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Fish silage fortified poultry feed, its effect on body growth and meat quality of broiler chicks

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ABSTRACT

A lowcost poultry feed was developed in the present investigation by utilizing fish silage generated from fish wastes. The liquefied silage which was initially prepared was dried with crushed maize (85:15). The dried fish silage was added at various ratio (5 %, 10 %, 15 %, Control) by replacing soybean meal. A starter and finisher feed was developed by incorporating various feed ingredients for feeding broiler chicks. It was observed in this study, that poultry feed which was prepared by replacing 5% fish silage showed better feed intake, body growth. The calculated FCR was found lower (1.66) in F1 feed (incorporating 5 % fish silage) when compared with other feeds. Better livability was exhibited by the chicks belonging to treatment groups, except for F2 group (97%). Broiler Performance Efficiency Factor (BPEF) was highest for the F1 group when compared to other treatment groups. Weight of internal organs was checked which showed better growth for F1 group chicks. The meat quality of the poultry was studied by analyzing the meat pH, cooking loss, and sensory analysis. It was noted that the meat qualities did not have much variation between the treatment groups and control groups. The overall acceptability of the poultry meat belonging to the treatment groups during the sensory evaluation was equally accepted by the sensory panelists. Hence it can be inferred that the incorporation of fish silage doesn't adversely affect the meat quality. Ensuring the repeatability of the experiment was a major challenge due to the inconsistent availability of bulk fish waste of the same species during the study (Challenges). Therefore, the poultry feed developed by incorporating fish wastes is an economical, time-saving, less labor-intensive, and highly beneficial approach to backyard poultry farmers.

Keywords: *Fish wastes, Fish silage, Poultry, Chicks, Broiler, Feed, Body growth, Meat quality*

Introduction

The fish industry is one of the fastest-growing sectors, as fish is considered an affordable and globally available source of protein [14]. The consumption of fish and fishery products is steadily increasing, particularly among coastal populations worldwide. Advancements in fishing operations, including large-scale industrial fishing, the use of mechanized fishing vessels, and high-power engines, have significantly contributed to the rapid growth of fish production.

Fish processing generates substantial quantities of waste, which contain valuable nutrients, particularly protein, that can be utilized effectively [35], [33]. On average, fish waste accounts for nearly half of the raw material volume in the industry and serves as a cost-effective nutrient source [31]. Typically, fish waste consists of the head (21%), gut (7%), liver (5%), skin (3%), and other components [15]. Discarding these wastes leads to the loss of significant nutritional value, which could otherwise be utilized for producing valuable byproducts.

Fish silage is one such promising byproduct that is easy to produce, economically viable, and can be incorporated into animal feed as an affordable protein supplement. It is a liquid product obtained from whole fish or fish parts by adding acids, enzymes, or lactic acid-producing bacteria. The liquefaction process is triggered by enzymes naturally present in the fish [13]. Converting fish processing waste into fish silage is a cost-effective alternative that addresses both protein deficiencies and environmental pollution concerns [4]. The addition of acid enhances enzymatic proteolysis, dissolving bones and preventing bacterial and fungal spoilage [39].

Fish silage, derived from fish processing waste, is a potential alternative to fishmeal as an animal protein source. Dried fish silage contains a protein concentration comparable to fishmeal and is relatively easy to produce. The use of fish silage in aquaculture has been widely studied [19], [8], [17] examined the use of fish silage as feed for *Arapaima gigas* (arapaima) and observed improved feed intake. Similarly, [25] and found that ensilage serves as an effective substitute for fishmeal, meat, and bone meal in Black-Finned Pacus rations.

However, limited research has been conducted on incorporating threadfin bream silage in broiler feed to evaluate its impact on growth parameters. Therefore, the present study was undertaken to address this research gap.

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Materials and Method

Fish wastes preparation

The collected fish wastes (Threadfin bream) were thoroughly cleaned, drained, weighed, and chopped well into small pieces and transferred to a plastic tank. 3.5 % (v/w) of formic acid and propionic acid each was added in the ratio of 1:1 [3] by maintaining the pH. pH was maintained near constant (3.5-4) by proper stirring. The contents in the tank were agitated thoroughly twice a day followed by recording the pH. On liquefaction, the liquid silage was filtered and mixed manually with crushed corn (maize) in 85:15 ratio and dried in solar cum biomass drier at 40 ± 2 ºC until the moisture drops below 10%. The dried silage was manually mixed with other poultry feed ingredients at various levels, i.e. 5, 10, 15 % (w/w) [27] & [3] and were compared with the control was replaced with soybean meal in place of fish silage.

Preparation of broiler feed

Four treatments of broiler starter feed was formulated as detailed in Table 1 to feed the chicks for initial 21 d. At the end of 21 d, finisher feed (four treatments) was prepared as mash feed as per the nutritional requirement of the chicks. The finisher feed composition is as given in Table 2. The proximate parameters of the main ingredients incorporated for preparing feed and the feed were studied.

Broiler growth studies

Around 120 number of one-day old broiler Cobb 500 strain was purchased. Prior to start, the rearing area was cleaned, and sanitized with chlorine water and the surroundings were covered with black plastic sheets in order to maintain ambient conditions inside the room. The brooder was hung at the center of the room, fixed with 100V bulb which provides sufficient heat to the area, aiding in the proper growth and development of the chicks. Lighting was provided for 23 h with 1h of dark. The area was divided into four compartments using a plastic net so that each group could be well separated from the other. Individual feeder and drinkers was maintained to each chamber. Once the chicks were brought to rearing area, each individual chick was weighed and then distributed equally to the compartments with each compartment was holding thirty chicks. Prepared feed was provided in the feeder and water in the drinker. Feeding was done both in the morning and evening throughout the rearing period. Chicks were weighed at weekly intervals. Chicks were vaccinated as per the recommendations of the veterinary specialist on 7th, 14th and 21st day. From day 1 to day 42, birds were fed with the formulated starter feed and finisher feed at the specified time as discussed before. On day 42, 10 birds from each group were randomly selected and sacrificed to dissect the internal organs in order to study their growth. Growth parameters such as feed intake, body growth, FCR, Livability and Broiler Performance Efficiency Factor (BPEF), (28)were calculated.

$$FCR = \frac{Quantity\ of\ feed\ intake\ (g)}{Body\ weight\ gain\ (g)}$$

$$Livability\ (\%) = \frac{Number\ of\ birds\ sold}{Number\ of\ birds\ at\ the\ beginning} \times 100$$

$$BPEF = \frac{Live\ weight\ (kg) \times Livability}{FCR \times Market\ age\ (days)} \times 100$$

Assessment of meat quality

Birds were sacrificed by cutting the jugular vein and was dissected to collect the breast muscle. Breast muscles from each feed trial was collected separately and provided with distinct code A, B, C, and D. Breast muscle was then used to study the pH, cooking loss and sensory analysis.

Analysis of pH of the muscle

Five grams of sample was weighed into a 100 mL beaker added with 45 mL of distilled water, homogenized and the pH of the slurry was measured using a pH meter (Eutech, pH 510, Massachusetts, USA). The mixture was macerated well. The resultant slurry was then subjected to analyze the pH in the pH meter.

Analysis of cooking loss (%)

Cooking loss (%) was calculated according to [40]. Around 100g of breast meat was dissected from each treatment group. The dissected meat was steam-cooked for 20 min. The cooked meat was then weighed to get the weight difference after cooking. The cooking loss (%) was calculated as

$$Cooking\ loss\ (\%) = \frac{Raw\ weight\ of\ the\ chicken - Cooked\ weight\ of\ the\ chicken}{Raw\ weight\ of\ the\ chicken}$$

Sensory analysis of the chicken meat

The breast muscle dissected from each broiler group (F0, F1, F2, F3) was subjected to sensory analysis. Around 5-10% of salt was added to dissected cleaned and cubically sliced breast muscle. The meat (100 g) was then steam-cooked at medium flame for 18-20 mins in an open pan with 300 mL of potable water. Meat samples were allowed to partially cool at room temperature for 10 min. Exactly 30 g of cooked and cooled meat from each treatment was weighed into a serving bowl coded with four respective treatments and subjected to sensory evaluation. Sixteen members of the sensory panel were preselected based on age, technicality and expertise in the area of food processing. The panelists were provided with the hedonic scale modified to 0-5 ratings to rate the meat quality as per the individual perception and evaluation. The quality parameters analyzed during the sensory evaluation were tenderness, juiciness, flavor, aroma and desirability. The procedure was repeated thrice and the mean was calculated.

Results and Discussions

Proximate composition of the main ingredients incorporated in poultry feed

Dried fish silage exhibited the highest protein content of 49.07 ± 0.32 %, followed by Soya Bean Meal with 42.5 ± 0.4% and the lowest value for Maize with 10.94 ± 0.32 %. Fat content was shown highest for dried fish silage at 8.3 ± 0.17 % and with the lowest value of 4.1 ± 0.3 %. For maize. Dried fish silage showed ash content of 26.29 ± 0.31 % and lowest for maize with 2.24 ± 0.04 %. Similarly, for moisture, highest value was exhibited by dried fish silage with 6.69 ± 0.02 % and the lowest for maize with 3.15 ± 0.05 %. Details of the proximate composition of the main ingredients are given in Table 3

Liquefied silage was filtered and the filtrate was mixed and dried along with crushed maize and consequently subjected for drying. Dried silage was used to prepare the broiler feed. Feed was prepared in four different compositions by incorporating dried fish silage in different rations (0, 5, 10 and 15 %) by replacing soybean meal. The nutritional value of soybean meal was reported to have 44 % protein content, 6.5 % ash 1.9 % fat, 6.2 % moisture [37], [5].

Crushed maize was reported to exhibit 10.94 ± 0.32% protein, fat 4.1 ± 0.3 %, ash 2.24 ± 0.04 % and moisture 3.15 ± 0.05 %. The proximate composition of the various maize species who found that generally protein content varied from 7.71 - 14.61%, fat content from 3.31 - 7.71%, ash 0.7- 1.3% and moisture 9.21 - 10.08% [18]. In this study, it was observed that the moisture content was comparatively less. Similar results were revealed by [2] where the moisture content of some of the selected species of maize ranged from 4.3 - 6.7 %. Almost similar values of proximate composition of maize with crude protein 8.9%, crude fat 4.47 %, moisture 6.8 % and ash 1.49 % [21].

Preparation of the poultry feeds by incorporating dried fish silage and analysis of biochemical composition.

Poultry feed was prepared by incorporating various ingredients in a particular rations. 2 types of feed including starter and finisher feed were prepared. Four types of treatment groups viz., F0 = Control feed without fish silage, F1 = Feed with 5 % fish silage, F2= Feed with 10 % fish silage, F3 = Feed with 15 % fish silage were prepared for both starter and finisher feed.

The proximate composition of the starter feed (Table 4)was analyzed which recorded the highest protein content of 23.57 ± 0.03% and the least for F0 group with 22.38 ± 0.02%. The fat content was highest for F3 with 3.76 ± 0.02% and least for F0 with 2.47 ± 0.15%. The highest moisture content was also for F3 feed with 8.63 ± 0.11% and the lowest for F0 with 7.84 ± 0.40 %. A similar trend was observed for ash having highest value for F3 with 7.03 ± 0.015 % and least for F0 at 5.59 ± 0.09 %.

Poultry finisher feed was also prepared with four different combinations. A similar trend was observed for poultry finisher feed (Table 5). The feed F3 exhibited the highest protein content of 20.93 ± 0.21% and the least for F0 with 19.37 ± 0.04 %. Similarly fat content was highest for F3 group with 3.52 ± 0.01% and lowest for F0 group with 2.32 ± 0.01%, the highest moisture content of 8.63 ± 0.01% was observed for F3 with and the least for F0 with 7.45 ± 0.01 %, highest ash content was exhibited by F3 with 6.60 ± 0.01 % and lowest for F0 with 5.39 ± 0.01 %. The results obtained in this study was compared with work done at Nigeria on the nutritional composition of the broiler starter and finisher feed observed that moisture content varied from 5.6 – 7.8 %, protein varied from 21.5 – 24.6 %, fat varied from 5.5 – 8.7% and ash content varied from 7.9 – 12.0 % (starter feed). Similarly for broiler finisher feed the moisture content varied from 7.8 - 5.6 %, protein content varied from 19.06 - 22.63 %, fat content varied from 5.37 - 8.41 % and ash content varied from 7.87 - 11.25 % [28]. The compound broiler starter feed available in Bangladesh was studied by [36] who noted that protein content exhibited a range of 21.6 - 23.5 %, fat content ranged from 5.3 - 6.2 %, ash content 6.5 - 9.1 % and moisture content varied from 10 - 12 %. He also studied the broiler finisher feed proximate composition which was in the range of 19.2 - 22.8 % for protein, 6 - 8 % for fat, 6.3 - 8.6 % for ash and 9.6 - 11 % of moisture. Similar studies were conducted by [38] studied the proximate composition of the broiler starter feed where the protein content ranged from 20.37 - 24.21 %, ash 4.16 - 6.7 %, and moisture 8.94 - 9.92 %. Similarly, for finisher feed the protein content was within the range of 19.64 - 20.84 %, ash 4.69 - 4.16 %, and moisture 8.52 - 10.44 %.

The average weekly feed intake by the broiler chicks for studying the growth parameters

The feed intake by the chicks for each week of feeding was recorded (Table 6).

In this study it was noted that the highest feed intake was for F2 group with 134.64 ± 2.69 and the lowest feed intake was for F0 group with 124.04 ± 0.06 g for the first week Similarly, during the second week, F2 group showed the highest feed intake with 405.51 ± 2.47 g and the lowest feed intake was recorded for F0 group with 342.48 ± 0.27 g. In the third week the highest feed intake was observed for F1 group with 591.53 ± 0.5 g and the lowest was for F2 group with 523.47 ± 2.48 g. In the fourth week, the highest feed intake was exhibited by F1 group with 681.85 ± 0.03 g and the lowest feed intake was observed for the F3 group with 587.4 ± 1.4 g. On the fifth week F2 group showed the highest feed intake with 611.21 ± 0.76 gand the lowest feed intake was for F0 group with 553.72 ± 0.06 g. At the end in of sixth week it was noted that highest feed intake was for F1 group with 595.62 ± 1.22 gand the lowest feed intake was for F3 group with 456.23 ± 1.2 g. Study conducted by [27], [10], [3] demonstrated a constant increase in feed consumption during their study period. The effect of incorporating oven-dried fish silage and soybean mixture in the ratio 1:1(w/w) for preparing poultry feed with four different combinations 0 %, 10 %, 20 % and 30 % didn't observe any significant difference in feed intake in broiler chicks when compared with that of control diet [33]. In contrast to the present study, it was reported by [6] that the broiler chicks exhibited a non-significant reduction in feed intake value which was fed with 5% and 10% fish silage with the values 3073 g (5 % fish silage) and 2832 g (10 % fish silage) during the 0 -6 week period.

The average weekly body growth (g) of the broiler chicks

The weekly growth rate of the broiler chicks belonging to each group was recorded periodically to study the growth pattern (Table 7). On the day of arrival, chicks were weighed individually before allocating randomly to each group. It was observed that all the chicks had shown the same weight range of around 47.2 - 47.6 g per bird. By the end of the first week (7^{th} d), it was noted that chicks belonging to F1 group had attained the highest body weight of133.7 ± 0.48 g per bird. The least growth was observed for the chicks belonging to F3 group with 120.2 ± 0.11 g per bird. A similar trend was followed by the end of 2^{nd} week (14^{th} d) where the chicks of F2 group recorded the highest growth of 422.1 ± 0.3 g per bird and the lowest growth was for the chicks belonging to F3 group with 323.41 ± 0.38 g per bird. By the end of 3^{rd} week (21^{st} d) it was observed that the chicks of F1 group exhibited the highest growth of 801.6 ± 0.21 g and the least weight was noted for F3 group with 626.2 ± 0.08 g per bird. By the end of 4^{th} week (28^{th} d) chicks belonging to F1 group had shown the highest body growth of 1170.3 ± 1.37 g per bird and the lowest growth was attained by chicks of F3 group with 924.5 ± 0.36 g per bird. By the end of the 5^{th} week (35^{th} d) similar trends was followed, which recorded highest growth for F1 group with 1503.6 ± 1.02 g per bird and the lowest growth was observed for F3 group with 1195.5 ± 0.34 g per bird. At the end of 6^{th} week (42 d) the highest growth was shown by the chicks belonging to F1 group with 1818.83 ± 1.83 g and the lowest by F3 group with 1406.2 ± 0.11 g per bird. It was observed a wide variation in the body growth pattern of the chicks. F1 group showed the highest body growth followed by F2 and F3. As per the reports the reports an inclusion of 10% of acid fish silage meal or fermented fish silage meal had not effected the body growth significantly in the body growth of the broiler chicks [21]. It was also observed that inclusion of fermented fish scraps, fermented herring or herring scraps at 5 – 10 % in broiler feed for 0-28 days has not showed any variations in body weight gain [30].

Food Conversion Ratio (FCR) of the feed group

The overall FCR of the feed was known by calculating the total feed intake and total body weight gain by the chicks belonging to each group (Table 8). The least value of FCR was given by F1 group with 1.66, followed by F2 group with 1.71, then by F0 group with 1.85 and finally by F3 group with 1.95 which is the highest value. FCR of the each feed group was significantly different from each other ($p < 0.05$). It was observed that a better FCR value was in broiler chicks when fed with feed prepared with fish silage which can be due to the presence of hydrolyzed protein along with the availability of essential amino acid such as histidine, threonine, methionine etc in the fish silage [34]. He also suggested that the difference found in the feed utilization may be due to the difference in raw material sources used to produce fish silage, age of animals, and bioassay conditions, can influence the broiler performance. The present study was consistent with other studies where the inclusion of fish silage at different levels did not affect the feed conversion ratio [12], [27], [6], [11] & [3]. The study conducted by [16] suggested the utilization of fish silage: soybean mixture as a promising economical alternative in broiler feeding, as the growing demand and price for fishmeal for the coming years.

Analysis of various measures of performance efficiency in broilers

Growth parameters of the chicks belonging to each treatment group were also studied including Broiler performance efficiency factor (BPEF), Weight of internal organs and livability. The data representing these parameters are presented below.

Livability(%)

Livability measures the percentage of mortality that occurred to the chicks during the period of rearing. It is reported that the normal value of livability comes to around 97 – 98 % which represents better efficiency of the chicks. The data representing the livability is given in the Table 9.It was observed that F0, F1 and F3 groups showed 100 % livability and group F2 showed a value of 96.67 %. This parameter gives a picture of the percentage of birds that stayed alive till the end of rearing until it was sold out. It helps to understand the mortality that occurred during the rearing period. In this experiment, it was observed that livability (%) was 100 for F0, F1 and F3 groups. Livability was reduced to 96.67 % for F2 and was not significantly different from other treatment groups. The details of livability was represented in Table 9. The mortality rate reported in thos study was upto 4% and it was in agreement with the standard reported by [10]. The standard mortality rate reported by [9] was 7 %. Hence the supplementation of fish silage and soybean could not have any adverse effect on the health and growth condition of the chicks. It wa observed that the variation in mortality rates can be due to the seasonal changes and this do not have any effect on treatment feeds [7]. The present experiment was in agreement with [3] who observed low mortality for all dietary treatments.

Weight of internal organs of the broiler chicks

On the last day of the rearing period, 10 birds from each group were randomly selected and sacrificed to analyze the weight of the internal organs of the chicks belonging to each group. The weight of the internal organs such as liver, gizzard, heart, proventriculus, spleen, thymus and Bursa of Fabricius. The weight of each organs were recorded and taken the average and represented in the Table 10.

The weight of the liver among the four different feed was highest for F1 group with 34.17 ± 3.35 and lowest for F3 group with 26.83 ± 3.35 g. For gizzard, it showed almost the same value for F0, F1, and F2 groups with 43 g, whereas it was least for F3 group with 31.83 ± 5.75 g. The heart was dissected and weighed which showed the highest value for F1 group with 5.25 ± 0.54 g and the lowest weight was observed for F3 group with 4.1 ± 0.54 g. The proventriculus was dissected, weighed, and found that F1 group showed the highest weight with 7.33 ± 0.4 g and the lowest value was noted for F3 group with 6.5 ± 0.4 g. Spleen was dissected, and weighed and found that F1 group showed the highest value of 1.12 ± 0.18 g and the lowest was for F0 group with 0.88 ± 0.88 g. Thymus was collected from chicks of different feed groups and found highest for F0 and F1 groups with 1.67 ± 0.42 g and the lowest value for F3 group with 0.78 ± 0.42 g. Bursa of Fabricius was highest for F0 group with 3.17 ± 0.21 g and the least value was for the F3 group with 2.67 ± 0.21 g.The effect of feed in the growth pattern of the organs can be studied by understanding the weight of the internal organs. The details of the weight of the internal organs are given in the Table.10. The growth of internal organs didn't have any adverse effect by incorporating fish silage in their diet. The weight of the internal organs in this study was in agreement with the study conducted by [3] who didn't notice any adverse effect by including fish silage in the poultry diet up to 20 %. There was no influential changes observed in the relative weight of the carcass parameters such as liver, heart, gizzard, breast and abdominal fat contents by the dietary incorporation of fish silage [7]. The present investigations are in accordance with the findings of the earlier workers who found the non-significant effect of supplementing fish viscera silage in the ration on the carcass yield of broiler chickens [20].

Broiler performance efficiency factor (BPEF)

The broiler performance efficiency factor (BPEF) was analyzed for understanding the performance efficiency of the feed with respect to the body growth and is represented in Table9. It is considered that the higher the value, better the BPEF factor. Hence a value of 100 or more is most desired to consider it as a better performance. In this study the values of BPEF showed significantly different between each group. BPEF was another criterion used for determining the efficiency of the experimental feed on the growth performance of the broiler chicks. Here as the value of BPEF is more, the better is the efficiency of the feed. The highest BPEF value was exhibited by F1 group (5 % fish silage) diet and the lowest for F3 diet (15 % fish silage). Similar values for the broiler performance efficiency factor have also been reported, aligning with the findings of the present study [29]. The range of BPEF in their study ranged from 272 - 310 within the treatment groups. From this present investigation, better efficiency was observed for F1 diet and the least performance for F3 diet.

Meat quality parameter

During the end of the rearing period, the chicks were dissected and breast muscle was collected for analyzing the meat quality parameters. The parameters analyzed were meat pH, cooking loss and sensory characteristics.

Meat pH for each feed group

Meat pH was analyzed after dissecting the breast muscle of the broiler birds from different feed groups and was checked for pH in order to understand if there is any significant difference between meats collected from different feed groups.

There was not much difference observed for different feed groups. The highest value was observed for F0 with 5.75 ± 0.01 and the lowest was observed for F3 group with 5.70 ± 0.01 even though it showed a significant difference between F0 group with F1, F2 and F3 group ($p < 0.05$).

Among the meat pH analysis F0 had shown highest pH with 5.75 which was significantly different from another treatment group. The lowest pH was for F3 with 5.70 which was prepared with 15 % fish silage. The details of meat pH of the treatment groups are given in the Table9. The results suggest that broiler chicks fed diets containing fish silage had similar meat quality characteristics as that of birds fed with the control diet The result obtained in this study was similar to the values obtained by (3) who included fish silage at various ratios of 10, 20, 30 % in the poultry diet. There were no significant differences in meat quality characteristics between dietary treatments. The values of the present study for meat pH was in comparable with the other studies reported in the literature (1).

Cooking loss (%) of each feed group

The dissected meat was analyzed to observe the difference in weight of the meat before cooking and after cooking and hence the percentage of cooking loss for the meat belonging to each treatment group was studied. The values of cooking loss (%) are represented in the Table 9. The highest cooking loss (%) was observed for F0 group with 21.05 ± 0.19 % and the lowest was observed for F1 group with 20.1 ± 0.49 %. It was observed that F0 group showed significant differences with the other three groups, F1, F2 and F3 ($p < 0.05$), whereas there was no significant difference observed between the three groups F1, F2 and F3.The cooking loss was calculated for the broiler meat by dissecting the breast muscle followed by steam cooking. It was observed from the present study that highest cooking loss was for the treatment group F0 and least for F1 group. It was also noticed that the F0 group was significantly different from other treatment group. Cooking loss, or weight loss during cooking, depicts the measurement of water holding capacity of the muscle. The observations of the present study on cooking loss were similar to the results of (2) who compared the meat quality of the chicks reared in two different housing. The observations didn't notice any significant difference between the groups.

Sensory characteristics of the cooked chicken meat

The chicken breast meat was dissected from the sacrificed broiler chicks and was steam-cooked with salt and subjected before the sensory panelists (17 members). Various sensory attributes were asked to score according to their perception. It was noticed that for all the groups aroma was scored as 1, which means that the fish taint was imperceptible. In the case of flavor for F0 group the score was 5 which depicts that the flavor was extremely desirable and for the remaining other groups it was scored as 4 which shows the slightly desirable flavor. In the case of tenderness it was given a similar scoring as 5 for F0 group which shows that the meat was extremely tender and for other groups the score was 4 which says that the meat was tender. In the case of juicines it was scored as 4 for all the treatments which says that the meat of all the groups were moderately juicy. The overall desirability all the four groups were equally scored as 4 which noticed that meat belonging to all the four treatment groups were equally desirable. Sensory scale scoring for the attributes are given in the Table 11.Sensory evaluation of the poultry breast meat was done by the panelist of 17 members to identify the difference in meat quality in comparison with control group.

It was observed that breast muscle attributes did not attribute any negative aspect by the addition of fish silage and the meat was properly accepted by the panelist. In this study a better flavor and tenderness was given by control group than treatment group. It was reported by (23) observeda lower tenderness to the broiler meat which was added with fish silage (5 %) and fish oil (1.7 - 2.5 %). In contrary, (24) reported that fish silage oil in feed (1.5 %) adversely affected the sensory quality of chicken meat (leg and breast) and caused rejection by the sensory panelists. The addition of fish oil in poultry feed (8.2 %) also produced unacceptable flavor in the meat (26). A fishy flavor in the breast meatwas noted for the poultry group which was fed with 30 % fish silage in the diet (3). He also observed that the addition of fish silage in diet up to 20 % fish silage didn't produce any fishy/off odour to the meat. The study conducted by (34) noted that the incorporation of oven dried silage in poultry diet up to 30 % didn't observe any alteration in the sensory quality of broiler meat. Hence in this study all three treatment group was within the acceptable limits when compared with control and didn't exhibit any fishy odour.

Conclusion

The poultry feed generated by incorporating fish silage is a promising technology for the efficient utilization of fish wastes. The feed was introduced to the broiler chicks which also exhibited better acceptability and body growth. The meat quality parameters analysed do not exhibit any off characteristics which may deteriorate the meat quality. Sensory acceptability of the meat was also better for the brolier chicks which was fed with feed incorporated with fish silage. The consistent availability of fish waste was further ensured by collaborating with the Fish Cutting Centre under KFDC, which assisted in procuring the required species and quantity of fish waste (Contributions). Hence a low-cost, energy-efficient poultry feed was developed from fish wastes which would be highly beneficial for backyard poultry farmers for rearing their birds

Future scope of the study

Further research can focus on optimizing the inclusion levels of fish silage to maximize poultry growth performance while maintaining feed efficiency and meat quality. Moreover further study can also be expanded by including different poultry breeds and long-term feeding trials will provide deeper insights into the broader applicability and economic viability of this feed formulation.

Conflict of interest

The authors state that there is no conflict of interest in this research work.

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Table 1: The ingredient composition of the broiler starter feed

Ingredients	F0	F1	F2	F3
Dried Fish silage	0.0	5.0	10.0	15.0
Soybean meal (S.B.M)	31.4	26.4	21.4	16.4
Maize	61.6	61.6	61.6	61.6
Premix	5.0	5.0	5.0	5.0
Oil	2.0	2.0	2.0	2.0

Note: F0*= Control feed without fish silage,* ***F1****= Feed with 5% fish silage,* ***F2****= Feed with 10% fish silage,* ***F3****= Feed with 15% fish silage*

Premix:*Protein-17.5%, Methionine-5%, Lysine-4.4%, Calcite-13.54% (Ca), DCP-5.7% (P), ME-2818 K Cal of energy*

Table 2: The ingredient composition of the broiler finisher feed

Ingredients	F0 (g)	F1 (g)	F2 (g)	F3 (g)
Dried Fish silage	0.0	5.0	10	15
Soybean meal (S.B.M)	25	20	15	10
Maize	68	68	68	68
Premix	5.0	5.0	5.0	5.0
Oil	2.0	2.0	2.0	2.0

Premix: *Protein-17.5%, Methionine-5%, Lysine-4.4%, Calcite-13.54% (Ca), DCP-5.7% (P), ME-2818 K Cal of energy*

Table 3: The proximate composition of the main feed ingredients

Ingredients	Protein (%)	Fat (%)	Ash (%)	Moisture (%)
Dried fish silage	49.07 ± 0.32	8.3 ± 0.17	26.29 ± 0.31	6.69 ± 0.02
Soybean meal (SBM)	42.5 ± 0.4	4.4 ± 0.2	9.8 ± 0.04	4.49 ± 0.36
Maize	10.94 ± 0.32	4.1 ± 0.3	2.24 ± 0.04	3.15 ± 0.05

Note: *Data are mean of triplicates ± standard deviation*

Table 4: Proximate composition of the four types of starter feed

Ingredients	Protein (%)	Fat (%)	Moisture (%)	Ash (%)
F0	22.38 ± 0.02	2.47 ± 0.15	7.84 ± 0.40	5.59 ± 0.09
F1	23.45 ± 0.04	3.37 ± 0.03	8.22 ± 0.08	6.8 ± 0.02
F2	23.55 ± 0.02	3.62 ± 0.02	8.62 ± 0.09	6.91 ± 0.05
F3	23.57 ± 0.03	3.76 ± 0.02	8.63 ± 0.11	7.03 ± 0.015

Note:1. *Data are mean of triplicates ± standard deviation*

Table 5: Proximate composition of the four types of finisher feed

Ingredients	Protein (%)	Fat (%)	Moisture (%)	Ash (%)
F0	19.37 ± 0.04	2.32 ± 0.01	7.45 ± 0.01	5.39 ± 0.01
F1	20.27 ± 0.15	3.12 ± 0.01	8.29 ± 0.05	6.45 ± 0.03
F2	20.77 ± 0.21	3.32 ± 0.02	8.53 ± 0.01	6.54 ± 0.01
F3	20.93 ± 0.21	3.52 ± 0.01	8.63 ± 0.01	6.60 ± 0.01

Note:1. *Data are mean of triplicates ± standard deviation*

Table 6: The average weekly feed intake by the broiler chicks

	Weekly feed intake (g)			
Week	**F0**	**F1**	**F2**	**F3**
1	124.04 ± 0.06^{b}	131.41 ± 0.03^{a}	134.64 ± 2.69^{a}	131.8 ± 2.07^{a}
2	342.48 ± 0.27^{c}	403.4 ± 0.07^{a}	405.51 ± 2.47^{a}	377.52 ± 0.95^{b}
3	568.21 ± 0.03^{b}	591.53 ± 0.5^{a}	523.47 ± 2.48^{d}	537.6 ± 1.58^{c}
4	611.28 ± 0.02^{b}	681.85 ± 0.03^{a}	606.2 ± 1.02^{c}	587.4 ± 1.4^{d}
5	553.72 ± 0.06^{d}	585.14 ± 1.33^{b}	611.21 ± 0.76^{a}	566.6 ± 2.98^{c}
6	521.07 ± 0.18^{c}	595.62 ± 1.22^{a}	586.53 ± 0.86^{b}	456.23 ± 1.2^{d}

Note: 1. *Data are mean of triplicates ± standard deviation. Values with different superscript letters in the same row are significantly different (p <0.05)*

Table 7: The average weekly body growth (g) of the broiler chicks

	Weekly growth (g)			
Days	**F0**	**F1**	**F2**	**F3**
1	47.1 ± 0.07^{a}	47.2 ± 0.23^{a}	47 ± 1.29^{a}	47.1 ± 0.27^{a}
7	122.3 ± 0.22^{c}	133.7 ± 0.48^{a}	129.2 ± 1.47^{b}	120.2 ± 0.11^{d}
14	340.3 ± 1.32^{c}	422.1 ± 0.3^{a}	397.2 ± 1.42^{b}	323.41 ± 0.38^{d}
21	672.7 ± 0.4^{c}	801.6 ± 0.21^{a}	757.8 ± 1.16^{b}	626.2 ± 0.08^{d}
28	982 ± 1.2^{c}	1170.3 ± 1.37^{a}	1107.7 ± 1.75^{b}	924.5 ± 0.36^{d}
35	1264 ± 0.09^{c}	1503.6 ± 1.02^{a}	1431 ± 2.1^{b}	1195.5 ± 0.34^{d}
42	1510 ± 1.29^{c}	1818.83 ± 1.83^{a}	1724.3 ± 1.21^{b}	1406.2 ± 0.11^{d}

Note:1 *Data are mean of triplicates ± standard deviation (M±SD). Values with different superscript letters in the same row are significantly different (p < 0.05)*

Table 8: Food Conversion Ratio (FCR) of the feed group

Feed	FCR
F0	1.85^{b}
F1	1.66^{d}
F2	1.71^{c}
F3	1.95^{a}

Note 1.*Values with different superscript letters in the same column are significantly different (p<0.05)*

Table 9: Livability (%), Broiler Performance Efficiency Factors (%), Meat pH, Cooking loss (%) of the broiler chicks

Feed	Livability (%)	Broiler Performance Efficiency Factors (BPEF)	Meat pH	Cooking loss (%)
F0	100^{a}	194.34^{c}	5.75 ± 0.01^{a}	21.05 ± 0.19^{a}
F1	100^{a}	260.76^{a}	5.72 ± 0.006^{b}	20.1 ± 0.49^{b}
F2	96.67 ± 5.7^{a}	232.05^{b}	5.71 ± 0.01^{b}	20.3 ± 0.24^{b}
F3	100^{a}	171.67^{d}	5.70 ± 0.01^{b}	20.5 ± 0.5^{b}

Note: 1. *Data are mean of triplicates ± standard deviation (M±SD). Values with different superscript letters in the same column are significantly different (p < 0.05)*

Table 10:Weight of internal organs of the chicks

Organs	F0	F1	F2	F3
Liver	30.5 ± 3.35^{c}	34.17 ± 3.35^{a}	33.5 ± 3.35^{b}	26.83 ± 3.35^{d}
Gizzard	43.17 ± 5.75^{a}	43.5 ± 5.75^{a}	43.33 ± 5.75^{a}	31.83 ± 5.75^{b}
Heart	4.33 ± 0.54^{b}	5.25 ± 0.54^{a}	5 ± 0.54^{a}	4.1 ± 0.54^{b}
Proventriculus	6.67 ± 0.4^{b}	7.33 ± 0.4^{a}	7.17 ± 0.4^{a}	6.5 ± 0.4^{b}
Spleen	0.88 ± 0.88^{c}	1.12 ± 0.18^{b}	1.11 ± 0.18^{b}	1.33 ± 0.2^{a}
Thymus	1.67 ± 0.42^{a}	1.67 ± 0.42^{a}	1.5 ± 0.42^{b}	0.78 ± 0.42^{c}
Bursa of fabricius	3.17 ± 0.21^{a}	3 ± 0.21^{a}	3 ± 0.21^{a}	2.67 ± 0.21^{b}

Note: 1. *Data are mean of triplicates ± standard deviation (M±SD). Values with different superscript letters in the same row are significantly different (p <0.05)*

Table 11: Sensory evaluation scores of the cooked breast muscle

Sensory attributes	F0	F1	F2	F3
Aroma	1	1	1	1
Flavor	5	4	4	4
Tenderness	5	4	4	4
Juiciness	4	4	4	4
Overall disirability	4	4	4	4

References

1. Abdullah, Y., Al-Beitawi, N., Rjoup, M.M.S., Qudsieh, R.I., & Ishmais, M.A. (2010). Growth performance, carcass and meat quality characteristics of different commercial crosses of broiler strains of chicken. *The Journal of Poultry Science*, 47(1), 13–21.

2. Aisha, S.M.F., El-Tinay, A.H(2004). Effect of genotype, malt pretreatment and cooking on invitro protein digestibility and protein fractions of corn. Food Chemistry., 84: 613-619

3. Al-Marzooqi, W., Kadim, I.T., Mahgoub, O. (2010). Ileal amino acids digestability coefficients of fish silage, fish meal and soyabean meal in broiler chickens. *Book of Proceedings.* 2nd Mediterraean Summit of WPSA. 459-464

4. Anuraj, K.S., Sreeparvathy, M., Shyama, K., Dipu, M.T.,Hari, R.(2014). Dried tuna waste silage as an alternate protein source for swine feeding. Indian Journal of Science and Technology., 2(3):49-52

5. Banaszkiewicz, T.(2011). Nutritional value of soybean meal. In Soybean and nutrition. InTech

6. Betancourt, L., Díaz, G.J., Aguilar, X., Ríos, J.(2005). Effect of ensiled trout (Oncorhynchus mykiss) intestines on productive traits of broiler chickens and the content of omega-3 fatty acids in liver, thighs and breast. Livestock Research for Rural Development, 17(9), p.106

7. Boitai, S.S., Babu, L.K., Pati, P.K., Pradhan, C.R., Tanuja, S., Kumar, A. Panda, A.K.(2018). Effect of dietary incorporation of fish silage on growth performance, serum biochemical parameters and carcass characteristics of broiler chicken. Indian Journal of Animal Research, 52(7): 1-5

8. BorghesI, R. (2004). Physico-chemical, nutritional and biological evaluation of acid, biological and enzymatic silages elaborated with discard and residue of the Nile Tilapia (*Oreochromisniloticus*). (Doctoral dissertation, University of São Paulo) 108p

9. Bulgen, A.(1996). Aviculture semi industrielle en climat tropical. Pressseagronomique de gembloux, p: 122.

10. Darsan, M.G., Sreekumar, K.P.Jalaludeen, A. (2009). Effect of feeding processed fish wastes on the growth and haematology of broilers. Indian Journal of Poultry Science. 44: 213-217.

11. Delgado, H. S., E. A. Sotelo. (2008). Preparation silage from Spanish mackerel (*Scomberomorus maculates*) and its evaluation in broiler diets. Animal Feed Science and Technology.141:129-135.

12. Espe, M., Haaland, H.Njaa, L.R., (1992). Substitution of fish silage protein and a free amino acid mixture for fish meal protein in a chicken diet. Journal of the Science of Food & Agriculture. *58*(3): 315-319.

13. FAO. 2003, Animal feed resources information system. http://www.fao.org.

14. Friedman, M., (1996). Nutritional value of proteins from different food sources. A review. Journal of Agriculture and Food Chemistry. 44(1): 6-29.

15. Ghaly, A.E., Ramakrishnan, V.V., Brooks, M.S., Budge, S.M. Dave, D.(2013). Fish Processing Wastes as a Potential Source of Proteins. Amino Acids and Oils: A Critical Review, Journal of Microbial Biochemical Technology. 5(4): 107-129.

16. Hardy, R.W.(2010). Utilization of plant proteins in fish diets: effects of global demand and supplies of fishmeal. Aquaculture Research. 41(5): 770-776.

17. Honczaryk, A. Maeda, L.S. (1998). Crescimento do pirarucu, *arapaima gigas*, utilizandodieta à base de ensiladobiológico de pescado. In: SimpósioBrasileiro de Aqüicultura, 10, *Anais. Recife: Persona,* 2, 93-100

18. Ikram, E.H.K., Eng, K.H., Jalil, A.M.M., Ismail, A., Idris, S., Azlan, A., Nazri, H.S.M., Diton, N.A.M.Mokhtar, R.A.M. (2009). Ora antioxidant capacity and total phenolic content of Malaysian underutilised fruits.

19. Jackson, A.J., Kerr, A.K.Cowey, C.B.(1984). Fish silage as a dietary ingredient for salmon. I. Nutritional and storage characteristics. Aquaculture. 38(3): 211-220

20. Javeed, A. Mahendrakar, N.S.(1996). Growth and meat quality of broiler chicks fed with fermented fish viscera silage. International Journal of Animal Science 11(1):.1-5.

21. Johnson, R. J., Brown, R., Eason, P. Sumner, J. (1985). The nutritional quality of two types of fish silage for broiler chickens. Journal of Science Food andAgriculture.36:1051-1056

22. Kataria, A., Chauhan, B. M. Punia, D. (1989). Antinutrients and protein digestibility (in vitro) of mung bean as affected by domestic processing and cooking. Food Chemistry. 32: 9-17.

23. Kjos, N.P., Herstad, O., Skrede, A. Øverland, M.(2001). Effects of dietary fish silage and fish fat on performance and egg quality of laying hens. Canadian Journal ofAnimal Science. 81(2), .245-251.

24. Krogdahl Å. (1985). Fish viscera silage as a protein source for poultry. 2. Experiments with meat-type chickens and ducks. ActaAgriScand A Animal Sci. 35: 24-32.

25. Lessi, E., Ximenes Carneiro, A. R. Lupin, H. M. (1989). Obtención de ensiladobiológico. In: Consulta de ExpertossobreTecnologia de ProductosPesqueros en America Latina, 2, Montevideo, Anais. Roma: FAO, 8p.

26. Lopez-Ferrer S, Baucells M.D, Barroeta A.C, Grashorn M.A. (1999). n-3 enrichment of chicken meat using fish oil: Alternative substitution with rapeseed and linseed oils. Poultry Science. 78: 356-365

27. Magana, L., Avila, E. Sotelo, A.(1999). Silage preparation from tuna fish wastes and its nutritional evaluation in broilers. Journal of the Science of Food and Agriculture.79(13):1915–1922

28. Malomo, G.A., Suleiman, Z.G., Bolu, S.A.Egberuare, T.A.(2013). Assessment of the Nutrient Contents of Finished Broiler Starter and Finisher Diets in Nigeria. Journal of Agriculture Research & Development. 12(1): 75-78

29. Murugan, M.Ragavan, A.(2017). Broiler Performance Efficiency Factor (BPEF) in Commercial Broiler Production Facilities with Special Reference to Climate. The Indian Veterinary Journal. 94 (03): 11 - 14

30. Nwokola, E.,Sim, J.(1990). Comparative Evaluation of Fermented Fish Waste, Fermented Whole Herring, and Fish Meal. Poultry Science, 69(2): 270-275

31. Oetterer, M., 2002. *Industrialização do pescadocultivado*. Guaíba: Agropecuária, 200p.

32. Raa, J., Gildberg, A.(1982). Fish silage: a review. *CRC* Critical Reviews in Food Science and Nutrition.16: 383-419

33. Raj, R., Varghese, S., Tabassum, A. (2020). Quality characteristics and stability of chicken cutlet fortified with Fish Protein Hydrolysate (FPH). Fishery Technology.57: 108-114

34. Ramirez, J.C.R., Espain, J.I.I., Leyva, R.G., Ulloa, J.A., Ulloa, P.R. (2016). Use of biological fish silage in broilers feed: Effect on growth performance and meat quality. Journal ofAnimal andPlant Science. 27 (3): 4293-4304

35. Ramírez, J.C.R., Ibarra, J.I., Romero, F.A., Ulloa, P.R., Ulloa, J.A., Matsumoto, K.S., Cordoba, B.V.,Manzano, M.Á.M.(2013). Preparation of biological fish silage and its effect on the performance and meat quality characteristics of quails (Coturnixcoturnix japonica). Brazilian Archives of Biology and Technology. 56 (6): 1002-1010

36. Roy, B.C., Ranvig, H., Chowdhury, S.D., Rashid, M.M. Chwalibog, A. (2004). Evaluation of compound broiler feeds manufactured in Bangladesh. Livestock Research for Rural Development , 16(11): 1-8

37. Strzetelski, J. (2006). The possibility of feeding cattle with byproducts of deep pressing of oil from oilseeds and bioethanol by products (in Polish), Wiadomości Zootechniczne, 44(3): 56-66

38. Vakili, R., Torshizi, M.E., Yaghobzadeh, M.M. Khadivi, H. (2015). Determination of Chemical Composition and Physical Feed Quality with Different Processing Parameters in Broiler Feed Mill Factories. In Biological Forum 7(1): 1098-1103

39. Wignall, J., Tatterson, I. (1976). Fish silage. Process Biochemistry., 11(10), 17-19

40. Zhuang, H., Savage, E.M.(2013). Comparison of cook loss, shear force, and sensory descriptive profiles of boneless skinless white meat cooked from a frozen or thawed state. Poultry. Science., 92(11): 3003-3009.