

Effect of Feeding Different Levels of Cellulose on the Growth Performance and Body Composition of *Oreochromis niloticus*

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ABSTRACT. This study evaluated the effect of different levels of α -cellulose on the growth performance and body composition of *Oreochromis niloticus*. Five isonitrogenous and isocaloric diets containing 0, 3, 6, 9 and 12% of α -cellulose were prepared and fed to fingerling *Oreochromis niloticus* (average weight 11.74 ± 0.19 g) for a period of 39 days. Significant differences ($P < 0.05$) were observed in the weight gain, specific growth rate (SGR), feed conversion ratio (FCR), and protein efficiency ratio (PER) of fish fed different levels of α -cellulose. The diet containing 3% cellulose showed the poorest weight gain, SGR, FCR, and PER values as compared to all other diets whereas the best values were observed for the diets containing 9 or 12% cellulose. Increasing the level of cellulose from 9 to 12% in the diet did not produce any further significant ($P > 0.05$) beneficial effects. The level of cellulose in the diet did not affect ($P > 0.05$) the feed intake or the condition factor (k) of fish. Supplementation of cellulose at 6% level in the diet produced similar results ($P < 0.05$) as compared to that of a diet without cellulose. The increasing level of cellulose in the diet increased body moisture and decreased crude protein and fat contents of fish. It may be concluded from these results that cellulose at a level of 9% in the diets of *Oreochromis niloticus* can improve their growth performance, FCR and PER and will produce leaner fish as compared to those without cellulose. Higher levels of cellulose may not have any further beneficial effects.

Cellulose fibre traditionally represents a typical filler material to balance the nutrients in experimental diets. It is a water insoluble dietary fibre and is generally assumed to be a nutritionally inert substance. Dietary fibre has, however, been reported to affect the digestibility and absorption of several nutrients including proteins and minerals (Southgate and Durnin 1970, Shah *et al.* 1982, Ward and Reichert 1986). The inclusion of cellulose in fish diets also increases the stomach emptying time (Hilton *et al.* 1983). The use of wide ranges of concentrations of cellulose and hemicellulose as diluents in experimental diets has obscured the true requirement for nutrients by altering the physiological responses of fishes to nutrients (NRC 1981).

Buhler and Halver (1961) reported that small amounts of α -cellulose had a beneficial effect on growth and protein utilization in chinook salmon (*Oncorhynchus tshawytscha*) but the larger amounts had an adverse effect. Addition of cellulose at 0 or 9% levels in the diets of Japanese eels (*Anguilla japonica*) did not noticeably affect their growth (Arai *et al.* 1971). Inclusion of carboxymethylcellulose (CMC) up to 12% (Morita *et al.* 1982) and cellulose at a level of 10% (Kono *et al.* 1987) in the diets of red sea bream (*Chrysophrys major*) improved their growth and feed efficiency, whereas the control diet containing 1% cellulose caused a decline in growth. Hilton *et al.* (1983) concluded that for rainbow trout (*Oncorhynchus mykiss*), the dietary fibre level should be less than 10%. Anderson *et al.* (1984) reported that a cellulose level above 10% is not desirable in the diets for *Oreochromis niloticus*. Dioundick and Stom (1990) observed that tilapia (*Oreochromis mossambicus*) fed with 10% cellulose supplemented diet exhibited depressed growth similar to fish fed a cellulose free diet. Shiau *et al.* (1988) observed significantly poorer feed conversion rates when carboxymethylcellulose was increased over 2% in the diets of hybrid tilapia.

Further studies are required to elucidate the physiological role of dietary cellulose and its nutritional effects in various fish species. The present experiment was conducted to evaluate the effect of feeding different levels of α -cellulose on the growth performance and nutrient utilization in *Oreochromis niloticus*.

Materials and Methods

Oreochromis niloticus with an average weight of 11.74 ± 0.19 g were collected from the fish hatchery of King Abdul Aziz City for Science and Technology (KACST) Deerab, Riyadh. To determine their initial body composition, 30 randomly selected fish were killed immediately and after recording their body weight and length, were stored at -30°C for the proximate analysis at a later stage. One hundred

and fifty fish were then randomly divided into 5 different groups with 3 replicates containing 10 fish in each replicate. The fish were kept in glass aquaria (100 × 42.5 × 50.0 cm) containing well aerated tap water having an average temperature of 28 ± 1 °C and fitted with a waste filtration system. Compressed air maintained the oxygen supply. Regular monitoring of water quality was carried out for temperature, pH, dissolved oxygen, ammonia, nitrite and nitrate levels. These parameters were kept within the tolerance limits for *Oreochromis niloticus*.

Five isonitrogenous and isoenergetic experimental diets containing 0, 3, 6, 9 or 12% of α -cellulose were prepared through the extrusion process using a sieve of 2 mm dia (Table 1). The proximate chemical composition of the diets is given in Table 2. The diets were dried at 60°C and then stored at -18°C throughout the experimental period. Each diet was randomly allotted to 3 replicates in different groups in a completely randomized design. The diets were offered twice daily at about 3% of body weight. The feed offered was adjusted every fortnightly in relation to body weight of fish and the intake was monitored closely depending upon the acceptance and rejection of feed offered. The daily feed intake and fortnightly weight gains were recorded. The experiment lasted for 39 days. At the end of the experimental period all the fish were killed and their body weight and length were recorded. To determine their carcass composition, the fish were cut into pieces and minced through a meat mincer. The homogenized samples were immediately frozen at -30 °C for further analysis. The proximate chemical composition was determined according to the methods of Association of Official Analytical Chemists (1984). The gross energy content of fish was calculated from the fat and protein contents using equivalents of 39.54 MJ/Kg crude fat and 23.64 MJ/Kg crude protein (Kleiber 1961).

Feed conversion ratio (FCR), specific growth rate (SGR), condition factor (k), protein efficiency ratio (PER) and net protein retention (NPR) were calculated as follows:

Feed conversion ratio = Kg feed consumed per Kg weight gain.

Specific growth rate (as percentage of body weight gain per day)

= 100 [In final wt.(g) - In initial weight (g)]/time (days).

Protein efficiency ratio = liveweight gain (g)/protein consumed (g).

Net protein retention = [increase in carcass protein / protein fed] × 100.

The condition factor (k) was calculated according to the equation $k = \frac{[W(g)/L(cm)^3] \times 100}{100}$, where *W* is the wet weight of the fish in grams and *L* is the length in centimetres. The data were statistically analysed using one way analysis of variance

technique and the means were compared by Fisher's LSD test according to Snedecor and Cochran (1989).

Table 1. Composition of the experimental diets (%)

Ingredients	Diets				
	A	B	C	D	E
Fish meal	41.00	41.00	41.00	41.00	41.00
Soybean meal	15.00	15.00	15.00	15.00	15.00
Maize	20.00	20.00	20.00	20.00	19.80
Cod liver oil	02.00	02.00	02.00	02.00	02.00
Corn oil	02.00	03.30	04.60	05.90	07.20
Dextrin	17.00	12.70	08.40	04.10	00.00
α -Cellulose	00.00	03.00	06.00	09.00	12.00
Mineral mixture ¹	02.00	02.00	02.00	02.00	02.00
Vitamin mixture ²	01.00	01.00	01.00	01.00	01.00
Total	100.00	100.00	100.00	100.00	100.00

¹Per Kg of the premix contains: CaHPO₄, 530g; K₂HPO₄, 80g; Na₂HPO₄, 90g; MgCl₂. 6H₂O, 100g; KCl, 67.5g; K₂SO₄, 80g; NaCl, 30g; KI, 0.05g; ZnSO₄.7H₂O, 2.5g; SeO₂, 0.03g; CuSO₄.5H₂O, 0.15g; FeSO₄.7H₂O, 18g; (NH₄)₆Mo₇O₂₄.H₂O, 0.01g; MnSO₄.H₂O, 0.5g; NaF, 1.2g; CoCl₂.6H₂O, 0.01g.

²Per Kg of the premix contains: Vitamin A, 400,000 I.U.; D₃, 200,000 I.U.; E, 5000 I.U.; K₃, 1g; B₁, 1g; B₂, 1.5g; B₆, 1g; Pantothenic acid, 5g; Niacin, 3g; Folic acid, 0.5g; B₁₂, 2mg; Biotin, 100mg; Vitamin C, 20g; (adopted from Lim 1989).

Table 2. Proximate chemical composition of fish diets (on % dry matter basis)

Parameters	Diets				
	A	B	C	D	E
Dry matter (%)	94.38	94.69	95.18	95.63	95.42
Crude protein	37.70	36.83	37.82	37.99	37.29
Crude fibre	01.88	03.72	06.31	08.57	11.34
Total fat	07.92	09.59	10.23	11.38	12.62
Ash	11.36	11.85	11.71	10.95	10.91
Nitrogen free extract	41.14	38.01	33.93	31.11	27.84
Gross energy (MJ/Kg)	19.09	19.00	18.80	18.81	18.56

Results

The data on the growth performance of *Oreochromis niloticus* fed different levels of α -cellulose is presented in Table 3. For weight gain, the differences between the diets containing 3 or 6%, 6 or 9% and 9 or 12% cellulose were non-significant ($P < 0.05$). The diet containing 3% cellulose showed the poorest ($P < 0.05$) weight gain. The specific growth rate of fish fed different levels of cellulose differed ($P < 0.05$) and the best SGR was observed for the diet containing 9 or 12% cellulose. The diet containing 3% cellulose showed the poorest SGR values. The level of cellulose in the diet did not affect ($P > 0.05$) the feed intake of fish. Similarly the condition factor of fish was not affected ($P > 0.05$) by the level of cellulose in the diet.

Although the increasing level of cellulose improved the feed conversion ratio (FCR), the differences between the diets containing 3 or 6% and 9% or 12% of cellulose were non-significant ($P < 0.05$). The best FCR values were observed for the diet containing 9 or 12% cellulose whereas the diet containing 3% of cellulose showed the poorest results. Increasing level of cellulose (up to 12%) in the diets

appeared to improve the efficiency of protein utilization. However, non significant differences ($P < 0.05$) were observed among the PER values for the diets containing 3, or 6% and 9 or 12% of cellulose. Although similar trends were observed for the net protein retention values, the results did not differ significantly ($P > 0.05$). Supplementation of cellulose at a 6% level in the diet produced similar results as compared to that of a diet without cellulose.

Table 3. Effect of feeding different levels of cellulose on the growth performance of *Oreochromis niloticus*

Parameters	Diets					
	A	B	C	D	E	S.E.*
Initial weight (g/fish)	11.98	11.81	11.56	11.51	11.86	$\pm 0.18^{NS}$
Final weight (g/fish)	31.56 ^{ab}	30.04 ^{bc}	30.71 ^{bc}	31.72 ^{ab}	32.68 ^a	± 0.88
Total weight gain (g/fish)	19.58 ^b	18.23 ^c	19.15 ^{bc}	20.21 ^{ab}	20.82 ^a	± 0.78
Specific growth rate (SGR)	2.48 ^b	2.39 ^c	2.50 ^b	2.60 ^a	2.60 ^a	± 0.05
Condition factor (k)	3.06	3.21	3.27	3.16	3.25	$\pm 0.29^{NS}$
Total feed consumed (g/fish)	23.91	23.91	23.91	22.99	22.99	$\pm 0.00^{NS}$
Feed conversion ratio (FCR)	1.22 ^b	1.31 ^a	1.25 ^{ab}	1.14 ^c	1.10 ^c	± 0.05
Protein efficiency ratio (PER)	2.29 ^b	2.19 ^c	2.22 ^{bc}	2.42 ^a	2.54 ^a	± 0.09
Net protein retention (NPR)	29.38	27.64	27.64	29.28	29.65	$\pm 1.21^{NS}$

* = Pooled standard error.

^{NS} = Non-significant.

^{a,b,c} = Different letters in the same row means significant at 5%.

The data on the proximate chemical composition of fish are presented in Table 4. Significant differences ($P < 0.05$) were observed in the moisture, fat, crude protein and gross energy contents of fish fed different levels of cellulose. The body moisture content increased with increasing level of cellulose in the diet and the highest value

was observed for diet containing 12% cellulose. Non significant differences ($P < 0.05$) were observed in the body moisture content of fish fed diets containing 3, 6, or 9% cellulose. The crude protein and fat contents of fish decreased with increasing levels of cellulose in the diets. The diets containing 3, 6, or 9% of cellulose did not differ ($P > 0.05$). Similar results were observed for the gross energy content of fish. The inclusion of cellulose (up to 12%) in the diets did not affect ($P > 0.05$) the body ash content.

Table 4. Data on the body composition of *Oreochromis niloticus* fed different levels of cellulose (on % wet basis)

Parameters	Diets					
	A	B	C	D	E	S.E.*
Moisture (%)	76.10 ^c	76.82 ^b	76.46 ^{bc}	77.16 ^b	77.98 ^a	± 0.46
Crude protein	13.99 ^a	13.97 ^a	13.86 ^{ab}	13.54 ^{bc}	13.22 ^c	± 0.27
Total fat	3.85 ^a	3.37 ^b	3.41 ^b	3.37 ^b	2.72 ^c	± 0.20
Ash	4.79	4.52	4.68	4.43	4.48	± 0.22 ^{NS}
Gross energy (MJ/Kg)	4.82 ^a	4.63 ^b	4.62 ^b	4.53 ^b	4.19 ^c	± 0.11

¹ = Composition of fish slaughtered at the beginning of the experiment (moisture, 72.01%; crude protein, 15.98%; total fat, 6.25%, ash, 4.57% and gross energy, 6.24 MJ/Kg).

* = Pooled standard error.

^{NS} = Non-significant.

^{a,b,c} = Different letters in the same row means significant at 5%.

Discussion

Purified cellulose and hemicellulose have been considered as practically indigestible for some fish species like rainbow trout and carps (Bergot 1993, Schwarz and Kirchgessener 1982). Viola and Arieli (1983) reported that a partial utilization of cellulose in the digestive tract of tilapia can be regarded as possible. The digestion of cellulose and other higher molecular weight polysaccharides emphasizes the importance of intestinal bacterial flora which assist in digesting these materials. According to Viola and Arieli (1982), the long digestive tract of tilapia allows the establishment of a polysaccharide decomposing microflora of fairly high efficiency, capable of utilizing cellulose along with other carbohydrates. High numbers of aerobes, facultative anaerobes and obligate anaerobes have been found in the intestine of tilapias (*Oreochromis niloticus*; *O. mossambicus*) (Sakata *et al.* 1980a,b, Sugita 1982a,b), which may explain the digestion of cellulose and similar apparently indigestible food ingredients by this fish. Although no cellulolytic activity was found in the extracts of pancreas and intestine of common carps (*Cyprinus carpio*), a considerable digestion of cellulose was observed by this fish in in-vivo experiments (Bondi and Spandorf 1954). The cellulose activity in fish most probably originates from the alimentary tract microflora rather than from cellulose secreting cells within the fish (Stickney and Shumway 1974). Stickney (1975) reported that the cellulose production in fish is independent of food habits. Similar findings were reported by Lindsay and Harris (1980), that the cellulolytic activity in the digestive tract of fish does not depend upon the ingestion of cellulose. Das and Tripathi (1991), who observed the presence of both endogenous and bacterial cellulose in grass carps, reported that the pattern of distribution of digestive enzymes depended on the type of diet ingested by fish.

The presence of cellulose activity in the gastrointestinal tract of fish suggests the necessity for providing cellulose as a dietary ingredient for fish. Buhler and Halver (1961) reported that small amounts of α -cellulose had a beneficial effect on growth and protein utilization in *Oncorhynchus tshawytscha* (chinook salmon) whereas larger amounts had an adverse effect. Dioundick and Stom (1990) concluded that the absence of cellulose in the diets of juvenile tilapia (*Oreochromis mossambicus*) is just as undesirable as its surplus. They reported that the best growth rate, survival, FCR and PER were obtained with 2.5 to 5% of supplemented cellulose. They also concluded that the trend for growth depression in tilapia fed 7.5 to 10% supplemented cellulose was associated with increased fibre content of the diets. In their diets, corn starch was substituted with equal amounts of α -cellulose which caused a proportionate decrease in the energy content of diets. The decrease in fish growth observed might not only have been due to higher fibre content but might also

have been because of reduction in the digestible energy content of diets. The diets used in the present study were isonitrogenous and isocaloric and differed only in the level of cellulose (0, 3, 6, 9, and 12%). The results of the present study agree with the findings of Arai *et al.* (1971), Hilton *et al.* (1983), Anderson *et al.* (1984), Kono *et al.* (1987) and Fihlo *et al.* (1994), who reported that crude fibre up to a level of 10% in fish diets can improve growth and feed efficiency. Anderson *et al.* (1984) concluded that a cellulose level above 10% is not desirable in the diets of *Oreochromis niloticus*. As elevated crude fibre content exerts a negative effect on the digestibility of nutrients (Kirschgessener *et al.* 1986), at higher levels of dietary fibre, the nutrient requirements for rapid growth cannot be satisfied. A complete absence of crude fibre from fish diets, has been regarded as unfavourable (Hartfiel 1983). Although an explanation for the poor growth rate, FCR and PER on diet containing 3% cellulose as compared to that without cellulose and improved growth performance, FCR and PER on diet containing 9% cellulose, observed in the present study can not be given, it is assumed that the 3% level of cellulose in the diet might not have been enough to activate the proper growth and establishment of intestinal microflora. The cellulose activity in fish probably originates from alimentary tract microflora (Stickney and Shumway 1974), the presence of which may be influenced by dietary means (Onarheim 1988). Similarly, the pattern of distribution of digestive enzymes in fish has also been reported to depend upon the type of diet ingested (Das and Tripathi 1991).

The body composition of fish is primarily influenced by diet composition, feeding practices, fish size, and can be controlled through nutrition (Burtle 1990). The results of the present study indicated that the level of cellulose in the diet affected the moisture, crude protein and fat contents of fish. Anderson *et al.* (1984) observed that the addition of cellulose in the diets of *Oreochromis niloticus* impaired their body fat content. Shiau *et al.* (1988) also reported significantly lower lipid contents in tilapia (*Oreochromis mossambicus*) fed diets containing 6, 10 and 14% of carboxymethyl cellulose (CMC) as compared to those fed 2% CMC. On the contrary, Leary and Lovell (1975) reported that the level of crude fibre in the diet had no effect on the chemical composition of channel catfish. A similar conclusion was drawn by Davis (1985). The whole body moisture content is inversely related to body lipid and decreases or increases as the lipid is stored or utilized (Shearer 1994). Although the reasons for the lower body fat and protein and higher moisture contents of fish on cellulose diets are not clear, it is hypothesized that the dietary cellulose might have influenced the process of lipogenesis. Some types of dietary fibres have been reported to modify the absorption of carbohydrates resulting in a flattening of post prandial glucose and insulin responses (Jenkins *et al.* 1978). Carcass fat plays an important role in consumer's acceptance and is related to dietary fat intake, off

flavours from rancidity, shelf life and appearance. The effect of dietary fibre on the production of leaner fish requires further study.

It can be concluded that cellulose up to a level of 9% in the diets of *Oreochromis niloticus* may improve their growth performance, FCR and PER and will produce leaner fish as compared to diets without cellulose. Higher levels of cellulose (12%) may not have any further beneficial effects.

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تأثير التغذية بمستويات مختلفة من مادة السليلوز على نمو وتركيب الجسم لسمكة *Oreochromis niloticus*

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مدينة الملك عبد العزيز للعلوم والتقنية

ص.ب. ٦٠٨٦ - الرياض ١١٤٤٢ - المملكة العربية السعودية

هدفت الدراسة إلى محاولة تقييم مدى تأثير المادة الغذائية المحتوية على خمس مستويات من الفاسليلوز على نمو أحد أنواع أسماك المياه العذبة *Oreochromis niloticus*. فلقد تم تغذية هذا النوع بمادة غذائية تحتوي على نسبة (صفر، ٣، ٦، ٩، ١٢٪) من الفاسليلوز ولمدة ٣٩ يوماً ولقد كان وزن السمكة عند التجربة يعادل تقريباً (٧٤، ١١ جم + ١٩، ٠ جم) لقد لوحظ الزيادة في معدل نمو السمك (SGR) ومعدل التحول الغذائي (FCR) وكذلك معدل كفاءة البروتين (PER) حيث كان معامل التثبيت ($P < 0.05$) عند تغذيتها بمستويات مختلفة من ألفاسليلوز إلا أن المادة الغذائية المحتوية على ٣٪ من السليلوز أعطت ضعفاً في معدل نمو الجسم ومعدل التحول الغذائي وكذلك في معدل كفاءة البروتين وذلك مقارنة في المستويات الأخرى من السليلوز. إن أفضل المستويات تأثيراً كان ٩ أو ١٢٪ من السليلوز ولكن الزيادة في المستوى من ٩-١٢٪ لا يعطي أي اختلاف في التأثير وقد بلغ معامل التثبيت ($P < 0.05$). كما أن مستوى السليلوز في المادة الغذائية لا يؤثر على عملية التغذية ولا على معامل التحول (k) وقد بلغ معامل

التثبت ($P < 0.05$) . أما عند تغذيتها في المادة المحتوية على ٦٪ من السليلوز فإنه يعطي نفس النتيجة عندما يتم التغذية بالمادة الغير محتوية على السليلوز حيث أن معامل التثبت كان ($P < 0.05$) . كما أن الزيادة في مستوى السليلوز في المادة الغذائية يزيد من كمية الرطوبة بالجسم ونقصان في البروتين وكذلك الدهون ومن هذا يمكن أن نستنتج أن المادة الغذائية المحتوية على ٩٪ من السليلوز تعتبر أفضل نسبة تؤثر على الزيادة في معدل التحول الغذائي (FCR) وكذلك معدل كفاءة البروتين (PER) وقلة في الدهون مقارنة بالتي تم تغذيتها بمادة غذائية لا تحتوي على سليلوز . كما أن الزيادة في معدل السليلوز لا يؤدي إلى أي نتائج ملحوظة .