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Growth Performance of the Nile Tilapia (*Oreochromis niloticus* L.) Fed Different Types of Diets Formulated from Varieties of Feed Ingredients

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Abstract

This research was designed to investigate the growth performance and feed utilization efficiency of juvenile Nile tilapia, *Oreochromis niloticus* L. fed different types of diets formulated from varieties of feed ingredients. For this purpose, six experimental diets were prepared. All the six experimental diets had soybean, bone meal and groundnut as basal feed ingredients which accounted as 60% of the total amount of ingredients. The rest 40% of each diet was 1Maiz:1Sorghumfor control diet or diet "A", coffee husk/pulp for diet "B", wheat bran for diet "C", beer sludge for diet "D", potato scrap for diet "E" and 2JCKM:1Wheat:1Rice for diet "F". After diet preparation, one hundred eighty fish having an average body weight of 3.27 g were randomly distributed into 18 aquaria (80 cm×30 cm×35 cm) in triplicates. During the experiment, the fish were fed three times a day at the rate of 10% of their body weight for 10 weeks. The results revealed that there was significant difference ($p<0.05$) on the growth performance and feed utilization efficiency of the fish that fed different types of experimental diets. The highest growth performance in terms of final body weight, weight gain and specific growth rate, and feed utilization efficiency were observed on the fish fed diet "A" followed by the fish fed diet "F", while the fish fed diet "B" had the lowest. The lower growth performance and feed utilization efficiency observed on the fish fed diet "B" might be due to high dietary fiber levels together with the presence of relatively higher anti-nutritional factors in coffee husk/pulp diet. However, all the fish had similar survival rate. As conclusion, except diet "B" all the tested diets are potential fish feed. However, further study should be done to evaluate the potential of those diets at later stage of the fish in different culture systems.

Keywords: Aquarium; Feed ingredients; Growth performance; *Oreochromis niloticus*

Introduction

The present shortage of animal proteins in Ethiopia as in many developing countries is attributed to the discrepancy between the rate of population growth and the rate of growth in animal protein production. The growth of human population and food production is thus not proportional. Moreover, increase in human population along with changing perceptions on quality food has led to increased demand for fish. The total fish catch from wild fish however; seem to have reached to its natural limits [1,2]. High price of fish will also result in overfishing of wild fish stocks and reduced food security for many customers that depend on fish as a source of food. Unless the fish supply is increased through sustainable aquaculture production, fish protein will become a scarce and costly commodity [3].

Similarly, the fish stocks of many Ethiopian lakes are confounded with serious problems due to irrational fishing [4]. The fishing of those lakes have increased dramatically by more than three to five folds since 1990's and has inflected sever destruction to different fish species such as the Nile tilapia and the African catfish [3-5]. Therefore, it is believed that aquaculture an alternative solution to increase fish production, especially in view of ever depletion of existing fisheries. However, one of the main bottleneck to boost aquaculture in Ethiopia is the absence of fish feed and most of the existing farmers involve in extensive pond culture system for most known fish species such as Nile tilapia and Common carp with few semi-extensive type of fish culture exist.

Currently Ethiopian fish farmers use cereal bran, kitchen leftovers and green leaves as fish feed. This is because commercially formulated feeds are not readily available in Ethiopia and even if they are available they are too expensive for most fish farmers. Often fish feed is the most expensive operating cost item accounting for over 50% of costs in semi-intensive aquaculture [6] and up to 70% in intensive aquaculture [7]. Conventionally, fishmeal and cereals have been used as protein and energy sources, respectively [8,9]. These ingredients are not affordable for fish farmers for semi–intensive aquaculture and do not go in line with food security interests [10,11]. Therefore, a search for cheap feed ingredients such as agro-industrial by-products as alternative source of protein to develop low-cost diets on the basis of sustainable feed ingredients for small and medium scale fish farmers is mandatory[3,11,12]. This study was therefore, conducted to identify and formulate fish feed from varieties of feed ingredients and evaluate their effects on the growth performance and feed utilization efficiency of juvenile *O. niloticus* in aquaria.

Materials and Methods

Description of the Study Area and Study Design

The study was conducted in biology laboratory, Hawassa University, Hawassa which is found in the southern part of Ethiopia at 275km south of Addis Ababa, the capital city of Ethiopia. It is located at 6°33'-8°33'N latitude and 36°22'-39°29'E longitude and situated at 1686m above sea level.

The experiment was designed to evaluate different feed ingredients on growth performance and feed utilization efficiency of *O. niloticus*.

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For this purpose, six experimental diets from different types feed ingredients were prepared in biology laboratory. Batches of fish were stocked into 18 glass aquaria (80 cm×30 cm×35 cm) having 80 litter water holding capacity at a stocking density of 10 fish per each glass aquarium in triplicates, and were reared for 10 weeks. Each aquarium was equipped with an air stone for continuous aeration. Feces and feed residuals were removed each day, while the water in each aquarium was changed in two days interval with 100% water volume with tap water [13].

Feed ingredients collection and diets formulation: Selected potential feed ingredients with a special focus on sources of plant origin were used in this study. Selection of the feedstuffs was based on the availability of the ingredients. The agro-industrial by-products available in Hawassa city such as wheat bran, coffee husk/pulp, beer waste, potato scrap and Jatropha seed cake meal were collected from different factories. Cereals such as maize, sorghum, wheat, rice, soybean, bone meal and groundnut were purchased from local markets. Later, six experimental diets containing 40% of 1Maiz:1Sorghum for control diet or diet "A", coffee husk/pulp for diet "B", wheat bran for diet "C", beer sludge for diet "D", potato scrap for diet "E" and 2JCKM:1Wheat:1Rice for diet "F" were formulated by mixing with basal feed ingredients (soy bean, bone/meat meal and groundnut). The basal feed ingredients accounted for 60% of the total feed ingredients (Table 1). After mixing, all the feed ingredients were sun-dried and grinded into powder using an electric hammer mill. The final mixture of each diet was made into moist pellets and then sun-dried and then manually crushed into smaller size (ranged from 1-2 mm size) and put into plastic bags.

Collection and Stocking of Juvenile ***O. niloticus:*** Juvenile *O. niloticus* of mixed-sex were collected in March 2012 from Lake Hawassa by using a beach seine (50 m×2.5 m) with a stretched mesh size of 20 mm. Immediately after captured, appropriate size of juvenile *O. niloticus* were hand-picked and placed in polyethylene bags containing approximately 25 liters of lake water. About 200 individual of juvenile *O. niloticus* were transported in each bag. Then, the fish were allowed to acclimatize for two weeks until the fish become more active and mass mortality due to stress during transportation ceased. During the acclimatization the fish were fed diet having only the basal feed ingredients and all dead and weak fish were removed daily. Then, the fish having an average body weight 3.27 g fish^{-1} were randomly distributed into each experimental aquarium.

Feed and feed supplement

The experimental fish were fed three times a day with feeding ratio of 10% of their body weight. The amount of the feed was adjusted once in two weeks intervals based on the body weight of the fish. Thus, the amount of daily supplementary feed or daily feed ration (DFR) was calculated using the average body weight (ABW), the total number of the fish (N) and the feeding rate per day (FRd^{-1}) using the following formula: DFR=ABW×N×FRd^{-1} [14].

Feed ingredients	Experimental diets					
	A	B	C	D	E	F
Soybean	280	280	280	280	280	280
Bone meal	160	160	160	160	160	160
Groundnut	160	160	160	160	160	160
1Maize:1 Sorghum	400					
Coffee husk/pulp		400				
Wheat bran			400			
Beer waste				400		
Potato scrap					400	
2JCKM:1Wheat:1Rice*						400
Total feed in g	**1000**	**1000**	**1000**	**1000**	**1000**	**1000**

*The 2:1:1 ratio is the recommended amount for JCKM as higher concentration of JCKM (>20%) reduced growth performance and feed utilization efficiency [12].

Table 1. Composition of the experimental diets (g/kg of feed).

Sampling of fish: During the experiment, dissolved oxygen concentration, water temperature and pH were measured daily using Hydrolab, Model "Multi 340I/SET. Body weight and length data were recorded in two weeks intervals. Fish mortality was also registered throughout the experiment.

Data management and analysis

Based on the data collected during the experiment, growth performance, in terms of final body weight (FBW), body weight gain (BWG,%), specific growth rate (SGR,%/day), feed utilization in terms feed conversion ratio (FCR), metabolic growth rate (MGR, gkg$^{0.8}$ day^{-1}), protein efficiency ratio (PER) and survival rate were measured. These values were calculated as described by Ridha [15]: BWG (%)=[(FBW-IBW)/IBW]×100; SGR (%/day)=[(lnFBW)-lnIBW)/d]×100; MGR=(BWG)/[{(IBW/1000)$^{0.8}$+(FBW/1,000)$^{0.8}$}/2]/d, FCR=FI (g)/BWG (g); PER=BMG(g)/CPF(g), SR=(NSF-NDF)/NSF×100; where FBW-final body weight, initial body weight, IBW-initial body mass, d-number of days, FI-feed intake, CPF-crude protein feeds, NSF-Number of stocked fish and NDF=number of dead fish.

Thus, all data were subjected to a one-way analysis of variance ANOVA, and the significance of the differences between mean values were tested using Tukey's multiple range test (P<0.05) using Minitab software, version 15.

Results

The mean values of growth performance, feed utilization efficiency and survival rate data of the juvenile *O. niloticus* reared in aquaria by feeding different experimental diets are summarized in Table 2. Similarly, the growth trends of juvenile *O. niloticus* for all experimental groups are presented by Figure 1.

The highest growth performance of juvenile *O. niloticus* in terms of final body weight (FBW), body weight gain (BWG) and specific growth rate (SGR) was observed on the fish fed with control diet followed by JCKM as compared with other fish that feed the rest of the experimental diets. Similarly, the best feed utilization efficiency of juvenile *O. niloticus* in terms of feed conversion ratio (FCR), metabolic growth rate (MGR) and protein efficiency ratio (PER) was observed on the fish fed control diet (diet "A"). In both cases the lowest growth performance and the poorest feed utilization efficiency of juvenile *O. niloticus* were observed on the fish fed coffee pulp and was significantly different (p<0.05) with the fish that fed the other diets. However, survival rate of the fish fed with all the diets were similar. In general, the order of growth performance and feed utilization efficiency of *O. niloticus* is A>F>E>D>C>B (Figure 1).

Discussions

The growth performance and feed utilization efficiency of juvenile *O. niloticus* were affected by different environmental factors such as water quality parameters including water temperature, pH, nitrogen waste, dissolved oxygen concentration, and food quantity and quality, genetic makeup, sex of the fish and their interaction [16,17]. However, the average values of all water quality parameters recorded during the experiment were not significantly different (P>0.05) and were within

Growth parameters	Experimental diets					
	A	B	C	D	E	F
Initial mean body weight (g fish^{-1})	3.2 ± 0.1a	3.3 ± 0.03a	3.2 ± 0.11a	3.3 ± 0.2a	3.3 ± 0.2a	3.3 ± 0.05a
Initial body length (cm)	6.5 ± 0.01a	6.6 ± 0.12a	6.3 ± 0.04a	6.5 ± 0.02a	6.3 ± 0.11a	6.4 ± 0.04a
Final mean body weight (g fish^{-1})	62.3 ± 0.41a	42.8 ± 0.19b	56.2 ± 0.21c	57.5 ± 0.23ce	58.3 ± 0.27ce	60.2 ± 0.321ae
Mean body weight gain (g fish^{-1})	59.1 ± 0.32a	39.5 ± 0.21b	53.0 ± 0.25c	54.2 ± 0.23ce	55.0 ± 0.31ce	56.9 ± 0.31ae
Final body length (cm)	17.3 ± 0.24a	15.2 ± 0.11b	16.3 ± 0.23ab	16.3 ± 0.11ab	16.5 ± 0.22ab	17.2 ± 0.21a
Specific growth rate (% day^{-1})	3.96 ± 0.11a	3.43 ± 0.09b	3.80 ± 0.03a	3.81 ± 0.03a	3.84 ± 0.04a	3.87 ± 0.03a
Feed conversion ratio	3.23 ± 0.02a	3.38 ± 0.05b	3.25 ± 0.3a	3.26 ± 0.05a	3.30 ± 0.03a	3.25 ± 0.03a
Metabolic growth rate (gkg$^{0.8}$ day^{-1})	13.28 ± 0.22a	11.63 ± 0.11b	12.82 ± 0.15a	12.89 ± 0.21a	12.96 ± 0.21a	13.09 ± 0.1a
Protein efficiency ratio	1.91 ± 0.03a	1.28 ± 0.01b	1.71 ± 0.11a	1.75 ± 0.02a	1.78 ± 0.03a	1.84 ± 0.03a
Survival rate (%)	100 ± 0.00a	100 ± 0.00a	100 ± 0.00a	100 ± 0.00a	100 ± 0.00a	100 ± 0.00a

*Mean values in the same row having the same letters are not significantly different (P>0.05)

Table 2. Mean values of growth parameters of juvenile *O. niloticus* fed with different experimental diets.

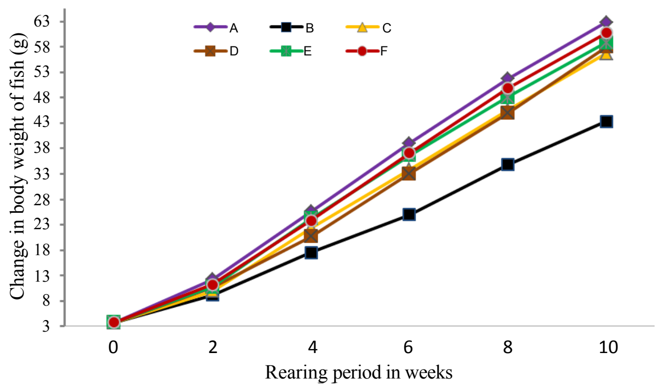

Figure 1: Growth performance of juvenile *O. niloticus* fed different types of diets.

a suitable range for the normal growth performance of *O. niloticus* [18-20]. The average values of pH ranged from 7.32 to 7.84 and dissolved oxygen concentration ranged from 6.75-6.95 mg/l were in agreement with the previous work of El-Sheriff and El-Feky [13,21] and Bahnasawy et al. [22]. Moreover, the initial body size of the fish recorded at the beginning of the experiment were homogenous and were not significantly different (P>0.05).

The results of the present study also revealed that all the experimental diets were accepted by juvenile *O. niloticus*. This implies that the different experimental feed ingredients did not affect the palatability of the diets. The reason might be due to the processing technique employed in this study which might have reduced some of the anti-nutrient factors in the feed ingredients. This result is in line with the previous work of Workagegn et al. [12] and Azzaza et al. [20] who reported that different processing techniques can reduce anti-nutritional factors and thereby increase palatability.

Variation in growth performance and feed utilization efficiency were caused due to differences in the quality of supplemental diets in terms of nutrient composition. The highest growth performance in terms of FBW (62.3 ± 0.41 g fish^{-1}), BWG (59.1 ± 0.32 g fish^{-1}) and SGR (3.96 ± 0.11% day^{-1} fish^{-1}) was observed on the fish fed control diet followed by the fish that fed diet F (60.2 ± 0.321 g fish^{-1} for FBW, 56.9 ± 0.31 g fish^{-1} for BWG and 3.87 ± 0.03% day^{-1} fish^{-1} for SGR) and were significantly (P<0.05) higher than the fish fed on diet "B". Similarly, the best feed utilization efficiency of juvenile *O. niloticus* in terms of feed conversion efficiency (3.23 ± 0.02), metabolic growth rate (13.28 ± 0.22) and protein efficiency ratio (1.91 ± 0.03) was observed on the fish that fed on control diet and was significantly (P<0.05) higher than the fish fed on diet "B". In both cases the lowest growth performance and the poorest feed utilization efficiency of juvenile *O. niloticus* were observed on the fish fed coffee husk and was significantly lower (p<0.05) from the fish fed on the rest of the diets.

The lower growth performance and feed utilization efficiency of the fish fed on diet "B" could be due to higher fiber level and anti-nutritional factors in this diet (coffee husk). The present result was in agreement with the work of Dioundick and Stom [23]; Ulloa [24] and Ulloa and Verreth [25] who reported that high levels of dietary fiber level and anti-nutritional factors such caffeine, total phenols, tannins and high potassium levels reduce growth performance, feed and protein utilization in fish and other domestic animals. Al-Ogaily [26] also reported that the best growth, feed and protein efficiency values for fingerlings of *O. niloticus* ranged from 90 and 120 g/kg dietary fiber levels. In line with this, lower growth performance and feed utilization efficiency of fish fed on diet "B" might be due to higher anti-nutritional factors and fiber level. Tacon [27] and De Silva and Anderson [28] also reported that the recommended fiber level for several fish species is 80 to 90 g/kg.

The present results confirmed the earlier work of Ulloa and Verreth [25], Reddy and Pierson [29] and Aderibigbe et al. [30] who reported that feed with higher concentration of ANF and fiber in fish diets reduces the digestibility of protein as well as the bioavailability of nutrients which intern reduces the growth performance of the fish. The present results also confirmed the earlier work of Ulloa [24] who reported that coffee hulks contains higher crude fiber (384 g/kg DM) and lower crude protein (48 g/kg DM) as compared with the wheat bran (crude fiber of 127 g/kg DM, and crude protein of 171 g/kg DM) and potato scrap (crude fiber of 105 g/kg DM, and crude protein of 353 g/kg DM). All plant ingredients with the exception of coffee hulks contained comparatively good nutritional level for better growth performance and feed utilization efficiency of *O. niloticus* and thus may have a high potential for inclusion in tilapia feeds. However, food conversion ratio of fish fed all types of diets are higher implying that all the diets contain lower content of protein used for body building and higher fiber content and anti-nutritional factors that limit availability of nutrients, thus, more roughage was produced. It is important to reduce those components in the diets using different techniques to increase their potential for fish feed. In conclusion, the present study showed that agro-industrial by-products such as wheat bran, potato scrap, brewery waste, and coffee husk are some of the promising fish feed ingredients. However, further research should be done on the fish until harvesting size in different production systems.

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References

1. FAO (2006) Fisheries Topics: Fisheries and Aquaculture Resources: FAO, Rome, Italy.
2. FAO (2009) Fisheries Topics: Fisheries Statistics and Information, FAO, Rome, Italy.
3. FAO (2012) The State of the World Fisheries and Aquaculture Part I: World Review of Fisheries and Aquaculture, FAO, Rome, Italy.
4. Rothuis A, Van Duijn AP, Dejen E, Kamstra A, Van Der Pijl W, et al. (2012) Business Opportunities for Aquaculture in Ethiopia LEI Report 2012-003.
5. Moard (2009) National Aquaculture Development Strategy of Ethiopia. State Minister, Agricultural Development, Addis Ababa.
6. De Siliva SS (1993) Supplementary Feeding in Semi-Intensive Aquaculture System, In: New MB, Tacon AGJ, Csavas I. (Eds), Proceedings of the FAO/ AADCP Regional Expert Consultation on Farm Made Aquafeeds Dec.14-18, 1992 Bangkok, Thailand, 24-60.
7. Thompson KR, Muzinic LA, Engler LS, Webster CD (2005) Evaluation of Practical Diets Containing Different Protein Levels, With or Without Fish Meal, for Juvenile Australian Red Claw Crayfish (*Cherax quadricarinatus*). Aquaculture 244: 241-249.
8. El-Sayed AFM (1999) Alternative Dietary Protein Sources for Farmed Tilapia, *Oreochromis Spp*. Aquaculture 179: 149-168.
9. Gatlin DMI, Barrows FT, Brown P, Dabrowski K, Gaylord TG, et al. (2007) Expanding The Utilization of Sustainable Plant Products in Aqua-Feeds: A Review. Aquaculture Research 38: 551-579.
10. Tacon AGJ, Foster IP (2000) Global Trends and Challenges to Aquaculture and Aqua-Feed Development in the New Millennium. International Aqua-Feed Directory and Buyers Guide 2001, Trust RAL, Uxbridge, Middlesex, UK.
11. Madalla N, Jauncey K, Richards R (2008) Novel Feed Ingredients For Nile Tilapia (*Oreochromis niloticus L.*). Phd Dissertation, Stirling University, Scotland, UK.
12. Workagegn KB, Ababbo ED, Tossa BT (2013) The Effect of Dietary Inclusion of *Jatropha curcas* Kernel Meal on Growth Performance, Feed Utilization Efficiency and Survival Rate of Juvenile Nile Tilapia. J Aquac. Res Development 4: 1-6.
13. El-Sheriff MS, El-Feky AMI (2009) Performance of Nile Tilapia (*O. niloticus*) Fingerlings: II. Influence of Different Water Temperatures. Int J Agric Biol 11: 301-305.
14. Nandlal S, Pickering T (2004) Tilapia Fish Farming In Pacific Island Countries: Tilapia Hatchery Operation. Noumea, New Caledonia, Secretariat of The Pacific Community.
15. Ridha MT (2006) Comparative Study of Growth Performance of Three Strains of Nile Tilapia, *O. niloticus, L*. At Two Stocking Densities. Aquaculture Research 37: 172-179.
16. Gjedrem T (1997) Selective Breeding to Improve Aquaculture Production. Aquaculture 28: 33-45.
17. Noor EL, Deen AIE, Mona SZ (2010) Impact of Climatic Changes (Oxygen and Temperature) on Growth and Survival Rate of Nile Tilapia (*O. niloticus*). Report and Opinion 2: 192-195.
18. Saber A, El-Shafai M, El-Gohary AF, Fayza AN, Peter Van-Der SN, et al. (2004) Chronic Ammonia Toxicity To Duckweed-Fed Tilapia (*Oreochromis niloticus*). Aquaculture 232: 117-127.
19. Xu JY, Miao XW, Liu Y, Cui SR (2005) Behavioral Response of Tilapia (*O. niloticus*) To Acute Ammonia Stress Monitored By Computer Vision. J Zhejiang Univ Sci 6: 812-816.
20. Azzaza MS, Dhrajef MN, Krajem MM (2008) Effects of Water Temperature on Growth and Sex Ratio of Juvenile Nile Tilapia: *Oreochromis niloticus (Linnaeus)* Reared in Geothermal Water in Southern Tunisia. J Therm Biol 33: 98-105.
21. El-Sheriff MS, El-Feky AMI (2009) Performance of Nile Tilapia, (*Oreochromis niloticus*) Fingerlings: I. Effect Of Ph. Int J Agri Biol 11: 297-300.
22. Bahnasawy HM, Abdel-Baky TE, Abd-Allah GA (2003) Growth Performance of Nile Tilapia (*Oreochromis niloticus*) Fingerlings Raised in an Earthen Pond. Arch Pol Fish 11: 277-282.
23. Dioundick O, Stom D (1990) Effects of Dietary Cellulose Levels on the Juvenile Tilapia, *Oreochromis mossambicus* (Peters). Aquaculture 91: 311-315.
24. Ulloa RJB (2002) Use of Coffee Pulp as Feed Ingredient for Tilapia Culture. Phd Thesis, Wageningen University, The Netherlands. ISBN: 90-5808-647-X.
25. Ulloa RJB, Verreth JAJ (2002) Growth, Feed Utilization and Nutrient Digestibility in Tilapia Fingerlings (*Oreochromis aureus steindachner*) Fed Diets Containing Bacteria-Treated Coffee Pulp. Aquaculture Research 33: 189-195.
26. Al-Ogaily S (1996) Effect of Feeding Different Levels of Cellulose on The Growth Performance and Body Composition of *Oreochromis niloticus*. Arabian Gulf Journal of Scientific Research 14: 731-745.
27. Tacon A (1990) The Essential Nutrients: Standard Methods for the Nutrition and Feeding of Farmed Fish and Shrimp, Argent Laboratories Press, Washington D.C. 1-117.
28. De Silva S, Anderson T (1995) Fish Nutrition in Aquaculture, First Ed. Chapman and Hall. London.
29. Reddy NR, Pierson MD (1994) Reduction in Anti-Nutritional and Toxic Components in Plant Foods by Fermentation. Food Res Int 27: 281-290.
30. Aderibigbe AO, Jonson CO, Makkar HPS, Becker K, Foidl N (1997) Chemical Composition and Effects of Heat on Organic Matter- and Nitrogen-Degradability and Some Anti-Nutritional Components of Jatropha Meal. Anim Feed Sci Tech 65: 223-243.