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Synergic Effects of *Carica papaya* Leaves and Fermented Fish Waste on Growth Performance, Carcass Yields, Sensory Attributes, and Profitability in Broiler Production

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Authors' contributions

This work was carried out in collaboration among all authors. Author RR contributed to the experimental design and implementation. Author GR contributed the data collection and analysis. Author SC did the interpretation of results. Author EJR contributed to the discussion and preparation of article. All authors read and approved the final manuscript.

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ABSTRACT

Poultry production sustainability requires innovative dietary supplements to improve performance while addressing environmental concerns. This research investigates the effects of supplementing broiler chicken diets with Carica papaya leaf meal (CPL) and fermented fish waste (FFW) in water on various growth parameters, carcass traits, sensory attributes, and profitability. A Randomized Complete Block Design (RCBD) with a 2x4 factorial arrangement was employed, evaluating two factors: CPL dietary supplementation at 10% and FFW water supplementation at 0%, 5%, 10%, and 15%. Each treatment combination was replicated four times with five broiler chicks per replication, totaling 160-day-old broilers. Results indicated that while CPL negatively influenced final body weight and weight gain, FFW positively impacted feed intake, final weight, and weight gain. Additionally, FFW supplementation led to significant increases in drumstick and thigh weights compared to the control, with notable interactions observed between CPL and FFW for breast, wing, and back weights. However, neither CPL nor FFW affected the weights of edible visceral organs. Sensory evaluation revealed no significant differences in meat quality attributes across treatments. Despite increased production costs, supplementation with CPL and FFW resulted in higher dressed weights and profitability, with the highest return on investment achieved by broilers receiving the standard diet plus 15% FFW supplementation. These findings suggest that optimized utilization of CPL and FFW at 10% and 15% respectively, presents an economically viable strategy for enhancing broiler growth, carcass quality, and profitability while leveraging nutritional benefits and reducing environmental waste.

Keywords: Circular economy; Fermented by-products; Nutrient valorization; Phytogenic feed additives; Sustainable poultry production.

1. INTRODUCTION

The ever-booming demand for animal-based protein sources inspired global poultry production to skyrocket. However, the traditional broiler chicken farm practices that are characterized by intensive use of resource-inputting feed ingredients and a high level of waste generation might cause societal concerns about environmental sustainability and one-off economic growth [1,2]. So, researches on relevant diets or dietary regimens that promote productivity, profitability, and sustainability of broilers is required.

In the last few years, phytogenic feed additives, fermented byproducts, and their derivatives have come to attention as possible substitutes for ordinary supplements in poultry diets. The leaves of *Carica papaya*, which have become a common agro-waste, come to the rescue again as the research shows that low to moderate levels (below 5–15% of the diet) of the lesser-known PLM do not influence body weight gain significantly as well as the birds' final weight or feed intake voluntarily [3,4, 5]. Nevertheless, if a high inclusion rate of PLM is used, it may interfere with the proteolytic process and lower the nutrient absorption tendency in the gastrointestinal tract using phytochemicals of the types alkaloids, saponins, tannins, and protease inhibitors [6,7]. Palatability and feed intake may also be affected due to the bitter taste associated with PLM compounds. While most trials demonstrate no significant impacts of low-level PLM on production measures like FCR, occasional studies report either improvements or decreases in feed efficiency depending on inclusion rates and dietary formulations. As such, the fermentation of fish processing waste produces nutrient-rich fermented fish waste (FFW) and provides essential contributions such as protein, amino acids, and bioactive compounds. Research shows that fermented fish waste can be a beneficial protein source for broiler chick diets, as it doesn't negatively impact growth performance, feed consumption, or feed conversion ratio [8]. Fish silage can replace up to 20% of soybean meal without compromising growth or meat quality [9,10]. Additionally, fermented fish waste can enhance feed nutritional value and improve gut health in chickens [11,12].

While prior research has delved into the individual effects of *Carica papaya* leaf meal (CPL) and FFW on broiler performance, exploring their combined synergistic potential remains scarce. Moreover, administering FFW through drinking water, an unexplored avenue, presents a novel approach to optimizing nutrient utilization and minimizing feed wastage. With that in mind, the present study is designed to deeply examine the profundity of CPL and FFW quality on various yarns of chicken production, including growth performance, carcass characteristics, meat sensory attributes, and economic efficiency as well. This study aimed at measuring feed intake and body weight gain, as well as studying feed conversion ratio and carcass yield, and evaluating these supplements' effects on meat quality and the possible profit margins that their use can provide. The addition of CLP and FFW to the ratio will be carried out by considering agronomic and economic factors using a holistic approach that will integrate the benefits of these ingredients. In a nutshell, putting into use the synergistic capability of these sustainable supplements is therefore geared towards achieving optimized broiler chicken production, minimizing environmental impacts, and maximizing economic returns.

2. MATERIALS AND METHODS

2.1 Experimental Design and Treatment

The study took place in the College of Agriculture's Poultry Project at Agusan del Sur State College of Agriculture and Technology (ASSCAT), which was located in Bunawan, Agusan del Sur, Caraga Region XIII, Philippines. Employing a Randomized Complete Block Design (RCBD), the experimental design featured a 2x4 factorial arrangement, incorporating two primary factors: Under Factor A, two levels of dietary supplement were examined: a control group fed a pure standard diet (SD) and a treatment group supplemented with 10% *Carica papaya* leaf meal (CPL). Factor B, concerning tap water supplements, comprised four levels: pure tap water, 5% fermented fish waste (FFW), 10% FFW, and 15% FFW. The experiment was replicated four times and each treatment combination consisted of five sample broiler chicks, resulting in a total of 160-day-old broiler chicks.

2.2 Experimental Animal

A total of 160-day-old Cobb broiler chicks were acquired from a reputable agrivet store. Upon procurement, the chicks were initially brooded for the first two weeks of the experiment. During this phase, they were provided with commercial chick booster feed and tap drinking water *ad-libitum*, within two compartments offering a floor space of 4x4 square feet each. Optimal heat was regulated using electric light bulbs, sustaining a consistent temperature range of 30-36°C throughout the brooding period. Furthermore, on the 10th day of brooding, the chicks were vaccinated against Newcastle Disease, utilizing the NCD BIBI, LaSota Strain vaccine. After the brooding phase, the chicks were randomly allocated to their respective experimental treatments and transferred to elevated cages. Each treatment group was allotted a floor space of 3x2 square feet per replication. All broiler chickens involved in the experiment were uniformly cared for and kept by standard management protocols in the Philippines.

2.3 Preparation of *Carica papaya* Leaf Meal and Fish Amino Acid, and Treatment Application

Fresh *Carica papaya* leaves were carefully collected and separated from their stalks before undergoing thorough washing and draining. The leaves were finely chopped and subjected to a sun-drying process lasting 4-6 days until reaching a consistent crispiness while retaining their characteristic green hue. Upon achieving a constant weight, the dried leaves were pulverized into a powder-like consistency. The resulting *Carica papaya* leaf meal was then integrated into the standard broiler starter and finisher diets, constituting a 10% inclusion rate based on recommendations by Akpolu and Moroye [7].

Preparation of fermented fish waste (FFW) adhered to established protocols outlined by Adajara and Taer [13], albeit with modifications. Initially, fish by-products, including internal organs, fins, scales, bones, and heads, were procured from the local public market. The components were washed and drained before being chopped into 1-inch pieces. A mixture of crude molasses was then combined with the chopped fish parts in a 1:1 ratio. The assemblage was subsequently enveloped in Manila paper and left to ferment for a duration of 15 days. Post-fermentation, the concoction underwent extraction, yielding liquid rich in fish amino acids. This extract was carefully collected, preserved in plastic jars, and stored in a shaded area to maintain its integrity.

Upon completion of the brooding phase of two weeks, 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 treatment combination and offering a floor space of 3x2 square feet per replication. One subset of the chicks received a pure standard diet (SD) and was further divided into four sub-groups, each receiving distinct water supplements: pure tap water (control), 5% FFW, 10% FFW, and 15% FFW, respectively. This allocation strategy adhered to the optimal FFW inclusion rates recommended by Shabani et al. [12]. Another subset of broiler chickens was provided with a diet supplemented with 10% *Carica papaya* leaf meal (CPL) and was similarly subdivided into four groups, receiving identical water supplementations as the previous subset. Experimental rations were dispensed twice daily, at 6:00 AM and 5:00 PM, and feed refusals were meticulously weighed each morning to ascertain feed intake levels.

2.4 Data Gathering

Feed intake was quantified by computing the disparity between the amount of feed provided and the feed refused, which was subsequently divided by the number of birds per replication. The final weight of the birds was documented upon the conclusion of the 35-day feeding trial. Weight gain was determined by computing the discrepancy between the final weight and the initial weight of the broilers, recorded at 2 weeks of age. Feed conversion ratio (FCR) was calculated by dividing the total feed consumption by the aggregate live weight of birds at the culmination of the feeding period, per treatment and per replication.

Carcass yield was determined by measuring the dress weight, representing the weight of birds following the removal of non-edible parts, at the conclusion of the 35-day feeding trial. The dressing percentage, indicative of the proportion of edible carcass meat relative to live weight, was computed using the formula:

Dressing Percentage (%) = (Dress Weight / Final Live Weight) x 100.

In addition to carcass yield, specific cut-up portions representing various meat characteristics were recorded for broiler carcasses across different treatment groups. Following the slaughtering process, carcasses were partitioned into distinct cut-up parts, including breast, thigh, drumstick, wings, and back. Each primal cut portion was individually weighed to ascertain its contribution to the overall carcass composition.

Furthermore, the influence of different dietary treatments on the development of edible visceral organs was assessed by documenting the weights of key organs, including the liver, gizzard, and heart, for broiler chickens upon the conclusion of the feeding trial. Following the slaughtering and dressing procedures, internal organs were carefully isolated and subjected to individual weighing to facilitate accurate assessment of their growth and development.

The sensory attributes of broiler meat across various treatment groups were evaluated utilizing a panel testing methodology. Consistent with the approach outlined by Taer and Taer [14], a panel comprising 20 evaluators, consisting of faculty members and students from ASSCAT, employed a 5-point hedonic scale to assess broiler meat samples for tenderness, juiciness, taste, aroma, and overall general acceptability. Scores ranged from 1 (indicating very tough) to 5 (reflecting very tender) for tenderness, juiciness, taste, and aroma, while general acceptability scores ranged from 1 (signifying not acceptable) to 5 (representing very much acceptable).

Concurrently, an economic feasibility analysis was conducted through a cost and return assessment across different dietary treatments. This evaluation encompassed the calculation of the total investment cost, incorporating expenses related to broiler chick procurement, feed expenditures, and non-feed production costs. Net income was determined by deducting total production costs from the gross sales revenue generated from broiler sales. The Return on Investment (ROI) percentage, a pivotal metric gauging profitability, was computed by dividing the net income by the total production cost per treatment and multiplying by 100. A higher ROI percentage denotes enhanced economic returns and profitability associated with the specific treatment combination involving papaya leaf meal and fish amino acid supplementation.

2.5 Statistical Analysis

The study analyzed data on growth performance, carcass yield, organ weights, sensory evaluation, and economic parameters in broiler chickens. The experimental design used a 2x4 factorial arrangement in a Randomized Complete Block Design. Data was analyzed using the Analysis of Variance (ANOVA) technique to assess the main and interaction effects of papaya leaf meal levels and fish amino acid levels on response variables. If significant differences were found, Duncan's Multiple Range Test (DMRT) was used to identify specific treatments. The statistical significance level was set at 0.05 for all analyses.

3. RESULTS

3.1 Feed Intake and Growth Response

Feed intake exhibited a significant association with the water supplement of fermented fish waste (FFW) (P<0.01), while dietary *Carica papaya* leaf (CPL) supplementation showed no significant effect (P>0.05) (Table 1). Broilers receiving 10% FFW in their drinking water demonstrated higher feed intake compared to those on 5% or 15% FFW, as well as those on 100% tap water (control). Numerically, feed intake increased from 2120.62 g in control birds to 2286.13 g in the 10% FFW group, albeit slightly reducing to 2222.25 g in the 15% FFW group, suggesting a potential quadratic response to FFW levels.

The final body weight of broilers was significantly influenced by both water and diet supplementation (P<0.05), with no observed interaction between water and diet. Broilers receiving 10% CPL exhibited reduced final weight relative to those on the standard diet (P<0.05). Regarding water treatments, weight displayed a numeric dose-response increase from 1170.63 g in control birds to 1396.38 g in those receiving 15% FFW. All FFW groups exhibited greater final weight compared to the control (P<0.05), with statistically similar performance observed among 5%, 10%, and 15% inclusion levels.

Weight gain of broiler chickens was significantly influenced by both dietary supplement and water enhancers (P<0.05), with no significant interaction effect. Birds receiving 10% CPL showed reduced weight gain compared to those on the standard diet (P<0.05). Regarding water enhancers, weight gain demonstrated a numerical increase from 739.00 g in control birds to 952.37 g in those on 15% FFW. All FFW groups gained more weight compared to the control (P<0.05), with statistically equal performance observed among each other.

Feed conversion ratio (FCR) of broiler chickens was significantly influenced by dietary supplementation with CPL and FFW in water. Broilers fed 10% CPL exhibited a higher FCR of 1.73 compared to those fed the standard diet, which had an FCR of 1.64. Additionally, different levels of FFW in water significantly affected FCR. Broilers provided with 100% tap water demonstrated the highest FCR of 1.82, while lower FCR values of 1.60-1.66 were observed for chickens supplemented with varying levels of FFW.

3.2 Carcass Yield, Weight of Meat Cuts and Weight Edible Viscera

Table 2 exhibited boiler chickens fed 10% CPL exhibited lower dress weights (1161.81 g) compared to those on the standard diet (1240.87 g). Conversely, increasing levels of FFW raised broiler dress weights from 1068 g (for 100% tap water) to 1276 g (for 15% FFW substitution). The dressing percentage, denoting the ratio of carcass weight to live weight, ranged from 90.56% to 91.87% across treatment groups. Thigh weights exhibited an upward trend from 109.9 g to 143.3 g with increasing supplementation of FFW from 0% to 15% in drinking water. Broiler chicken diets with CPL and FFW resulted in significantly higher drumstick weights compared to the control group receiving pure standard diet (SD) and plain tap water. Supplementing with 10% CPL led to a 21.3% increase in drumstick weight (137.31 g) over the control group (113.88 g). Broilers receiving FFW at 5% showed a 48.7% increase in drumstick weight compared to the control, at 169.25 g. Significant increases in drumstick weight over the control were also observed with 15% FFW and 10% FFW supplements, at 28.3% and 22.3% heavier, respectively.

Significant interaction effects of diet and water supplementation were noted on breast, wings, and back weights of broiler chickens. Within chickens fed 10% CPL, 10% FFW resulted in the heaviest breast weight of 370 g compared to 269 g for no FFW supplements. Within those fed SD, 5% FFW yielded the highest breast weight of 377.25 g (Table 3). For broilers on 10% CPL, 15% FFW supplementation yielded the highest wings yield of 137.75 g compared to 87.25 g for tap water. In SD-fed birds, all FFW levels elicited wings weights ranging from 104.25 g to 121.50 g. Broilers fed the CPL diet supplemented with 10% FFW exhibited increased back weights to 232.50 g compared to 149.50 g for other tap water treatments. In SD-fed birds, only tap water augmented a 198.50 g back muscle yield.

Supplementing broiler chicken diets with CPL and drinking water with FFW, either alone or in combination, did not significantly impact weights of the edible visceral organs - heart, liver, and gizzard (Table 4). Heart weights ranged from 12.87 g to 13.87 g between diet groups and 12.25 g to 13.50 g in water supplements. Liver

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

Levels of supplement		Feed intake (g)	Final weight (g)	Weight gain (g)	FCR
Dietary supplement	SD	2224.87^{NS}	1371.81^{b}	929.37^{b}	1.64^{a}
	10% CPL	2183.62^{NS}	1264.62^{a}	826.62^{a}	1.73^{b}
Water supplement	TW	2120.62^{a}	1170.63^{a}	739.00^{a}	1.82^{a}
	5% FFW	2188.00^{b}	1322.38^{b}	890.63^{b}	1.65^{b}
	10% FFW	2286.13^{c}	1383.50^{b}	930.00^{b}	1.66^{b}
	15% FFW	2222.25^{b}	1396.38^{b}	952.37^{b}	1.60^{b}
P-Value					
Levels of dietary		**0.056^{NS}**	**0.013***	**0.024***	**0.04***
Levels of water		**0.001****	**0.002***	**0.007***	**0.006***
Level diet x Levels of water		**0.25^{NS}**	**0.26^{NS}**	**0.28^{NS}**	**0.50^{NS}**

*Column means of different superscripts a, b, c are statistically significant at 0.05 levels, *Significant, **highly significant, NS not significant. SD-standard diet, CPL-Carica papaya leaf meal, TW-tap water, FFW-fermented fish wastes*

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

Levels of supplement		Dress wt. (g Kg^{-1} LW)	Dressing %	Thigh wt. (g Kg^{-1} LW)	Drumstick wt. (g Kg^{-1} LW)
Dietary supplement	SD	1240.87^{b}	90.56^{NS}	127.75^{NS}	149.81^{b}
	10% CPL	1161.81^{a}	91.87^{NS}	128.62^{NS}	137.31^{a}
Water supplement	TW	1068.25^{a}	91.38^{NS}	109.88^{a}	113.88^{a}
	5% FFW	1200.13^{b}	90.62^{NS}	123.75^{b}	169.25^{c}
	10% FFW	1260.50^{b}	91.25^{NS}	135.88^{c}	139.25^{b}
	15% FFW	1276.50^{b}	91.63^{NS}	143.25^{c}	151.88^{c}
P-Value					
Levels of dietary		**0.044***	**0.27^{NS}**	**0.76^{NS}**	**0.013***
Levels of water		**0.002***	**0.94^{NS}**	**0.01****	**0.001****
Level diet x Levels of water		**0.29^{NS}**	**0.65^{NS}**	**0.74^{NS}**	**0.38^{NS}**

*Column means of different superscripts a, b, c are statistically significant at 0.05 levels *Significant, **Highly significant, NS Not significant. SD-standard diet, CPL-Carica papaya leaf meal, TW-tap water, FFW-fermented fish wastes, g kg-1 LW, grams per kilogram live weight*

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

Levels of supplementation		Breast wt. (g Kg^{-1} LW)	Wings wt. (g Kg^{-1} LW)	Back wt. (g Kg^{-1} LW)
SD	TW	369.25^{b}	114.50^{ab}	198.50^{ab}
	5% FFW	377.25^{c}	115.25^{ab}	164.50^{a}
	10% FFW	293.75^{a}	104.25^{a}	175.50^{a}
	15% FFW	360.75^{b}	121.50^{b}	186.75^{ab}
10% CPL	100% SD	269.00^{a}	87.25^{a}	149.50^{a}
	5% FFW	307.25^{ab}	125.75^{c}	204.50^{b}
	10% FFW	370.25^{c}	123.75^{b}	232.50^{c}
	15% FFW	361.75^{b}	137.75^{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 of different superscripts a, b, c are statistically significant at 0.05 levels *Significant, **Highly significant, NS Not significant. SD-standard diet, CPL-Carica papaya leaf meal, TW-tap water, FFW-fermented fish wastes, g Kg-1 LW, grams per kilogram live weight*

Table 4. Effects of dietary papaya leaf meal and water-based fermented fish waste supplementation on heart, liver, and gizzard weights in broiler chickens

Levels of supplement		Heart wt. (g Kg^{-1} LW)	Liver wt. (g Kg^{-1} LW)	Gizzard wt. (g Kg^{-1} LW)
Dietary supplement	SD	12.87^{NS}	37.18^{NS}	21.56^{NS}
	10% CPL	13.37^{NS}	38.18^{NS}	22.06^{NS}
Water supplement	TW	12.25^{NS}	37.00^{NS}	20.50^{NS}
	5% FFW	13.38^{NS}	37.13^{NS}	22.88^{NS}
	10% FFW	13.37^{NS}	38.25^{NS}	21.88^{NS}
	15% FFW	13.50^{NS}	38.38^{NS}	22.00^{NS}
P-Value				
Levels of dietary		**0.25^{NS}**	**0.07^{NS}**	**0.74^{NS}**
Levels of water		**0.16^{NS}**	**0.16^{NS}**	**0.74^{NS}**
Level diet x Levels of water		**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^{-1} LW, grams per kilogram live weight

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

Levels of supplement		**Tenderness**	**Juiciness**	**Taste**	**Aroma**	**General Acceptability**
Dietary supplement	SD	2.73	2.54	2.76	2.48	2.76
	10% CPL	2.87	2.54	2.85	2.64	2.96
Water supplement	TW	2.84	2.62	2.84	2.62	2.87
	5% FFW	2.84	2.56	2.68	2.62	2.84
	10% FFW	2.81	2.46	2.71	2.46	2.87
	15% FFW	2.71	2.53	3.00	2.53	2.87
P-Value						
Levels of dietary		**0.26^{NS}**	**1.00^{NS}**	**0.54^{NS}**	**0.30^{NS}**	**0.06^{NS}**
Levels of water		**0.87^{NS}**	**0.91^{NS}**	**0.47^{NS}**	**0.85^{NS}**	**0.99^{NS}**
Level diet x Levels of water		**0.11^{NS}**	**0.83^{NS}**	**0.94^{NS}**	**0.11^{NS}**	**0.28^{NS}**

^{NS} Not significant. SD-standard diet, CPL-Carica papaya leaf meal, TW-tap water, FFW-fermented fish wastes

Table 6. Profitability analysis on raising broiler fed with CPL-diet with FFW-water

	Treatments							
	SD/TW	**SD/5% FFW**	**SD/10% FFW**	**SD/15% FFW**	**10% CPL/TW**	**10% CPL/5% FFW**	**10% CPL/10% FFW**	**10% CPL/15% FFW**
I. Cash Outflow								
A. Cost of feed Consume	72.00	72.00	72.00	72.00	66.00	66.00	66.00	66.00
B. Transportation	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81
C. Cost of Broiler	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
D. Supplementation	0.00	0.00	0.00	0.00	0.25	0.25	0.25	0.25
Papaya Leaf Meal								
Fish Amino Acid	0.00	0.93	1.86	2.79	0.00	0.93	1.86	2.79
E. Vaccine	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
F. Water	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
G. Light	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
H. Rental	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
I. Housing Construction	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25
Total Cost of Production	**117.14**	**118.07**	**119.00**	**119.93**	**111.14**	**112.07**	**113.00**	**113.93**
II. Total Cash Inflow	1.06	1.25	1.28	1.37	1.07	1.15	1.25	1.19
Dressed weight(kg)/broiler	137.80	162.50	166.40	178.10	139.10	149.50	162.50	154.70
Gross Income								
III.Net Profit	20.66	44.43	47.40	58.17	27.96	38.36	50.43	40.77
IV. Return of Investment	17.64	38.00	44.00	49.00	25.00	34.00	45.00	36.00

weights ranged from 37.18 g to 38.18 g across diet groups, while the 15% FWW supplementation resulted in slightly heavier numerical liver weights compared to control tap water (38.38 g vs. 37.00 g). Gizzard weights varied non-significantly from 20.00 g to 22.88 g between groups.

3.3 Sensory Evaluation

Sensory analysis revealed that dietary treatments and water supplements, either independently or in combination, did not exert significant effects on the tenderness, juiciness, taste, aroma, or overall acceptability of broiler chicken meat (p>0.05) (Table 5). Tenderness scores remained statistically similar across treatment groups, ranging from 2.56 to 3.06. Juiciness was unaffected, with means varying non-significantly between 2.43 and 2.75. Ratings for meat taste ranged from 2.62 to 3.06 and aroma scores from 2.25 to 3.00 across groups. General acceptability exhibited a comparable narrow range from 2.62 to 3.12.

3.4 Profitability Analysis

The profitability analysis underscored the influence of supplementing broiler chickens with *Carica papaya* leaf (CPL) in the diet and fermented fish waste (FFW) in the water on production costs and net profit ratio (Table 6). Broilers receiving 15% FWW exhibited the highest production cost (P119.93), whereas those supplemented with 10% CPL in tap water (without FFW) demonstrated the lowest (P111.14). Regarding dressed weight, supplementation with 15% FWW in water yielded the highest value (1.37 kg) compared to only 1.06 kg in unsupplemented (tap water) control birds. Among all treatments, chickens raised on standard diet plus 15% FWW yielded the highest profit at Php58.17, translating to a return on investment of 49.00%.

4. DISCUSSION

4.1 Feed Intake

The observed positive impact on intake with FFW supplementation (10%) could stem from enhanced palatability, improved nutrient bioavailability, or enhanced gut health. Previous research has explored the effects of incorporating different levels of FFW in broiler chicken diets. Shabani et al. [12] noted that supplementing broiler feed with 6-12% FFW led to enhancements in body weight gain, feed intake ratio, gastrointestinal microflora, and blood biochemical parameters. Similarly, Shabani et al. [15] demonstrated that FFW inclusion levels up to 12% increased beneficial cecal bacteria, digestive enzyme activity, and nutrient digestibility in broilers. However, Abun et al. [16] reported that while 10% dietary FFW increased metabolizable energy and nitrogen retention, higher inclusion rates of 15-20% FFW diminished these measures in native chickens. Additionally, Garcés et al. [9] noted reductions in weight gain when exceeding 20% fish silage.

The study's finding of no significant impact of papaya leaf meal supplementation on feed intake in broilers corroborates previous research findings. Specifically, Rahman et al. [17] observed no significant difference in feed intake with papaya leaf extract supplementation in drinking water. Similarly, Singh et al. [18] reported that papaya leaf meal did not significantly affect feed intake. Akpolu and Moroye [7] also did not observe any significant effects on intake in their study exploring papaya leaf meal in turkey poult diets.

4.2 Final Weight, Weight Gain, and FCR

Despite occasional reports of diminished weight gain, the bulk of research indicates that PLM supplementation does not significantly impact final body weight or feed intake measures in broilers. For instance, Unigwe et al. [3] observed consistent weight gain across groups provided with up to 15% PLM, with no notable variations in feed intake. Similarly, Sari et al. [4] found that incorporating 9% PLM did not affect broiler performance or feed consumption. Rahman et al. [17] recently discovered that administering papaya leaf extract in drinking water had no discernible effect on feed intake or final weight compared to control birds. The bitter taste and chemical composition of PLM, characterized by high concentrations of anti-nutritive compounds like saponins, may negatively impact voluntary feed intake and subsequent weight gain. Banjoko et al. [6] propose that alkaloids, tannins, and other phytochemicals in papaya leaves could diminish feed palatability at higher dietary inclusion rates. Akpolu and Moroye [7] suggest that high tannin PLM levels might affect protein bioavailability. All FFW groups exhibited greater final weight compared to the control, with statistically similar performance observed among 5%, 10%, and 15% inclusion levels. Several studies have provided evidence supporting the benefits of supplementing broiler chickens with FFW for improving growth rates and weight gain. For instance, Shabani et al. [12] demonstrated that broilers fed diets containing up to 12% FFW exhibited significantly increased final body weights and weight gains compared to control birds. Similarly, Shabani et al. [15] found that incorporating 6-12% dietary FFW elevated weight gain in broilers by up to 9.7% over non-FFW-supplemented birds.

However, some studies have reported contradictory results regarding the efficacy of FFW supplementation in broiler diets. For example, Abun et al. [16] found no significant differences in final body weight or weight gain between native chickens fed diets containing various levels of FFW compared to a control group without FFW. Broilers receiving 10% CPL had lower weight gain due to anti-nutritional compounds. On the other hand, FFW treatments led to increased weight gain, with the highest gain seen in birds supplemented with 15% FFW. Overall, FFW supplementation resulted in higher weight gain compared to the control, indicating that FFW provides nutrients, enzymes, or metabolites that support growth and performance.

Our recent study revealed that integrating 10% *Carica papaya* leaf (CPL) into broiler diets seemingly led to impaired FCR, as evidenced by the higher FCR value of 1.73 in CPL-supplemented birds compared to the control group on a standard diet, displaying an FCR of 1.64. This finding contrasts with much of the existing literature, which demonstrates no significant effect of related papaya leaf meal (PLM) supplementation on FCR in broilers at inclusion levels up to 15% [3,6].

Broiler chickens consuming only tap water exhibited the highest FCR of 1.82, while those supplemented with 5–15% FFW in water achieved a superior FCR of 1.60–1.66. This finding aligns with previous research by Shabani et al. [15], who reported enhancements in FCR with 6-12% dietary FFW due to improved digestion and absorption. However, Kiflay [19] found poorer FCR in broilers fed 12% fish offal meal. The observed reductions in FCR with water-based FFW suggest beneficial influences on feed efficiency and productivity. Unlike feed supplementation, administering FFW in water may have facilitated more consistent intake across birds and feeding bouts compared to timed meal feeding [10].

4.3 Carcass Yield

Surprisingly, birds fed 10% CPL exhibited lower dress weights (1162 g) compared to those on the standard diet (1241 g). Despite CPL's known growth-promoting bioactives, its fiber content may have diluted dietary energy, leading to reduced dress weights. This finding is consistent with prior research indicating that CPL supplementation diminishes dress weight relative to control or standard diets. For example, Sari et al. [4] reported no significant effects on body weight gain or feed conversion ratio with up to 9% CPL inclusion in broiler diets. In contrast, supplementing broiler diets with increasing levels of fermented fish waste (FFW) yielded dose-dependent improvements in dress weights. Numerous studies have demonstrated that FFW supplementation enhances dress weight relative to control diets. For instance, Taufikurrahman and Rostini [8] found that 15% FFW inclusion increased egg production in Alabio ducks, indicating improved growth and body weight. Similarly, Abun et al. [16] reported that 10% FFW resulted in the highest metabolizable energy and nitrogen retention in chickens, augmenting growth and muscle mass. The enhancements in dress weight with FFW likely stem from its high-quality protein, amino acids, fatty acids, minerals, and other growth-supporting nutrients [11]. Shabani et al. [12] reported increased crude protein content from 42.7% to 56.3% following fermentation, with protein digestibility rising to 81.61%. Additionally, Garcés et al. [9] found that fish silage amino acid content exceeded FAO recommendations for poultry, with digestibility values exceeding 80%.

4.4 Weight of Thigh and Drumsticks

FFW supplementation significantly increased thigh muscle weights in a dose-dependent manner. This implies that nutrients in FFW likely help stimulate muscle growth and development in the thighs of broilers. In contrast, CPL supplementation did not affect thigh weights. This suggests that, unlike FFW, CPL does not provide significant benefits for thigh muscle growth in broilers under the tested conditions. Both FFW and CPL supplementation increased drumstick weights compared to the control diet. FFW had a particularly large effect, with 5% and 15% supplementation increasing drumstick weights by 48.7% and 28.3%, respectively. Very few studies have directly examined the effects of CPL and FFW on the weights of specific broiler chicken cuts like the thigh and drumstick.

However, Ezenwosu et al. [20] found no significant differences in carcass and organ weights between a control diet and diets with up to 15% dried CPL. In contrast, Onu [21] reported that 2% dietary CPL improved carcass yield and meat production in broilers. Regarding FFW, Taufikurrahman and Rostini [8] noted positive effects of fermented fish waste on the egg production and quality of Alabio ducks, consistent with the drumstick weight improvements seen here.

4.5 Weight of Breast, Wings and Back

Significant interaction effects exist 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. Regarding breast weight, the combination of 10% CPL with 10% FFW resulted in the highest breast weights compared to tap water alone, suggesting a potential synergistic effect. For wing weights, 15% FFW maximized yields in CPL-fed broilers, while all FFW levels increased weights in standard diet-fed chickens. For back weights, 10% FFW optimized weights in CPL-supplemented broilers, while tap water enhanced yields in broilers on the standard diet. These interactions imply that the combinations of CPL and FFW have synergistic effects on lean muscle tissue accretion in broiler chickens. Certain ratios may promote optimal nutrient utilization for muscle group growth. CPL carries bioactive phytochemicals like flavonoids, tannins, saponins and alkaloids [20,4] that can affect hormonal and cell signaling pathways for muscle protein synthesis. Quercetin flavonoids can trigger MAPK and mTOR pathways to elevate muscle protein synthesis [22]. Saponins stimulated IGF-1 and myostatin expression, augmenting muscle growth [23]. FFW is an excellent protein source with essential amino acids, fatty acids, and micronutrients for skeletal muscle [12]. Amino acids serve as protein building blocks, while omega-3 fatty acids regulate muscle metabolism [11]. Zinc and selenium increase antioxidant status, protecting against oxidative tissue damage during growth [24]. The combination of phytochemicals and nutrients in CPL and FFW could exert synergistic benefits on protein synthesis, blood flow, and oxidative stress in developing muscles.

4.6 Edible Visceral Organs

Supplementation of broiler chickens with Carica papaya leaf meal (CPL) and fermented fish waste (FFW), whether individually or in combination, did not yield significant effects on the weights of internal organs such as the heart, liver, and gizzard. This suggests that neither CPL nor FFW supplementation conferred advantages in increasing yields of edible visceral organs in broiler chicken production. Limited studies have directly investigated the impact of dietary CPL and drinking water FFW supplementation on internal organ weights in broilers. For instance, Ezenwosu et al. [20] found no notable differences in liver, kidney, or heart weights between a control diet and CPL-supplemented diets, consistent with the current study's neutral organ weight outcomes. Conversely, Onu [21] reported increases in liver, heart, and gizzard weights with 2% CPL supplementation. Regarding FFW, while Abun et al. [16] observed increases in liver weight with fermented catfish waste, other studies found no significant impacts of fish silage on internal organ weights. The lack of significant effects may be attributed to inadequate supplementation lengths or levels to induce hypertrophic responses. Furthermore, genetic variations among broiler strains can influence organ growth capacities. Interactions between CPL and FFW may also influence organ weight outcomes [25].

4.7 Sensory Evaluation

The preservation of tenderness and juiciness, indicating moisture content and texture, across all treatment groups, alongside unchanged taste and aroma scores, suggests no impairment of flavor or odor in the meat. Comparable general acceptability scores among the supplemented and control groups further imply that the supplements would not negatively influence consumer approval. Despite numerical increases in certain sensory traits for some treatments, the lack of statistical significance suggests negligible effects on perception. The overall sensory quality remained consistent with the control, indicating maintained quality. This suggests bioactive compounds in CPL and nutrients in FFW do not adversely alter muscle composition or chemistry post-slaughter. The neutral impact on sensory meat-eating properties suggests lipid oxidation, which can influence aroma and consistency, also does not appear markedly affected. Studies conducted by Hasanah et al. [26], Muhammed et al. [11], and Shabani et al. [15] presented contrasting findings. Potential reasons may include variations in supplementation levels, type and quality of CPL and FFW affecting bioactive compounds, differences in broiler breed, age, raising conditions, processing, and inconsistencies in sensory analysis methods. Further research is warranted to optimize strategies for consistently enhancing broiler meat sensory properties with CPL and FFW.

4.8 Economic Profitability

Supplementing broiler feed with *Carica papaya* leaf meal (CPL) and water containing fermented fish waste (FFW) resulted in increased overall production costs relative to an unsupplemented control diet, with the highest cost attributed to 15% FFW water supplementation. However, despite the initial rise in production expenses, these costs were offset by higher dressed weights and sales revenue from the supplemented broilers, particularly those receiving 15% FFW. This translated into higher profit margins, with the net profit ratio being the highest for broilers raised on a standard diet plus 15% FFW water supplementation, achieving a remarkable 49% return on investment. Optimized utilization of CPL and FFW presents an economically viable strategy for boosting yields and profitability compared to conventional diets alone. This finding aligns with similar improvements reported in profitability metrics associated with CPL by Ezenwosu et al. [20] and Unigwe et al. [3], as well as with FFW by Garcés et al. [9], Shabani et al. [16], and Tanuja et al. [27]. However, contrasting results were observed by Sari et al. [4] and Banjoko et al. [6], who found no direct profitability impacts from CPL. Possible explanations may include variations in CPL inclusion levels or the utilization of different profitability indicators. Notably, the profitability effects of FFW were not discussed by Abun et al. [28]. These variations underscore the importance of optimizing supplementation strategies to maximize profitability gains. Nonetheless, the current and most recent findings collectively support the notion that CPL and FFW supplementation can enhance broiler production economics.

5. CONCLUSION

The comprehensive investigation into the effects of dietary *Carica papaya* leaf meal (CPL) and fermented fish waste (FFW) in water on broiler chicken growth, carcass traits, sensory characteristics, and profitability yielded noteworthy conclusions. Supplementation of broiler drinking water with FFW (e.g., 10%) notably improved feed intake, final body weight, weight gain, feed conversion ratio, and carcass parameters, including dress weight, thigh weight, drumstick weight, breast weight, wing weight, and back weight. However, excessively high levels of FFW (e.g., 15%) may slightly reduce feed intake. Conversely, incorporating CPL at 10% in broiler diets had adverse effects, reducing final body weight, weight gain, and dress weight, possibly due to the anti-nutritional compounds present in CPL, although it did not significantly affect feed intake or sensory qualities. An intriguing observation was the synergistic effects observed on breast, wing, and back weights with the combination of CPL in the diet and FFW in drinking water, suggesting specific supplement ratios can optimize lean muscle accretion. Neither CPL nor FFW influenced the weights of edible visceral organs like the heart, liver, and gizzard. Sensory evaluation confirmed no adverse effects on tenderness, juiciness, taste, aroma, or overall acceptability of broiler meat with these supplements, indicating maintained palatability and consumer acceptance. Despite initial increased production costs, economic analysis revealed higher dressed weights and net profit ratios, particularly for broilers receiving the standard diet with 15% FFW supplementation, resulting in a remarkable 49% return on investment. Collectively, these findings suggest optimized utilization of CPL and FFW presents an economically viable and sustainable strategy for enhancing broiler growth, carcass quality, and profitability while leveraging nutritional benefits and reducing environmental waste.

ETHICS APPROVAL

The study carefully adheres with the rules and regulations on the scientific procedures of using animals under the Philippines Republic No. 8485, otherwise known as the “Animal Welfare Act of 1998”, and research ethical standards at Agusan del Sur State College of Agriculture and Technology (ASSCAT).

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COMPETING INTERESTS

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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