Emir. J. Agric. Sci. 1996. 8: 1- 12

Effect of Replacing Dietary Starch with Glucose on the Productive Performance of *Oreochromis mossambicus*

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ABSTRACT

In a feeding experiment, the influence of replacing 0, 25, 50, 75 and 100% of dietary starch with glucose on the productive performance of *O. mossambicus* fry (0.8 ± 0.002 g) was studied. Fish in each experimental group were fed a daily ration of 2% of the metabolic body weight ($W^{0.8}$) for 8 weeks. Fish fed the glucose free diet (100% starch) attained the highest ($P<0.05$) final body weight and specific growth rate. These values decreased significantly ($P<0.05$)as glucose was increased in the diets. The lowest ($P<0.05$) growth performance and feed utilization efficiency among all groups were observed with fish fed starch free diet (100% glucose). Treatment did not affect survival rate. Plasma glucose values increased as a function of increasing glucose level in the diets. Values of the hepatosomatic index were significantly ($P<0.05$) higher for all groups fed diets containing glucose than the group fed glucose free diet (100% starch).

Key words : tilapia, dietary strach and glucose, growth, body composition, plasma glucose, hepatosomatic index.

INTRODUCTION

In feeding animals, carbohydrates are the least expensive source of dietary energy (Wilson, 1994). Fish prefer to utilize protein and fat as a primary energy source instead of carbohydrate (Nagai and Ikeda, 1971). In order to decrease the level of protein utilized as energy source in fish feed, many studies have been conducted by adding energy from non-protein sources (Watanabe et al.,1979; Watanabe,1982). The utilization of dietary carbohydrates depends on its source, intake level and fish species (Hilton and Atkinson, 1982). Some fish species are able to utilize simple sugars better than complex carbohydrates, while others are not (Buhler and Halver, 1961).

Warmwater fish species showed higher growth rate and better feed efficiency when fed complex carbohydrates than simple sugars (Furuichi and Yone, 1982; Wilson and Poe, 1987). In contrast, Akiyama et al.(1982) found that chum salmon , a coldwater fish utilizes glucose as an energy source better than fructose, galactose or lactose. Also warmwater fishes are able to utilize higher levels of carbohydrates than coldwater or marine fish species (Wilson, 1994). Luquet (1991) stated that tilapia could utilize up to 40% carbohydrates in their diet, while Hilton and Atkinson (1982) reported that a carbohydrate level of more than 14% in rainbow trout diet decreased growth performance.

The objective of the present study was to determine the effect of two dietary carbohydrate sources (starch and glucose) on growth performance, feed utilization efficiency, protein utilization , body composition and plasma glucose of *Oreochromis mossambicus*.

MATERIALS AND METHODS

Experimental Fish and Management :

Two hundred and fifty equal-sized, one month old, half-sibs *O. mossambicus* fry hatched in the Aquaculture Laboratory of United Arab Emirates University, with an average initial body weight of 0.8 ± 0.002 g, were randomly stocked in 20 L Fiberglas tanks at the rate of (25 fish/tank). Each tank was part of a closed recirculatory system with a common reservoir of water maintained at 26 ± 1°C. Water flow rate to each tank was 3 L/min, air was provided to the system through a central airblower. Impurities were removed and ammonia level was reduced by pumping the water through a biological filter. Photoperiod was 12 h light and 12 h darkness.

At the beginning of the experiment, 50 fry from the same batch used in the feeding experiment were killed to determine the initial body composition of the fish. All fish in the experimental tanks were counted and bulk weighed every week.

Growth in terms of weight gain (%) and specific growth rate (SGR %/day), survival rate (%), feed conversion ratio (FCR as g diet/g gain), protein efficiency ratio (PER), protein productive value (PPV) energy utilization (EU) in addition to carcass composition and plasma glucose fluctuations were determined.

Feeds and Feeding :

Five isonitrogenous (35% crude protein) and isocaloric (18.75 kJ GE/g diet) experimental diets were formulated using practical ingredients (Table 1). Starch was replaced at 0, 25, 50, 75 and 100 % by D(+) glucose monohydrate (Riedel-de Haen) in diets 1, 2, 3, 4 and 5, respectively. The ingredients for each diet were thoroughly hand-mixed and moistened with water. The homogenized dough was then pressed through a meat mincer provided with a 2 mm die. All experimental diets were oven-dried at 55° C for 12 h, crumbled and sieved to the appropriate size for feeding. Prepared diets were kept at 18° C until used. Proximate compositions of the experimental diets are presented in Table 1. Each experimental diet was fed to duplicate groups of fish 6 days a week for a period of 8 weeks (56 days) at daily rate of 2% of fish metabolic body weight ($W^{0.8}$). Feeding rate was adjusted every week according to body weight and the daily feed amount was divided into 3 equal portions given at 8.30, 13.30 and 18.30 h, respectively.

Plasma Glucose and Liver Samples :

At the end of the feeding experiment, ten fish were sampled from each tank and killed for body composition. At the same time, a random lot of three fish was taken and the liver of each fish was removed and weighed. The remaining fish were starved for 24 h and two fish were randomly taken from each tank and blood was sampled from the caudal vein . The remaining fish were fed each test diet and two fish were taken randomly at 2, 4, 8 and 16 h after feeding from each tank for blood collection. The sampled fish were not reused. Blood samples were immediately centrifuged at 3000 rpm for 3 min. and the resulting plasma from each tank were pooled and measured for glucose level using the Du Pont Dimension clinical chemistry system (Du Pont, Wilmington, DE, USA).

Proximate Analysis :

Diets and fish were chemically analysed in triplicate by the standard methods (AOAC, 1984) for moisture, crude protein, ether extract, crude fiber and ash. Nitrogen-free extract was calculated by subtraction of {100 - (crude protein % + ether extract % + crude fiber %)}. Gross energy content of diets and fish were calculated by using the factors 23.86 kJ/g protein, 39.77 kJ/g fat and 16.74 kJ/g carbohydrate according to Wee and Wang (1986).

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

	Diet				
	1	2	3	4	5
Ingredient (%) :					
Fish meal (65% CP)	40.0	40.0	40.0	40.0	40.0
Soybean meal (44% CP)	14.0	14.0	14.0	14.0	14.0
Starch	40.0	30.0	20.0	10.0	00.0
Glucose	00.0	10.0	20.0	30.0	40.0
Sunflower oil	4.0	4.0	4.0	4.0	4.0
Vitamin mixture*	2.0	2.0	2.0	2.0	2.0
Proximate composition (%) :					
Moisture	9.11	10.31	10.74	11.98	11.46
Crude protein	35.14	34.69	34.49	35.36	35.91
Ether extract	4.30	4.13	4.24	4.28	3.29
Crude fiber	1.63	1.52	1.47	1.44	1.27
Ash	9.92	9.85	9.69	9.64	9.24
NFE	39.90	39.50	39.37	37.30	38.83

*) Vitamin mixture: Shrimp tonic. JV Marine East. Co.Ltd, Thailand. (A. 3000 000 IU; D_3, 12 000 IU; $B_1$1250 mg; B_2 12 000 mg; B_6 , 1250 mg; B_{12} 4250 mg; E. 12 500 mg; E 250 mg; C, 50 000 mg; K_3 ,5000 mg; Nicotinamic, 30 000 mg; Panthotecat, 15 000 mg; Folic acid, 1500 mg; lacinamide, 20 000 mg; Insitol, 112 500 mg; Lecithin, 25 000 mg and Choline 37 500 mg).

Statistical Analysis:

One-way ANOVA was used to detect statistical differences among mean treatments according to the methods of Duncan's multiple range test (Duncan, 1955) was used to determine significant differences ($P<0.05$) between means of different treatments.

RESULTS

Results presented in Table 2 indicate that fish group fed diet 5 (40 % glucose) showed the lowest final weight gain values (P<0.05), while the din final weight among group 1 (40 % starch) and other groups (2 and 4) which were fed diets containing 30 and 10 % starch, respectively, were in significant (P>0.05). The growth results of

Table 2: Productive performance of *O. mossambicus* as affected with the source of carbohydrate fed.

	Diet					
	1	2	3	4	5	± SE
Initial wt (g)	0.80	0.80	0.80	0.80	0.80	0.00
Final wt (g)	4.05^{a}	3.83^{ab}	3.48^{b}	3.68^{ab}	2.87^{c}	0.17
Survival (%)	100.00	100.00	92.00	100.00	100.00	2.53
Weightgain^{1} (%)	407.54^{a}	379.70^{ab}	336.64^{b}	361.79^{ab}	260.36^{c}	21.04
SGR^{2} (%/day)	2.90^{a}	2.80^{ab}	2.63^{b}	2.73^{ab}	2.28^{c}	0.11
Feed intake (g/fish/day)	0.106^{d}	0.107^{c}	0.100^{e}	0.119^{a}	0.117^{b}	0.004
FCR (g feed/g gain)	1.76^{b}	1.85^{b}	1.90^{b}	1.79^{b}	2.40^{a}	0.088
PER^{3}	1.62^{a}	1.56^{a}	1.53^{a}	1.58^{a}	1.18^{b}	0.058
PPV^{4} (%)	28.49^{a}	28.52^{a}	27.22^{a}	27.29^{a}	19.27^{b}	1.251
EU^{5} (%)	25.63^{a}	26.70^{a}	23.46^{b}	23.28^{b}	16.35^{c}	1.295
Hepatosomatic index^{6}	0.075^{b}	0.120^{a}	0.115^{ab}	0.115^{ab}	0.120^{a}	0.008

Means with the same superscript in the same row are not significantly different (P<0.05).

1) Weight gain % = 100 x Weight gain (g) / Initial weight (g)

2) SGR = 100 [(Log$_e$ Final weight - Log$_e$ Initial weight)/Time, days)]

3) PER = Body weight gain (g)/ Dietary crude protein fed (g)

4) PPV = 100 x Tissue crude protein deposition (g)/ Dietary crude protein fed(g)

5) EU = 100 x Energy deposition (kJ/fish)/ Dietary energy fed(kJ/fish)

6) Hepatosomatic index = Liver weight (g)/ fish body weight (g)

group 3 (20 % starch) seems to be affected by the mortality of two fishes due to mechanical injuries. As the glucose percentage in the diets was elevated, SGR was decreased. Also group 5 had the worst FCR value (2.40 g diet/ g gain) which was significantly different P<0.05), whereas the differences between group 1,2 ,3 and 4 were not significant. The protein utilization (PPV) of group 5 showed the lowest significant values (P<0.05), only 19.27 % of the dietary protein was retained in fish body, while 28.49% of the dietary protein was retained in the fishes body when they were fed a diet containing 40% starch (group 1). No significant differences were detected between the PPV of groups 1, 2, 3 and 4. About 35 % of the retained energy (EU) were lost when starch was completely replaced with glucose. Only 17.27 % of the dietary energy were retained in fish body when they were fed 40 % glucose diet, whereas 25.63 % were retained when fish were fed 40 % starch diet.

As shown in Table 2, liver weight as a percentage of body weight (hepatosomatic index) was significantly (P<0.05) higher for all groups fed diets containing glucose than that of fish fed the glucose free diet (diet 1).

Body composition of the experimental groups are presented in Table 3. In contrast to ash content, body crude protein and fat in group 5 where the main carbohydrate source in diet was glucose were slightly reduced (P<0.05) when compared o the other groups.

Table 3: Body composition (% wet weight) and Gross energy content (kJ/g DM) of *O. mossambicus* fed the test diets

	Diet					
	1	2	3	4	5	± SE
Moisture	69.90^{b}	70.35^{b}	71.70^{a}	70.50^{b}	71.75^{a}	0.314
Crude protein	17.52^{a}	17.31^{ab}	17.61^{a}	17.25^{ab}	16.56^{b}	0.196
Crude fat	9.97^{a}	9.78^{a}	8.34^{b}	9.27^{a}	8.42^{b}	0.278
Ash	3.80^{b}	3.71^{b}	3.85^{b}	3.84^{b}	4.31^{a}	0.082
GE (kJ/g DM)	27.06	27.04	26.57	26.45	25.84	0.507

Means with the same superscript in the same row are not significantly different (P<0.05).

Plasma glucose levels reached the highest peak 4 h after feeding (Figure 1). In general, the plasma glucose values increased as a function of increasing levels of glucose in the experimental diets and fish fed the highest level of starch (40 %) had the lowest plasma glucose value.

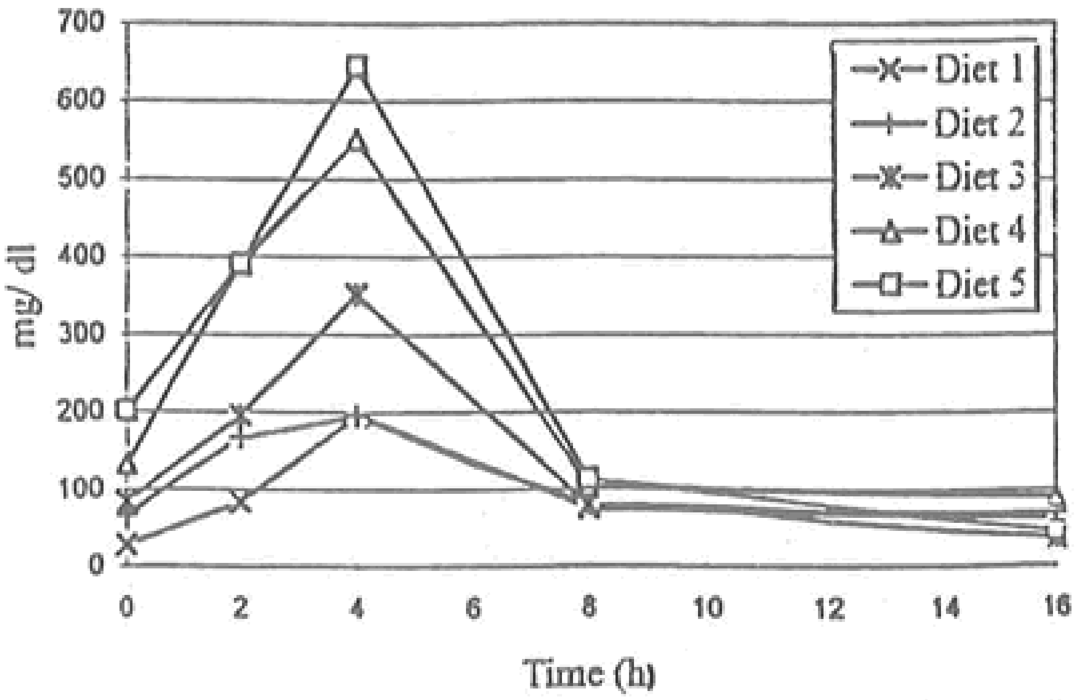

Fig. 1 . Plasma glucose concentration for tilapia fishes fed different experimental diets. Zero h is the end of 24-starving period and 2.4.8 and 16 h are the post-feeding time

DISCUSSION

The growth performance of fish in the present study is in accordance with the previous results reported by Furuich and Yone (1982), Anderson et al.(1984), Wilson and Poe (1987); Hung et al.(1989) and Tung and Shiau (1991). Fish groups fed starch free diet (group 5) had lowest significant ($P>0.05$) final weight gain and SGR. The differences between groups 1, 2, 3 and 4, fed diets containing different percentages of starch and glucose, were not significant ($P>0.05$). Values for final weight gain in the present study were higher than those obtained by Tung and Shiau (1991). They reported percentage weight gain of 246.3 % and 225.2 % for groups fed starch and glucose, respectively. These growth variations are probably due to the different fish species and/or the fish size used.

Feed utilization values (FCR, PER, PPV and EU) obtained in the present study were in agreement with the results of Shiau and Lin (1993). FCR of the fish groups fed diets containing starch was significantly better ($P<0.05$) than that fed only glucose as a carbohydrate source. The more starch is provided in the diets to an appropriate level, the more protein is deposited in fish body. Anderson et al. (1984) reported that *Oreochromis niloticus* had the greatest PER and PPV when they were fed dextrin and least with glucose. It seems that tilapia fish tend to utilize starch as an energy source better than glucose, these results were similar to those obtained by Wilson and Poe (1987) with Channel catfish. Nagai and Ikeda (1971) suggested that in fish the interconversion rate between glucose and glycogen (carbohydrate) would not be so efficient. Wilson (1994) concluded that if carbohydrates were not provided in fish diets, the protein would be catabolized as an energy required for intermediary metabolism . It seems that the efficiency of energy retention is greater in diets with starch than in diets containing glucose (Qadri and Jameel, 1989).

Oraly adminstrated glucose lead to higher plasma glucose levels than fish fed starch diet (Fig. 1). Wilson and Poe (1987) found that plasma glucose concentration of channel catfish fed 167 mg glucose/ 100 g body weight was increased from 71 mg/dl after 24 h fasting period to 171 mg/dl after 3 h from feeding. These values were less than that obtained after 4 h from feeding in the present experiment (Fig. 1). The glucose administrated in this study was between 0.5 and 1.7 g glucose / 100 g body weight which is higher than that fed by Wilson and Poe (1987). The values obtained in present experiment are also higher than that obtained by Shiau and Lin (1993) for hybrid tilapia. The same phenomena was observed by Furuichi and Yone (1971) for red sea bream; Wilson and Poe (1987) for channel catfish. Wilson (1994) concluded that glucose in fish diet lead to a persistent hyperglycemia.

Qadri and Jameel (1989) suggested that when higher levels of carbohydrate are included in fish diets, the starch produce the most sparing, while glucose produce the least. They also found that as glucose level increased, the carcass fat were decreased, this is in agreement with the results of the present experiment. The fish fed glucose diets had higher hepatosomatic index than the group fed glucose free diet. This is in agreement with the trend obtained by Shiau and lin (1993).

However the results of Plisetskaya (1990) and Mommsen and Plisetskaya (1991) showed that insulin level in fish blood is similar to mammals and that the intolerance of fish to use large amount of orally administrated glucose might be due to a similar conditions known as non-insulin-dependent diabetes mellitus. Furichi and Yone (1981) pointed out that fish blood-insulin , with respect to the time to reach the maximum level and the maximnm activity, were very similar to those observrd for diabetic human. Palmer and Ryman (1972); Thorpe and Ince (1974) suggested that the inability of fish to utilize high levels of glucose is due to the lack of sensitivity hormone toward glucose level.

CONCLUSION

1. *Oreochromis mossambicus* has the ability, like almost all warmwater fish, to utilize highamount of carbohydrates in its diet.

2. They utilize starch as an energy source better than glucose.

3. If it is necessary to use glucose, its level should not exceed 10 % of the total diet.

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مجلة الإمارات للعلوم الزراعية (١٩٩٦) ٨ : ١-١٢

تأثير إحلال النشا الغذائي بالجلوكوز على الأداء الإنتاجي للبلطي الموزمبيقي .

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قسم الإنتاج الحيواني ، كلية العلوم الزراعية ، جامعة الإمارات العربية المتحدة ، ص.ب ١٧٥٥٥ العين ، الإمارات العربية المتحدة .

ملخص :

في تجربة غذائية لدراسة تأثير استبدال صفر ، ٢٥، ٥٠، ٧٥ و ١٠٠٪ من نشا العليقة بالجلوكوز على الأداء الإنتاجي لأسماك البلطي الموزمبيقي (٨. + ٢. ٠٠. جم). تم تغذية الأسماك في جميع مجموعات التجربة ب ٢٪ من الحيز التمثيلي (الوزن ^٠.٨) لمدة ٨ أسابيع. وقد أظهرت الأسماك التي تم تغذيتها على العلائق الخالية من الجلوكوز (١٠٠٪نشا) أعلى وزن نهائي وأعلى معدل نمو نسبي (P<0.05). هذه المعدلات انخفضت معنويا بارتفاع مستوى الجلوكوز في العليقة . أما المجموعة التي تم تغذيتها على عليقة خالية من النشا (١٠٠٪ جلوكوز) فقد أظهرت أقل نمو وكفاءة استفادة من الغذاء. ولم يكن هناك تأثير لمصدر الكربوهيدرات على معدلات النفوق ، وزاد أيضا وزن الكبد بالنسبة لوزن الجسم معنويا (P<0.05) في كل المجموعات التي تحتوي علائقها على جلوكوز عن التي تم تغذيتها على عليقة خالية منه (١٠٠٪ نشا).

كلمات مفتاحية : نشا وجلوكوز غذائي ، نمو ، تركيب الجسم ، الجلوكوز في بلازما ، دليل الكبد النسبي ، بلطي.