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EFFECT OF DIFFERENT LEVELS OF FERMENTED WATER HYACINTH LEAF MEAL ON FEED UTILIZATION AND PERFORMANCE OF JUVENILE NILE TILAPIA

Yibrehu EMSHAW [1, 2], Abebe GETAHUN [2] and Akewake GEREMEW [2]

[1]*Departmernt of Aquatic Biodiversity, Ethiopian Biodiversity Institute, Addis Ababa P.O.box 30726, Ethiopia*

[2]*Departmrent of Zoological Sciences, College of Natural and Computational Sciences, Addis Ababa University, Addis Ababa P.O box 1176, Ethiopia*

Email: yibrehu27@gmail.com

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ABSTRACT: This study was conducted to evaluate the effects of different inclusion levels of water hyacinth leaf meal fermented with *Aspergillus niger* on feed utilization efficiency and growth performance of Nile tilapia (*Oreochromis Niloticus* L.). Fermented water hyacinth leaf (FWHL) at 0, 10, 20 and 30% inclusion levels were incorporated into four isonitrogenous (35% CP), and isoenergetic (18 KJ g^{-1} g) test diets. The fishes were stocked in 80 liters aquarium units, in a closed, recirculating indoor system. The diets were fed to triplicate groups of fish fingerlings (1.6 g average body weight) twice a day, at 6% of body weight/day, for three months. The study demonstrated that Nile tilapia fed FWHL at levels 30% had a significant negative impact (P<0.05) on weight gain, specific growth rate, feed utilization efficiency, and whole body composition. But, there was no significant change on the performance of Nile tilapia fed diets supplemented with 10% and 20% FWHL when compared with the control group. Therefore, supplementation of fermented water hyacinth leaf meal to diets of Nile tilapia is recommended up to 20% because it is cheaper than fish meal and corn.

Keywords: Body composition, Feed utilization, Growth performance, Nile tilapia, Water hyacinth

INTRODUCTION

Since 1984, aquaculture has experienced the world's fastest rate of animal production growth. Today, more than 61.5% of all fish are produced through aquaculture. With the exception of Sub-Saharan Africa, aquaculture is growing, intensifying, and developing almost everywhere in the world as the demand for aquatic food products is anticipated to rise (FAO, 2012). According to the World Bank's 2013 report, Sub-Saharan Africa's per capita fish consumption will fall by 1% annually to 5.6 kg between 2010 and 30. However, the total demand for fish food would increase significantly (by 30% between 2010 and 2030) as a result of the population's rapid growth, which is projected to average 2.3% annually between 2010 and 2030. Its development can lessen the strain on natural resources and help meet future food needs (FAO, 2006).

The price of conventional feedstuffs has continued to rise due to their scarcity and is no longer affordable for rural livelihoods, despite the significance of aquaculture production (Téguia et al., 2008; Naylor et al., 2021). The price of fish feed makes up between 50 and 60 % of the total operating costs of aquaculture production (Workagegn et al., 2013). The development of low-cost aquaculture systems suitable for small-scale farmers in the developing world has been severely hampered by the scarcity of and high price of conventional pelleted fish feed (Fagbenro and Arowosegbe, 1991; Kaleem and Sabi, 2021; Moyo et al., 2021).

Researchers, particularly those who specialize in fish nutrition are looking for alternative feed components or processes to create environmentally friendly and cost-effective aqua feeds that can lower feed costs and the competition between humans and fish for food. Fish feed ingredients that can be found locally are typically less expensive and more readily available than commercial feeds (Adéyèmi et al., 2020). Finding an alternative protein source for fish feed ingredients is necessary to meet the demand for sustainable aqua-feed production due to the scarcity and limited availability of fish feed ingredients, particularly protein feeds (Makkar et al., 1997). However, a number of factors, including low palatability, poor digestibility, ant nutritional elements, high fiber content, and low protein content, limit the incorporation of plant feed materials in fish feeds (Kokou and Fountoulaki, 2018; Alfred et al., 2020). Plants can be processed and fermented to get around those issues for fish feed uses (Francis et al., 2001; Ansari et al., 2021).

Pontederia crassipes, a free-floating perennial herb of fresh water ecosystems, is native to the Amazon basin and has since naturalized throughout tropical and subtropical South America. It is a member of the Pontederiaceae family (Lu et al., 2007; Adeyemi and Osubor, 2016). It is also widely dispersed in Ethiopia's water bodies, where it causes socioeconomic and environmental issues (Tewabe , 2015; Gezie et al., 2018; Dersseh et al., 2019) that worsen poverty by

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impacting the country's agriculture, fisheries, and biodiversity (Asmare, 2017), all of which are vital to people's ability to support themselves.

It has potential uses despite its negative consequences. It is currently receiving a lot of attention as a substitute plant feed ingredient in fish, poultry, and other animal feed as it is less costly than commonly used ingredients (Aderolu and Akinremi, 2009). However, incorporation is limited because of its relatively high fiber profile and low protein content, which may limit how effectively it is used by fish as a feed ingredient (Konyeme et al., 2006).

Studies have shown that the use of solid state fermentation technologies can address the underutilization of this weed (Singhania et al., 2009; Shamim et al., 2017). Solid-state fermentation is preferred over other fermentation techniques because it is more cost-effective, uses readily available inexpensive substrates, and has a relatively low risk of contamination, as evidenced by the fact that microorganisms can grow on moistened solid substrates without access to free water (Osma et al., 2007). Do Santos et al. (2015) reported that solid state fermentation technology with Rhyzopus sp. and *Aspergillus niger* increased the protein content and decreased the crude fiber content of cactus pears after fermentation. Moreover, the availability of well-established information on the evaluation of *Aspergillus niger* fermented water hyacinth leaf as the alternative plant-based feed source in tilapia diet is scanty.

This study, therefore, evaluates the nutritional potential of fermented water hyacinth leaf meal as an alternative plant feedstuff in Nile tilapia (*Oreochromis niloticus* L.) diets.

MATERIAL AND METHODS

Water hyacinth collection and fermentation

Water hyacinth *(Pontederia crassipes)* was harvested from Qoqa Reservoir and the leaf was separated from the whole plant and washed thoroughly with tap water to remove adhering dirt. Approximately 250 g of fresh leaf was taken from the collected water hyacinth plant, oven-dried at 60 °C for 48 h until a constant weight was obtained for dry matter determination. The remaining sample of leaf was sundried by spreading thinly on plastic sheets until fully dried. Then, the dried water hyacinth leaf was ground and passed through a 2 mm meshed sieve to ensure homogeneity. Finally, water hyacinth leaf powder was fermented by filamentous fungi species, *Aspergillus Niger* following different fermentation procedures. *Aspergillus niger* is nontoxic and environment friendly fungi species that is widely used for nutrient improvement of low quality animal feeds.

Experimental system and animals

The experiment was conducted in aquariums built by Addis Ababa University, Department of Zoological Sciences. The experiment was conducted in 12 aquarium units of 80 L capacity. These are linked to a plumbing system that continuously supplies water. Each aquarium received 2 L m^{-1} of thermo-regulated recirculating water, with a photoperiod of 12 h of light and 12 h of darkness. A compressor that supplied additional aeration through an air tube system and air stones was used. Weekly measurements were made of the dissolved oxygen, pH, nitrite (NO2), nitrate (NO3), and ammonia (NH3) levels in the water. They had the following average values over the course of the study: pH 7.2, 28.7 °C, 0.16 mg.L^{-1} ammonia, 0.20 mg.L^{-1} nitrite, 49 mg.L^{-1} nitrate, and 5.3 mg.L^{-1} dissolved oxygen; and they were within acceptable ranges for tilapia.

The Lake Chamo strain of Nile tilapia brood stock was used for production of fry for this study. An average weight of 1.6 g of Nile tilapia fingerlings were randomly distributed in to 12 aquarium units. The experiment was conducted for about three months.

Animal ethics/rights

An international protocol for animal ethics was followed in this study. As a result, the European Union regulation on the use of animals for research (European Union, 2010) was used in this research.

Diet Formulation and preparation

Generally, all experimental diets were formulated to contain 350 g kg^{-1} protein, 100 g kg^{-1} lipid and 18 kJ g^{-1} energy. These levels were based on requirements for Nile tilapia (NRC, 1993). The grains (Table 1) used in this study were purchased in Addis Ababa from commercial sources. The diets were designed using the as-fed principle. Fish meal and soybean meal are the primary sources of dietary protein used in formulation, while wheat and corn grains are the primary sources of carbohydrates. A binder (high viscosity carboxymethyl cellulose) and a premix of vitamins and minerals for poultry were also added. The lipid in the diets was obtained from soy oil.

Previously fermented water hyacinth leaf meal was used to formulate the diets for Nile tilapia at different inclusion levels. Fermented water hyacinth leaf was incorporated in the diet at inclusion levels of 10% (FWHL10), 20% (FWHL20) and 30% (FWHL30). To create a homogeneous mixture, all ingredients were finely ground and passed through a 500 mm sieve. After adding water (20–30%) slowly while stirring continuously, the resulting homogenate was moistened before being run through an electrical meat mincer. The meat mincer's "expeller-like strands" were dried for 24 h in a convector-fan oven at 35 to 40 °C. They were then reduced to crumbles and put through a sieve with a 1mm mesh size. The resulting pellets were employed in this study, and their proximate composition and energy were also examined.

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Table 1 - Composition of diets (g·kg⁻¹ as-fed) fed to Nile tilapia with varying inclusion levels of fermented water hyacinth leaf.

Ingredients	Control	FWHL10 %	FWHL20 %	FWHL30 %
FWHL	-	100	200	300
FM	321	288.9	256.8	222.7
SM	360.2	323.7	287.6	250.3
WG	115	101	89	76.4
CG	103.8	91	79.8	70.9
SB oil	30	25.4	16.8	9.7
VMP[1]	50	50	50	50
CMC[2]	20	20	20	20

[1] contains ($mg{\cdot}kg^{-1}$); vitamin A (retinol)=2100, vitamin D3 (chole-calciferol)=50, vitamin E (tocopheryl acetate)=10000 I.U, vitamin k3=2000, Thiamine=1,000, Riboflavin=4,000, Niacin=10,000, Pantothenic acid=5,000, Pyridoxine=750, Folic acid=250, Vitamin B12=8, Vitamin H as Biotin=30, Betain=100,000, Antioxidant=125,000; **Minerals:** Manganese=80,000, Zinc=50,000, Iron=20,000, Copper=5,000, Iodine=1,200, Cobalt=200, Selenium=200; FM=Fish meal; FWHL=Fermented water hyacinth leaf; Soybean meal; WG Wheat grain; CG=Corn grain; SB oil=Soybean oil; VMP=Vitamin mineral premix; [2]Carboxymethyl cellulose (high viscosity).

Chemical composition

In an oven with a 105 °C setting, weight loss was used to measure moisture. A known quantity of the sample was burned at 550°C to a constant weight to produce ash. Crude protein was created by converting the total nitrogen determined using the Kjeldahl method. The 6.25 factor was applied. Using the Soxhlet method, petroleum ether was used to extract the total lipids. The sum of the calories in proteins, lipids, and carbohydrates, which are 5.5, 9.1, and 4.1 $kcal{\cdot}g^{-1}$, respectively, was calculated. By difference, carbohydrates were calculated using the following equation:

Carbohydrates are equal to 100 less (moisture, protein, lipid, and ash)

Analysis of experimental data

Multiple biological parameters, including growth performance, food conversion ratio, and diet protein, lipid, and energy utilization, were determined using experimental data gathered during the growth trial and diet analysis results.

Growth efficiency

Fish weight gain and a specific growth rate were the parameters used in this study to evaluate growth performance (SGR). The most typical fish growth expression is SGR. Weight gain (WG) is the variation in fish body weight over time between the initial and final weights: (FBW-IBW)/IBW 100 = WG; Where, FBW (g) stands for final body weight and IBW (g) for initial body weight (g). These are average body weights.

Specific growth rate

The percentage increase in body weight per day over any given time period is used to express the instantaneous change in weight of fish. Natural logarithms of body weight are used in the calculation, and it expresses growth as a percentage. SGR = $\frac{(\text{In FBW} - \text{InIBW})}{\text{D}} \times 100$

Feed conversion Ratio

The amount of dry feed fed per unit of live weight gain is known as FCR. It frequently acts as a gauge of the diet's effectiveness. Less food, or a lower FCR, is needed to produce a unit of weight gain the more growth-friendly the diet (Lucas et al., 2019). It was determined to be: FCR = $\frac{\text{Feed fed (g)}}{\text{Live weight gain (g)}}$

Protein efficiency ratio

According to De Silva and Anderson (1995), the protein efficiency ratio (PER) is the proportion between the weight gain of fish and the protein fed. PER = $\frac{\text{Weight gain (g)}}{\text{Crude protein fed (g)}}$

Productive Protein value

Productive protein value (PPV), also known as efficiency of protein utilization (Gerking, 1971), measures the amount of protein in the diet by comparing it to the amount of protein that is retained in fish tissues. Fish samples taken before and after feeding with the evaluated protein are used to determine PPV, which is typically expressed as a percentage of protein fed. PPV = $\frac{\text{Protein retained in tissue}}{\text{Dietary protein consumed}} \times 100$

In comparison to PER, PPV is a more precise criterion for evaluating dietary protein because it considers the conversion of the dietary protein into body protein rather than the overall increase in body weight (Hepher, 1988).

Nutrient Deposition = $\left[\frac{(\text{IBW} \times \text{FBN}) - (\text{IBW} \times \text{IBN})}{(\text{feed intake} \times \text{feed nutrient})}\right] \times 100$

Where, FBW= final body weight (g), IBW= initial body weight (g), FBN= final body nutrient and IBN= initial body nutrient.

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Due to practical limitations, it was not possible to guarantee that all food was consumed during experiments with fish or to remove uneaten food from the aquariums. Therefore, the amount of feed fed (instead of feed consumed/intake) was used for the calculation of FCR, PER, and PPV (ANPU- Apparent Net Protein Utilization) without adjustment for any wastage. In actuality, this might cause the ratios to be underestimated and the feed to be overestimated.

Body composition of fish

To determine the body composition of fish, whole body proximate analysis and the hepatosomatic index (HSI) were used. Following the procedures outlined above, the proximate analysis included the analysis and expression of moisture, crude protein, crude lipid, and ash as a percentage of fresh weight. Following the completion of each experiment, 20 randomly chosen fish from each treatment, including the control, were euthanized by clove oil overdose, dissected, and had their livers removed. The livers were then weighed and used to calculate the hepatosomatic index (HSI), which was calculated as follows:

$$HSI=\frac{\text{liver weight}}{\text{body weight}}\times 100$$

Statistical analysis

This study's experimental design was primarily a completely randomized design (CRD), in which various dietary treatments were assigned to the experimental units at random (aquariums). The study's null hypothesis was that there is no discernible difference between the dietary treatment methods. Statistical Packages for Social Sciences were used to conduct the statistical analyses for this study (SPSS ver. 20). One-way analysis of variance (ANOVA) was used to compare the means of the various dietary treatments and to test for differences between the means that might be statistically significant (Duncan, 1955). Differences were considered significant at a p-value of 0.05.

RESULTS

Table 2 lists the approximate composition and energy content of the experimental diets. There were no significant difference between the diets in crude protein (342.5–353.2 $g.kg^{-1}$), crude lipid (102.9–112.7 g. kg^{-1}) and ash (104.9–139.5 g. kg^{-1}) contents. Whereas, there was a significant difference ($P<0.05$) in nitrogen free extract (256.4-280.2 g. kg^{-1}). Diet 4 (FWHL 30) had significantly higher ($P<0.05$) crude fiber content (356 $g.kg^{-1}$) than the other treatments. Fermented water hyacinth leaf (FWHL) alone contained the highest crude protein and the lowest crude fiber content than the raw counterparts.

Table 3 indicates the price of each ingredients used in the study. Water hyacinth was the least expensive ingredient (10 birr kg^{-1}) than the other ingredients as its cost is calculated only for harvesting and processing i.e. it was not purchased elsewhere from the market. It was eight and four times less expensive than fish meal and corn grain respectively. Table 4 shows the initial and final mean weights, percentage weight gain (WG), and specific growth rate (SGR) of Nile tilapia fed the experimental diets containing fermented water hyacinth leaf. Inclusion of FWHL at 10 and 20% level resulted comparable growth performance with the control group. Inclusion level of FWHL at 30% resulted significantly lower weight gain ($P<0.05$) than the other treatments (Table 4).

Feed intake of the different diets ranged between 20.06 g and 26.79 g per fish at the end of the experiment. Diets with 30% inclusion of fermented water hyacinth leaf has significantly lower feed intake ($P<0.05$) which could be accompanied by the decrease in feed conversion ratio (FCR). Table 5 displays the fish samples' initial and final whole body proximate compositions. The moisture contents of the fish fed the control diet and diets containing 20% fermented water hyacinth were significantly lower. Except for fish fed 10% and 20% of fermented water hyacinth leaf, which shows relatively comparable whole body contents with the control diet, the inclusion of fermented water hyacinth leaf at 30% significantly affected the CP, CL, and GE contents of fish in the whole body.

Table 2 - Chemical composition of diets fed to Nile tilapia in this study.

Components ($g{\cdot}kg^{-1}$)	RWHL	FWHL	Control	FWHL10	FWHL20	FWHL30
Dry matter	927.8	913.0	920.2	914.7	910.3	908.6
Crude protein	94.9	195.6	353.2	350.8	348.9	342.5
Crude lipid	47.6	41.1	112.7	102.9	105.6	107.4
Crude fiber	297.8	158.5	259	276	298	356
Ash	191.2	246.3	104.9	119.5	125.9	139.5
NFE	315.6	255.0	256.4	260.8	269.7	280.2
Gross energy ($KJ{\cdot}g^{-1}$)	16.5	17.3	19.7	18.9	19.4	18.5

NFE = Nitrogen free extract; RWHL=Raw water hyacinth leaf, FWHL = Fermented water hyacinth leaf

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Table 3 - Price of ingredients used in the study (Ethiopian Birr .kg^{-1})

Ingredients	Price
Fermented water hyacinth leaf	10
Fish meal	80
Soya bean meal	65
Wheat grain	50
Corn grain	40

Table 4 - Growth and feed utilization (per fish) of Nile tilapia fed fermented water hyacinth based diets.

Parameter	1	2	3	4
	Control	FWL 10	FWL 20	FWL 30
IBW	1.63±0.12	1.64±0.23	1.66±0.05	1.65±0.20
FBW	10.15±0.19[a]	10.01±0.02[a]	9.98±0.12[a]	7.64b±0.05[b]
WG	307.4±1.57[a]	296.14±1.58[a]	288.48±1.13[a]	249.28±0.96[b]
SGR	2.92±0.07[a]	2.84±0.06[a]	2.79±0.08[a]	2.25±0.09[b]
S	95.3±2.4	95±5	97.23±2.49	98.58±2.19
FCR	1.81±0.01[a]	1.78±0.02[a]	1.76±0.03[a]	1.41±0.02[b]
FI	26.79±0.10[a]	25.23±0.14[a]	24.96±0.07[a]	20.06±0.04[b]
PER	1.03±0.08[a]	0.92±0.02[a]	0.89±0.03[a]	0.65±0.0.02[b]
PPV	17.11±0.18[a]	16.89±0.04[a]	16.81±0.12[a]	12.96±0.07[b]
HIS	2.56±0.13[a]	2.51±0.02[a]	2.47±0.11[a]	1.9±0.21[b]

IBW (g) = initial body weight; FBW (g)=final body weight; SGR (% day^{-1})=specific growth rate; FI (g)=feed intake; FCR=feed conversion ratio; PER=protein efficiency ratio; PPV (%)=productive protein value; S(%)=survival; HIS=hepatosomatic index. Values are means±SD of three replicates, and values within the same row with different letters are significantly different (P<0.05).

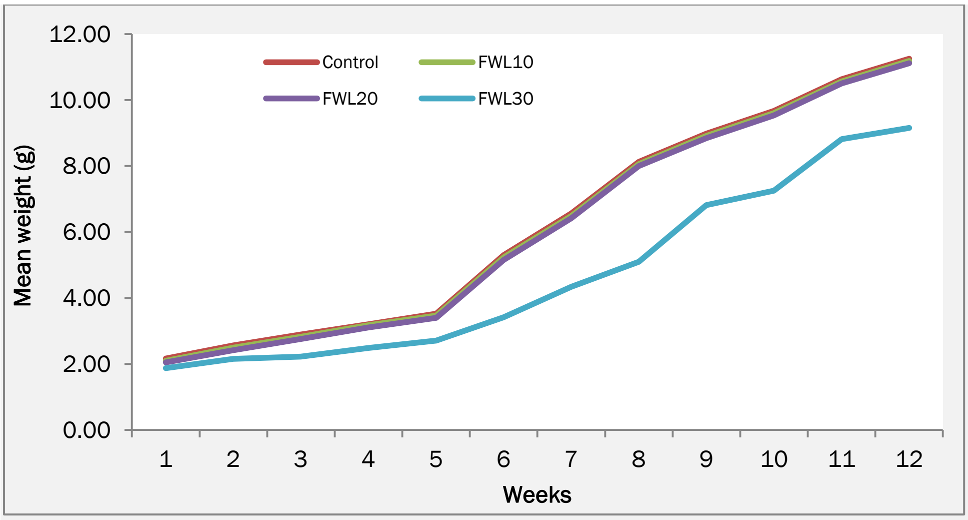

Figure 1 - Shows growth response of Nile tilapia fed fermented water hyacinth based diets for twelve weeks.

Table 5 - Whole body proximate composition (% wet Weight) and energy of Nile tilapia fed fermented water hyacinth based diets.

Components		1	2	3	4
	Initial carcass	Control	FWHL 10	FWHL 20	FWHL 30
MC	78.6	73.27±0.32[a]	75.03±0.21[b]	74.91±0.10[b]	76.30±0.36[c]
CP	14.9	15.61±0.10[a]	14.53±0.21[a]	14.29±0.20[a]	11.03±0.21[b]
CL	4.9	6.37±0.15[a]	6.35±0.21[a]	6.30±0.10[a]	3.87±0.15[b]
Ash	3.9	4.5±0.10[a]	4.2±0.10[a]	4.3±0.1[a]	5.2±0.10[b]
GE	5.1	5.9±0.10[a]	5.5±0.10[a]	4.67±0.15[a]	3.95±0.10[b]

MC = Moisture content; CP= crude protein; CL= crude lipid; GE= gross energy; FWHL= fermented water hyacinth leaf with the corresponding number; Values are means SD (n = 3) and values within the same row with different letters are significantly different (p<0.05).

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DISCUSSION

Statistically, inclusion of FWHL at 10 and 20% exhibited equivalent feed utilization and growth performance with the control group. Since inclusion of FWHL at 10 and 20% equivalent in growth and feed utilization efficiency with the control diet, it can be added up to 20% of formulated feeds without negative impact on feed efficiency metrics and growth performance. However, at 30% inclusion level of fermented water hyacinth leaf, growth and feed utilization efficiency was significantly reduced ($P<0.05$). The accuracy of the randomization process between the experimental treatments was demonstrated by statistical analysis, which revealed no significant differences in initial body weight among the various experimental treatments.

In comparison to the other ingredients used in the present study, the cost of water hyacinth was very low (Table 3) as it is not purchased from the market. It is eight times less costly than fish meal and five times less than the cost of wheat grain. Its price is calculated for harvesting and processing.

The fermentation process, which reduces the crude fiber and some of the anti-nutritional contents present in water hyacinth leaf, may be the cause of the relatively similar results in growth performance and feed utilization parameters between 10% and 20% inclusion of fermented water hyacinth leaf with the control group. This is because fermentation is a special process that could increase the nutritional value of feed ingredients while significantly lowering the anti-nutritional factors and fiber content in the plant-based feed ingredients (Bairagi et al., 2002; Uchida and Murata, 2002; Singhania et al., 2009; Shamim et al., 2017). According to Bake et al. (2015), fish fed with ingredients from fermented plant sources showed better growth performance.

According to El-Sayed (2003), the significantly lower weight gains and SGRs in fish fed diets containing water hyacinth meals above 20% inclusion levels may be caused by the plant's high fiber content, which is difficult to reduce through fermentation because of high inclusion level. This claim is in line with research by Jimoh and Aroyehun (2011) and Bake et al. (2015), who found that higher inclusion levels of meals containing the majority of plant protein sources led to poor growth and nutrient utilization. This finding is also consistent with the findings of Nwanna et al. (2008), who found that feeding fish a diet containing crude fiber above 4.7% resulted in poor growth performance. These findings corroborated reports of Nwanna and Ajani's (2005) on the growth and blood parameters of catfish fed diets containing more than 20% water hyacinth meal.

In line with the current study, Sayed-Lafi et al. (2018) found that fermented water hyacinth up to a 20% level was suitable and had no negative effects on the growth and feed efficiency of young grass carp (*Ctenopharyngodon idella*) (Val, 1844). Similar findings to those of the current study were also reported by Konyeme et al. (2006) and Fouzi and Deepani (2018). Cruz et al. (2011) provide additional evidence in support of the idea that feeding *Cachama blanca* a practical diet supplemented with fermented aquatic plants at a 15% level boosts growth rates and feed efficiency equivalent to the control diet.

Other fermented non-conventional feeds, like fermented duckweeds, *Lemna minor* and *Spirodela polyrhiza* and the water fern, *Azolla filiculoides* in *Piaractus brachypomus* and *Oreochromis niloticus* L. feeds have growth performance and feed utilization efficiency that is comparable to the control diet (Bashir and Suleiman, 2018). The ability of Nile tilapia juveniles to utilize the nutrients of hyacinth meal for growth is shown by the improved growth performance obtained from 10 and 20% incorporation of *Pontederia crassipes* leaf meal equivalent to the control diet.

Kraidy et al. (2020) on the other hand found that *Heterobranchus longifilis* fed a diet containing raw water hyacinth at a 20% inclusion level had lower growth performance and feed utilization efficiency than fish fed the Control diet. This discrepancy may be caused by the different fish species, the rearing system, the feed composition, and the use of raw (unfermented) water hyacinth in the prior study, which had high crude fiber and antinutritional contents. Except for ash content, which was significantly higher in diet 4 (30% FWHL), there was a significant decrease in the whole body composition of CP, CL, and GE contents in diets fed 30% inclusion of fermented water Hyacinth.

The fermentation process, which could enhance the nutritional value of feed ingredients and greatly reduce the anti-nutritional factors and fiber content in the plant-based feed ingredients, may be the cause of the significantly higher body composition of CP, CL, and GE in diets containing 10 and 20% fermented water hyacinth leaf equivalent to the control diet. Some authors claimed that feeding fish feed containing fermented plant-based ingredients improved their growth performance and body composition (Bake et al., 2015; Jafer et al., 2018).

CONCLUSION

Nile tilapia fed up to 20% fermented water hyacinth leaf for three months showed acceptable growth and feed utilization efficiency. According to the study, high concentrations (30%) of fermented water hyacinth leaf could harm fish growth and feed utilization. Water hyacinth may be a readily available alternative ingredient for fish meal formulation in underdeveloped nations like Ethiopia. Additionally, incorporating water hyacinth into fish feed may help to slow the spread of this invasive plant in the water bodies. Moreover, the use of fermented water hyacinth leaf in fish feed can reduce the cost as it is less costly than conventional fish feed ingredients.

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DECLARATIONS

Acknowledgments

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Computing Interest

The authors declare that they have no competing interests

Authors' contribution

All authors are involved in the preparation of this manuscript

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