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USE OF POTATO AS AN ALTERNATIVE SOURCE OF CARBOHYDRATE IN TILAPIA (*OREOCHROMIS NILOTICUS*) FISH FEED

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Abstract

The study was conducted to evaluate the potentiality of potato as an alternative source of carbohydrate in fish feed and its effect on the growth performance, glucose level and survivability of tilapia (*Oreochromis niloticus*). The experiment was designed into four treatments with three replications in each including control T_1 (feed without rice bran and potato), T_2 (feed with rice bran), T_3 (feed with raw potato) and T_4 (feed with boiled potato). Tilapia fry (average *6.27±0.07* g) were randomly distributed in each treatment as 40 fish per 300L tank and feed with experimental diets (protein 35%). Significantly higher ($P<0.05$) survival rate of the fishes were observed in T_4 (85%) followed by T_2 (72.5%), T_3 (57.5%) and T_1 (47.5%). Feed conversion ratio (FCR) was significantly lower in T_4 (2.76) compared to T_2 (2.89) T_3 (3.2) and T_1 (3.93). Specific growth rate (SGR) was significantly higher ($P<0.05$) in T_4 (3.11%) followed by T_2 (2.94%), T_3 (2.85%) and T_1 (2.68%). Higher ($P<0.05$) condition factor (CF) was also observed in T_4 (3.19) compared to T_2 (2.85), T_3 (2.77) and T_1 (2.64). Higher glucose level was found in T_4 ($P<0.05$) compared to T_2, T_3 and T_1. The water quality parameters such as temperature, dissolved oxygen (DO), pH, ammonia, nitrate, nitrite and phosphate were not significantly ($P>0.05$) differed among the treatments. The results indicated that boiled potato treated feed would be effective as energy rich growth promoter in tilapia culture. However, further investigation is needed in farm condition adding varying levels of potato in feed.

Keywords: Rice bran, glucose, condition factor, FCR, SGR, growth performance.

Introduction

Carbohydrate is the major energy source in fish feed. Traditionally, grains such as wheat, maize and grain by-products such as wheat bran, rice bran etc. are commonly used as energy rich ingredients in the fish diets (Tacon, 1993). These ingredients are also used in poultry and cattle feed. Hence, the ingredients price is increasing every year as the demand of animal feed increasing over the time. Fish feed industries are mostly using low cost fibrous feed ingredient as carbohydrate source which result poor growth rate due to lower digestibility and lower rate of utilization. To ensure optimum growth rate of yearly fish production; research should be focused on the use of alternative sources of carbohydrate in fish feed; which will assure better digestibility, nutrient utilization, optimum growth rate and better water quality and ultimately reduce production cost (Falayi *et al*., 2003, 2004).

In Bangladesh, rice bran is the most widely used feed ingredient as carbohydrate source in fish feed. The current inclusion level of

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rice bran in fish feed ranges from 20 to 50% (Mamun-Ur-Rashid *et al*., 2013). Rice bran contains relatively higher amount of dietary fiber (approx. 23.34 %), which decreases the digestibility and energy utilization rate in most monogastric animals particularly in fish. Moreover, maximized use of rice bran in fish feed leads to an increased amount of fecal waste production containing higher indigestible fiber that ultimately decomposed and impaired water quality. Rice bran contains certain anti-nutritional factor such as trypsin inhibitor. This factor binds and reduces supply of the essential amino acid trypsin and ultimately lower growth rate of fishes (Bhosale and Vijayalakshmi, 2015). Using an alternative energy rich feed ingredient with higher non fiber carbohydrate content would results higher rate of feed utilization and better fish growth and water quality. Potato (*Solanum tuberosum*) is well known for its high energy content and most widely used carbohydrate source in human food. Nutritionally, it contains substantially higher amount of starch and a good source of vitamins and minerals (Navarre *et al*., 2009). Therefore, it appears that potato could be an effective alternative source of high energy carbohydrate in fish feed. Annual total potato production in Bangladesh was 8.95 million tonnes in 2014 with an annual growth rate of 2.33% (BBS, 2015). Farmers produce colossal amount of potatoes, they have to sell at low cost due to lack of storage facilities and consequently, these potatoes are dumped. Moreover, out of the total production, a significant amount of potatoes are considered to be culled due to diseased, damaged, out of grade, irregular size and low quality. These cull potatoes are wastage, disposed and dumped every year in rural Bangladesh. Recently, scientists are paying attention to the use of cull potatoes as livestock feed (Schroeder, 2012, Sultana *et al.* 2016). In the aqua industry in Bangladesh, use of cull potatoes would have two fold benefits: i) it would save potato farmers economically and ii) it would provide a great source of low cost and high energy carbohydrate for fish feed.

From the nutritional point of view, potato has higher starch and essential amino acids along with low fiber content compared to rice bran (Navarre *et al.,* 2009; Bhosale and Vijayalakshmi, 2015). It was hypothesized that use of cull potato in fish feed would result higher energy supply, energy utilization, fish growth and better water quality. Hence, the objectives of this study were to evaluate i) the effects of substitution of rice bran with potato on growth performance and nutrient utilization in fish and ii) effects of the use of cull potato as fish feed on water quality.

Materials and Methods

Description of the experimental site

The experiment was conducted in 12 cisterns situated at the Faculty of Fisheries, Bangabandhu Sheikh Mujibur Rahman Agricultural University. Each of the cisterns was (250 ×125 ×50) cm in size. The water depth of 30 cm was maintained for each of the cistern. Each cistern was provided with inlet and outlet system to exchange of water.

Collection of fish fry

The tilapia fry (average weight 6.27±0.07g) were collected from a private hatchery, Mymensingh. The collected fry were conditioned before release into cisterns. Weight and length of collected fry were measured using electronic balance and measuring scale.

Experimental design

The experiment was designed into four treatments including T_1 (feed without rice bran and potato), T_2 (feed with rice bran), T_3 (feed with raw potato) and T_4 (feed with boiled potato). The Completely Randomized Design (CRD) was followed to perform this experiment. Each treatment was consisted of three replicates. Each cistern was stocked with 40 fish by using random selection. Feed were formulated according to the experimental design using rice bran, raw potato, boiled potato and feed without rice bran and potato (served as control).

Feed formulation

Potatoes and rice bran were collected from the local market. The potato were divided for raw and boil potato. They were then sliced and ground separately into meal by using electric blender. After that feed ingredients including fish meal, bone meal, soybean meal, mustard oil cake, ata (binder) and vitamin mineral premix were used for the preparation of feeds for all treatment. A feed with 35% protein containing all ingredients were prepared except rice bran and potato. The prepared feeds were divided into four lots and weights were taken with electronic balance. The required amount of rice bran, raw and boiled potato were mixed with the feed ingredient separately. After mixing ingredients, adequate water were added and converted into pellets by pelleting machine. After formulation of the feed, the proximate compositions of the formulated feeds were determined following the standard methods given by Association of Official Analytical Chemists (AOAC, 1980) (Table 1).

Feeding and sampling of the experimental fish

The fry of the experimental fish were fed two times daily at morning and afternoon. At first feeds were applied at the rate of 5% of the body weight and then increased according to their demand. The weight and length of six experimental fish were recoded fortnightly. The sample fish were selected randomly.

Growth parameters

Growth and feed utilization parameters over the experimental period were calculated; these include initial and final average weight (g), gain in weight (g and %), feed conversion ratio (FCR), specific growth rate (SGR) and Condition factor (CF).

The growth parameters of fish were calculated using the following equations were:

Table 1. The proximate composition of experimental fish feed (dry matter basis)

Nutrients (%)	T_1	T_2	T_3	T_4
Moisture	13.50	12.50	11.00	11.00
Crude lipid	8.80	7.20	7.02	7.04
Crude protein	35.00	35.00	35.00	35.00
Ash	24.4	19.90	16.15	16.12
Crude fiber	4.40	5.80	7.56	6.70
Carbohydrate	13.90	19.60	23.27	24.14

Weight gain (g) = Mean final weight (g) − Mean initial weight (g)

$$\text{Percent weight gain (\%)} = 100 \times \frac{\text{[Mean final weight (g) – Mean initial weight (g)]}}{\text{[Mean initial weight (g)]}}$$

$$\text{Average daily weight gain (ADG) (g)} = \frac{\text{[Mean final weight (g) – Mean initial weight (g)]}}{\text{[Duration of experiment (day)]}}$$

$$\text{Specific growth rate (SGR) (\% bw.day}^{-1}\text{)} = 100 \times \frac{(\log_e W_2 - \log_e W_1)}{\text{[Duration of experiment (day)]}}$$

Where,

W_1 = Initial live body weight (g) of fish
W_2 = Final live body weight (g) of fish

$$\text{Food conversion ratio } (FCR) = \frac{\text{[Total amount of feed fed (g)]}}{\text{[Total weight gain (g)]}}$$

The Condition factor (CF) is also called Fultons condition factor which was calculated by using the following formula (Fulton, 1911).

$$\text{Condition factor } (CF) \text{ (\%)} = 100 \times \frac{\text{[Final mean body weight (g)]}}{\text{[Mean standard length (cm)]}^3}$$

Water quality parameters

Water quality parameters including temperature, dissolve oxygen (DO), pH, ammonia, nitrate, nitrite and phosphate were recorded in each cistern on sampling date. The following methods were used for measuring the water quality parameters: The temperature was measured by a Celsius thermometer, dissolved oxygen (mg/l) was measured by a digital DO meter (HQ40d multi) and pH was determined by a digital pH meter (HANNA instrument Test Kit). Ammonia (mg/l), nitrate (mg/l), nitrite (mg/l) and phosphate (mg/l) were determined by using a direct reading UV spectrophotometer (DR 5000).

Glucose test

Glucose test was performed during the experimental period (90 days) at 15 days interval. Three fishes from each tank were randomly selected for the determination of blood glucose. Then bloods were taken from fish and glucose was measured by a glucose meter (TysonBio Evolve Meter Glucose monitoring system, Taiwan).

Statistical analysis

Statistical analyses were performed using the software R (R Development Core Team, 2013). The analyses focused on making inference about the effect of potato as an alternative

Table 2. Growth parameters (mean±SE) of tilapia (*O. niloticus*) in different dietary treatments

Parameters	Dietary treatments				RSE	Significance
	T_1	T_2	T_3	T_4		
Initial weight (g)	6.23±0.03	6.30±0.02	6.12±0.05	6.42±0.05	0.065	< 0.001
Final weight (g)	69.40±0.07^a	88.78±0.04^c	79.76±0.28^b	105.50±0.05^d	0.198	< 0.001
Weight gain (%)	70.19±0.04^a	91.64±0.33^c	81.83±0.23^b	110.09±0.14^d	0.231	< 0.001
Initial length (cm)	5.80±0.07	6.40±0.05	6.30±0.07	6.50±0.14	0.090	< 0.001
Final length (cm)	13.80±0.07^a	14.60±0.35^c	14.22±0.14^b	14.90±0.01^c	0.437	< 0.001
Length gain (%)	8.89±0.30^a	9.11±0.07^b	8.80±0.14^a	9.33±0.17^c	0.495	< 0.001
SGR (% bw.day^{-1})	2.68±0.003^a	2.94±0.001^c	2.85±0.003^b	3.11±0.001^d	0.011	< 0.001
FCR	3.93±0.002^a	2.89±0.001^c	3.2±0.001^b	2.76±0.010^d	0.014	< 0.001
CF (%)	2.64±0.01 ^{a}	2.85±0.01^b	2.77±0.02^a	3.19±0.03^d	0.271	< 0.001
Survival rate (%)	47.5	72.5	57.5	85.0	-	-

T_1 = control; T_2 = feed with rice bran; T_3 = feed with raw potato; T_4 = feed with boiled potato; SGR = specific growth rate; CF = condition factor; RSE = residual standard error. Alphabetic letters in the superscripts of same row are significantly different from each other *(P<0.001)*.

energy source in different treatments. The data were fitted with simple liner models using the lm function where growth and water quality parameters were as response variable and treatments as independent variable. Model residuals were reported as the degree of uncertainty and model P value were reported as the level of significance of a certain response variable among the treatments.

Results and Discussion

Growth performance of tilapia *(O. niloticus)*

The result related to fish growth parameters are shown in Table 2. The initial weight of tilapia was 6.23 g, 6.30 g, 6.12 g and 6.42 g in the treatments T_1, T_2, T_3 and T_4, respectively. The final weight and weight gain were significantly affected by diet and the highest weight gain was observed in the treatment T_4 compared to other treatments (*P<0.001*). Similarly, the final length and length gain were significantly different (*P<0.001*) among the treatments and the best results were observed in the T_4. The specific growth rate of fish was increased significantly (*P<0.001*) with different source of carbohydrate in fish feed. The specific growth rate (SGR) was the highest in boiled potato feed group T_4 (3.11%) compared to the T_2 (2.94%), T_3 (2.85%) and T_1 (2.68%), respectively. The survival rate was numerically higher in T_4 compared to T_2, T_3 and T_1 group of fish. Feed conversion ratio (FCR) of tilapia fish were 3.93, 2.89, 3.2 and 2.76 in group T_1, T_2, T_3 and T_4, respectively. The FCR varied significantly among the treatments (*P<0.05*) and the best FCR was observed in group T_4.

Similar observations of growth parameters were reported in case of Labeo rohita fed with potato peel diet reported by *Maske* and *Satyanarayan* (2012) and Verma and Satyanarayan (2016). Highest growth and survival rate of tropical gar fish larvae were found feeding potato treated feed (*Frías-*

Quintana *et al.,* 2017). Like fish, higher weight gain and survival rate and good FCR was recorded from monogastric animal such as poultry ration containing potato meal (Sultana *et al.,* 2016). In the current study, the FCR were slightly higher. This may be due to the fact that the study was performed in the lab condition. Therefore, it is needed in farm trial using different levels of potato in fish feed. Jauncey (1982) conducted an experiment on growth and immunity of fry of tilapia where the carbohydrate supplementation significantly affected the whole fish body composition. These results suggested that carbohydrate supplementation plays a role in enhancing feed intake with a subsequent enhancement of fish body composition. The better feed intake may have been due to improved nutrient digestibility. Better digestibility increased feed utilization and improved fish growth (Choudhury *et al*., 2002). In the present study, best growth rate was observed in boiled potato fed due to the fact that starch was readily available as a source of energy and had a better utilization rate compared to the rice bran fed group. However, raw potato fed group revealed comparatively lower growth and survival rate compared to rice bran and boiled potato fed group. It was assumed that in raw potato the availability of starch is lower. Moreover, there might be some chemicals that interfere the growth performance of tilapia. Hence it was presumed that detail chemical screening is needed in order to assess the potentiality of the use of raw potato as fish fed.

The condition factor (CF) of fish is an important fishery management tool. The CF reflects, through its variations, information on the physiological state of the fish in relation to its welfare. The CF compares the well-being of a fish and is based on the hypothesis that heavier fish of a given length are in better condition (Bagenal and Tesch, 1978). The CF was used as an index of growth and feeding intensity (Fagade, 1979). The CF of tilapia in the present study ranged from 2.64 to 3.19%. Significantly higher (P<0.001) CF was observed in group T_4 fed boiled potato compared to T_2 group fed rice bran (P<0.001). However, no difference was found in CF between control group T_1 and raw potato fed group T_3. The condition factor of tilapia was recorded from 1.64 to 1.86 feeding with different level of maltose (Ighwela *et al.* 2011). Aziz *et al.* (2015) found 2.10 to 2.27 condition factors for tilapia cultured in cage. The condition factor of tilapia in the present study was slightly higher than these studies might be difference in feeding ration and cultured condition. Ayoade (2011) reported that higher condition factors indicated good health with an isometric growth which is desirable for fish in fish farms

Effect of potato treated feed on glucose levels of tilapia

The measured glucose was increased with the progress of the experimental periods (Figure 1). Glucose level of tilapia was found 81 mg/dL at the 15th day of measurement which was reached up to 91.8 mg/dL at 90th days of measurement in the group T_4 compared to the control group T_1 (22.5 at 15th and 48.6 at 90th day of measurements). The 2nd highest glucose was found in group T_2 where the T_3 stood 3rd position. The mean glucose level was significantly different among the dietary treatments *(P*<0.001*)*.

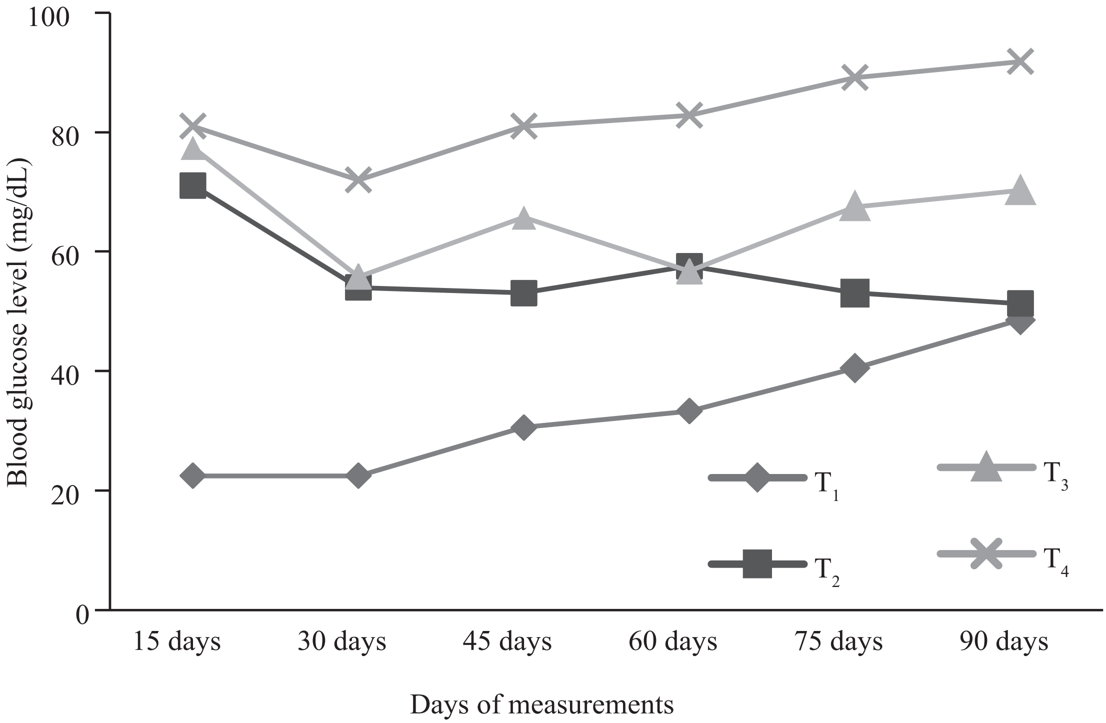

Fig. 1. Blood glucose levels of tilapia (*O. niloticus*) in different treatment at different sampling days.

Table 3. Water quality parameters (mean±SE) in different dietary treatments

Parameters	Dietary treatments				Significance
	T_1	T_2	T_3	T_4	
Temperature (°C)	28.45±0.697	29.36±0.605	29.14±0.648	29.37±0.516	>0.05
pH	8.33±0.214	8.31±0.228	8.39±0.239	8.30±0.264	>0.05
Ammonia (mg/l)	1.02±0.035	1.03±0.051	1.03±0.035	1.00±0.028	>0.05
Nitrite (mg/l)	0.14±0.028	0.14±0.019	0.14±0.016	0.14±0.015	>0.05
Nitrate (mg/l)	35.88±0.472	36.08±0.476	36.45±0.590	35.87±0.434	>0.05
Phosphate (mg/l)	3.00±0.587	3.09±0.587	3.04±0.533	3.13±0.588	>0.05
DO with aeration (mg/l)	8.40±0.346	8.24±0.364	8.30±0.352	8.40±0.416	>0.05

Dietary carbohydrates have effect on plasma glucose level in fish (Hemre *et al*., 2002). It was reported that the plasma glucose of tilapia fluctuated from 34.54 to 52.45 mg/dL, (Barreto and Volpato, 2006). Researchers showed that the blood glucose levels in tilapia were varied from 45 to 130 mg/dL (Fernandes and Volpato, 1993, Barcellos *et al*., 1999, Yavuzcan *et al*., 1997). The plasma glucose values for the present study were within the range of the previously reported result for tilapia.

Effects on water quality parameters

An overview of the results related to water quality parameters are shown in Table 3. Temperature is one of the most important physical parameter, which directly influences the physical, chemical and biological nature of water body. The range of water temperature during the experimental period was 28.45°C to 29.37°C. There is no significance variation (P>0.05) of temperature among the different treatments. Aminul (1996) reported that the suitable water temperature ranged from 25°C to 35°C for fish culture. The values of water temperature from the study were in the same line as reported by Karim et al., (2017) and Kohinoor (2000) which indicated the productivity can be assumed at optimum. So the temperature found in this experiment was sustainable for fish culture.

The average pH among the treatments were ranged from 8.30 to 8.39. Michael (1998) reported that the suitable pH range for fish production was 7.3 to 8.4. Therefore, the pH value was suitable for tilapia fish growth in the present study.

The DO concentrations with aeration of the experimental tanks in different treatments ranged from 8.24 to 8.40 mg/l. No significant difference of DO were observed among the different treatments *(P*>0.05*)*. DoF (1996) reported that the range of suitable dissolved oxygen for fish culture would be 5-8 mg/1. From the above statement, the level of dissolved oxygen in the present study was within the productive range and suitable for fish culture.

The ammonia-nitrogen level of tank water ranged between 1.01 to 1.02 mg/l. Hassan (1992) indicated safe levels of unionized ammonia at 1.05 mg/l and 1.0 mg/l for nitrite. Therefore, the ammonia level during the present study was within the suitable range for fish production and no significant difference (P>0.05) was observed among the treatments.

The nitrate and nitrite level of tank water were measured between 35.76 to 36.05 mg/l and 0.13 to 0.14 mg/l, respectively. According to Stone and Thomforde (2004) nitrate is relatively nontoxic to fish and not cause any health hazard except at exceedingly high levels (above 90 mg /l). Therefore, the nitrate level in the present study was within the suitable range for fish production. Nitrite enters a fish culture system after feed is digested by fish and the excess nitrogen is converted into ammonia, which is then excreted as waste into the water. Kamstra (2001) stated that recommended concentration of nitrite in culture system was less than 0.15 mg/l for freshwater fishes. The level of nitrite in the present study was within the productive range and suitable for tilapia fish culture.

The phosphate level of water ranged between 3.0 to 3.13 mg/l and dissolve oxygen (DO) 8.25 to 8.40 mg/l. Boyd (1982) reported that tolerable limit of phosphate in fish culture system is 0.20-1.15 (mg/l). The phosphate concentration as per WHO standard is 2.5 mg/l for drinking water (Amankwaah *et al.*, 2014). Stefan *et al.* (2013) conducted a research on tilapia fish culture depends on the incorporation of yeast and recommended that phosphate concentration in the culture system ranged from 1.5 mg/l to 3.7 mg/l. The level of phosphate in the present study was within same range with the previous study and hence, within the productive range for fish culture.

Conclusion

The results of the present study revealed that the growth performance of tilapia is significantly higher in boiled potato treated feed than the fish feed with rice bran and raw potato diet. Tilapia diet with different carbohydrate source significantly effect on survivability of tilapia. In case of blood glucose concentration, significant variation was found among the treatments and higher glucose concentration was found in tilapia feed diet with boiled potato. Carbohydrate source did not significantly effect on water quality parameters among the different treatment. The study will enable to evaluate the positive effect on fish growth and utilization of nutrient and improvement of water quality. The results of this study open a new potential for the use of potato as an alternative carbohydrate source of fish feed for better growth and production.

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