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Digesta characteristics in relation to nutrient digestibility and mineral absorption in Nile tilapia (*Oreochromis niloticus* L.) fed cereal grains of increasing viscosity

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Abstract

Soluble non-starch polysaccharides (NSP) present in cereal grains may affect performance of Nile tilapia through changes in digesta characteristics. The objective of this study was to investigate whether dietary cereal grains of increasing viscosity induce changes in digesta viscosity, dry matter and volatile fatty acids (VFA) and if these changes explain differences in nutrient digestibility and mineral absorption. Four experimental diets were formulated by adding 40% grains to a basal diet to obtain a range of dietary viscosities, increasing in the order of maize, barley, wheat and rye. The diets were assigned to 16 tanks with 40 fish (mean weight 70 g) each. Digesta viscosity increased with increasing grain viscosity ($P<0.001$), whereas digesta dry matter decreased with increasing grain viscosity ($P<0.05$). No significant differences were found among diets in total concentration and type of VFA. Nutrient digestibility was not significantly correlated with digesta viscosity. Of all nutrients, only starch digestibility was significantly negatively correlated with digesta dry matter in the middle intestine ($r=-0.57$; $P=0.03$). Absorption of sodium was significantly negatively correlated with digesta viscosity in all intestinal segments ($r=-0.76$ to -0.82; $P<0.001$) and positively correlated with digesta dry matter in all intestinal segments ($r=+0.60$ to $+0.67$; $P<0.05$), except for the proximal intestine ($P=0.18$). Of the other minerals, potassium and magnesium absorption were positively correlated with digesta dry matter in the distal ($r=+0.56$; $P=0.03$) and proximal ($r=+0.54$; $P=0.04$) intestine, respectively. Phosphorus absorption was significantly negatively correlated with dry matter in the stomach ($r=-0.55$; $P=0.03$), middle ($r=-0.58$; $P=0.02$) and distal ($r=-0.54$; $P=0.04$) intestine. In conclusion, viscous cereal grains induce increases in digesta viscosity and decreases in digesta dry matter in Nile tilapia. These changes do not explain differences in nutrient digestibility among diets, but seem more related to differences in mineral absorption. The strong negative correlations between digesta viscosity and sodium absorption suggest negative effects of dietary viscous grains on intestinal water balance.

Keywords: Nile tilapia; Non-starch polysaccharides; Digesta; Viscosity; Nutrient digestibility; Mineral absorption

1. Introduction

Nile tilapia (*Oreochromis niloticus*) is an important species for aquaculture (El-Sayed, 1999). Due to its omnivorous feeding habit, vegetable ingredients such as

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cereal grains may constitute a major part of its diet (Belal, 1999; El-Sayed, 1999). In poultry, much of the variation in nutritional value of cereal grains is explained by the soluble non-starch polysaccharide (NSP) content of the endosperm cell walls (Rowe et al., 1999). Soluble NSP depress digestibilities of starch, protein, and fat and reduce mineral absorption, resulting in poor growth performance (Choct and Annison, 1990; Bedford et al., 1991; Van der Klis et al., 1995; Choct et al., 1996). These anti-nutritional effects are mediated by increases in digesta viscosity, intestinal fermentation activity and associated changes in intestinal water balance (Choct et al., 1996; Choct, 1997). High digesta viscosity reduces the diffusion rate of substrates and enzymes and hinders their interaction at the mucosal surface (Choct, 1997). Furthermore, increased endogenous intestinal secretion of water, nutrients and other electrolytes has been suggested to explain reduced nutrient digestion (Choct, 1997). Finally, high viscosity also increases residence time of the digesta and therefore increases intestinal volatile fatty acid (VFA) production. The resulting drastic changes in gut ecology may decrease nutrient digestion and ultimately have been shown to reduce performance of broiler chickens (Choct et al., 1996).

In fish, few studies have investigated the effects of dietary soluble NSP on digesta characteristics and nutrient digestibility. In Nile tilapia, rainbow trout (*Oncorhynchus mykiss*) and African catfish (*Clarias gariepinus*) high dietary concentrations of purified isolated soluble NSP have been shown to affect digesta viscosity and digesta dry matter with associated reductions in growth and nutrient digestibility (Storebakken, 1985; Amirkolaie et al., 2005; Leenhouwers et al., 2006). In African catfish, dietary viscous grains increased digesta viscosity and intestinal fermentation activity with a resulting decrease in nutrient digestibility (Leenhouwers et al., 2007).

The objective of the current study was to investigate whether dietary cereal grains differing in viscosity induce changes in digesta viscosity, digesta dry matter and digesta VFA in Nile tilapia, and if these possible changes explain differences in nutrient digestibility and mineral absorption.

2. Materials and methods

2.1. Diets

Four experimental diets were formulated by adding 40% of maize, wheat, barley and rye to a basal diet (Table 1). These grains have different *in vitro* viscosities (maize 0.90 cP; wheat 1.32 cP: barley 1.33 cP and rye 13.6 cP) and thus the resulting differences in dietary viscosity (Table 2) were expected to induce differences in digesta viscosity, dry matter and VFA. In broiler chickens, the amounts of NSP in maize appear insufficient to influence digesta viscosity and consequently nutrient availability (Chesson, 2001). Therefore, maize was included in this study as a reference.

Table 1
Formulation of the experimental diets (%)

Ingredients	Diets			
	Maize	Wheat	Barley	Rye
Maize [a]	40	–	–	–
Wheat [b]	–	40	–	–
Barley [c]	–	–	40	–
Rye [d]	–	–	–	40
Fish meal [e]	48.4	48.4	48.4	48.4
Soy oil [f]	3.0	3.0	3.0	3.0
Palm oil [g]	3.0	3.0	3.0	3.0
Premix [h]	1.0	1.0	1.0	1.0
$CaCO_3$	1.9	1.9	1.9	1.9
$Ca(H_2PO_4)_2{\cdot}H_2O$	0.7	0.7	0.7	0.7
Diamol [i]	2.0	2.0	2.0	2.0
Y_2O_3 [j]	0.01	0.01	0.01	0.01

[a] Research Diet Services, Wijk bij Duurstede, The Netherlands.
[b] Research Diet Services, Wijk bij Duurstede, The Netherlands.
[c] Variety "Orthega", Lochow-Petkus, Bergen, Germany.
[d] Research Diet Services, Wijk bij Duurstede, The Netherlands.
[e] Danish herring meal, bran Skagen FF with a protein content of 70%.
[f] Refined soya oil, produced by Romi Smilfood, Heerenveen, The Netherlands.
[g] Refined palm oil, Produced by Romi Smilfood, Heerenveen, The Netherlands.
[h] Mineral premix composition (mg kg^{-1} feed): iron (as $FeSO_4{\cdot}7H_2O$), 50; zinc (as $ZnSO_4{\cdot}7H_2O$), 100; cobalt (as $CoSO_4{\cdot}7H_2O$), 2.4; copper (as $CuSO_4{\cdot}5H_2O$), 5; selenium (as Na_2SeO_3), 1; manganese (as $MnSO_4{\cdot}4H_2O$), 25; magnesium (as $MgSO_4{\cdot}7H_2O$), 300; chromium (as $CrCl_3{\cdot}6H_2O$), 1; iodine (as $CaIO_3{\cdot}6H_2O$), 5. Vitamin premix composition (mg kg^{-1} feed): thiamin, 30; riboflavin, 30; nicotinic acid, 200; pantothenic acid, 100; pyridoxine, 30; cyanocaobalamin, 0.05; ascorbic acid, 500; alpha-tocopheryl acetate, 200 IU; folic acid, 15; retinylacetate, 15000 IU; cholecalciferol, 2000 IU; menadione nicotinamide bisulphite (51%), 8; inositol, 200; choline (as choline chloride), 1000; anti-oxidant BHT (E300-321), 100; calcium propionate, 1000.
[i] Diamol [Acid insoluble ash, (AIA), GM, Franz Bertram, Hamburg, Germany] added as an inert marker for measuring nutrient digestibility.
[j] Yttrium oxide added as an inert marker for measuring NSP digestibility and mineral absorption.

Before addition to the diets, all grains were ground in a centrifugal mill (Retsch ZM100, Haan, Germany) to pass a 1-mm screen. All ingredients were thoroughly mixed and pelletised dry to produce 3-mm sinking pellets. Yttrium oxide (Y_2O_3) was added to all diets as an inert marker to calculate apparent digestibility coefficients of NSP and apparent absorption coefficients of minerals. Diamol (acid insoluble ash, AIA) was added as an inert marker to calculate digestibility of other nutrients. Pellets were dried in an air dryer at 80 °C and stored at 4 °C until use. Chemical