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The effect of inclusion of fish waste meal on the growth performance and carcass characteristics of broiler chicken

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Abstract

This research was carried out with the aim of assessing the effect of incorporating fish waste meal as a substitute for soybean on the growth and carcass characteristics of broiler chickens. A total of 180 day-old broiler chicks of the Cobb-500 strain were used in this study. They had an average initial body weight of 41.36 ± 0.5 g. The chicks were assigned randomly to four dietary treatments, with three replications per treatment. Each replicate consisted of 15 chicks, and a completely randomized design (CRD) was used. The four broiler starter and finisher diets that were tested contained different levels of fish waste meal (FWM), specifically: 0% (T1), 7% (T2), 13.5% (T3), and 20% (T4). The daily DM, crude protein (CP), and metabolizable energy (ME) intakes of broilers were highly significant ($P < 0.001$) during the starter, finisher, and entire experimental periods. During the starter, finisher, and entire period, broilers in the T4, T3, and T2 groups had significantly better daily DM intake ($P < 0.05$). The daily CP intake of broilers in T4 and T3 had significantly better CP intake ($P < 0.005$) than the control group (T1) during the finisher and entire phase. Similarly, improved ME intake and BW gain ($P < 0.05$) were observed in T4, T3 and T2 during the finisher phase and the entire experimental period. The FCR of broilers fed FWM in the diets was considerably lower ($P < 0.05$) than the control group during the finisher and entire phase. The eviscerated carcass yield, breast, and drum-thigh weight were significantly better ($P < 0.05$) in FWM treatment diet groups compared to the control group. There is a significant decline ($P < 0.05$) in the weight of abdominal fat in T4 and T3 compared to the control group. Including 20% FWM in broilers' diets has resulted in a lower feed cost per kg of BW gain and the highest net return (NR) and marginal rate of return (MRR) than T3, T2, and control T1. Therefore, incorporating fish waste meal at 20% has improved DM intake, body weight gain performance, carcass yield, and is economically viable for broiler production.

Keywords: Broiler chicken, Fish waste meal, Non-conventional, Growth performance, Carcass characteristics, Least cost feed

Introduction

Poultry production accounts for over 35% of all animal protein consumed globally (FAO, 2022). Mottet and Tempio (2017) also projected that poultry will continue to be the primary source of animal protein for the growing human population in the coming years. As a result, the poultry industry is expected to expand significantly to meet the increasing demand. However, despite this growth, challenges still persist in the development of the poultry sector. To this end, Ethiopia's poultry sector development encountered several challenges, including shortage of quantity and quality feed, disease outbreaks, input supply, poor market linkages and marketing infrastructure, lack of infrastructure, and inconsistent government policies and regulations (EIAR, 2017).

Many efforts have been undertaken to reduce feed costs and increase profitability (Guaiume, 2007). One such endeavour is looking into the possibility of using non-conventional feeds to replace conventional feeds. Using locally produced fish waste meal as a protein source could be a sensible solution to replace expensive plant protein sources like soybean, peanut, noug seed, and cottonseed cake. Fish waste meal, a byproduct of fish processing, contains valuable nutrients like protein, lipids, minerals, and vitamins and can serve as a cheap, locally available alternative feedstuff for poultry. Fish meal made from fish waste has a typical crude protein content of 60-72% and metabolizable energy of 2000-3000 kcal/kg (Hardy, 2010). When included in poultry diets, fish waste meal has been found to improve growth performance, feed efficiency, and gut health due to its rich omega-3 fatty acid and amino acid profiles (Khosravi et al., 2015). This approach would significantly improve the economic performance of the operation and reduce the feed ingredient competition between humans and livestock over the available grains (Anyanwu, 2008).

Therefore, fish waste represents a sustainable source of nutrients that can reduce the cost of poultry production. Research has shown that fish waste meal can be used to replace a portion of the conventional protein sources in poultry diets without affecting growth and egg performance. In a particular study, Adebayo et al. (2018) found that replacing soybean meal with fish waste meal up to 10% resulted in no significant difference in the performance and carcass characteristics of broilers. According to a study by Sarker et al. (2019), fish waste meal can be used as a partial replacement for soybean meal in broiler diets without affecting growth performance, feed intake, or feed conversion ratio. Another study by Rahman et al. (2019) reported that fish waste meal can be used as a complete replacement for fish meal in layer diets, resulting in similar egg production and quality. Alemayehu et al. (2015) and Asrat et al. (2008) proposed that 10 and 16.6% of fish waste meals might be included in the diet of growing chicks without impacting feed intake, growth, egg production, and health, respectively.

However, few studies have been carried out to assess the effect of a fish waste meal on feed intake, growth performance, and carcass features of broiler chickens in places where fish waste may be acquired to generate a fish waste meal. As a result, this study aimed to evaluate the effect of substituting soyabean seed for fish waste meals in the diet of broiler chicks on weight gain, feed intake, and carcass parameters.

Materials and methods

Study area

The experiment was conducted at Wolaita Sodo Agricultural Technical Vocational and Education Training College (ATVET Poultry Farm), Wolaita, Ethiopia.

Preparation of experimental feed

Fish waste was obtained from the Omo River and promptly transported to the Areka Agricultural Research Center for processing. The waste was converted into fish waste meal (FWM) by cooking it for 15 to 20 minutes at temperatures ranging from 80-90°C, following the methodology described by Meeker (2006). The high cooking temperature serves to denature the proteins and break down the cellular structure of the fish, allowing for the efficient extraction of the oil or fat fraction from the solid material. After cooking, the fat fraction was separated from the solid material by ladling it off the surface of the drum.

To further process the cooked offal, it was dried for a period of 10 to 12 days by spreading it out on a plastic sheet and repeatedly turning it until the moisture content fell below 15%. A white cloth was used to dry the fish waste meal after milling it to a particle size of 5mm using a wooden mortar, a technique based on the protocol outlined by Miles and Jacob (2003). This was done to prevent recontamination of the product.

Preparation of experimental ration

The ration formulation was based on the chemical analysis of the feed ingredients. Starter and finisher treatment diet rations containing fish waste meal at 0, 7, 13.5, and 20% were incorporated in the broiler diets. Ration formulation software called FeedWin Version 2.2 was employed to prepare the diets, as shown in Table 1. The rations were formulated to be almost isocaloric and isonitrogenous to satisfy the nutritional needs of broiler chickens. The metabolizable energy (ME) content of 3000 kcal/kg DM and CP content of 22% during the starter phase (1–21 days) and the ME content of 3200 kcal/kg DM and CP content of 20% during the finisher phase (22–49 days) (Leeson and Summers, 2005).

Experimental design and bird management

A total of 180 day-old broiler chicks belonging to the Cobb-500 strain obtained from Alema Farms PLC. The chicks were weighed and assigned randomly into four different dietary treatment groups, using a complete randomized design (CRD). Each treatment group was replicated three times, with each replication consisting of fifteen chickens. The experimental period lasted from day 0 to day 49 of age.

The birds were grown for seven weeks in a 1.50 x 1.65 m deep litter floor enclosure (pen) with wire mesh partitions (Yibrehu et al., 2012). At a depth of 10 cm, wood shavings were used as the litter material. Before the commencement of the experiment, the experimental house (pens, waterer, and feeding troughs) was cleaned, formalin-disinfected, and aerated. The chicks were provided a source of heat and light in the form of 250-watt electric lights with gradual height adjustments. It was necessary to make heat changes by lowering or raising the bulbs in accordance with the inside temperature and by watching the bird's behaviour. Each pen had a bulb in the middle, hanging slightly above the bird's level. The temperature was kept at 35°C during the first week and lowered each week until it reached an ambient temperature of 24°C. Iso-management conditions like floor space, light, temperature, ventilation, and relative humidity were provided to each group.

Table 1. The proportion of ingredients composition of broiler starter and finisher rations experimental diets

	Starter phase (1-21 d)				Finisher phase (22-49 d)			
Ingredient %	T1	T2	T3	T4	T1	T2	T3	T4
Maize	36	36	39	40	50	53	54	55
Barley	3	3	3	3	2	2	2	2
Wheat middling	12.35	14.45	14.95	14.45	6.4	6.45	6.95	6.45
NSC	18	19	19	19	11	11	13	13
Soybean roasted	28	18	8	1	28	18	8	1
Fish waste meal	0	7	13.5	20	0	7	13.5	20
Limestone	2	2	2	2	2	2	2	2
DL-Methionine	0.2	0.1	0.1	0.1	0.15	0.1	0.1	0.1
Salt	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Vit-Mineral premix	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
L-Lysine	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Total	100	100	100	100	100	100	100	100
Nutrient content calculated (% DM basis) FeedWin Software								
CP	22.4	22.2	22.5	21.9	20.2	20.4	20.3	20.5
ME(kcal/kg)	2999.58	2999.65	2999.46	2999.84	3199.47	3199.95	3199.89	3199.30
DM	91.4	91.1	91.4	91.2	90.7	90.9	91.3	91.4
CF	3.5	3.7	3.9	4	3.7	3.9	3.1	3.8
EE	3.48	4.01	4.52	4.84	4.59	4.7	5.4	5.5
Ash	9.48	9.75	10	10.2	7.8	7.5	8	8.8
Ca	0.78	1.01	1.08	1.12	0.85	0.91	0.96	0.95
P	0.69	0.61	0.64	0.58	0.48	0.58	0.55	0.68

SBM= Soybean meal, NSC= Noug seed cake, T1= 0% Fish waste meal, T2 = 7% Fish waste meal, T3 = 13.5% Fish waste meal, T4 = 20% Fish waste meal

Fresh, clean drinking water was available during the whole experimental period. The chickens were vaccinated at one and three weeks of age against Newcastle disease and at two and four weeks against Gumboro disease through ocular and drinking water methods, respectively.

Data collection

Growth performance and nutrient intake measurement

The amounts of feed offered and refused per pen were recorded daily. The feed refusal was collected daily before offering fresh feed and weighed. DMI was calculated by the difference between offers and refusals on a DM basis. The DM, CP, and ME intakes were computed by multiplying the feed's daily and total feed consumption by the DM, CP, and ME contents. The average body weight gain (BW gain) was calculated as the difference between the two successive weights divided by the number of chickens. Average daily gain (ADG) was calculated as the mean of the final BW change divided by the number of experimental days. The FCR was calculated as the ratio of average feed intake to average BW gain.

Carcass characteristics measurement

At the end of the trial, two broilers from each replication were chosen randomly for carcass examination. The carcass characteristics were determined following the procedure described by Kubena et al. (1974). The selected broilers were starved for twelve hours and weighed before slaughter. By serving the jugular vein, exsanguinations and hand plucking were followed to slaughter and process the broiler's carcasses. The cut of the eviscerated carcass and the non-edible offal components were determined. Carcasses were manually eviscerated and suspended from the evisceration line for 15 minutes before being weighed. Commercially, the carcass yield of the breast and drumsticks-thighs were examined. The dressing percentage was calculated by multiplying the carcass weight-to-slaughter weight ratio by 100. The weight of the giblets (heart, gizzard, and liver) and the abdominal fat were considered.

Partial budget analysis

The costs of feed ingredients were used to calculate the feed cost for each treatment. The average selling prices of broilers were obtained by calculating the average carcass yield of birds multiplied by the price of broiler carcasses at the supermarkets. The profit was

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calculated as the difference between the selling price and the total costs of broiler production. The difference in sales and purchase prices was considered a total return (TR) in the analysis. The net return (NR) was calculated by subtracting the total variable cost (TVC) from the total return. The change in net return (ΔNR) was calculated as the difference between the change in total return and the change in total variable cost (ΔTVC) (Knott et al., 2003): $\Delta NR = \Delta TR - \Delta TVC$

The marginal rate of return (MRR) was used to measure the increase in net return associated with each additional unit of expenditure (ΔTVC):

$$MRR = \Delta NR / \Delta TVC$$

Statistical analysis

The collected data were subjected to analysis of variance with the Statistical Analysis System (SAS 2008), following the general linear model (GLM) procedure. Duncan's Multiple Range Test evaluated a treatment difference between group means at a 5% significance level (Duncan, 1997). The following model was used for the experiment.

$Y_{ij} = \mu + T_i + e_{ij}$

Where:

Y_{ij}= response variables (DM intake, CP intake, ME intake, BW gain, FCR, carcass characteristics)

μ = Overall mean

T_i = The fixed effect of i^{th} FWM inclusion level at (0%, 7%, 13.5% and 20% FWM)

e_{ij}= Random error variation of the ij^{th} (mean 0 and variance σ)

Results and discussion

Dry matter and nutrient intake

The effect of including various levels of fish waste meal on the DM and nutrient intake of broiler chicken is presented in Table 2. During the starter phase, the treatment groups had highly significant differences ($P < 0.001$) in daily and total DM intake. The treatment diets containing 20% FWM (T4) have significantly ($P < 0.05$) higher daily and total DM intake compared to T3, T2, and T1, respectively. A similar increase in broilers' average daily feed intake during the last part of the starter period. Similar results in DM intake were observed by Karimi (2006) when the level of fish meal was increased by 2.5% or 5% in chicken diets.

Table 2. Dry matter and nutrient intake of broiler chicken-fed diets with different levels of FWM

Parameter	Phase	Dietary treatments					P-value
		T1	T2	T3	T4	SEM	
DMI (g/bird/day)	Starter	43.50^{d}	46.81^{c}	53.18^{b}	59.68^{a}	0.75	<0.001
	Finisher	89.47^{d}	96.94^{c}	104.13^{b}	110.31^{a}	1.07	<0.001
	Entire	69.77^{d}	75.46^{c}	82.30^{b}	88.60^{a}	0.63	<0.001
Total DMI (g/bird)	Starter	913.54^{d}	983.08^{c}	1116.91^{b}	1253.26^{a}	15.82	<0.001
	Finisher	2505.39^{d}	2714.44^{c}	2915.79^{b}	3088.55^{a}	30.03	<0.001
	Entire	3418.93^{d}	3697.51^{c}	4032.70^{b}	4341.81^{a}	31.2	<0.001
CPI (g/bird)	Starter	11.07^{d}	12.38^{c}	14.05^{b}	16.18^{a}	0.2	<0.001
	Finisher	22.14^{d}	24.06^{c}	26.32^{b}	28.35^{a}	0.27	<0.001
	Entire	17.39^{d}	19.05^{c}	21.06^{b}	23.13^{a}	0.16	<0.001
MEI (kcal/bird/day)	Starter	151.06^{c}	153.96^{c}	160.96^{b}	169.14^{a}	2.14	0.001
	Finisher	329.65^{d}	348.74^{c}	360.17^{b}	372.73^{a}	1.71	<0.001
	Entire	172.48^{d}	184.63^{c}	194.16^{b}	204.85^{a}	1.433	<0.001

^{abcd}Means within a row with different superscript letters are significantly different; T_1 = basal diets with 0% FWM; T_2 = basal diets with 7% FWM; T_3 = basal diets with 13.5% FWM; T_4 = basal diets with 20%; FWM; DMI = Dry matter intake; CPI = crude protein intake; MEI = Metabolazable energy intake; SEM = standard error of the mean and P = probability value

When the level of a fish west meal increased from 7% (T2) to 20 % (T4), the daily as well as the total dry matter intake highly increased ($P < 0.05$). This is likely due to the fact that fish waste meal is a high-protein food source that is rich in essential amino acids and other nutrients that are important for animal growth and development. The results obtained from the overall experiment period were in agreement with Karimi (2006), who reported that broilers fed with 1.25, 2.5, and 5% fish meal had a significantly higher average feed intake compared with chicken-fed diets without fishmeal over the whole experimental period (0–42 days). A similar result in feed intake was also reported by Asrat et al. (2008) when cooked and sun-dried fish offal meals were incorporated up to 16.6% in the diets of Rhode Island Red chicks. There was a significant difference ($P < 0.001$) in CP and ME intake among dietary treatments during the starter, finisher, and entire period. Chicken under T4 had significantly ($P < 0.05$) higher CP and ME intake than the groups T2, T3, and the control (T1). This is due to the fact that fish waste meal is a high-protein and energy-dense feed source that can provide broiler chickens with the necessary nutrients to support growth and development. However, there is no significant ($P > 0.05$) difference between T2 and the control (T1) in ME intake during the starter phase.

Body weight gain and feed conversion ratio (FCR)

The effects of the inclusion of fish waste meal at different levels on the final BW, BW gain, and ADG of broiler chicken during the starter and finisher phases and overall experimental periods are shown in Table 3. There were significantly higher ($P < 0.05$) BW, BWG, and ADG in the starter and finisher phases and overall experimental periods. During the entire growth period, the chickens with treatment T2, T3, and T4 FWM had significantly higher ($P < 0.05$) ADG and BWG than the control (T1). The ADG and BWG of chicken fed in T4 were significantly ($P < 0.05$) higher than in T3, T2, and T1, respectively. This might be due to the FWM provision of more complete amino acids and proteins with higher digestibility, which promote greater appetite and feed intake and lead to better performance. The current result at the starter phase agrees with Ponce and Gernat (2002), who reported a higher body weight gain at the end of the starter phase in broiler-fed diets containing 10% or 20% tilapia by-product meal. However, the current result disagrees with Karimi (2006), who reported that the average body weight and daily gain were not influenced by 2.5% or 5% fishmeal replacement to the diet during the starter period. The variation could be due to the lower level of fish meal used compared to the current study.

The FCR of broiler chickens was significantly different ($P < 0.05$) during the finisher phase and the entire growth period. The treatment T4, T3, and T2 groups had a lower FCR ($P < 0.05$) compared to the control (T1) group. This might be due to fish meal's lower metabolizable energy content than many other protein sources, like soybean meal. Broilers would have to consume more fish meal to get the same energy intake, lowering the FCR. The improved BW gain may be due more to higher protein intake than calories. FWM is also highly digestible, but some nutrients may not be utilised quite as efficiently as in other protein sources. Some components, like calcium phosphates, can lower digestibility. This would require more fish meal to get the same amount of absorbed nutrients.

This study disagrees with Mengistu (1998) reported FCR value of 3.58 in broilers fed commercial diets from 0-63 days. The current research disagrees with that of Karimi (2006), who noted that fishmeal inclusion levels did not influence the FCR of chicken during the finisher period (21-42 days) and the entire growth period. Adesehinwa et al. (2005) also reported no change in the FCR of broiler chicken when an imported fish meal was replaced by local fish waste. The feed conversion ratio obtained in all fish waste meal supplemented groups is lower than that reported by the same source for broilers fed from 1.18 to 4.72% local fish waste.

Table 3. Growth performance of broiler chicken-fed diets with different levels of FWM

Parameter	Phase	Dietary treatments					
		T1	T2	T3	T4	SEM	P-value
Initial BW (g/bird)	Starter	41.31	41.57	41.1	41.45	0.5	0.91
	Finisher	566.67^{d}	628.67^{c}	690^{b}	761.33^{a}	7.99	<0.001
Final BW (g/bird)	Starter	566.66^{d}	628.66^{c}	690.00^{b}	761.33^{a}	7.99	<0.001
	Finisher	1655.33^{d}	1717.33^{c}	1822.67^{b}	1944.33^{a}	10.84	<0.001
BW change (g)	Starter	525.35^{d}	587.09^{c}	648.98^{b}	719.88^{a}	7.95	<0.001
	Finisher	1088.66^{c}	1088.66^{c}	1132.67^{b}	1183^{a}	9.13	<0.001
	Entire period	1614.02^{d}	15.76^{c}	1781.57^{b}	1902.88^{a}	10.62	<0.001
ADG (g/bird/d)	Starter	25.01^{d}	27.95^{c}	30.9^{b}	34.28^{a}	0.37	<0.001
	Finisher	38.88^{c}	38.88^{c}	40.45^{b}	42.25^{a}	0.32	< 0.001
	Entire period	32.94^{d}	34.19^{c}	36.36^{b}	38.83^{a}	0.21	<0.001
FCR	Starter	1.73	1.67	1.72	1.74	0.03	0.53
	Finisher	2.3^{b}	2.49^{a}	2.57^{a}	2.61^{a}	0.04	0.002
	Entire	2.12^{b}	2.21^{a}	2.26^{a}	2.28^{a}	0.02	0.005

[abcd]Means within a row with different superscript letters are significantly T1 = basal diets with 0% FWM; T2 = basal diets with 7% FWM; T3 = basal diets with 13.5% FWM; T4 = basal diets with 20%; FWM;SEM = standard error of the mean and P = probability value

Carcass yield

The effects of different fish meal levels on broiler chicken carcass characteristics are presented in Table 4. There was a significant difference (P < 0.001) in slaughter weight among treatment groups. Chicken fed T4 had a significantly higher (P < 0.05) slaughter weight, followed by T3, T2, and the control (T1) group, respectively. The higher slaughter weight might be attributed to the increased DM intake of broilers and body weight gain.

Table 4. Carcass yield characteristics of broilers fed different levels of fish waste meal

Parameter	Dietary treatments				SEM	P-value
	T_1	T_2	T_3	T_4		
Slaughter weight (g)	1610.2^{d}	1693.67^{c}	1793.33^{b}	1911.8^{a}	25.28	0.001
Dressed carcass (g)	1453.7^{d}	1545.83^{c}	1648^{b}	1767.8^{a}	22.12	<0.001
Dressed carcass (%)	90.28^{b}	91.28^{ab}	91.92^{a}	92.47^{a}	0.51	0.039
Eviscerated carcass (g)	1088.7^{d}	1177.83^{c}	1297.67^{b}	1432.5^{a}	26.9	<0.001
Eviscerated carcass (%)	67.62^{c}	69.51^{bc}	72.39^{ab}	74.92^{a}	1.08	0.001
Breast (g)	305.5^{c}	324.83^{bc}	336.66^{b}	385.5^{a}	6.98	<0.001
Breast (%)	18.76^{d}	18.99^{c}	19.19^{b}	20.178^{a}	1.08	0.001
Drumstick-thigh (g)	137.67^{d}	173.667^{c}	201^{b}	254.67^{a}	0.352	<0.001
Drumstick-thigh (%)	8.55^{c}	10.24^{b}	11.18^{b}	13.28^{a}	0.185	<0.001

^{abcd}Means within a row with different superscript letters are significantly different T_1= basal diets with 0% FWM; T_2= basal diets with 7% FWM; T_3= basal diets with 13.5% FWM; T_4= basal diets with 20% FWM; SEM = standard error mean; p = probability

There was a significant difference in the eviscerated carcass and dressed carcass weight among the treatment groups ($P < 0.001$). Broiler groups receiving treatment diets of 20% (T4) and 13.5% (T3) FWM had significantly higher ($P<0.05$) eviscerated carcass weights than the other treatment groups. The treatment groups T3 and T2 (7% FWM) also had a considerably ($P < 0.05$) higher eviscerated carcass weight compared to the control group (T1). The improved growth performance (BW, ADG) of broilers fed fish waste meal suggests they accumulated more muscle protein over time. Since muscle protein makes up the majority of carcass weight, higher protein deposition would translate to heavier carcasses. Fish waste meal provides more protein and amino acids to support muscle growth. Also, fish waste meal could potentially stimulate the release of anabolic hormones like growth hormone that favour muscle protein synthesis and fat storage. Higher hormone levels of this type would lead to greater accretion of weight in the form of muscle and fat tissue, resulting in heavier carcasses.

The current results disagree with Ponce and Gernat (2002), who reported no difference in the percentage of carcass yield between broiler chicken-fed tilapia by-product meal and the control diet. Adesehinwa et al. (2005) also reported a similar finding when an imported fish meal is replaced by a local fish meal at 3.45% and 4.72%.

Breast weight

There was a significant difference (P < 0.001) in average breast weight among treatment groups. Chicken fed T4 (20% FWM) had significantly higher (P < 0.05) breast weight, followed by T3, T2, and the control (T1) group, respectively. Also, T3 and T2 had significantly (P<0.05) higher breast weight than the control group (T1) chicken. This improvement might be due to the fact that the growth performance of broilers on fish waste meal likely resulted in increased deposition of muscle protein over time, including in the breast muscles. Since breast meat weight primarily reflects muscle mass, higher protein gains would translate to heavier breasts. Fish waste meal provides more protein and amino acids to support muscle growth. This study agrees with Kim (2005) report that better breast muscle weight was obtained when chicks were supplemented with fishmeal. The increase in breast meat weight with an increasing level of FWM observed in the current study could be due to the high quality of dietary protein methionine and lysine in FWM (Sasidhar, 2006).

Drumstick–thigh weight

The drumstick-thigh weight and percentage of the experimental broilers are presented in Table 4. There was highly significant difference (P < 0.001) among the treatment groups in drumstick-thigh weight. Improved or higher drumstick-thigh weights (P < 0.05) were recorded in broilers fed 20% fishmeal in the diet, followed by T3, T2, and the control group across the treatment. A comparable drumstick-thigh weight (349.5 g) is reported by Adesehinwa et al. (2005) in broiler chicken fed 4.72% local fish waste. However, the chickens fed T3 and T2 had no significant (P > 0.05) differences in drumstick-thigh percentage. The current study, comparable with Mikulec et al. (2004), indicated broiler chicken drumstick-thigh was 20.6% obtained from diets containing 6 and 4% fish waste meal. The drumstick-thigh yield improvement in broilers fed fish waste meal diets versus a control diet is due to a greater supply of nitrogen compounds (lysine, arginine), stimulators of muscle gain (leucine, glutamine), fatty compounds (Omega-3 FAs), and minerals that promote muscle and bone development.

Giblet and abdominal fat weight

The weight and percentage of edible offal (gizzard, liver, and heart) are presented in Table 5. Gizzard and heart weight were significantly different (P < 0.001) among the treatment groups. Broiler chicken fed T4 had a higher (P < 0.05) gizzard weight than T3, T2, and T1. However, there were no determinant differences (P > 0.05) between T2 and the control group (T1). The gizzard development and function depend on the availability of protein in the diet. By providing a source of high-quality protein, fish waste meal may help stimulate the growth and development of the gizzard in broiler chickens, leading to an increase in its weight. The current study agrees with Adesehinwa et al. (2005), who reported a change in gizzard weight and no change in liver weight in broilers fed different levels of local fish waste. The enlargement of the gizzard could be due to the response of broiler chickens to metabolic activity. This result agrees with Svihus (2011), who reported that the increased size of the gizzard was an attempt by broilers to improve nutrient digestibility through extended retention time and to grind and mix the feeds.

Table 5. Giblet and abdominal weights of broilers fed different levels of fish west waste meal

Paramètres	Dietary treatments					
	T_1	T_2	T_3	T_4	SEM	P-Value
Total giblets	70.83^{c}	74.33^{bc}	79.83^{ab}	83.67^{a}	2.89	0.025
Giblet (%)	4.4	4.39	4.45	4.38	0.17	0.992
Gizzard (g)	32.33^{b}	35.33^{b}	36.16^{ab}	41.33^{a}	1.85	0.02
Gizzard (%)	2.01	2.01	2.09	2.16	0.1	0.71
Liver (g)	31	30.33	34.5	32.66	1.54	0.25
Liver (%)	1.93	1.79	1.92	1.71	0.1	0.34
Heart (g)	7.50^{b}	8.66^{ab}	9.16^{ab}	9.66^{a}	0.54	0.05
Heart (%)	0.46	0.51	0.51	0.5	0.03	0.65
Abdominal fat (g)	51^{a}	49.83^{ab}	49^{b}	47^{b}	2.19	0.006
Abdominal fat (%)	3.17^{a}	2.95^{ab}	2.625^{b}	2.56^{b}	0.137	0.01

^{abc}Means within a row with different superscript letters are significantly different T_1= basal diets with 0% FWM; T_2= basal diets with 7% FWM; T_3= basal diets with 13.5% FWM; T_4= basal diets with 20% FWM; SEM = standard error mean; p = probability

The dietary treatment groups showed that the abdominal fat weight was significantly different among treatments (P < 0.01). The FMW in T4 had significantly lower abdominal fat (P < 0.05) in the broiler chicken compared to the control T1 groups. The abdominal fat content of broilers decreases when the dietary FWM inclusion level increases to 20% (P < 0.05). The decrease in abdominal fat might be due to the amino acids in the fish waste meal having the potential to inhibit hepatic fatty acid synthase activity and increase the stimulation of glycogenesis, leading to an effective decrease in fat storage (Loizzo et al., 2018).

Partial budget analysis

A partial budget analysis for broilers fed different levels of a fish waste meal is presented in Table 6. Broiler chicken in the control diet (T1) had the least net return of the other treatment groups. The highest net return was observed in chicken-fed T4, followed by T3 and T2. The reasons for the high net return marked in these groups could be a higher DMI and CPI; as a result, a higher growth rate manifested itself in BWG and carcass weight. The total feed price per kg and the total cost per bird decrease when the level of FWM inclusion increases. The least total feed consumed per bird was obtained for the chicken feed under T1 (control), followed by T4, T3, and T2 diets. In other words, as the FWM inclusion rate increased, the profit also increased. Better NR and MRR were achieved when the broiler chicken was fed in T4 and T3.

Table 1. Partial budget analysis for broilers fed different levels of fish waste meal FWM.

Parameter	T1	T2	T3	T4
Cost				
Chicken cost (ETB)	33.0	33.0	33.0	33.0
Total feed consumed/ chicken (kg)	3.7	4.1	4.4	4.7
Per unit feed cost/ kg (ETB)	14.5	13.0	11.8	10.8
Total cost of feed /chicken(ETB)	53.9	52.8	51.9	51.2
Total cost/chicken	97.4	96.2	95.4	94.6
Income				
Average carcass weight (kg)/chicken	1.1	1.2	1.3	1.4
Price/kg of the carcass (ETB)	105.0	105.0	105.0	105.0
Total income/chicken (ETB)	113.4	122.9	135.5	150.2
Net return/chicken (ETB)	16.0	26.6	40.1	55.5
Marginal rate return (MRR)	0.2	0.3	0.4	0.6

T_1= basal diets with 0% FWM; T_2= basal diets with 7% FWM; T_3= basal diets with 13.5% FWM; T_4= basal diets with 20% FWM; ETB = Ethiopian birr; Kg = kilogram

Conclusion

This study highlights the importance of fish waste meal inclusion at various levels as a potential protein source for broiler chickens. Incorporating the fish waste meal at 20% has improved the DM intake, body weight gain performance, and carcass yield and is economically efficient for broiler production.

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Conflict of interest

The authors declare that they do not have any conflicts of interest.

Data availability

The data used to support the findings of this study are available from the corresponding author upon request.

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