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Effects of dietary inclusions of oilseed meals on physical characteristics and feed intake of diets for the Nile Tilapia, *Oreochromis niloticus*

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ABSTRACT

The present study investigated the effects of the inclusion of three oilseed by-products (soybean, copra and palm kernel meals) on some physical characteristics of pelletized feeds as well as on voluntary feed intake and faecal matter production by the Nile tilapia, *Oreochromis niloticus*. The dietary inclusion of soybean meal resulted in a significantly higher feed bulk density relative to the fishmeal control diet. The inclusions of copra and palm kernel meals, however, resulted in lower feed bulk densities. Sinking rates, water stabilities and nutrient retention efficiencies of feed pellets were directly related to feed bulk densities. The soybean meal diet had the fastest sinking velocities, greatest water stability and highest nutrient retention rates. The dietary inclusion of soybean meal, however, significantly impaired feed intake compared to the other three diets. Mean daily feed intakes of the control, palm kernel meal and copra meal diets corresponded to 28.88, 27.01 and 28.31 g during the experimental period and varied significantly from the mean daily intake of the soybean meal diet which corresponded to 20.01 g. Faecal matter production (g dry mass kg^{-1} ingested feed) was significantly higher in the tilapia groups fed the copra and palm kernel meals. The results obtained from this study show that 30% inclusions of unrefined forms of copra and palm kernel meal in Nile tilapia diets is possible, without adversely affecting feed intake or pellet nutrient losses prior to ingestion.

1. Introduction

Fish feeds, according to Aarseth (2004) and Aarseth et al. (2006) should be resistant to mechanical stress such as handling and transportation. Pellets that break up into small particles and leach nutrients can reduce water quality of the culture environment and lead to poor animal growth, inefficient feed conversion, and low survival (Obaldo et al., 2002). Nutritional quality is also related to the physical quality of feed products, because formation of fragments and dust represents a direct loss of feed and feed conversion, thus increasing production cost (Thomas and van der Poel, 1996). Pellet water stability is an important quality parameter in the manufacture of aquaculture diets since feeds represent the single most expensive component in aquaculture. Pellets should be able to maintain their physical integrity with minimal disintegration and nutrient leaching while in the water until consumed by the animal (Obaldo et al., 2002; Halver and Hardy, 2002). Factors that affect the physical quality of feeds include the method of diet preparation and processing, types of ingredients and diet composition and types of binding agents (Obaldo et al., 1999; Aarseth, 2004). According to Thomas et al. (2001), the use of low-cost fishmeal replacers in diet formulations is an important factor that can significantly affect the physical qualities of the feed pellets, although the diet meets the nutritional requirements for the target species.

Nutritional studies aimed at replacing fishmeal in aquafeeds with more economical and environmentally sustainable alternatives have become increasingly common due to the stagnated global production and high cost of fishmeal. The low cost and wide-availability of oilseed meals, particularly copra and palm kernel meals in many tropical countries where aquaculture is practiced have generated much interest in their potential use in fish diets. The presence of high fibre contents and/or anti-nutritional factors (ANFs) in unrefined forms of these meals, however, limits their inclusion in aquafeeds to very low levels. The selected inclusion level for the oilseed meals in this study for example, is reflective of the possible presence of ANFs and the fact that very high fishmeal replacement on a weight-for-weight basis by these unrefined plant protein sources is not feasible because of

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Table 1
Proximate composition (% dwb) of the key raw materials used for the formulation of the different experimental diets.

Ingredients	DM	CP	CL	CF	Ash
Fishmeal[a]	90.73	72.30	11.28	1.00	13.00
Soybean meal[b]	89.40	50.00	2.01	3.82	5.89
Palm kernel meal[b]	91.20	17.81	13.24	18.41	3.30
Copra meal[b]	87.85	19.63	8.10	16.00	7.01

DM: dry matter; CP: crude protein; CL: crude lipid; CF: crude fibre.
[a] Danish fishmeal: FF Skagen A/S, Skagen, Denmark.
[b] Expeller-pressed oilseed meals sourced from Kumasi, Ghana.

their relatively lower protein contents and unbalanced essential amino acid profiles. Despite the recommended maximum dietary inclusion levels of 15% for copra and palm kernel meals in fish diets (Jauncey, 1998; Hertrampf and Piedad-Pascual, 2000), some studies have demonstrated the possibility of including higher levels of these byproducts in tilapia diets without negatively affecting feed intake and growth performance. Copra inclusion levels beyond 30% significantly reduced feed conversion efficiencies of Nile tilapia (Santos et al., 2009). At up to 35% inclusion, Nile tilapia rations containing palm kernel meal did not depress growth performance (de Oliveira et al., 1997). Similarly, 30% dietary inclusions of palm kernel meal did not adversely affect growth performance and nutrient digestibility in *Oreochromis mossambicus* (Lim et al., 2001). Because of the negative synergistic effects of inherent ANFs coupled with generally poor essential amino acid profiles, most of the studies on copra, palm kernel and soybean meals as fishmeal replacers have been focused on their effects on diet digestibility (Mukhopadhyay and Ray, 1999; Ng and Chong, 2002; Köprücü and Özdemir, 2005; Mamun et al., 2007), as well as growth rate and survival in fishes (Jackson et al., 1982; Olude et al., 2008; Santos et al., 2009) with very little focus on their effects on the physical characteristic of feeds.

Studies on the effects of dietary inclusions of plants ingredients on feed physical characteristics are particularly important because the non-starch polysaccharide fractions of plant ingredients have the potential to reduce expansion and affect the hardness of feeds (Ainsworth et al., 2007). Hardness and water stability are important factors which determine nutrient retention capacity as well as the sinking velocity of pellets (Baeverfjord et al., 2006; Chevanan et al., 2009; Kraugerud et al., 2011). The hardness of pellets generally affects their preference and acceptability by fish, where softer pellets are usually preferred to harder pellets (Aas et al., 2011; Skoch et al., 1983). High water-stable diets are known to prolong digestion and intestinal absorption of nutrients in fish (Pillay and Kutty, 2005; Venou et al., 2009). Fish feed pellets should therefore aim to have physical properties that promote high feed intake and efficient digestion. Water stabilities as well as sinking velocities must be adjusted to the eating habits of the cultured fish species (Lovell, 1989; Baeverfjord et al., 2006; Sørensen, 2012). The aim of this study was thus to investigate the effects of the inclusion of three oilseed by-products, soybean, copra and palm kernel meals on some physical characteristics of pelletized feeds as well as on their intake by the Nile tilapia, *Oreochromis niloticus*.

2. Materials and methods

2.1. Diet formulation

Four diets including a fishmeal-based control diet were formulated for physical characteristics as well as the feed intake assessments. The proximate compositions of the key raw materials (Table 1) and formulations as well as nutritional compositions (% dry weight basis (dwb)) of the experimental diets (Table 2) are presented below. The control diet (CTRL) had fishmeal as the main protein source whiles the test diets contained the test ingredients at 30% inclusions. All the basal ingredients used in the feed formulation were finely-ground and sieved to obtain a homogenous mixture and weighed out according to their respective formulations. Mineral and vitamin premixes were added to each diet. Pre-gelatinised tapioca flour was used as the binder and the diets pelletized with a meat grinder fitted with a 2 mm die plate. The resulting pellets were oven-dried at 40 °C for 48 h.

Table 2
Diet formulation (g kg^{-1} as fed) and proximate composition (% dwb) of control and test diets used for the digestibility trial.

	Control diet	Test diets		
		CM diet	PKM diet	SBM diet
Ingredients				
Fishmeal	425	298	298	298
Soybean meal	–	–	–	300
Copra meal	–	300	–	–
Palm kernel meal	–	–	300	–
Wheat bran	385	269	269	269
Palm oil	90	63	63	63
Vitamin premix	40	28	28	28
Diphosphate	30	21	21	21
Cassava starch (binder)	30	21	21	21
Proximate composition				
Dry matter	93.7	93.0	93.1	93.5
Crude protein	32.3	30.1	25.3	35.1
Crude lipid	14.6	10.8	15.2	13.9
Ash	10.9	10.4	8.5	9.7

CM diet: copra meal diet; PKM diet: palm kernel meal diet; SBM diet: soybean meal diet.

2.2. Feed bulk densities and pellets sinking velocity measurements

Feed bulk densities were measured following the methods of Aarseth et al. (2006) by pouring feed samples through a funnel into tared 1000 ml measuring cylinders and weighing the content on a balance. The procedure was repeated 3 times for all the feed samples. Sinking velocities of the different feed pellets were measured in a 1.5 m high transparent plastic tube with a sealed bottom and a diameter of 15 cm. The tube was filled with municipal water of drinking quality heated up to 25 °C to simulate the temperature of the natural growing environment for tilapia. The sinking velocities of the pellets were measured by adapting the methods of Lekang et al. (1991). Sinking velocities of the various feed types were measured with a digital stop-watch over a distance of 100 cm between two points at the 10 and 110 cm marks after pellets were dropped from a height of 5 cm above the water surface. To ensure accurate depth recordings, a large-tipped marker was used to mark the 10 and 110 cm depths around the cylinder. The 10 cm marking from the top of the tube was to allow feed pellets to reach terminal or constant velocity before timing. Single pellets of around the same lengths (1 cm) were randomly selected for sinking velocity measurements and sinking velocities were recorded as cm s^{-1}. Thirty (30) pellets were randomly chosen for each diet for the test and feed pellets that came into contact with the tube wall during a fall were excluded.

2.3. Nutrient leaching rates and water stability of the feeds

The pellet water stability and nutrient leaching tests were based on modifications of the horizontal shaking methods employed by Obaldo et al. (2002) and Baeverfjord et al. (2006). One gram samples of each feed were weighed to the nearest 0.1 mg on an analytical balance (Mettler Toledo model XP204) into pre-weighed 3.5 cm × 2 cm × 0.5 cm histology casettes with 1 mm × 1 mm openings. Actual pellet movements within the plastic casings were not