}	2.88^{NS}	2.57^{NS}	2.63^{NS}
	10% FFW	2.8^{NS}	2.51^{NS}	2.63^{NS}	2.42^{NS}	2.88^{NS}
	5% FFW	2.6^{NS}	2.63^{NS}	2.63^{NS}	2.3^{NS}	2.69^{NS}
	15% FFW	2.8^{NS}	2.57^{NS}	2.94^{NS}	2.70^{NS}	2.9^{NS}
P-Value						
Levels of CPL		0.27^{NS}	1.00^{NS}	0.54^{NS}	0.30^{NS}	0.06^{NS}
Levels of FFW		0.88^{NS}	0.91^{NS}	0.47^{NS}	0.85^{NS}	0.99^{NS}
Level CPL x Levels of FFW		0.12^{NS}	0.83^{NS}	0.94^{NS}	0.11^{NS}	0.28^{NS}

Note: NS: Not significant, SD: Standard diet, CPL: *Carica papaya* leaf meal, TW: Tap water, FFW: Fermented fish wastes

treatments nor the water supplements, whether considered independently or in combination, had a significant effect on the tenderness, juiciness, taste, aroma, or overall acceptability of broiler chicken meat ($p > 0.05$) Table 5. Tenderness scores were statistically similar across all treatment groups, ranging from 2.6 to 3.2. Juiciness was also unaffected, with mean scores varying non-significantly between 2.57 and 2.78. Taste ratings ranged from 2.63 to 3.1, while aroma scores varied from 2.3 to 3.05 across different groups. Overall acceptability showed a narrow range, with scores from 2.63 to 3.3 as indicated in Table 5.

4. Discussion

Carica papaya (papaya) leaf meal is often used as a feed additive in animal diets, particularly for poultry, due to its nutritional benefits. The nutrient composition can vary depending on factors like the maturity of the leaves, soil conditions, and processing methods. However, a general breakdown of the nutrient components in *Carica papaya* leaf meal typically includes: Crude Protein has the range of 18-30% Papaya leaves are rich in protein, making them a good source of this essential nutrient for animal growth and health.

The Feed intake of the broiler showed positive for FFW (fermented fish waste) supplementation on the broiler diets. This may be due to FFW being attributed to enhanced palatability feed, and improved nutrient bioavailability, and also it has valuable significance for better gut health and physiology of broilers. Various studies have investigated the effects of different FFW levels on broiler performance. As Shabani et al.[10] found supplementing broiler feed with 6-12% FFW improved body weight gain, feed intake ratio, gastrointestinal microflora, and blood biochemical parameters. In another study, Taer and Taer[15] reported that FFW inclusion levels of up to 12% increased beneficial cecal bacteria, digestive enzyme activity, and nutrient digestibility in broilers. Conversely, Singh et al.[19] observed that while 10% FFW increased metabolizable energy and nitrogen retention, higher inclusion rates of 15-20% reduced these measures in native chickens. Additionally, Garcés et al.[9] noted that exceeding 20% FFW in diets led to reductions in weight gain.

The present study found no significant impact of papaya leaf meal supplementation on feed intake in broilers which is supported by Shabani et al.[16]. Similarly, Li et al.[13] reported that papaya leaf meal did not significantly affect the feed intake of the chicken. Akpolu and Moroye[7] also found no significant effects on feed intake when incorporating pawpaw leaf meal into turkey poultry diets.

The Final weight, weight gain, and FCR of the broiler with papaya leaf meal (PLM) supplementation do not significantly affect final body weight or feed intake in broilers. Unigwe et al.[3] observed consistent weight gain in broilers given up to 15% PLM, with no significant variations in feed intake. Sari et al.[4] reported that incorporating 9% PLM did not impact broiler performance or feed consumption Shabani et al.[16] also found that administering papaya leaf extract in drinking water had no discernible effect on feed intake or final weight compared to control chicken.

The bitter taste and chemical composition of papaya leaf meal (PLM) including high concentrations of anti-nutritive compounds like saponins, may negatively affect voluntary feed intake and subsequent weight gain. Banjoko et al.6 suggest that alkaloids, tannins, and other phytochemicals in papaya leaves could reduce feed palatability at higher inclusion rates. Similarly, Akpolu and Moroye[7] propose that high tannin levels in PLM might impair protein bioavailability.

In contrast, supplementation with fermented fish waste concentrations from 5%, 10% and 15%. (FFW) generally leads to greater final weights in broiler production. All FFW-supplemented groups in the study showed significantly higher final weights compared to the control group, with no notable differences in performance between 5%, 10%, and 15% inclusion levels. Several studies highlight the benefits of FFW supplementation for improving growth rates and weight gain in broilers. Shabani et al.[12] demonstrated that broilers fed diets containing up to 12% FFW had significantly increased final body weights and weight gains compared to control birds. Similarly, Shabani et al.[12] found that including 6-12% dietary FFW boosted weight gain in broilers by up to 9.7% compared to non-FFW-supplemented birds.

However, some studies have reported conflicting results regarding the efficacy of fermented fish waste (FFW) supplementation in broiler diets. For instance, Singh et al.[19] found no significant differences in final body weight or weight gain between native chickens fed various levels of FFW and a control group without FFW. Additionally, broilers receiving 10% *Carica papaya* leaf (CPL) had lower weight gain, potentially due to the presence of anti-nutritional compounds. Contrastingly, FFW treatments generally resulted in increased weight gain, with the highest gains observed in birds supplemented with 15% FFW. These findings suggest that FFW may provide nutrients, enzymes, or metabolites that support growth and performance.

The feed conversion ratio (FCR) of broiler diets containing 10% CPL was shown to be affected by this supplementation. The FCR of the birds fed CPL was 1.73, whereas that of the control group on a regular diet was 1.64. This result deviates from a large body of prior research, which indicates that supplementing broilers with papaya leaf meal (PLM) at inclusion levels of up to 15% has no discernible impact on the feed conversion ratio[3,6].

In terms of water supplementation, broiler chickens consuming only tap water exhibited the highest FCR of 1.82, while those supplemented with 5–15% FFW in water achieved superior FCRs ranging from 1.60 to 1.66. This observation aligns with previous research, which reported improvements in FCR with 6-12% dietary FFW, likely due to enhanced digestion and absorption[19]. However, Kiflay et al.[20] found a poorer FCR in broilers fed a diet containing 12% fish offal meal. The observed reductions in FCR with water-based FFW supplementation suggest beneficial effects on feed efficiency and productivity. Unlike feed supplementation, administering FFW in water may have facilitated more consistent intake among birds and during feeding periods compared to timed meal feeding[12].

The carcass yield of the broiler which fed a diet with 10% *Carica papaya* leaf (CPL) exhibited lower dressed weights (1162 g) compared to those on the standard diet (1241 g). Although CPL is known for its growth-promoting bioactive compounds, its high fiber content may have diluted the dietary energy, leading to reduced dressed weights. This finding aligns with previous research showing that CPL supplementation can decrease dressed weight compared to control or standard diets. For instance, Sari et al.[4] found no significant effects on body weight gain or feed conversion ratio with up to 9% CPL inclusion in broiler diets.

In contrast, increasing levels of fermented fish waste (FFW) supplementation in broiler diets have consistently led to dose-dependent improvements in dressed weights. Numerous studies have demonstrated that FFW enhances dressed weight compared to control diets. For example, Singh et al.[19] reported that a 15% FFW inclusion increased egg production in Alabio ducks, which correlates with improved growth and body weight. Similarly, Singh et al.[19] found that a 10% FFW diet resulted in the highest metabolizable energy and nitrogen retention in chickens, thereby boosting growth and muscle mass.

The improvements in dressed weight with FFW supplementation are likely due to its rich content of high-quality protein, essential amino acids, fatty acids, minerals, and other nutrients that support growth. Taer and Taer[15] observed that fermentation increased the crude protein content of FFW from 42.7% to 56.3%, with protein digestibility rising to 81.61%. Additionally, Garcés et al.[9] noted that the amino acid content in fish silage surpassed the FAO recommendations for poultry, with digestibility values exceeding 80%.

The Weight of the thigh and drumsticks of the broiler with the FFW supplementation significantly increased thigh muscle weights in a dose-dependent manner or increasing the level of FFW, suggesting that the nutrients in FFW likely promote muscle growth and development in the thighs of broilers. In contrast, CPL supplementation did not affect thigh weights, indicating that CPL does not provide significant benefits for thigh muscle growth under the tested conditions. Both FFW and CPL supplementation increased drumstick weights compared to the control diet, with FFW having a particularly pronounced effect. Specifically, 5% and 15% FFW supplementation increased drumstick weights by 48.7% and 28.3%, respectively.

Few studies have directly examined the effects of CPL and FFW on specific broiler chicken cuts like the thigh and drumstick. However, Ezenwosu et al.[21] found no significant differences in carcass and organ weights between a control diet and diets containing up to 15% dried CPL. In contrast, Onu[22] reported that a diet with 2% CPL improved carcass yield and meat production in broilers. Regarding FFW, Taufikurrahman and Rostini[8] observed positive effects of fermented fish waste on egg production and quality in Alabio ducks, aligning with the drumstick weight improvements seen in this study.

The Weight of breast, wings, and back muscles were significant interaction effects between dietary *Carica papaya* leaf meal (CPL) and drinking water fermented fish waste (FFW) supplementation on the breast, wings, and back weights of broiler chickens. Breast Weight on the combination of 10% CPL with 10% FFW resulted in the highest breast weights compared to the control group receiving tap water, suggesting a potential synergistic effect.

The current result findings imply that the combinations of CPL and all groups of FFW of more than 15% show more effectiveness and may have synergistic effects on lean muscle tissue accretion in broilers. Specific ratios of CPL and FFW may enhance nutrient utilization for the growth of different muscle groups.

CPL contains bioactive phytochemicals like flavonoids, tannins, saponins, and alkaloids which can influence hormonal and cellular signaling pathways involved in muscle protein synthesis[4,21]. For example, quercetin flavonoids can activate enhancing muscle protein synthesis[23]. Additionally, saponins have been shown to stimulate IGF-1 and suppress myostatin expression, further promoting muscle growth[24].

FFW provides a rich source of high-quality protein, essential amino acids, fatty acids, and micronutrients crucial for skeletal muscle development[10]. Amino acids serve as the building blocks for protein, while omega-3 fatty acids regulate muscle metabolism[11]. Trace elements like zinc and selenium enhance antioxidant status, protecting against oxidative tissue damage during growth[25].

The combined phytochemicals and nutrients in CPL and FFW may exert synergistic effects on protein synthesis, blood flow, and oxidative stress, thereby supporting optimal muscle development in broilers.

The visceral organs of broiler with the supplementation of broiler chickens with *Carica papaya* leaf meal (CPL) and fermented fish waste (FFW), whether individually or in combination, did not significantly affect the weights of internal organs such as the heart, liver, and gizzard. This indicates that neither CPL nor FFW supplementation enhances the yields of edible visceral organs in broiler production. Few studies have directly explored the impact of dietary CPL and drinking water FFW supplementation on internal organ weights in broilers. In line with the neutral organ weight results of the current investigation, Ezenwosu et al.[21] found no statistically significant variations in the weights of the liver, kidney, or heart between broilers fed a control diet and those fed a diet enriched with CPL. In contrast, Onu[22] discovered that supplementing with 2% CPL increased the weights of the liver, heart, and gizzard.

Regarding FFW, Abun et al.[26] Observed increased liver weights in broilers fed fermented catfish waste, whereas other studies have shown no significant impact of fish silage on internal organ weights. The lack of significant effects in this study could be due to several factors. First, the duration and levels of supplementation may not have been sufficient to induce hypertrophic responses in the internal organs. Additionally, genetic variations among broiler strains can affect their capacity for organ growth. Interactions between CPL and FFW might also influence the outcomes related to organ weights[27].

Palatability and quality broiler meat show the preservation of tenderness and juiciness across all treatment groups, as indicated by consistent moisture content and texture, suggesting that neither *Carica papaya* leaf meal (CPL) nor fermented fish waste (FFW) supplementation impaired the flavor or odor of the meat. Taste and aroma scores remained unchanged, and the comparable general acceptability scores among both supplemented and control groups imply that these supplements would not negatively affect consumer approval. Although there were numerical increases in certain sensory traits for some treatments, the lack of statistical significance indicates these effects are negligible on perception. Overall, the sensory quality remained consistent with the control, suggesting that the bioactive compounds in CPL and the nutrients in FFW do not adversely alter muscle composition or chemistry post-slaughter.

The neutral impact on sensory meat-eating properties also implies that lipid oxidation, which can affect aroma and consistency, was not significantly influenced by the supplements. This aligns with studies by Shabani et al.[10] and Muhammed et al.[11] which presented varied findings. These discrepancies may be attributed to differences in supplementation levels, the type and quality of CPL and FFW, variations in broiler breed, age, raising conditions, processing methods, and sensory analysis techniques.

5. Conclusion

A notable observation was the synergistic effect of combining CPL in the diet with all level supplementations of FFW, especially with 15% in drinking water, particularly on breast, wing, and back weights. This finding suggests that specific ratios of these supplements (CPL and FFW) can optimize lean muscle growth. Incorporating 10% CPL in broiler diets had adverse effects on final body weight, weight gain, and dress weight. This negative impact is likely due to anti-nutritional compounds present in CPL. Sensory evaluations confirmed that the supplements did not adversely impact the tenderness, juiciness, taste, aroma, or overall acceptability of broiler meat, maintaining its palatability and consumer acceptance. Further research is needed to optimize strategies for consistently enhancing broiler meat properties with supplementation of CPL and FFW.

Declarations

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

Asnakew Mulaw Berihun has made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation and preparing the manuscript.

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Availability of data and materials

All the data are ready to give the available data to the readers by requesting via email and any communication platform.

Ethical considerations

The authors confirmed that all authors have checked and submitted the original manuscript for the first time to the present journal. The authors checked the final draft of the manuscript for plagiarism, fabrication, and duplication of data.

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