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# The Effect of Inclusion Level and Time on Digestibility of Starch for Common Carp (*Cyprinus carpio*, Cyprinidae)

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## Abstract

The effect of the level of inclusion and time on the digestibility of cornstarch for common carp (*Cyprinus carpio*, Cyprinidae) was determined. Raw cornstarch was included into a casein-based reference diet at four levels of inclusion (10, 20, 30 and 40%) and digestibility coefficients calculated over two time points (days 6-10 and days 13-17). Starch digestibility was significantly affected by the level of inclusion, being higher at the 30% (90.4%) and 40% (94.2%) inclusion levels than at the 10% (77.3%) inclusion level. Time had no significant effect on starch digestibility.

## Introduction

Carbohydrates serve solely as energy sources and therefore have no essential component or dietary requirement. In aquaculture diets, carbohydrates are utilized to limit, as far as possible, the catabolism of other dietary nutrients for energy (Erfanullah and Jafri 1995; Garcia-Gallego et al. 1995), since they are a much less expensive alternative to protein and lipid as an energy source. Of the potential sources of carbohydrate for use in the production of commercial diets, starch is the most commonly utilized.

Although possessing the necessary digestive apparatus, fish are generally considered to digest starch poorly. Compared to the digestibility of protein and lipid, starch digestibility in fish is low with digestibility coefficients below 60% commonly reported (Inaba et al. 1963; Chiou and Ogino 1975; Bergot and Breque 1983; Hemre et al. 1989; Pfeffer et al. 1991). However, the digestibility of starch for fish is not uniform, varying with the source of starch (Degani et al. 1986; Arnesen and Krogdahl 1993), species of fish (Bergot and Breque 1983; Hemre et al. 1989; Chu et al. 1991; Pfeffer et al. 1991; Arnesen and Krogdahl 1993), the technological treatment of the starch (Inaba et al. 1963; Chiou and Ogino 1975; Bergot and Breque 1983; Chu et al. 1991; Pfeffer et al. 1991), the inclusion level of starch in the diet (Inaba et al. 1963; Spannhof and Plantikow

1983; Hemre et al. 1989; Arnesen and Krogdahl 1993) and the feeding regime employed (Bergot and Breque 1983; Pfeffer et al. 1991).

Starch plays an important role in the formulation of commercial and experimental diets. A detailed knowledge of the digestibility of starch is therefore required for the effective formulation of aquaculture diets. Starch digestibility must be species-specific and take into account the factors which may affect digestibility. The present study was undertaken to determine the digestibility of starch for common carp, *Cyprinus carpio*, and the effect of inclusion level and time on starch digestibility.

## Materials and Methods

Three hundred common carp (*Cyprinus carpio*, Cyprinidae), mean weight 43.6 g (range 7.0 to 87.5 g, SD 18.2 g), were netted by a professional fisherman from Reedy Lake and Lake Connewarre, Victoria, Australia. Animals were stocked at 15 fish per 70-l aquaria. Each aquaria received a continuous flow of recirculated freshwater (600 ml·minute<sup>-1</sup>) with additional aeration. Fish were held at 20 ± 1°C on a 12-h light: 12-h dark photoperiod.

The experimental ingredient used was raw starch (corn flour) (Goodman Fielder Mills, NSW, Australia). Dry weight carbohydrate and energy contents were 99.5% and 19.0 MJ·kg<sup>-1</sup>, respectively.

Starch was incorporated into a casein-based reference diet at 10, 20, 30 and 40% inclusion on a dry-weight basis, giving final levels of starch in the test diets of 19-46% (Table 1). Diets were extruded using a Hobart #12 chopper attachment (Hobart Corporation, Troy, Ohio), 1/8-inch die hole diameter, powered by a Model A120 Hobart Mixer (Hobart Corporation, Troy, Ohio). Diets were air dried at 50°C and stored at -18°C until use.

Each experimental diet was fed to four replicate aquaria of fish at a feeding rate of 2.0% body weight·wet weight diet·d<sup>-1</sup>. Daily rations were divided into four equal portions fed at hourly intervals. Feeding continued for 17 d. Animals were fed the experimental diets for 5 d prior to the commencement of feces collection. Feces were collected by siphoning over 2-h period each morning and dried at 50°C. Dried feces were pooled per replicate over two periods of 5 consecutive days, days 6-10 and 13-17.

Table 1. Formulation (% dry matter) of the reference (ref) and experimental diets (% inclusion) and analyzed Cr<sub>2</sub>O<sub>3</sub> content.

Dietary components	Diet type				
	Ref	10%	20%	30%	40%
Casein	60.0	54.0	48.0	42.0	36.0
Corn flour	10.0	19.0	28.0	37.0	46.0
Tuna oil	9.0	8.1	7.2	6.3	5.4
α-cellulose	15.0	13.5	12.0	10.5	9.0
Vitamin and mineral premix	5.0	4.5	4.0	3.5	3.0
Cr <sub>2</sub> O <sub>3</sub>	1.0	1.0	1.0	1.0	1.0
Analyzed Cr <sub>2</sub> O <sub>3</sub>	1.00	0.97	0.96	0.95	0.86

Chromium oxide ( $\text{Cr}_2\text{O}_3$ ) content of the diets and feces was determined by colorimetric spectrophotometry as described by Furakawa and Tsukahara (1966).

Data were analyzed using repeated measures analysis of variance with *post hoc* analysis performed using Scheffé's test (Zar 1984). Analyses were performed using StatView 512+™ statistical analysis software (Brain Power Inc., California, USA).

## Results

Repeated measures analysis of variance revealed a significant effect of inclusion level ( $P=0.0004$ ), but not time ( $P=0.3874$ ), on digestibility of starch (Table 2). The interaction between inclusion level and time was also not significant ( $P=0.5617$ , Table 2) and the data were therefore pooled over time. Pooled apparent digestibility coefficients for starch included in the reference diet at graded levels are shown in Table 3. *Post hoc* analysis using Scheffé's test revealed that the digestibility of starch at 10% inclusion (77.3%) was significantly lower ( $P<0.05$ ) than that of starch at 30% (90.4%) and 40% inclusion (94.2%). The change in digestibility of starch with inclusion showed a positive regression described by the formula:

$$\text{Starch digestibility (\%)} = 74.2 + 0.53 \cdot \text{inclusion} \quad (P<0.05, r^2=0.404)$$

Table 2. Two factor repeated measures analysis of variance of the digestibility of starch for common carp with inclusion level and time.

Source	df	Sum of squares	Mean square	F-test	P value
Inclusion of level (A)	3	1,248.506	416.169	13.001	0.0004
Subjects w. groups	12	384.132	32.011		
Repeat measure (B)	1	62.424	62.424	0.805	0.3874
AB	3	166.429	55.476	0.715	0.5617
B x subjects w. groups	12	930.954	77.58		

Table 3. Apparent digestibility coefficients (%) of raw starch at graded inclusion levels for common carp. Data for each inclusion level have been pooled over time. Values are mean  $\pm$  standard error (n=4)

Inclusion level (%)	ADC (%)
10	77.3 $\pm$ 3.8 <sup>a</sup>
20	87.8 $\pm$ 2.7 <sup>ab</sup>
30	90.4 $\pm$ 1.9 <sup>b</sup>
40	94.2 $\pm$ 1.4 <sup>b</sup>

Values with the same superscript are not significantly different at  $P<0.05$ .

## Discussion

The digestibility of starch for common carp was not affected by time. The lack of significant change in the digestibility of starch over time indicates that the experimental animals had adapted to both the aquarium facilities and the experimental diets prior to feces collection. Thus, common carp have the ability to readily adapt to diets containing high levels of raw cornstarch.

Starch digestibility varied significantly with the level of inclusion. The digestibility of starch ranged from 77.3% at 10% inclusion to 94.2% at 40% inclusion. Chu et al. (1991) found the dry matter digestibility of cornstarch for common carp at 30% inclusion to be 70.3%, a value somewhat lower than the 90.4% measured for 30% inclusion in the present trial. However, digestibility of the carbohydrate portion of the cornstarch in the study of Chu et al. (1991) was found to be 98.0%, which is in better agreement with the cornstarch digestibility coefficients measured in the present study. Since the cornstarch used by Chu et al. (1991) contained 96.6% carbohydrate, the large difference between dry matter and carbohydrate digestibility coefficients observed by Chu et al. (1991) indicates that the inclusion of 30% cornstarch adversely affected the digestibility of ingredients in the reference diet. This results in the apparent dry matter digestibility of cornstarch being reduced. Chiou and Ogino (1975) reported lower digestibility of raw starch for common carp than the values obtained in this study, ranging from 60% to 50% at inclusion levels ranging from 14.0% to 49.2%. However, the test ingredient used in that study was potato starch.

The digestibility of raw starch for common carp reported in the present study was higher than the literature values for rainbow trout (Bergot and Breque 1983; Pfeffer et al. 1991), Atlantic salmon (Arnesen and Krogdahl 1993) and white sturgeon (Herold et al. 1995). The omnivorous nature of common carp, and the resultant increased natural dependence upon dietary complex carbohydrate for energy, would suggest that carp are better adapted anatomically and physiologically to digest raw starch than the carnivorous rainbow trout, Atlantic salmon or white sturgeon.

In rainbow trout it has been reported that feeding rate affects the digestibility of the starch component of the diet, with digestibility greater at restricted feeding levels (Bergot and Breque 1983; Pfeffer et al. 1991). Bergot and Breque (1983) found raw cornstarch digestibility to decrease from 54.5% to 38.1% with an increase in feeding rate from 0.5% to 1.0% body weight-wet weight diet·d<sup>-1</sup>. Similarly Pfeffer et al. (1991) found the digestibility of raw maize starch to decrease from 45% to 22% with a change from restricted (1% body weight-wet weight diet·d<sup>-1</sup>) to satiety feeding. The high digestibility coefficients in the present study suggest that a feeding rate of 2% body weight-wet weight diet·d<sup>-1</sup> did not adversely affect digestibility of raw cornstarch for common carp.

The digestibility of starch in the present study was found to increase with the level of inclusion from approximately 78% at a 10% inclusion level to greater than 90% at a 40% inclusion level. This is contrary to previous studies

where digestion of starch decreased with the level of inclusion in the diet (Inaba et al. 1963; Chiou and Ogino 1975; Spannhof and Plantikow 1983; Hemre et al. 1989). In those studies, digestibility of starch for carp (Chiou and Ogino 1975) was decreased to a lesser extent than for rainbow trout (Inaba et al. 1963) or Atlantic cod (Hemre et al. 1989). The decrease in digestibility of starch has been attributed to the presence of  $\alpha$ -amylase inhibitors in the starch (Sturmbauer and Hofer 1986; Natarjan et al. 1992), the adsorption of  $\alpha$ -amylase by starch (Spannhof and Plantikow 1983) and a decrease in gut transit time (Spannhof and Plantikow 1983). However, carp have been shown to be capable of increasing the secretion of  $\alpha$ -amylase several fold to maintain  $\alpha$ -amylase activity in the presence of inhibitors (Sturmbauer and Hofer 1986) and  $\alpha$ -amylase activity has been shown to be increased in carp (Kawai and Ikeda 1972) and in other species (Nagase 1964; Kawai and Ikeda 1972) in response to high carbohydrate diets, suggesting a positive feedback system. Common carp also possess a longer relative gut length than rainbow trout.

Spannhof and Plantikow (1983) found that when daily intake of starch per gram body weight was considered, and not simply the inclusion level of starch in the diet, the amount of starch absorbed by rainbow trout increased initially (up to 0.4 g starch per 100 g body weight·d<sup>-1</sup>). Starch absorption subsequently plateaued and then decreased with further increases in the daily intake of dietary starch. In the present study, common carp were fed at a restricted rate of 2% body weight-wet weight-diet·d<sup>-1</sup>, resulting in a daily starch intake of 0.92 g per 100 g body weight·d<sup>-1</sup> for the 40% inclusion level test diet. Considering the natural omnivorous diet of common carp, as opposed to the carnivorous diet of rainbow trout, it is reasonable to suggest that common carp is able to accommodate a higher daily consumption of starch prior to overloading the intestinal  $\alpha$ -amylase system.

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### References

- Arnesen, P. and A. Krogdahl. 1993. Crude and pre-extruded products of wheat as nutrient sources in extruded diets for Atlantic salmon (*Salmo salar*, L.) grown in sea water. *Aquaculture* 118: 105-117.
- Bergot, F. and J. Breque. 1983. Digestibility of starch by rainbow trout: effects of the physical state of starch and of the intake level. *Aquaculture* 34: 203-212.
- Chiou, J.Y. and C. Ogino. 1975. Digestibility of starch in carp. *Bulletin. Japanese Society of Scientific Fisheries* 41: 465-466.
- Chu, K.S., I.K. Han, T.H. Won and B.C. Park. 1991. Studies on the nutrient availabilities of feed ingredients in Israeli carp (*Cyprinus carpio*). *Asian-Australian Journal of Animal Sciences* 4: 263-274.

- Degani, G., S. Viola and D. Levanon. 1986. Effects of dietary carbohydrate source on growth and body composition of the European eel (*Anguilla anguilla* L.). *Aquaculture* 52: 97-104.
- Erfanullah and A.K. Jafri. 1995. Protein sparing effect of dietary carbohydrate in diets for fingerling *Labeo rohita*. *Aquaculture* 136: 331-339.
- Furakawa, A. and H. Tsukahara. 1966. On the acid digestion method for the determination of chronic oxide as an index substance in the study of digestibility of fish feed. *Bulletin. Japanese Society of Scientific Fisheries* 32: 502-506.
- Garcia-Gallego, M., J. Bazoco, M.D. Suarez and A. Sanz. 1995. Utilization of dietary carbohydrates by fish: a comparative study in eel and trout. *Animal Science* 61: 427-436.
- Hemre, G.I., O. Lie, E. Lied and G. Lambertsen. 1989. Starch as an energy source in feed for cod (*Gadus morhua*): digestibility and retention. *Aquaculture* 80: 261-270.
- Herold, M.A., S.S.O. Hung and K. Fynn-Aitkins. 1995. Apparent digestibility coefficients of carbohydrates for white sturgeon. *Progressive Fish-Culturist* 57: 137-140.
- Inaba, D., C. Ogino, C. Takamatsu, T. Ueda and K.I. Kurokawa. 1963. Digestibility of dietary components in fishes II. Digestibility of dietary protein and starch in rainbow trout. *Bulletin. Japanese Society of Scientific Fisheries* 29: 242-244.
- Kawai, S.-I. and S. Ikeda. 1972. Studies on the digestive enzymes of fishes II. Effects of dietary change on the activities of digestive enzymes in carp intestine. *Bulletin. Japanese Society of Scientific Fisheries* 38: 265-270.
- Nagase, G. 1964. Contribution to the physiology of digestion in *Tilapia mossambicus* Peters: Digestive enzymes and the effects of diets on their activities. *Zeitschrift fur vergleichende Physiologie*: 49: 270-284.
- Natajara, M., B. Ross and L.G. Ross. 1992. Susceptibility of carp and tilapia  $\alpha$ -amylase to purified wheat amylase inhibitor. *Aquaculture* 102: 265-274.
- Pfeffer, E., J. Beckmann-Toussaint, B. Henrichfreise and H.D. Jansen. 1991. Effect of extrusion on efficiency of utilization of maize starch by rainbow trout (*Oncorhynchus mykiss*). *Aquaculture* 96: 293-303.
- Spannhof, L. and H. Plantikow. 1983. Studies on carbohydrate digestion in rainbow trout. *Aquaculture* 30: 95-108.
- Sturmbauer, C. and R. Hofer. 1986. Compensation for amylase inhibitors in the intestine of the carp (*Cyprinus carpio*). *Aquaculture* 52: 31-33.
- Zar, J.H. 1984. *Biostatistical analysis*. Second edition. Prentice-Hall, New Jersey. 718 pp.