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Research Article

Effects of Partial Replacement of Fishmeal by Locally Available Ingredients on Growth Performance and Feed Utilization Efficiency of Nile Tilapia, *Oreochromis niloticus*

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ABSTRACT

The present study was aimed at evaluating the effects of partial replacement of fishmeal with locally available feed ingredients on growth performance, feed utilization efficiency body composition and apparent digestibility coefficient of protein (ADCp) of Nile tilapia. For this purpose, seven experimental diets were prepared using 0%, 10% and 20% Jatropha, Alfalfa and Brewery waste as partial replacement of fishmeal. Healthy mixed-sex Nile tilapia with an average body weight of 6.5 ± 0.56 g were collected from Ziway Fish and Other Aquatic Life Research Center and stocked in fiberglass plastic tanks in triplicates at a stocking density of 20 fish per tank. The fish were fed three times a day with a control diet for one week and then with experimental diets for a period of four months at a rate of 3-6% body weight of fish. For ADCp studies, fish were reared for 20 days and were fed with control and test diets having an internal marker. Data were collected twice a month. The result showed that the fish fed with control diet,10%Jatropha, 10% Alfalfa and 10% and 20% Brewery waste based diets showed significantly better final body weight (28.7-30.0 g) specific growth rates (1.39-1.47%/day),feed conversion ratio (1.44-1.56) and protein utilization efficiency (0.60-0.66) than the fish fed with 20% Jatropha and Alfalfa based diets (23.8-26.0 g for final body weight, 1.25-1.33%/day for specific growth rate, 1.95-1.97 for food conversion ratio and 0.49-0.54 for protein utilization efficiency). The final survival rates of the experimental fish (73.3-86.6%) did not differ significantly (P>0.05) among feeding treatments. In conclusion, the fish meal can be replaced using the three ingredients up to 10% without negative effects on the growth and feed utilization of Nile tilapia.

Keywords: Feed ingredients; Growth performance; Digestibility; growth; Nutrition; Recirculation system

INTRODUCTION

Now-a-days, the demand for fish food is increasing rapidly due to its high nutritional values, the rise of animal protein price, and rapid human population growth [1], which create demand and supply gap. It is in this regard, aquaculture plays a major role to fill this gap. Currently, fish production has increased from 61.8 million tons in 2011 to 80 million tons in 2016 [2]. This spectacular increase in production was attributed to species diversification, system diversification, and adoption of improved and new aquaculture technologies [1,3]. Although several fish species are being included as candidate species for culture, still tilapia occupies a better position in freshwater aquaculture. According to FAO [2], tilapia is the second most important species next to carps contributing about 17% of the total aquaculture production. Among several tilapia species, the most commercially cultured species is Nile tilapia [1]. This is due to its cultivable characteristics such as its social preferences, tolerance to stress and diseases and, suitable to grow in a wide range of environmental conditions, feeding at the lower food chain, and easy to improve its growth and feed utilization performance through selective breeding [4,5].

Although several factors affecting for increasing Nile tilapia production, the increasing of feed cost, which constitutes about 50 to 70% of the total operational cost of aquaculture particularly for intensive and super-intensive farming, is the main challenge affecting the overall production of the fish [6] . The main factors for the high cost of fish feed are rapid growth of the aquaculture industry, limited sources of quality fish feed ingredients such as fish meal, fish oil, and soybean meal [7,8], and also a high demand for human consumption. It is recognized that developing a better quality fish diet from locally available feed ingredients is considered

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alternative feed ingredient to the fishmeal that can be one of the most important inputs in aquaculture development [6]. Thus, there is a need to find an alternate sources of protein to develop low-cost fish feed to replace these costly feed ingredients. In this regard, Jatropha, Alfalfa, and Brewery waste can be some potential plant feed ingredients in the future to partially replace a fishmeal as they have relatively good protein sources. Therefore, the main objective of this study was to evaluate these locally available feed ingredients as partial replacement of fishmeal and their effects on digestibility, growth performance and feed utilization efficiency and body composition of Nile tilapia.

MATERIALS AND METHODS

Collection of feed ingredient and feed formulation

The study was conducted at Ziway Fish and Other Aquatic Life Research Center (ZFOALRC). It is geographically found in Ziway town located at 7'9°N and 37'° E with an elevation of 1638 m above sea level. The center is located 162 km southeastern part of Addis Ababa the capital city of Ethiopia. Two types of experimental diets were formulated. The first type of diets was formulated to evaluate the digestibility of three plant ingredients, while the second type of diets was formulated to evaluate the effects of different level of replacement of fish meal with the three different feed ingredients on the growth performance, feed utilization efficiency and body composition of the Nile tilapia. The three experimental plant feed ingredients, Jatropha leaf, Alfalfa leaf, and Brewery waste were collected from different localities, while the basal feed ingredients such as bone meal, wheat bran, fishmeal, chromium trioxide (CrO_3), and minimal and vitamin premix were purchased from the local market. All the ingredients were oven-dried at 600°C for 24 hrs and were powdered using an electric grinding machine. For digestibility test, four diets i.e., one control diet, basal diet, and three 30% of Jatropha, Alfalfa, and Brewery waste-based diets mixed with 70% basal diets were prepared Table 1. All the reference and test diets were mixed with 0.5% chromium trioxides as an internal marker [9]. For growth performance evaluation, seven experimental diets, one control diet, and six (10% and 20% of each of the three test ingredients) test diets were formulated as described in Table 2. All the diets were then mixed with water and pelleted using a pelleting machine and dried in an oven at 600°C for 24 hrs. The pellet was then broken into 0.2 mm diameter pellets using an electric crusher machine and was kept in polyethylene plastic bags and preserved at 40°C in a refrigerator. The apparent digestibility coefficient and proximate composition of all formulated diets were analyzed.

Table 1: Amount of ingredients in gram per kilogram used for apparent protein digestibility test and their proximate nutrient composition.

Ingredients	Test diet				Proximate nutrient composition					
	Control diet	30% ABD	30% JBD	30% BBD	DM	CP	CL	CF	NFE	Ash
Fish meal	153.5	107.4	107.4	107.4	925.8	464	133	46	74.2	222.3
Bone meal	153.5	107.4	107.4	107.4	924.7	641.4	225.7	84	102.6	202.9
Wheat bran meal	678	475	475	475	913.3	133	109.2	86	21.28	133
Alfalfa	0	298.2	0	0	906.1	189	84.8	103	30.2	108.8
Jatropha	0	0	298.2	0	913.7	96.3	53.3	86	15.41	97.7
Brewery waste	0	0	0	298.2	843	146	171.6	83	23.4	76
Chromic oxide	5	5	5	5						
Premix (Equal amount of mineral and vitamin)	10	7	7	7						

NB.N.B. Control diet (for Treatment I), 30% ABD is 30% Alfalfa based diets, (for Treatment II), 30% JBD is 30% *Jatropha* based diets, (for Treatment III), 30% BBD is 30% brewery waste based diets (for Treatment IV), DM= Dry Matter, CP=Crude Protein, CL=Crude Lipid, CF=Crude Fiber, NFE=Nitrogen Free Extract

Table 2: Amount of ingredients in gram per kilogram and their replacement level.

Type of ingredients	Types of diet						
	Control diet	Alfalfa based diet (ABD)		Jatropha based diet (JBD)		Brewery waste based diet (BBD)	
		g/kg (10% ABD)	g/kg (20% ABD)	g/kg (10% JBD)	g/kg (20% JBD)	g/kg (10% BBD)	g/kg (20% BBD)
Fish meal	267.8	241	214.2	241.1	214.2	241	214.2
Bone meal	267.8	267.8	267.8	267.8	267.8	267.8	267.8
Wheat bran	454.4	454.4	454.4	454.4	454.4	454.4	454.4
Alfalfa leaf	0	26.8	53.6	-	-	-	-
Jatropha leaf	0	-	-	26.8	53.6	-	-
Brewery Waste	0	-	-	-	-	26.8	53.6
Premix (equal amount of mineral and vitamin)	10	10	10	10	10	10	10
Total in g	1000	1000	1000	1000	1000	1000	1000

N.B. Control is control diet, (for Treatment I), 10% ABD is 10% Alfalfa based diet (for Treatment II), 20% ABD is 20% Alfalfa based diet (for Treatment III), 10% JBD is 10% *Jatropha* based diet (for Treatment IV), 20% JBD is 20% *Jatropha* based diet (for Treatment V), 10% BBD is 10% brewery waste based diet (Treatment for VI), and 20% BBD is 20% brewery waste based diet (for Treatment VII).

Experimental fish and design

For digestibility test, a total of 240 healthy mixed Nile tilapia fingerlings with an initial body weight of 26 ± 1.3 g were randomly sampled from ZFOALRC in October 2019 and stocked in 12 fiberglass plastic tanks in triplicates at a stocking density of 20 fingerlings per tank. The fish were then fed three times a day at 3% of the body weight of the fish daily. For growth performance evaluation, a total of 420 healthy mixed-sexes Nile tilapia fingerings with an initial body weight of 6.5 ± 0.56 g collected from the same research center were stocked in 21 fiberglass plastic tanks in triplicates at a stocking density of 20 fish per tanks having 100 litter water capacities. The fish were then acclimatized for one week and were fed three times a day with a control diet at 6% of their body weight daily. After a week, the fish were fed with different experimental diets at 6% body weight of fish for two months, subsequently reduced to 3% for the remaining two months. The amount of the feed was adjusted based on the general standards of the National Research Council, NRC, [10] guideline required for Nile tilapia cultured in the water recirculation system. Uneaten feed and faeces were continuously removed by siphoning.

Data collection and analysis

From the first experiment, faeces were collected from each tank following the method used by Obirikorang [11]. The samples were then transferred to a centrifuge tube and revolved for 10 minutes to discard the supernatant. The settled faecal waste was oven-dried at 60°C for 24 hrs and stored at 4°C for analysis. For the second experiment, body measurements such as body weight and body length of the fish were recorded to the nearest of 0.1 g and 0.1 cm using a sensitive electronic weighing balance (LD610-2) and a ruler by taking 50% of the fish every 15 days interval. The mortality of the fry was recorded daily. At the end of the experiment, the final body weight and length of all fish were recorded for growth evaluation. Later, three fish from each tank were randomly sampled and slaughtered for fillet sampling and then body nutrient composition such as dry matter content (DM), crude protein (CP), crude lipid (CL), crude fiber (CF), ash content and nitrogen-free extract (NFE) were analyzed. Water quality parameters such as water temperature, pH, dissolved oxygen, conductivity and total dissolved solids were measured regularly using Potable Multi-Parameter Kit. Total ammonia concentration was recorded once a week by titration method.

Using data recorded, the following growth parameters were calculated using the formula described by Eyo [12].

I. Apparent protein digestibility coefficient (APDC)

- The APDC of the control ($APDC_{cd}$) and test ($APDC_{td}$) diets were calculated as: $APDC = 100 \times [1\text{-}(F/D) \times (D_i/F_i)]$ (where; D = percent nutrient of diet, F = percent nutrient of faces, D_i = percent of CrO_3 of diet and F_i = percent of CrO_3 of faces
- The apparent protein digestibility of the test diet (APDCti) was calculated as: $APDC_{ti} = APDC_{td} + [(APDC_{td} - APDC_{rd}) (0.7 \times Dr/0.3\ xD_i)]$ where; D_r = percent of nutrient of reference diet, Di = percent of nutrient of test ingredients

II. Growth performance

- Body weight gain (BWG) = Final body weight (FBW) – Initial body weight (IBW)
- Daily growth rate(DGR) = Body weight gain/Number of experimental days
- Specific growth rate (SGR% per day) = ((LnFBW- LnIBW)/ Number of days) × 100

III. Feed utilization efficiency

- Food conversion ratio (FCR) =Amount of dry food intake/ Weight gain
- Protein efficiency ratio (PER)= Body weight gain/amount of crude protein

IV. Survival rate and condition factors

- Survival rate (SR%) = Number of harvested fish/Number of stocked fish ×100
- Condition factor (CF) = Final body weight/ (Final body length 3) ×100

Finally, based on the data recorded basic statistics were computed using SAS versions 9. The significant difference of each treatment on growth, feed utilization and body composition were computed using one-way ANOVA (Analysis of Variance) in SAS version 9 software package. For between treatments significant variation, a comparison of the different parameters was performed using Tukey HSD standardized range test α = 0.05 level of significance comparison.

RESULTS

Apparent protein digestibility coefficient

The apparent protein digestibility coefficient of the control and the three test diets is presented in Table 3. The results showed that the apparent protein digestibility of diets ranged from 68.2-88.1%, in which the control diet has the highest apparent digestibility coefficient compared to the test diets. The significantly ($P < 0.05$) lower apparent protein digestibility coefficient was recorded for Alfalfa based diets than for the test ingredients.

Growth performance and feed utilization efficiency

The growth performance of Nile tilapia feed with different diets is presented in Table 4. The results showed that the fish fed with the control diet showed the highest growth performance (FBW=30.0 ± 0.1 g, WBG=23.6 ± 0.20 g and SGR=1.47 ± 0.01), while the fish fed with 20% Alfalfa-based diet was the lowest (FBW=23.8 ± 0.10 g, WBG=17.4 ± 0.10 g and SGR=1.25 ± 0.05). The fish fed with the control diet, 10% Alfalfa, 10% Jatropha and 10% and 20% Brewery waste-based diets had significantly ($P < 0.05$) higher growth performance than fish fed with 20% Alfalfa and Jatropha based diets Table 3. Moreover, except for the fish fed with 20% Alfalfa and Jatropha based diets, the progress of the growth performance of the fish was the same (Figure 1).

The feed conversion ratio (FCR), protein efficiency ratio (PER) and Fulton condition factor (FCF) of the fish feed with control and experiment diets are presented in Table 5. The fish fed with the control diet had the lowest feed conversion ratio (1.44 ± 0.02) with highest protein efficiency ratio (0.66 ± 0.01); while the fish fed with 20% Alfalfa based diet had the highest feed conversion ratio

Table 3: Apparent Protein Digestibility Coefficient (APDC) of experimental diets.

Parameters	Types of diets used			
	Control diet	30% ABD	30% JBA	30% BBD
Crude protein in diet	36	35	35.7	35.8
CrO_3 in diet	4.8	4.5	4.6	4.6
Crude protein in faeces	4.7	9.6	5.6	6.2
CrO_3 in faeces	4.7	4.4	4.4	4.5
APDC in %	88.1 ± 0.4[a]	85.7 ± 0.6[a]	85.2 ± 0.9[a]	68.2 ± 0.3[b]

NB. Control diet (treatment I), 30% ABD is 30% Alfalfa based diets, (Treatment II), 30% JBD is 30% *Jatropha* based diets, (Treatment III), 30% BBD is 30% brewery waste based diets (Treatment IV), all the four treatments were triplicates.

Table 4: Mean values of different growth parameters such as Initial Body Weight (IBW), Initial Body Length (IBL), Final Body Weight (FBW), Final Body Length (FBL), Body Weight Gain (BWG), Body Length Gain (BLG), Daily Growth Rate (DGR) and Specific Growth Rate (SGR) and their standard errors.

Diet	IBW (g)	IBL (cm)	FBW (g)	FBL (cm)	BWG (g)	BLG (cm)	DGR (g/day)	SGR (SGR %/ day
Control diet	6.40 ± 0.1[a]	7.4 ± 0.6[a]	30.0 ± 0.1[a]	13.3 ± 0.10[a]	23.6 ± 0.20[a]	5.80 ± 0.10[a]	0.23 ± 0.0[a]	1.47 ± 0.01[a]
10% ABD	6.53 ± 0.14[a]	7.49 ± 0.14[a]	28.8 ± 0.02[a]	13.2 ± 0.14[a]	22.3 ± 0.17[a]	5.78 ± 0.15[a]	0.21 ± 0.01[a]	1.42 ± 0.02[a]
20% ABD	6.45 ± 0.02[a]	7.27 ± 0.3[a]	23.8 ± 0.10[b]	12.5 ± 0.07[b]	17.4 ± 0.10[b]	5.26 ± 0.07[b]	0.16 ± 0.01[c]	1.25 ± 0.05[c]
10% JBD	6.57 ± 0.06[a]	7.33 ± 0.09[a]	29.3 ± 0.45[a]	13.1 ± 0.02[a]	22.5 ± 0.05[a]	5.76 ± 0.04 [a]	0.21 ± 0.01[a]	1.39 ± 0.01[a]
20% JBD	6.43 ± 0.08[a]	7.35 ± 0.2[a]	26.0 ± 0.30[b]	12.5 ± 0.05[b]	19.6 ± 0.02[b]	5.12 ± 0.02[b]	0.19 ± 0.01[b]	1.33 ± 0.01[b]
10% BBD	6.48 ± 0.01[a]	7.41 ± 0.06[a]	29.2 ± 0.25[a]	13.2 ± 0.10[a]	22.7 ± 0.02[a]	5.79 ± 0.07[a]	0.22 ± 0.01[a]	1.43 ± 0.00[a]
20% BBD	6.43 ± 0.06[a]	7.37 ± 0.02[a]	28.7 ± 0.68[a]	13.0 ± 0.04[a]	22.5 ± 0.74[a]	5.75 ± 0.02[a]	0.21 ± 0.01[a]	1.42 ± 0.03[a]

NB means with different superscript are significantly different, Control is control diet, (Treatment I), 10% ABD is 10% Alfalfa based diet (Treatment II), 20% ABD is 20% Alfalfa based diet (Treatment III), 10% JBD is 10% *Jatropha* based diet (Treatment IV), 20% JBD is 20% *Jatropha* based diet (Treatment V), 10% BBD is 10% brewery waste based diet (Treatment VI), and 20% BBD is 20% brewery waste based diet (Treatment VII), where all treatments were triplicates.

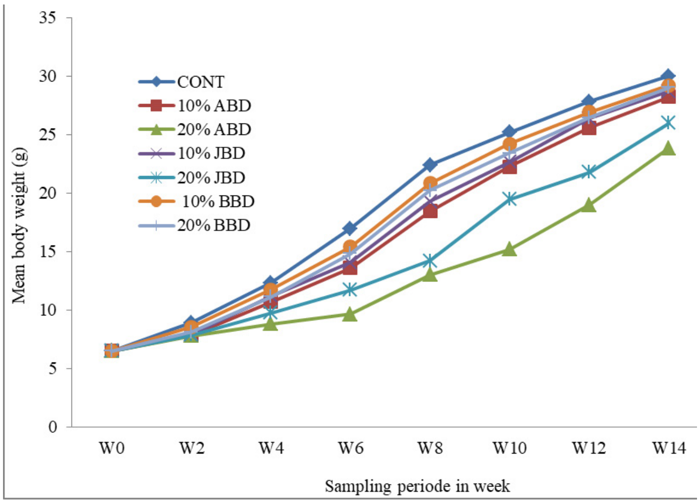

Figure 1: The weight of experimental Nile tilapia during sampling week, where W_o to W_{14} are numbers of rearing weeks from Zero to 14 weeks, CONT is control diet, 10% ABD is 10% Alfalfa based diet, 20% ABD is 20% Alfalfa based diet, 10% JBD is 10% Jatropha based diet, 20% JBD is 20% Jatropha based diet, 10% BBD is 10% brewery waste based diet and 20% BBD is 20% brewery waste based diet.

(1.97 ± 0.01) with the lowest protein efficiency ratio (0.49 ± 0.02). Statistically, the fish fed with the control diet had significantly lower feed conversion ratio with a significantly higher protein efficiency ratio than the fish fed with 20% Alfalfa based diet. However, the condition factor was similar in all groups of fish. The mean survival rates of Nile tilapia at different levels of fish meal replacement ranged from 73.3% to 86.6% in which the fish fed at 20% Jatropha based diet and control diets showed the minimum and maximum survival rates.

Diet and fish body nutrient compositions

The proximate compositions of the control and experimental diets together with the body composition of the fish fillet are presented in Table 6. The results showed that the proximate composition of the diets had the highest lipid content (7.80 ± 2.2 - 14.3 ± 2.4%) and fiber content (7.3 ± 2.4 - 10.3 ± 3.1%) were significantly different ($P < 0.05$) from at least form their lowest values. However, dry matter content (90.4 ± 3.6 - 92.6 ± 3.2%), crude protein (35.7 ± 1.5 - 36.0 ± 1.9%), ash content (10.6 ± 3.1 - 13.2 ± 2.1%) and NFE (5.71 ± 1.2 - 5.78 ± 1.6%) were not significantly different among diets ($P > 0.05$). Similarly, the fish fillet composition such as crude protein (54.0 ± 1.3 - 56.3 ± 2.1%) and crude fiber (30.1 ± 0.8 - 31.2 ± 0.9%) was not significantly different among treatments. In other hands, the fish fed with 20% JBD had the lowest ash content (13.9 ± 1.73%) and was significantly lower than the rest of the treatments.

Water quality parameters

The results of the water quality parameters are presented in Table 7. The temperature ranged from 25.7 to 29.2° C, pH from 7.57 ± 0.05 to 7.61 ± 0.05, DO from 3.68 ± 0.02 to 3.75 ± 0.02 mg L^{-1} and NH_4 from 0.18 ± 0.05 to 0.19 ± 0.01 mg L^{-1}. The water quality parameters observed during the experimental period due to different diets were not statistically significant.

DISCUSSION

Apparent protein digestibility coefficient

The present results of APDC for Brewery waste (85.2%) and Jatropha (85.7%) used as a replacement of fishmeal were within

Table 5: Mean value of feed utilization such as Feed Conversion Ratio ((FCR) and Protein Efficiency Ratio ((PER) and Fulton condition factor ((K) and Survival rate ((SV) with their standard error.

Diet	FCR	PER	K	SR
Control	1.44 ± 0.02[a]	0.66 ± 0.01[a]	1.32a ± 0.01[a]	86.7 ± 0.01[a]
10% ABD	1.56 ± 0.20 [a]	0.62 ± 0.04[a]	1.24a ± 0.04[a]	83.3 ± 0.04[a]
20% ABD	1.97 ± 0.01[b]	0.49 ± 0.02[b]	1.22a ± 0.02[a]	76.7a ± 0.02[a]
10% JBD	1.54 ± 0.06[a]	0.60 ± 0.02[a]	1.26 ± 0.02[a]	76.7 ± 0.02[a]
20% JBD	1.95 ± 0.02[b]	0.54 ± 0.08[ab]	1.34 ± 0.08[a]	80.3 ± 0.08[a]
10% BBD	1.54 ± 0.06[a]	0.64 ± 0.01[a]	1.28 ± 0.01[a]	76.7 ± 0.01[a]
20% BBD	1.55 ± 0.05[a]	0.62 ± 0.04[a]	1.27 ± 0.04[a]	73.3 ± 0.04[a]

NB: Control is control diet, ((Treatment V), 10% ABD is 10% Alfalfa based diet ((Treatment II), 20% ABD is 20% Alfalfa based diet ((Treatment III), 10% JBD is 10% *Jatropha* based diet ((Treatment IV), 20% JBD is 20% *Jatropha* based diet ((Treatment V), 10% BBD is 10% brewery waste based diet ((Treatment VI), and 20% BBD is 20% brewery waste based diet ((Treatment VII), where all treatments were triplicates
Superscripted letters show statistically significant results

Table 6: Proximate compositions of diets and fillet ((Dry Mater Content ((DM), Crude Protein ((CP), Crude Lipid ((CL), Crude Fiber, Nitrogen Free extract and ash content).

Diets	Nutrient composition of diets							Nutrient composition of fillet		
	DM ((%)	CP (%)	CL (%)	CF (%)	NFE	Energy (kJ/g)	Ash (%)	CP (%)	CL (%)	Ash (%)
Control	92.6 ± 3.2[a]	36.0 ± 1.9[a]	9.8.3 ± 2.4[a]	7.3 ± 2.4[a]	5.8 ± 1.4[a]	9.1 ± 2.9[a]	10.8 ± 3.3[a]	56.3 ± 2.1[a]	31.2 ± 0.90[a]	19.1 ± 1.30[a]
10% ABD	91.3 ± 3.6[a]	35.7 ± 1.5[a]	9.1 ± 2.2[b]	8.5 ± 2.7[ab]	5.7 ± 1.4[a]	9.0 ± 2.2[a]	12.4 ± 3.2[a]	55.5 ± 1.8[a]	31.7 ± 0.20[a]	17.5 ± 2.06[a]
20% ABD	92.0 (± 3.9[a]	35.8 ± 2.0[a]	8.8 ± 2.3[b]	8.9 ± 2.7[ab]	5.7 ± 1.6[a]	8.8 ± 2.3[a]	11.3 ± 2.8[a]	53.7 ± 1.4[a]	31.6 ± 1.10[a]	19.1 ± 0.3[a]
10% JBD	92.3 ± 3.8[a]	36.0 ± 1.9[a]	9.6 ± 2.1b[c]	9.2 ± 2.9[ab]	5.8 ± 2.1[a]	8.9 ± 2.6[a]	10.6 ± 3.1[a]	55.4 ± 1.5[a]	30.6 ± 0.93[a]	17.3 ± 1.73[a]
20% JBD	90.4 ± 3.6[a]	36.0 ± 2.0[a]	7.80 ± 2.2[c]	10.2 ± 3.1b	5.8 ± 1.8[a]	8.9 ± 2.4[a]	13.2 ± 2.1[a]	54.3 ± 1.5[a]	30.6 ± 1.14[a]	13.9 ± 1.73[b]
10% BBD	91.6 ± 3.9[a]	35.8 ± 1.7[a]	9.2 ± 2.1[bc]	9.7 ± 2.5[ab]	5.7 ± 1.4[a]	9.0 ± 3.1[a]	12.6 ± 3.0[a]	55.5 ± 2.8[a]	31.2 ± 0.18[a]	21.4 ± 1.38[a]
20% BBD	90.7 ± 3.4[a]	36.0 ± 1.9[a]	8.50 ± 2.1[bc]	8.3 ± 2.1[ab]	5.8 ± 1.2[a]	8.8 ± 2.8[a]	10.5 ± 2.7[a]	54.0 ± 1.3[a]	30.1 ± 0.80[a]	20.4 ± 1.00[a]

NB: Control is control diet, ((Treatment V), 10% ABD is 10% Alfalfa based diet ((Treatment II), 20% ABD is 20% Alfalfa based diet ((Treatment III), 10% JBD is 10% *Jatropha* based diet ((Treatment IV), 20% JBD is 20% *Jatropha* based diet ((Treatment V), 10% BBD is 10% brewery waste based diet ((Treatment VI), and 20% BBD is 20% brewery waste based diet ((Treatment VII), where all treatments were triplicates
Superscripted letters show statistically significant results

Table 7: Overall water quality parameters of recirculation tank.

Parameters				
Temperature	pH	Dissolved oxygen	NH_4^+	
Control (	27.1 ± 0.05[a]	7.61 ± 0.05[a]	3.75 ± 0.01[a]	0.19 ± 0.01[a]
10% ABD	27.4 ± 0.07[a]	7.60 ± 0.05[a]	3.75 ± 0.02[a]	0.18 ± 0.05[a]
20% ABD	27.3 ± 0.17[a]	7.60 ± 0.04[a]	3.74 ± 0.04[a]	0.19 ± 0.06[a]
10% JBD	27.2 ± 0.08[a]	7.59 ± 0.02[a]	3.72 ± 0.02[a]	0.18 ± 0.05[a]
20% JBD	27.1 ± 0.65[a]	7.58 ± 0.01[a]	3.72 ± 0.01[a]	0.18 ± 0.07[a]
10% BBD	27.1 ± 0.06[a]	7.58 ± 0.01[a]	3.69 ± 0.02[a]	0.19 ± 0.01[a]
20% BBD	27.1 ± 0.55[a]	7.57 ± 0.05[a]	3.68 ± 0.02[a]	0.175 ± 0.06[a]

Superscripted letters show statistically significant results

the range recommended by National Research Council, NRC [10] who reported that APDC of ingredients above 70% was considered as good. However, APDC for the Alfalfa diet (68.2%) failed below the recommended range of APDC for Nile tilapia reported by NRC [10]. However, according to Bhujel [13], APDC above 60% is recommended in which the result obtained for Alfalfa in the present study is within the range of this recommendation.

Effects of different diets on growth feed utilization and body compositions

The present results showed that up to 10% fishmeal replacement with Alfalfa did not significantly affect the growth performance and feed utilization of Nile tilapia and was higher than the value reported by Ali [14] and Chatzifotis [15] who reported that fishmeal replacement above 5% reduces growth in fish. The higher replacement in the present study could be due to the effect of oven dry (1000°C for 30 minutes) of Alfalfa, which could reduce some heat liable ant-nutrients found in the ingredients that could increase better feed utilization efficiency of Nile tilapia. When the inclusion level of Alfalfa increased from 10% to 20%, the growth and feed utilization efficiency of the fish were affected negatively. Such observation was also reported by Kassahun [16], who stated that the lower weight gain was observed due to a higher level of crude fiber as higher fiber affects the digestibility of the feed.

Jatropha is one of the main sources of protein that contains essential amino acids, and it can replace a fish meal if anti-nutritional factors are reduced or removed [17]. The present result agreed well with the reports of Workagegn [18] and Cruz [19] in which inclusion of Jatropha as partial fish meal replacement ranged from 15-20% has no significant effect on the growth and feed utilization performance of fish. However, lower than the values reported by Akinleye [20], Kumar [21] and Krome [17], who stated that 30-45% fish meal replacement by Jatropha didn't affect the growth and feed utilization parameters of Nile tilapia. Shamna [22] reported that fish meal replacement at different levels in Jatropha showed variations in protein and lipid contents. However, the present result shows that there was no significant difference in their lipid and ash contents.

The present study showed that up to 20% fish meal can be replace with brewery waste without any negative effect on the growth performance of fish, which agreed well with the work of Olvera-Novoa [23], who reported that 15% fish meal replacement with brewery replacement didn't show a significant effect on the growth of Mozambique tilapia. Thobaiti [8] also reported that the replacement of fish meal with brewery waste up to 20% had no negative effects on growth response in terms of final weight, weight gain, SGR and survival in other fish species such as Clarias gariepinus. In general, variation in the level of inclusion of different plant feed ingredients and their effects in growth and feed utilization may be due to variations in anti-nutritional factors of ingredients and size of fish, types of fish, effect of feed processing that affects anti-nutritional factors of ingredients and genetic variations in fish species [13,24,25]. In other hands, furthermore, the proximate composition of the fillet considered for the present study showed high moisture and lower ash contents when fish fed with 20% Alfalfa-based diet.

Fulton's condition factor and survival rate

Fulton's' condition factor denotes the good health status of a fish. The condition factor of all groups of Nile tilapia fed with different diets was similar, implying that condition factors were not influenced by the tested diets. The condition factors obtained in the present study showed a slightly higher than the standard condition factor for Nile tilapia (i.e. one), however, these values indicate that all the group fish are living in a good health condition as mentioned by Ighwella [25].

The survival rate was not affected by the different levels of replacement of fish meal with tested diets. The reason may be the presence of minimum requirement of nutrients in experimental diets [26] and with optimum water quality parameters such as temperature that enables the fish to acquire good resistance [27]. The physicochemical parameters are the main limiting factor in the water recirculation aquaculture system. The basic water quality parameters considered for the present study at different treatments did not significantly affect by the type of diets used in the experiments. Workagegn [27] and Abeyneh [28] also reported that different levels of water quality parameters affect the growth performance and feed utilization of Nile tilapia. In conclusion, a fish meal can be replaced using the three feed ingredients up to 10% without negative effects on the growth rate, feed utilization and body composition of Nile tilapia.

DECLARATIONS

Funding information

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Data availability statement

The data can be available when requested

CONFLICT OF INTEREST

The authors have no declared any conflict of interest

CODE AVAILABLE

The statistical software used in this study was SAS versions 9.

AUTHORS' CONTRIBUTIONS

Teshome Belay Eshete was involved in data collection and analysis and draft paper preparation while Kassaye Balkew Workagegn and Natarajan Pavanasam involved in the designing and developing the research methodology, data analysis, reviewing and editing.

ETHICAL APPROVAL

The overall research procedures were approved by Hawassa University research committee and thus all applicable international and national guidelines for the care of animals and the use of animals were followed by the authors.

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