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Original Article

The effects of different grain sources on gut evacuation rate and nutrient digestibility in common carp, *Cyprinus carpio*

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Abstract: The main objective of this study was to investigate whether dietary cereal grains of different carbohydrate sources can change nutrient digestibility, evacuation rate and the number of bacterial colony in gut. Common carp with an average weight of 244.7±6.3 g were divided randomly into sixteen 500-L tanks with a stocking density of 18 fish per tank. Four experimental diets were formulated by inclusion of four cereal grains (wheat meal, barley meal, corn meal and rice meal) in a basal diet in a ratio of 40%. The four experimental treatments with four replicates were assigned in 16 tanks. Inclusion of different types of cereal grain affected growth related parameters in *C. carpio*. Corn and wheat diets led to larger weight gains and better feed conversion ratios compared to barley diet (324 and 321 versus 305 g for final weight; 1.93 and 1.90 versus 2.25 for fed conversion ratio). Protein and dry matter digestibility in the common carp fed rice diet were lower in comparison to other cereal grains (73 and 58 versus 79-82 and 67-70%). The maximum and minimum bacterial colony numbers (133 and 63 cfu.gr^{-1}×10^{-7}) were observed in fish fed wheat and corn diets, respectively. Evacuation time showed a delay by feeding on barley diet and almost all dry matter left in part I of the intestine after 30 min (first sampling), but this rate was recorded 70% for corn diet .In conclusion, although dietary grains change evacuation time and bacterial colonial number in common carp, this condition does not have a great impact on nutrient digestibility.

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Introduction

Common carp, *Cyprinus carpio*, as an omnivorous species generally feeds on pond bottom. However, in intensive systems, most fish nutrients requirement are met by component feed and fast growth in aquaculture production systems are mostly dependent on pellet diet (Olsen and Hasan, 2012). A review on the global use of commercial diets revealed that the ratio of commercial feed used for carps reached 50% in 2010, while it was 20% in 1995 (Tacon et al., 2011).

Grains and their byproducts are the most important carbohydrate sources in fish feed and these ingredients can reach 50% of feed content in omnivorous fish. An increase in carbohydrate content is always associated with an integrated part of cell wall mainly composed of hexoses and pentoses, which is called non-starch polysaccharide (NSP) (van Barneveld, 1999). These component generally cannot be digested because of lack and/or shortage of enzyme secretion by mono-gastric animals, including fish (Kuzmina et al., 1996; Ravindra et al., 1999). Increasing NSP has a negative effect on body weight and feed conversion ratio (Smeets et al., 2018). In addition, NSP in diet can influence fish gastro-intestinal anatomy and its development (Leenhouwers et al., 2006), gastric evacuation rate (Lee et al., 1992; Storebakken et al., 1999), microbial activity (Amirkolaie et al., 2006; Leenhouwers et al., 2007a, b), nutrient digestibility (Refstie et al., 1999; Amirkolaie et al., 2006; Leenhouwers et al., 2007b), digesta viscosity (Storebakken, 1985; Refstie et al., 1999; Leenhouwers et al., 2006, 2007a) and also viscosity and moisture content of the faeces (Tran-Tu et al., 2017). These impacts, however, can vary depending on the physicochemical properties of NSP (Sinha et al., 2011).

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Increasing NSP content in fish feed can depress digestive function in the gastro-intestinal tract (Storebakken, 1985; Refstie et al., 1999). Because of enzyme limitation, a big part of NSPs remains indigested in the gut and cannot be used as a source of energy for fish (Sinha et al., 2011), and so many nutrients are wasted as feces (Tran-Tu et al., 2017). Thereby a lower growth performance is expected with high-NSP diets. The binding of NSPs to intestinal brush border membrane (De Lange, 2000) increases intestinal secretion of water, nutrient and electrolyte (Choct, 1997). Feed ingredients with low digestibility may potentially influence the gastrointestinal emptying by increasing the volume of digesta (Storebakken et al., 1999).

Gut evacuation rate can be also affected by type of NSP. An increased viscosity induced by soluble dietary NSP reduced digesta passage rate (Johansen et al., 1996). The delay of digesta evacuation rate induced by viscose ingredient may also stimulate microbial degradation leading to volatile fatty acid production as end product (Amirkolaie et al., 2006; Leenhouwers et al., 2007a, b; Sinha et al., 2011). These products may lower the pH of intestine and through that changes normal microbial community in the intestine (Sinha et al., 2011). An increase in bacterial activity was also observed in mono-gastric animals fed diet contained soluble NSP (Salanitro et al., 2001).

Due to limited availability of fishmeal and fish oil, plant ingredients of aqua-feed have been increasing. NSPs constitute an important part of cereal grains (Sinha et al., 2011) which are commonly used as feed ingredients in omnivorous fish (Leenhouwers et al., 2007b). While some literature is available on the effects of carbohydrate sources, e.g. cereal grains on nutrient digestibility and digesta viscosity in African catfish (Leenhouwers et al., 2006, 2007a), Nile tilapia (Leenhouwers et al., 2007b) and Atlantic salmon (Refstie et al., 1999), there is little information related to the impacts of cereal grains on common carp. Therefore, the main goal of the current study was to investigate whether or not dietary cereal grains with different NSP sources can change nutrient digestibility, evacuation rate and the number of bacterial colony in common carp.

Materials and Methods

Experimental diets, animal, and system: Common carp fingerlings were bred at the reproduction facility of a nearby farm and adopted to the experimental conditions for seven days before the start of the experiment. Afterward, the juveniles with an average weight of 224.7±8.3 g were randomly divided into sixteen 500-L tanks with a stocking density of 18 fish per tank.

A basal diet was formulated using locally grown feed ingredients (Behdaneh, Kaboli factory, Mazandaran) (Table 1). Four cereal grains, including wheat, barley, corn and rice were used on the basis of their NSP contents to have different types of NSP in the experimental diets. Corn contains very low soluble NSPs while barley has a large amount of soluble NSPs (Sinha et al., 2011). The other two grains contain moderate levels of soluble NSPs (Englyst, 1989; Sinha et al., 2011). The experimental diets were formulated by inclusion of the four cereal grains to the basal diet in a ratio of 40%.

Before pelleting, the diet components were finely grounded and mixed. To prepare the diet, first water was added to the mash and mixed to form dough. Afterward, the dough was pressed by screwing in a pasta maker through a die (3 mm). The wet pellets were then dried in an air dryer (50°C) and kept refrigerated until use.

Experimental procedure: The four experimental treatments were randomly distributed in 16 tanks with 4 replicate treatment. The fish were allowed to acclimatize with the experimental tanks and diets one week before the experiment initiation. To begin the experiment, the fish were weighted and randomly distributed in the experimental tanks. The fish were fed by hand twice a day (8.00 and 16.00) at a ratio of 2.5% biomass. The water supply was maintained from an underground source and aerated before use. The photoperiod regime during the experiment was 12 h light and 12 h dark.

Water quality parameters were monitored daily to

Table 1. Feed ingredients and nutrients composition (% dry weight) of the four experimental diets. Each value is the mean of three sub-samples.

	Diets			
Ingredients	40% corn	40% wheat	40% rice	40% Barley
Corn meal	40			
Wheat meal		40		
Rice meal			40	
Barley meal				40
Fish meal	15	15	15	15
Soya bean meal	18	18	18	18
Wheat gluten	15	15	15	15
Wheat bran	5	5	5	5
Canola oil	4	4	4	4
Mineral premix[a]	1.5	1.5	1.5	1.5
Vitamin premix[b]	1.5	1.5	1.5	1.5
Proximate composition (%)				
Dry matter	93.6	94.2	94.3	94.1
Crude ash	16.1	14.2	14.3	18.2
Crude protein	32.8	33.2	31.7	32.8
Crude lipid	8.0	8.2	8.3	8.1
Total NSP	9.1	10.9	4.5	12.9
Soluble NSP	3.3	4.8	1.3	6.8
Insoluble NSP	5.8	4.1	3.2	4.2

[a] Mineral premix consisted of (mg kg^{-1} premix): 2600 mg Mn, 600 mg Cu, 6000 mg Fe, 4600 mg Zn, 50 mg Se, 100 mg Iu, 50 mg Co, 100000 mg cholin chloride, up to 1 kg carrier.
[b] Vitamin premix consisted of (mg kg^{-1} premix): 1200000 IU Vitamin A, 400000 IU Vitamin D3, 3000 IU Vitamin E, 1200 mg K3, 5400 mg C, 200 mg H2, 200 mg B1, 3360 mg B2, 7200 mg B3, 9000 mg B5, 2400 mg B6, 600 mg B9, 4 mg B12.

ensure that they were in an appropriate range for the fish. Water temperature was maintained at 26±1°C and water flow rate was set at 6 L min^{-1} and pH was 7.3-7.9, during the experiment. Oxygen concentrations were measured in the tanks using a digital oxygen detector being > 6.1 mg L^{-1}.

At the day 56th, all fish were weighed. There was no mortality thorough the experimental period. In the course of the final week of the study, faeces were amassed from the tank bottom by pipette nearly 3 hrs post feeding. The daily faeces samples were pooled to obtain the required volume of faeces. To calculate apparent digestibility coefficients, the indicator method was employed with chromic oxide (Cr_2O_3) as a marker (6 g kg^{-1}). Apparent digestibility (%) of nutrients is stated as a ratio of absorption of dietary nutrients according to below:

$ADC=(1-[Marker_{diet}/Marker_{faeces}x\ Nutr_{faeces}/Nutr_{diet}\ ])x100$

Where ADC= parent digestibility coefficient, AIA_{diet} =dietary Marker concentration, $Marker_{faeces}$=faecal Marker concentration, $Nutr_{diet}$=Nutrients of the diet, and $Nutr_{faeces}$=Nutrients of the faeces.

Gut evacuation rate measurement started following 72 hrs of fasting. After this period, the fish were fed once at 1% of body weight. The sampling was conducted at 0.5, 4, 8, 16, 24, 36 and 48 hrs after feeding. At every sampling time, one fish from each tank was killed by overdosed clove essence solution. The whole gut was removed from abdominal cavity of the fish and separated to three equal segments: the proximal, middle, and distal part of the intestine (part I, II, and III, respectively). The division of the intestine was conducted based on having equal lengths per intestine section. The contents of these three parts were collected separately for dry matter measurement. The evacuation rate calculation was based on dry weight of the samples (Adamidou et al., 2009) by the use of formula introduced by Elliot (1972):

$$\log Wt = \log A - rt.$$

Where Wt is the geometric average weight of intestine dry matter content (digesta) at time t, A is a factor measured from the regression formula and r is the rate of intestine evacuation. The dry weights of intestine content (Intestine I, II, and III) were

Table 2. Growth performance in common carp fed with different types of cereal grain over 8 weeks experimental period. Different letters show significant difference among the treatments.

Growth parameters	Diets			
	Corn	Wheat	Rice	Barley
Initial weight (g)	229.8±9.1	220.0±3.4	220.3±3.4	228.5±6.38
Final weight (g)	324.7±12.9	321.8±10.8	306.9±10.4	305.7±9.4
Weight gain (g)	94.9±9.1^{a}	101.8±9.6^{a}	86.5±6.3^{ab}	77.2±4.5^{b}
SGR (%/day)	0.62±0.03^{a}	0.68±0.04^{a}	0.59±0.03^{ab}	0.52±0.03^{b}
FCR	1.93±0.12^{a}	1.90±0.13^{a}	2.20±0.09^{b}	2.25±0.08^{b}

Values are means of triplicate groups±SD.

regressed against time in order to examine a possible fit to a model for calculating time and rate of intestinal evacuation.

At the end of the experimental period, common carps were also subjected to bacterial colony analysis after 72 hrs fasting. Prior to dissection and homogenization, the fish were rinsed in sterilized distilled water, cleaned with ethanol (70.0%) and then washed again with sterilized distilled water to eliminate all superficial bacteria. The intestinal samples were dissected out under sterile conditions. Subsequently, three samples from the mid segment of each intestine were collected and diluted with sterilized normal saline solution (0.85% NaCl w/v). The diluted samples were transferred to nutrient agar plates to count the number of colony by a colony counter device (Rogosa et al., 1951).

Chemical analysis: The dry matter analyses of feed and faeces samples were conducted by drying samples at 103°C for 24 hrs until constant weight (ISO 6496, 1983). A muffle furnace determined the ash content through incineration at 550°C for 4 hrs (ISO 5984, 1978). By applying the Kjeldahl method (ISO 5983 1979), crude protein (N×6.25) was measured after acid digestion. Extracted in a Soxhlet apparatus, lipid was derived by petroleum ether. Chromic oxide was measured spectrophotometrically using method introduced by Furukawa and Tsukahara (1966). Total and insoluble dietary NSP were analyzed according to Englyst and Cummings (1984). Soluble NSP were calculated as the difference between total and insoluble NSP.

Fish performance: Weight gain was determined by the difference between initial and final body weights. Feed conversion ratio (FCR) was calculated per tank from feed intake data and weight gains: FCR = feed consumed (g) / wet body weight gain (g). Specific growth rate (SGR) was calculated as follows and expressed as a percentage:

$$SGR=100\ (\text{Ln}\ W_{final}-\text{Ln}\ W_{initial})\times days^{-1}(\%/da)$$

The calculations were based on the dry weight of the diets.

Data analysis: The data are presented here as means± SD for each treatment. Proportional data (as %) were arcsine transformed and tested for normality (Kolmogorov-Smirnov test). one-way ANOVA was used to detect significant effects of the grain treatments on fish performance parameters and digestibility. Tukey's test was used for multiple pairwise comparisons between means. Significance effects were identified when $P<0.05$ in each of the statistical tests applied. Individual tanks were treated as experimental units in all analyses. Non-linear regression model (exponential) was applied to relate the values of dry matter of intestine and evacuation time at three parts of intestine using Microsoft Excel 2010.

Results

Data on the growth performance of common carp are presented in Table 2. Inclusion of different types of cereal grain affect weight gain, SGR and FCR in *C. carpio* ($P<0.05$). Both corn and wheat diets increased weight gain and SGR and improved FCR compared to diet with barley ($P>0.05$). However, final weight of common carp was not influenced by inclusion of the grain sources ($P>0.05$).

The results also demonstrated that the inclusion of

Table 3. Nutrient digestibility in common carp feeding on different types of cereal grains over 8 weeks experimental period. Different letters show significant difference among the treatments.

Parameters	Diets			
	Barley	Wheat	Rice	Corn
Dry matter	70.2±2.02[a]	70.9±0.89[a]	58.0±1.15[b]	67.27±1.25[a]
Protein	82.4±0.91[a]	82.8±1.31[a]	73.5±1.45[b]	79.9±1.55[a]
Fat	93.3±1.10	93.6±1.04	92.6±1.6	95.7±2.50

Values are means of triplicate groups±SD. Means with the different letters are significantly different (P<0.05).

Table 4. Evacuation time in common carp intestine fed with different types of cereal grain and correlation coefficient (r) of the regression lines based on exponential model of gastric evacuation.

Treatments	Evacuation time (hrs)			r
	50%	75%	90%	
Barley (meal)	9.24	15.35	30.70	-0.9313
Wheat (meal)	6.93	11.51	23.02	-0.9548
Rice (meal)	6.13	10.18	20.37	-0.9515
Corn (meal)	5.47	9.10	18.20	-0.9668

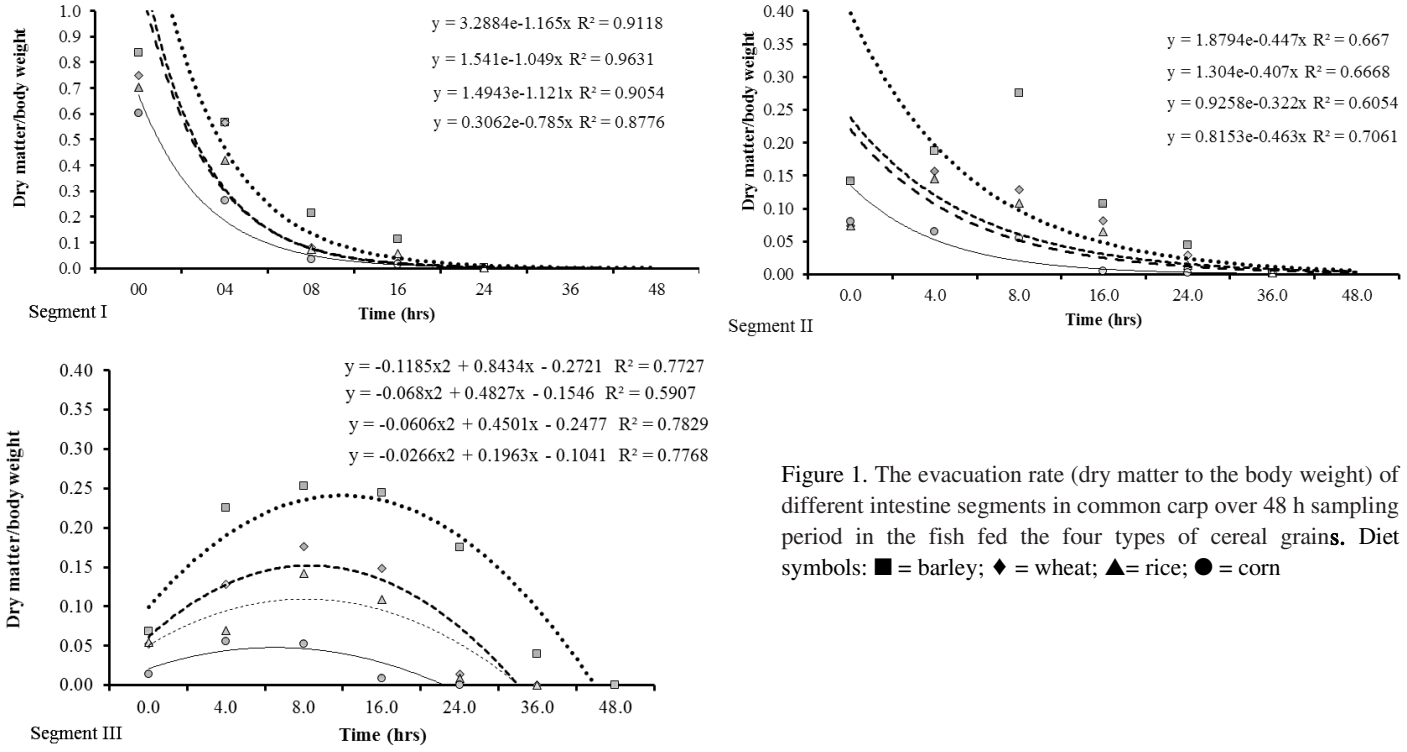

Figure 1. The evacuation rate (dry matter to the body weight) of different intestine segments in common carp over 48 h sampling period in the fish fed the four types of cereal grains. Diet symbols: ■ = barley; ♦ = wheat; ▲= rice; ● = corn

different types of cereal grain affected dry matter and protein digestibility of *C. carpio* (P<0.05; Table 3). Protein and dry matter digestibility were observed lower in common carp fed rice diet in comparison to the other cereal grains examined (P<0.05). However, fat digestibility was not affected by the type of the cereal grains (P>0.05).

The evacuation rate of carp intestine was influenced by the cereal grain types (Table 4). Although most intestine content was evacuated 18-30 hrs after feeding, corn diet needed 18 hrs to evacuate 90% of the intestine content followed by rice, 20 hrs, wheat, 23 hrs with the longest evacuation time of 30 hrs observed in barley treatment. Data collected from three segments of the intestine revealed that grain types changed evacuation rate in common carp (Fig. 1). Evacuation time showed chorological delays by feeding on barley diet and almost all dry matter left in part I after 30 min (first sampling), but this rate was recorded 70% for corn diet. The other two treatments

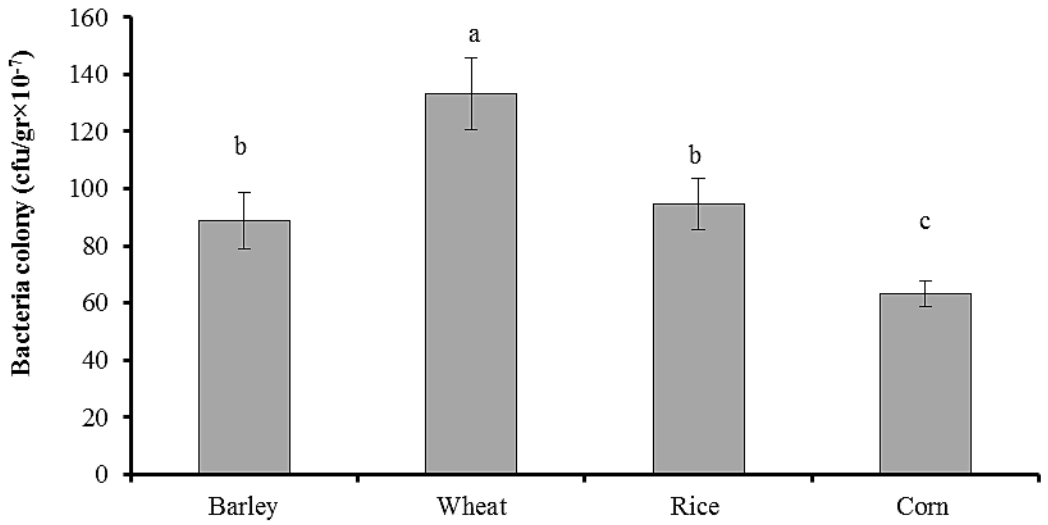

Figure 2. Bacteria colony number in common carp intestine feeding on different types of cereal grains over 8 weeks experimental period. Different letters above the bars show significant difference among the treatments.

were somewhere in between corn and barley records. The slops of equations related to four cereal grains also showed a longer evacuation time for barley in comparison to other diets being similar for three parts of the common carp intestine.

Intestinal bacterial colony was affected by the cereal sources (Fig. 2). The highest bacterial colony number (133 cfu.gr^{-1}×10^{-7}) was observed in fish fed wheat diet followed by rice and barley diets (P<0.05). The lowest number of bacterial colony (63 cfu.gr^{-1} ×10^{-7}) was counted in common carp fed corn diet (P<0.05).

Discussion

In the current study, type of cereal grain affected evacuation rate of intestine in common carp. This finding is similar to the results of Adamidou et al. (2009) who observed that replacement of fishmeal by faba bean and chickpea affected gastrointestinal evacuation time in European sea bass. Similarly, different gastric evacuation rates were also observed in gilthead sea bream when fed raw corn and wheat compared with extruded ones (Venou et al., 2003).

The results also revealed that feeding on barley diet led to the highest residence time of digesta in common carp. It appears that high content of beta glucan in barley (Bach Knudsen, 1997) as a soluble NSP can increase viscosity reflected in the reduction of intestinal evacuation time (Spiller, 1984; Storebakken, 1985). Similar results were also reported by Bach Knudsen (2001) and Adamidou et al. (2009) in European sea bass. In contrast, low soluble NSP content of corn diet, especially beta glucan (Bach Knudsen, 1997) reduces digeta viscosity (Leenhouwers et al., 2007b), thereby intestinal emptying time is delayed. Similarly, Singh et al. (2011) observed that fast evacuation rate of soya and /or corn based diet to be caused by low digesta viscosity. The evacuation rates were almost similar for both rice and wheat diets in the current study, although there is a trend toward a lower evacuation rate in wheat diet. High solubility of arabinose and xylose in wheat diet (Bach Knudsen, 1997) may reduce evacuation rate by inducing a higher digesta viscosity (Spiller, 1991).

The type of cereal grains affected bacterial colony number. In general, dietary NSP is expected to increase bacterial colony through a negative impact on digestibility thereby a larger remaining material for bacterial degradation in the intestine (Metzler-Zebeli et al., 2010). The previous results showed that bacterial colony is highly related to soluble NSPs content of grains (Choct, 1996; Choct et al., 2004). Besides the substrate, the bacterial degradation is dependent on fish species and its gastrointestinal tract structure. While bacterial community can be easily

colonized by wheat diet in carp intestine, microbial degradation of wheat diet was reported to be low for African catfish (Leenhouwers et al., 2007a). The lowest bacterial colony in corn diet can be related to low NSPs content of this grain (Sinha et al., 2011). Furthermore, a high evacuation rate of corn diet does not allow the microbial community to establish in the fish intestine. Bacterial colony numbers in rice diet were almost similar to those in barley treatment. Lower bacterial activity in rice diet may be related to lower fiber content of rice in comparison to the other grain sources (Pluske et al., 1998).

The digestibility data revealed that protein and dry matter digestibility of rice diet were lower than those of other diets were. Because of low fiber and high starch content of rice (Jantrarotai et al., 1994; Guimarães et al., 2008), we expected a larger digestibility values for this ingredient. However, the results did not meet our expectation. In addition, few studies on the evaluation of rice as a feed ingredient suggested a larger dry matter digestibility in comparison to other cereal grains (e.g., in Nile tilapia, Guimaraes et al. 2008; in mirror carp, Ufodike and Matty, 1983). Nevertheless, it seems that rice protein is not digestible enough to fish (Palmegiano et al., 2008). This may be related to a lower amino acid digestibility in rice protein (Oujifard and Seyfabadi, 2012).

The type of cereal grains did not affect fat digestibility in common carp. This is similar to the results of Leenhouwers et al. (2007b) who observed that cereal grains did not change protein and fat digestibility in African catfish. It seems that the negative impacts of NSP contents of grains on fat digestibility are not very large on fish (Amirkolaie et al., 2005; Leenhouwers et al., 2007a), although extensive impacts were previously proved for chicken (Pasquier et al., 1996; Singh et al., 2012).

The present result also revealed that nutrients digestibility was not influenced by both gastrointestinal evacuation time and intestinal bacterial colonization. It appears that a delay in evacuation time, which may be associated with a longer exposure of feed to enzymes, did not change significantly nutrient absorption in common carp. Similar observations were made in Atlantic salmon (Sveier et al., 1999) and European sea bass (Adamidou et al., 2009) when dietary factors changed gastric evacuation rate. Similar to delaying time, bacterial degradation does not seem to improve digestibility in common carp. A larger number of bacterial colony caused by wheat diet did not lead to an enhanced digestibility coefficient. It seems that intestinal microflora, which are largely responsible for degradation of digesta (Amirkolaie et al., 2006), do not have a significant impact on nutrient digestion. Therefore, it can be suggested that the effect of intestinal microbial degradation on nutrient digestibility is negligible to change nutrient digestibility. Moreover, lower level of degradation in fish intestine might have caused such a little impact of bacterial colony number on nutrient digestibility. The concentration of short chain fatty acids, which are indicators of degradation, is much lower in fish intestine (18 mmol; Amirkolaie., 2006) in comparison with warm blood animals like rat and cow (160 and 150 mmol respectively; Rechkemmer et al., 1998).

In conclusion, addition of dietary grains with different NSP sources changes evacuation time and bacterial colonial number in common carp. However, these changes were not reflected in nutrient digestibility. Fat digestibility is not affected by cereal grain sources containing different levels of NSPs in common carp. The current result may confirm the idea that due to structure of fish gastrointestinal tract, the impacts of microbial degradation and/or digesta movement rate in the gut is not considerable to have a great effect on nutrient digestibility.

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چکیده فارسی

بررسی اثر منابع کربوهیدراتی مختلف بر سرعت عبور غذا و قابلیت هضم پذیری در ماهی کپور معمولی (*Cyprinus carpio*)

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چکیده:

هدف اصلی این تحقیق بررسی اثرات منابع کربوهیدراتی مختلف بر هضم‌پذیری مواد مغذی، نرخ تخلیه و تعداد کلونی باکتریایی در دستگاه گوارش بود. ماهیان کپور معمولی با وزن اولیه ۸/۳۲±۲۴۴/۶۷ گرم در شانزده تانک ۵۰۰ لیتری با تراکم ۱۸ قطعه در هر تانک پخش شدند. چهار غذای آزمایشی با افزودن چهار محصول غلات (آرد گندم، آردجو، آرد برنج و آرد ذرت) به یک غذای پایه در یک نسبت ۴۰٪ تهیه شد. چهار تیمار آزمایشی هر کدام با چهار تکرار در شانزده تانک قرار گرفتند. افزودن منابع مختلف کربوهیدراتی فاکتورهای رشد را در کپور معمولی تحت تاثیر قرار داد. ماهیان تغذیه شده با ذرت و گندم رشد بالاتر و ضریب تبدیل بهتری در مقایسه با ماهیان تغذیه شده با غذای حاوی جو نشان دادند (۳۲۴و۳۲۱ گرم در مقایسه با ۳۰۵گرم در وزن نهایی: ۱/۹۳ و ۱/۹۰ در مقایسه با ۲/۲۵ برای ضریب تبدیل غذایی). قابلیت هضم‌پذیری پروتئین و ماده خشک در غذای برنج در کپور معمولی کمتر از بقیه غلات بود (۷۳ و ۵۸٪ در مقایسه با ۷۹-۸۲ و ۶۷-۷۰٪). بیشینه و کمینه تعداد کلونی‌های باکتریایی ($cfu.gr^{-1}\times10^{-7}$ ۱۳۳ و ۶۳) به ترتیب در ماهی‌های تغذیه شده از گندم و ذرت دیده شد. استفاده از غذای حاوی جو موجب تاخیر در نرخ تخلیه دستگاه گوارش شده و تقریباً همه ماده خشک در قسمت ابتدایی روده بعد از ۳۰ دقیقه (اولین نمونه گیری) باقی مانده بود، در حالی‌که نرخ تخلیه‌ای برای غذای حاوی ذرت ۷۰٪ بود. در جمع بندی می‌توان گفت، اگرچه غلات موجود در غذا توانست سرعت تخلیه و تعداد کلونی‌های باکتری دستگاه گوارش ماهی کپورمعمولی را تحت تاثیر قرار دهد، ایجاد چنین شرایطی اثر بزرگی بر هضم پذیری مواد مغذی ایجاد نکرد.

کلمات کلیدی: روده، کربوهیدرات، تجزیه، مواد غذایی، سرعت تخلیه.