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Effects of Different Carbohydrate Sources on the Growth Performance, Feed Utilization and Body Composition of Nile Tilapia Fingerlings (*Oreochromis niloticus*) in an Indoor Culture System

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Abstract

Study was conducted to determine the ability of Nile tilapia fingerlings to utilizing different sources of carbohydrate in their diets. Five iso-nitrogenous (45% crude protein) and iso-caloric (17.5 KJ g^{-1}), isolipidic (5%) diets with different dietary carbohydrate sources (tapioca, corn, wheat, sago and rice flours) were evaluated on the growth performance, feed utilization efficiency and body composition of Nile tilapia fingerlings in a 60-day feeding trial. Fish (initial weight of 2.37±0.12g; and initial total length of3.65±0.22cm) were fed twice daily at 5% body mass. Dietary carbohydrate sources had significant effects ($p<0.05$) on weight gain, specific growth rate (SGR), feed conversion rate (FCR), protein efficiency rate (PER), and all nutrient retention values. Protein, carbohydrate and gross energy composition of the fish body were also significantly differed ($p<0.05$) among treatments. The overall performance of fish fed with corn starch was not comparable to the performance of fish fed with other starches. Therefore, second order polynomial regression analysis indicated corn starch as the best carbohydrate source for better growth and development in Nile tilapia fingerlings.

Keywords: Starch level, Growth performance, Nile tilapia, *Oreochromis niloticus*

INTRODUCTION

Carbohydrates are the cheapest sources of energy that are commonly included in the diets of various fish species (Zhou *et al.*, 2013). Although carbohydrates are not as well utilized in fish compared to terrestrial animals, they can have the beneficiary protein sparing effect (Zamora-Sillero, Ramos, Romano, Monserrat, & Tesser, 2013). A reduction to protein catabolism for energy (protein sparing) makes more protein be provided for physical growth and thus maximizes protein retention and decreases nitrogen release (R.P. Wilson, 1994;J.

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Wang et al., 2016).Carbohydrates are required as energy supply but also provide a protein-sparing effect in many fish species (Peres & Oliva-Teles, 2002;Stone, 2003); (Lee, Kim, & Lall, 2003); (Y. Wang et al., 2005) However, the ability to utilize different carbohydrate sources varies among fish species. Common carp, red sea bream (Furuich, & November, 1982) Tilapia (Anderson et al., 1984). Yellowtail(Furuichi, 1986.) and channel catfish (Robert P Wilson & Poe, 1987)respond better to starch than glucose while white sturgeon shows a similar growth when fed starch and glucose (S. S. O. Hung, Fynn-Aikins, Lutes, & Xu, 1989). In contrast, Chinook salmon (Buhler & Halver, 1961) grows better when fed glucose instead of starch. It was reported that dextrin is the best carbohydrate source for blunt snout bream compared to native corn, wheat starch, glucose, maltose and cellulose (Ren *et al.*, 2015). Juvenile flounder can efficiently utilize dextrin compared to glucose while its biological control of pathogenic microbes (Leenhouwers *et al.*, 2008;Romano et al., 2016). Carbohydrate-rich agriculture products or by-products (barley, corn, canola, oat, pea, soybean, sunflower, rice, tapioca, sago and wheat) are excellent potential carbohydrate sources for aqua feeds as these sources are available in abundance and cheaper (Delbertmiii *et al.*, 2007;Arnesen & Krogdahl, 1993;Muller *et al.*, 2017).

Several studies have been reported on the use of carbohydrate sources in producing aqua feeds for protein sparring effect, growth and development of fishes. Corn starch has been incorporated in the feed for common carp(Ufodike&Matty, 1983;. Asian catfishes (L. T. Hung, Moreau, & Lazard, 2003). Atlantic salmon (Ah-Hen *et al.*, 2014), Barramndi (Glencross *et al.*, 2012). A problem in the development of complete artificial diets for aquaculture is the high protein requirement of many species of fish since this component contributes a high proportion of feed costs.. An alternative approach is to spare protein in the diet with less expensive ingredients such as lipids and carbohydrates (Halver, 1972) but there is a limit to the amount of non-protein energy that can be tolerated and this depends largely on the species of fish. Thus, carnivorous species (e. g. Salmonids) develop high levels of liver glycogen and suffer mortality when fed an excess of carbohydrate (Phillips et al., 1948). In contrast, omnivorous and herbivorous species such as catfish and carp appear more able to use dietary carbohydrate as an energy source (Brett and Groves, 1979). Nile tilapia (Anderson *et al.*, 1984) and hybrid tilapia (Shiau and Chuang, 1995). Although no dietary requirement for carbohydrate has been demonstrated in fish (NRC, 1993), it has been suggested that an appropriate level of carbohydrate in fish diet should be provided so that protein and lipids will not be catabolized disproportionately for the supply of energy and metabolic intermediates for the synthesis of other biologically important compounds (Steffens 1989; Shiau and Huang 1990 and Wilson 1994). The literature indicates that a level of ≤ 20 % digestible carbohydrate seems to be optimal for marine and coldwater fishes whereas higher levels can be used by fresh-or warmwater fishes (Wilson 1994). The relative utilization of dietary carbohydrates by fish varies and appears to be related to their complexity. In general, the complex carbohydrates such as starch and dextrin are utilized by most fishes better than simple sugars like glucose.

Fish and shrimp have limited access to carbohydrate sources in the natural environment which are not well adapted to the digestive system for complete metabolism at high levels of (Enes, Panserat, Kaushik, & Oliva-Teles, 2009). One of the limitations for the use of carbohydrates in aquaculture or captive conditions is its low digestibility (Honorato, Almeida, Da Silva Nunes, Carneiro, & Moraes, 2010). Nevertheless, anoptimal dietary carbohydrate level of 22.5% was established for O. *niloticus* fingerlings with a practical diet containing 20-25% carbohydrate (45% protein, 5% lipid and gross energy 17.5kJg1). A diet containing more than 25% digestible carbohydrate depressed the fish growth. Dietary lipid can be partially replaced by dextrin without its reducing growth and protein utilization (Lee et al., 2003). Raw corn starch and broken rice was incorporated as dietary carbohydrates sources in Asianred tail catfish fry feed without affecting its growth performance and nutrient metabolism *(Hamid et al.*, 2011). Meanwhile, it has been observed that wheat starch and sucrose are another proper dietary carbohydrate sources for tiger shrimp (Niu *et al.*, 2012) but no specific carbohydrate source established for tinfoil barb, against this background, an experiment was designed and evaluated the nutritional values of selected carbohydrate sources on growth, Feed utilization efficiency, body composition, nutrient retention, liver and intestinal short-chain fatty acid of tinfoil barb.22.5% was used as the optimal carbohydrate inclusion level in all the treatment and determined the best sources.

MATERIALS AND METHODS

Nile tilapia fingerlings were purchased from commercial farmers. The fingerlings were acclimatized in a 1000L fiberglass tank for fifteen days and fed a 32% crude protein commercial diet. The source of water was from the mains city which was de-chlorinated and gently aerated, and the experiment was subjected to indoor natural temperature and photoperiod. After the acclimatization period, a total of 300 fish were equally distributed to fifteen 100-L glass aquaria. The aquaria were randomly assigned to test diets in triplicates. The fish were fed to apparent satiation two times daily (0900 and 1600 h) at 4-6% body weight for 60 days. At every 15 days, the fish in each tank were bulk weighed using an electronic balance. Fifteen-day intervals were chosen to minimize fish stress (Wu, Ye, Gao, Yang, & Zhang, 2016).

Experimental diets:

Five isonitrogenous (45% crude protein) and isocaloric (17.5kJg^{-1}), isolipidic (5%) diets with different dietary carbohydrate sources were formulated using Winfeed 2.8 software (Cambridge, UK) utilizing tapioca starch, corn, wheat, sago and rice flour as the carbohydrate source. Tapioca starch, corn, wheat, sago and rice flour was incorporated into the diets as fed basis (Table 1). Diets were formulated to be iso-caloric by decreasing dietary lipid inclusion where percentage of dietary carbohydrate increased and to contain less than 10% lipid as specific growth rate. Some Carp and Tilapia species declined in growth when fed with feed which contain lipid above 10% (Ramezani-Fard, Kamarudin, Harmin, & Saad, 2012).

Table 1: Feed and proximate composition (% as fed basis) of the experimental diets

Ingredient	**Carbohydrate sources**				
	Tapioca starch	**Corn starch**	**Wheat flour**	**Sago starch**	**Rice flour**
Fishmeal [1]	69.93	69.93	69.93	69.93	69.93
Crude palm oil [2]	5.57	5.57	5.57	5.57	5.57
Vitamin premix [3]	1	1	1	1	1
Mineral premix [4]	1	1	1	1	1
Tapioca starch	22.5	-	-	-	-
Corn starch	-	22.5	-	-	-
Wheat starch	-	-	22.5	-	-
Sago starch	-	-	-	22.5	-
Rice starch	-	-	-	-	22.5
<u>Proximate composition</u>					
Moisture	8.37±0.06	7.18±0.06	8.61±0.06	8.39±0.06	8,47±0.21
Crude protein	46.63±0.25	46.77±0.21	47.05±0.25	46.84±0.15	46.55±0.15
Crude lipid	4.34±0.02	4.09±0.07	4.08±0.17	5.11±0.19	4.45±0.06
Ash	7.92±0.22	7.56±0.09	7.76±0.09	8.13±0.48	8.45±0.42
Crude fiber	5.04±0.57	5.52±0.16	5.78±0.10	5.59±0.07	5.59±0.32
NFE	27.62±0.06	27.42±0.04	26.78±0.04	27.46±0.08	36.35±0.10
G E (kJ g^{-1})	17.08±0.01	17.08±0.01	17.07±0.01	17.04±0.01	17.11±0.01

[1] fishmeal (local mix species) with a dry matter, crude protein and crude lipid at respectively on a as is basis[2] vitamin premix (g $kg^{-1 premix}$): ascorbic acid,45; choline chloride, 75; thiamin mononitrate, 0.9; niacin, 4.5; riboflavin, 1; pyridoxine,1; retinyle acetate,0.6; cholecalciferol, 0.08; Ca-pantothenate, 3; myo-inositol, 5; vitamin k minodione, 1.7; α-tocopheryl acetate (500 IU G^{-1}), 8; biotin, 0,02; folic acid, 0.1; vitamin $B_{12,}$ 0.001[3] Mineral premix (g kg^{-1} premix): NaCl, 40; $CuSO_4$. $5H_2O$, 3; Kl, 0.04; $MnSO_4$. H_2O, 3; $ZnSO_4$. $7H_2O$, 4; $CaCO_3$, 215, 90; $CoSO_4$, 0.02; $FeSO_47H_2O$, 20; $Ca(H_2PO4)$. H_2O,500; MgCH, 124; $NaSeO_3$, 0.03; NaF,1.[4] α-1 cellulose was purchased from sigma (C8002). nitrogen free extract NFE=100- (moisture+ protein+ lipid + ash + fibre)

Feed preparation:

The diets were processed using a single screw extruder (Brabender KE-19) with 1.5 mm die. Three-barrel temperatures were set at 80, 100, and 120 °C while the die head temperature was 140°C. The extruder was operated at a screw speed of 150 rpm, with a compression ratio of 3:1. The extruded pellets were dried in an oven at 50 °c for overnight. The test diet was broken into 1 mm crumbles and stored in airtight plastic bags at -20c until used.

α-cellulose

Cellulose, a polysaccharide composed of long chains of β (1, 4) linked D-glucose units, was used as filler or source of fibre in fish feed formulation. The same batch ofα-cellulose was used throughout the research which was purchased from sigma (C8002).

Water quality analysis

The water quality parameters were monitored daily to ensure that it is within the acceptable range. Dissolved oxygen (DO) was measured by YSI DO and temperature meter model 57 (YSI Inc, USA) and ammonia nitrogen (NH3-N) was measured by an Ammonia-Nitrogen LaMotte test tab reagent test kit (LaMotte, USA). Temperature and pH were measured by YSI pH and temperature meter (YSI Inc., USA) respectively.

Growth measurement

The effects of fed tested diets were measured in terms of growth performance of the fish. The protein efficiency ratio (PER), feed conversation ratio (FCR), specific growth rate (SGR), weight and length as well as the weight gain and survival were calculated using the following equations:

Protein efficiency ratio (PER) = body weight gain/protein intake
Feed conversion ratio (FCR) = weight of feed consumed/body weight gain
Specific growth rate (SGR, % d^{-1}) = 100 x (in final body weight – in initial body weight)/days of feeding
Weight gain (WG, %) = 100 x (final body weight – initial body weight)/initial body weight
Survival (%) = 100 x (initial stocking – dead fish/initial stocking)

Apparent nutrient digestibility:

During the second month of the experiment, the feces were collected from each aquarium every morning before feeding. The feces were collected on filter paper for drying and subsequent chemical analysis. Apparent nutrient digestibility were calculated using the formula of Maynard and Loosli (1969). Apparent nutrient digestibility (%) = 100 - (100 X % Cr2 O3 in feed X % Nutrient in feces) % Cr2 O3 in feces %.
Nutrient gain = 100 x (nutrient gain/nutrient intake)

Protein retention value, PRV (%) = 100 x (final body weight x % protein final) - (initial body weight x % protein initial)/ (total dry protein intake intake)
Lipid retention value, LRV (%) = 100 x (final body weight x % lipid final) - (initial body weight x % lipid initial)/ (total dry lipid intake)
Carbohydrate retention value, CRV (%) = 100 x (final body weight x % carbohydrate final) – (initial body weight x % carbohydrate initial)/ (total dry carbohydrate intake)
Energy retention value, ERV (%) = 100 x (final body weight x % energy final) – (initial body weight x % energy initial)/ (total dry energy intake)

Ten fishes were randomly selected from each tank and sacrificed after feeding trial following anesthetization. Liver and internal organs were removed and weighed. Hepatosomatic index and Viscerosomatic index were calculated using the following equation.
Hepatosomatic index (HSI) = 100 x (liver weight/body weight)
Viscerosomatic index (VSI) = 100 x (weight of the whole digestive tract/body weight).

Body indices:

Five fish in each aquarium were euthanized with a lethal aqueous dose (50 mg l) of MS222 (tricaine methane sulfonate, Sigma, St. Louis, MO, USA) and weighed. The viscera that comprised intestine, intraperitoneal fat, liver and spleen were removed and weighed. The viscera weight was then divided by the weight of whole body of the fish and multiplied by 100 to calculate the VSI. From the same fish, the liver was then weighed, divided by the fish weight and multiplied by 100 to calculate the HSI according to (Romano et al., 2016).

Proximate composition: The initial whole-body proximate composition of 20 fish were measured from the stock at the beginning of the experiment. However, at the end of the experiment, 10 fish that were randomly obtained from each aquarium were anaesthetized and kept at -20°C until analysis. The proximate composition of fish samples and experimental diets were analysed in triplicates according to (Horwitz, 1990)). Dry matter was assessed by oven drying the samples at 105°C till a constant weight and lipid were determined by petroleum ether extraction with Foss Tecator Lipid Analyzer. Crude protein percentage was estimated by a protein analyser (Foss 2400 Kjeltec Analyzer Unit) following a 60 min acid digestion. Total ash content was determined by incinerating the samples at 600°C for 5hrs while crude fibre was estimated by acid digestion followed by alkaline digestion (Foss Tecator Fibertec 2010 Hot Extractor). Gross energy content was determined using a bomb calorimeter (IKA C 200 Oxygen Bomb calorimeter).

Statistical analysis: All data were subjected to one-way analysis of variance (ANOVA) after prior confirmation of data homogeneity using statistical analysis system 9.4 for windows (SAS Inc., USA). Differences among dietary treatments were identified using turkey's test. All percentage data were arsine transformed. Specific growth rate (SGR) was estimated from second order polynomial regression analysis.

RESULTS AND DISCUSSION

Growth performance and feed efficiency: Nomortality was recorded during the study, and the diets were well accepted. Fish growth and PER were significantly affected ($P<0.05$) by the dietary carbohydrate sources (Table 2). The fish fed corn starch exhibited the highest growth, which was significantly ($P<0.05$) greater than those fed the tapioca starch, wheat, sago and rice flour. The PER was significantly ($P<0.05$) higher among fish fed corn starchwhile fish fed rice flour had the lowest. The best FCR was observed among fish fed corn starch, but no significant difference ($P<0.05$) was detected among the treatments. Fish fed sago starch had the highest gross energy significantly difference ($P<0.05$) than that of fish fed corn starch. Consequently, there was no significant effect ($P<0.05$) of carbohydrate sources observed for fish body protein, ash, fibre and carbohydrate (Table 2).

Table 2: Growth performance and feed utilization Nile tilapia fingerlings fed with different carbohydrate sources after sixty days.

Parameter	Carbohydrate sources				
	Tapioca starch	Corn starch	Wheat flour	Sago starch	Rice flour
Survival (%)	100	100	100	100	100
Initial body weight (g)	$2.37±0.12^a$	$2.33±0.21^a$	$2.37±0.12^a$	$2.43±0.12^a$	$2.27±0.15^a$
Final body weight (g)	$5.87±0.20^b$	$6.87±0.20^a$	$5.80±0.19^b$	$5.83±0.06^b$	$5.17±0.09^b$
Body weight gain (g)	$3.43±0.27^b$	$4.54±0.38^a$	$3.43±0.06^b$	$3.40±0.03^b$	$2.90±0.19^c$
Body weight gain (%)	$147.1±7.17^b$	$194.85±11.53^a$	$144.1±10.87^b$	$139.92±3.61^c$	$127.75±7.0^d$
Initial total length (cm)	$3.65±0.22^a$	$3.63±0.18^a$	$3.64±0.21^a$	$3.63±0.12^a$	$3.63±0.12^a$
Final total length (cm)	$6.33±0.09^a$	$6.43±0.07^a$	$6.21±0.20^a$	$6.23±0.26^a$	$6.13±0.12^a$
SGR (% d^{-1})	$5.83±0.45^b$	$7.56±0.60^a$	$5.72±0.51^b$	$5.66±0.18^b$	$4.83±0.31^c$
DFI (% BW d^{-1})	$4.36±0.05^b$	$5.13±0.03^a$	$4.62±0.01^b$	$4.51±0.04^b$	$4.57±0.07^b$
FCR	$5.19±0.17^b$	$6.60±0.03^a$	$5.13±0.17^b$	$5.13±0.04^b$	$5.13±0.17^b$
PER	$3.27±0.00^b$	$4.17±0.08^a$	$3.27±0.00^b$	$3.27±0.01^b$	$2.27±0.04^c$
HIS	$2.87±2.52^a$	$2.92±0.58^a$	$2.87±0.33^a$	$2.87±0.33^a$	$2.80±0.58^a$
VSI	$2.50±1.20^b$	$3.22±1.15^a$	$2.50±0.88^b$	$2.67±0.67^b$	$1.25±0.88^c$

Values are means ± SE of three replicates. Different superscripts in the same row indicate significant differences ($p < 0.05$).SGR=specific growth rate; FCR=feed conversion ratio; PER=protein efficiency ratio; HIS= Hepatosomatic index; VSI= Viscera somatic index

Fish fed corn starch had the highest VSI and HIS. From the second order polynomial regression analysis, corn starch was the best dietary carbohydrate source estimated for the Nile tilapia fingerlings better growth and development (fig.1).

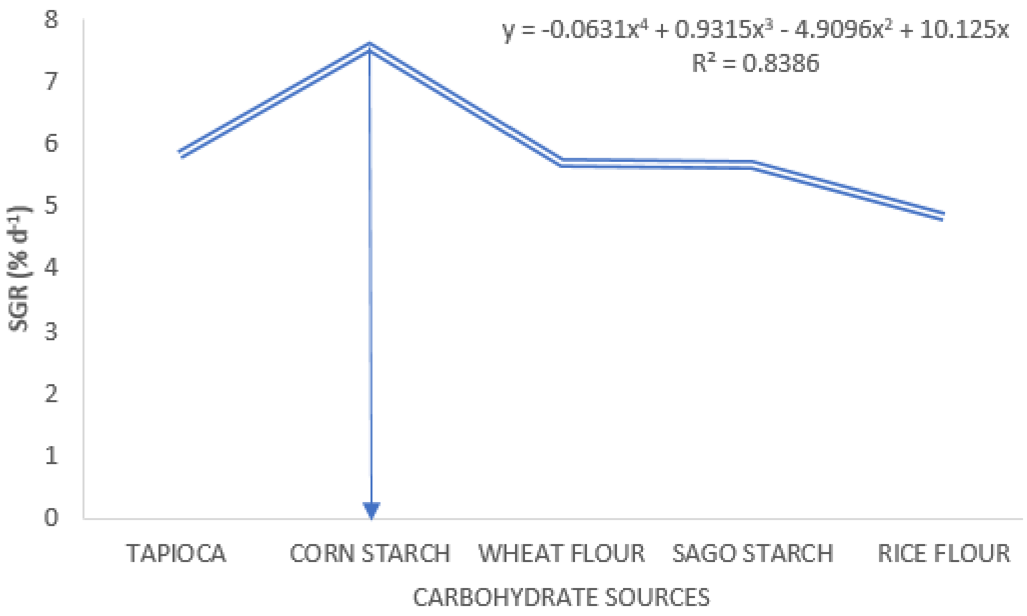

Figure 1: Relationship between specific growth rate of Nile tilapia fingerlings and dietary carbohydrate sources

The whole body proximate composition of the fingerlings at the beginning and end of the experiment are shown in (Table 3). The results showed that the dietary carbohydrate source had no significant effect on the fish composition except crude lipid. Body lipid increased by 4.84-8.08% following the feeding. Body lipid in fish fed with wheat flour was significantly higher (P<0.05) than those of fish fed other starch sources.

Table 3: Whole body proximate composition (%wet weight basis) of Nile tilapia fingerlings fed different carbohydrate sources after sixty days

		Carbohydrate sources				
Component	**Initial**	**Tapioca starch**	**Corn starch**	**Wheat starch**	**Sago starch**	**Rice starch**
Moisture	77.23±0.01	73.08±0.98^{ab}	73.43±0.15^{a}	72.58±0.15^{b}	72.54±0.13^{b}	72.68±0.35^{b}
C. protein	14.41±0.10	15.08±0.65^{b}	15.06±0.18^{a}	15.52±0.23^{a}	15.42±0.84^{b}	15.34±0.41^{c}
C. lipid	4.84±0.03	7.76±0.35^{b}	7.49±0.12^{b}	8.08±0.17^{a}	7.20±0.23^{c}	7.17±0.20^{c}
Ash	2.31±0.12	2.45±0.06^{c}	2.51±2.09^{c}	2.49±0.01^{bc}	2.71±0.09^{a}	2.52±0.19^{b}
C. fiber	0.16±0.02	0.13±0.03^{a}	0.18±0.01^{a}	0.12±0.01^{a}	0.12±0.02^{a}	0.13±0.04^{a}
NFE.	1.47±0.05	1.51±0.01^{c}	1.91±0.07^{c}	1.87±0.13^{c}	2.47±0.29^{b}	2.54±0.17^{a}
GE (kJ g^{-1})	5.67±0.11	5.76±0.27^{c}	5.77±0.04^{c}	5.42±0.04^{b}	6.77±0.03^{a}	5.33±0.03^{b}

Values are means ± SE of three replicates. Different superscripts in the same row indicate significant differences ($p < 0.05$).

Nutrient retention values was significantly affected (P<0.05) (table4). Fish fed corn starch had the highest protein, lipid and energy retention, in general the carbohydrate retention was low in all fish groups. However, fish fed corn and Sago starch had significantly higher (P<0.05)carbohydrate retention compared to other treatments. Fish fed tapioca starch achieved the lowest values in the retention of all nutrients (Table 4).

Table 4: Protein, carbohydrate and lipid retention of Nile tilapia fed different carbohydrate sources after 60 days

Carbohydrate sources	**Retention (%)**			
	Protein	**Lipid**	**Carbohydrate**	**Energy**
Tapioca starch	24.18 ± 0.24^{d}	74.25 ± 0.58^{d}	3.54 ± 0.29^{cd}	29.44 ± 0.09^{d}
Corn starch	29.48 ± 0.05^{c}	82.74 ± 0.88^{e}	5.16 ± 0.09^{a}	40.52 ± 0.30^{c}
Wheat flour	27.13 ± 0.07^{b}	79.00 ± 1.45^{a}	3.77 ± 0.02^{c}	37.04 ± 0.20^{b}
Sago starch	29.01 ± 0.09^{a}	76.24 ± 1.20^{c}	4.46 ± 0.09^{b}	39.85 ± 0.19^{a}
Rice flour	25.03 ± 0.27^{c}	78.75 ± 0.88^{b}	3.87 ± 0.12^{c}	26.80 ± 0.05^{e}

Values are means ± SE of three replicates. Different superscripts in the same row indicate significant differences ($p < 0.05$).

DISCUSSION

Omnivorous and herbivorous fishes can readily accept the dietary inclusion of starch and exhibit carbohydrate protein-sparing effect compared to carnivorous fish (German *et al.*, 2010;Hemre, Mommsen, & Krogdahl, 2002b).Starches from different sources have different morphology based on their botanical origins (Singh, Kaur, & McCarthy, 2007). Starch utilization by fish can be affected by this source factor because of the differences in amylose and amylopectin contents in the starches (Jobling, 2012).Corn, tapioca and other starches has been used as an aquafeed binder to stabilize pellet from disintegration in water and prevent nutrient leaching (Paolucci & Maria Grazia Volpe, 2012). It is also an important ingredients for the production of extruded aquafeeds.The results ofthe present study indicated the *O. niloticus* fingerlings grow well in an indoor culture system when wheat bran or corn meal were added in their diets at 22.5 % level. The level of carbohydrate sources used in the present study was selected on the basis of the conclusion drawn by various workers (Cowey and Sargent 1979; Anderson *et al.* 1984; Al-Asgah and Ali 1994; Al-Ogaily *et al.*, 1994 and Wilson 1994), that both simple and complex carbohydrate up to levels of 25 % level can be used as energy sources for several fish species. Al-Asgah and Ali (1994) reported that , inclusion of maize grain at the 25 % level in tilapia diet has been shown to improve the growth performance and nutrient utilization in comparison with other carbohydrate sources like corn starch, dextrin sucrose and glucose. However, the increasing level (25-43 %) ofmaize grain in the diets ofNile tilapia decreased their growth performance (Al-*Ogaily et al.* 1994). Viola and Arieli (1983) also reported a decrease in the performance of both carp and tilapia when fed pelleted diets containing high levels (65 - 75 %) of different grains. The best growth performance was obtained on the wheat bran containing diet followed by corn meal diet in comparison with others, whereas the akalona diet showed the poorest performance. Shalaby *et al.* (1989) reported that, wheat, maize and rice increased the growth performance of common carp more than barley and sorghum when fed fish meal-soybean meal diets with cereal grains and grain by-products. The variation between the results of this study and those reported by Shalaby *et al.* (1989) may be the result of species.O. *niloticus*fingerlings readily accepted all the test diets. Different physiological responses toward dietary treatments were probably due to this dissimilarity in nature and complexity of the starches from different plant sources. Similar trend was observed in Masheer(Delbertmiii *et al.*, 2007;Russell, Davies, Gouveia, & Tekinay, 2001) Carbohydrate starches and flours were accepted in this study but showed a significant effect on the growth, feed efficiency, body indices and all the body composition even though these sources were provided at 22.5% diet. In general, fish fed with corn starch showed a higher growth performance and better feed utilization than fish fed tapioca and sago starches, wheat and rice flours. Response to different dietary starch sources is species-dependant. Gilthead seabream (Sparus aurata) shows a better growth performance when fed diets containing wheat or barely than corn or rice (Castro *et al.*, 2019). Bagrid catfish (Mystus nemurus) performs better with diets containing rice or corn compared to diets with dextrin or sago (Hamid *et al.*, 2011). Mirror carp (Cyrinus cftg) responded better to the inclusion of rice in its diet compared to tapioca(Ufodike & Matty, 1983). In contrast, no significant difference has been observed in growth of European sea bass (Dicentrarchus labrax) and atlantic salmon (salmo salar) fed different starch sources (Castro et al., 2019;*Russell et al.*, 2001).Dextrin was reportedas the best carbohydrate source for blunt snout bream compared to native corn, wheat starch, glucose, maltose and cellulose (Ren *et al.*, 2015). Juvenile flounder can efficiently utilize dextrin compared to glucose (Leenhouwers *et al.*, 2008;Romano *et al.*, 2016).

In this studyfish fed corn starch had the highest HSI and VSI values compared to tapioca wheat, sago and rice. It could be presumed that the excess energy from the dietary carbohydrate was converted in to lipid and deposited as glycogen in the liver resulting in an increase of HSI as those observed by earlier researches (Mohanta, Mohanty, Jena, Sahu, & Patro, 2009;Gao *et al.*, 2019). European sea brass fed fishmeal-based diets with corn starch inclusion has a higher HSI compared to those fed diets with fishmeal being replaced by plants proteins such as soybean meal, wheat and corn gluten(Guerreiro, Oliva-teles, & Enes, 2015). Hybrid striped bass fed diet with a carbohydrate inclusion has a higher HSI compared to those fed a starch-free and high lipid diet although fish fed and high lipid diet has a higher VSI(Y. Wang *et al.*, 2005).

Moisture and lipid compositions in hybrid bass and mirror carp are also affected with different dietary corn starch treatments (Ufodike & Matty, 1983). In contrast, the body composition of gilthead seabream remains unaffected when fed corn, barley, wheat or rice (Couto, Peres, Oliva-teles, & Enes, 2016). The PER and protein retention of tinfoil barb in the present study indicated a protein sparing effect by different starch sources. The protein sparing effect was not observed when different dietary carbohydrate levels of tapioca starch were tested. The high VSI, lipid retention and whole body lipid in tinfoil barb fed corn starch indicated that corn starch induced a higher de-novo conversion of carbohydrate to lipid compared to other starches.

CONCLUSION

Starch sources affected growth, feed utilization efficiency, body composition and nutrient retention of Nile tilapia fingerlings. The overall performance of fish fed on corn starch was not comparable to the performance of fish fed on other starches. This demonstrated that no other starch that has the potential to be used directly as a replacement of corn starch in terms of growth and development of the fish fingerlings. Therefore, corn starch at 22.5% can be used for effective growth and development.

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