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Short communication

Physical properties of extruded aquafeed with a combination of sago and tapioca starches at different moisture contents

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ABSTRACT

This study was conducted to determine the effects of sago–tapioca starch ratio and moisture level of feed mixture on the physical properties of a Malaysian mahseer (*Tor tambroides*) extruded diet. Fifteen iso-nitrogenous diets containing varying ratios of sago–tapioca starch (20:0, 15:5, 10:10, 5:15 and 0:20) and varying moisture contents (200, 300, and 400 g/kg) were formulated. The feed mixtures were extruded using a single-screw extruder. The barrel temperature profile was set at 80–100–120 °C while the die temperature was set at 160 °C. The physical properties of extruded diets (bulk density, expansion rate, floatability, water stability, pellet durability index, sinking velocity and scanning electron microscopy) were investigated. The results showed that increasing moisture level of diet from 200 g/kg to 400 g/kg increased ($P<0.05$) the value of all physical properties examined. The best moisture level to produce best floating extrudates using sago or tapioca or their combination was 400 g/kg. Sago starch and combinations of the sago–tapioca starch performed as good as tapioca starch alone.

1. Introduction

Aquaculture is one of the fastest growing food production activities in the world. It plays a significant role in many countries by providing a higher income, better nutrition, and better employment opportunities (Kannadhason et al., 2011). Thus, the aquafeed technology is moving in tandem with the aquaculture growth with the usage of extrusion procedures for the improvement of digestibility. Chang and Wang (1999) stated the advantages of extrusion cooking process for aquaculture feed production including improved feed conversion ratio, control of pellet density, greater feed stability in water, better production efficiency and versatility. During extrusion cooking various reactions take place including thermal treatment, gelatinization, protein denaturation, hydration, texture alteration, partial dehydration, and destruction of microorganisms and other toxic compounds (Kannadhason et al., 2011). According to Chang and Wang (1999), the gelatinization that occurs during extrusion process improves durability of the feed rations and digestibility of starch.

Starch is used in extrusion cooking of aquafeed to produce puffed products. It is responsible for the expansion of extruded diets while other ingredients such as proteins, fats, and fibers act as diluents (Kannadhason and Muthukumarappan, 2010). In Malaysia, the main local sources of starch are tapioca and sago (Tan et al., 2002). These two starches may be used as the replacement of maize starch which is commonly used in the aquafeed industry. Using these starches could reduce feed production cost and feed price. Sago starch has several advantageous properties, including easy to gelatinize due to its low gelatinization temperature, high viscosity, easily molded and low syneresis of gel (Takahashi, 1986). A preliminary study

Abbreviations: BD, bulk density; DM, dry matter; ER, expansion ratio; PDI, pellet durability index; SV, sinking velocity; WS, water stability.

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Table 1
Composition of the test diets (g/kg) containing varying tapioca–sago starch ratios.

Ingredient	Diets (Sago g/kg:Tapioca g/kg)				
	0:200	50:150	100:100	150:50	200:0
Sago starch	0.0	50.0	100.0	150.0	200.0
Tapioca starch	200.0	150.0	100.0	50.0	0.0
Fishmeal[a]	400.0	400.0	400.0	400.0	400.0
Soy bean	281.9	281.9	281.9	281.9	281.9
Rice bran	15.5	15.5	15.5	15.5	15.5
Vitamin premix[b]	10.0	10.0	10.0	10.0	10.0
Mineral premix[c]	10.0	10.0	10.0	10.0	10.0
Vegetable oil[d]	82.6	82.6	82.6	82.6	82.6

Nutrient information of complete feed [g/kg; calculated using United States-Canadian Tables of Feed Composition (1982)]: crude protein, 371.9; crude lipid, 137.3; crude fiber, 31.2; arginine, 24.3; histidine, 91.9; isoleucine, 19.0; leucine, 28.8; lysine, 26.9; methionine + cysteine, 12.7; phenylalanine + tyrosine, 28.4; threonine, 14.9; tryptophan, 4.34; valine, 19.4; gross energy (kJ/g), 19.1–19.3.

[a] Malaysian fishmeal (630 g/kg crude protein).

[b] Vitamin (mg/kg complete feed): ascorbic acid, 450; myo-inositol, 50; choline chloride, 750; niacin, 50; riboflavin, 10; pyridoxine, 10; thiamin mononitrate, 10; Ca-pantothenate, 30; retinyl acetate, 10; cholecalciferol, 10; vitamin K menadione, 20; α-tocopheryl acetate (500 IU/g), 80; biotin, 2; folic acid, 1; vitamin B_{12}, 0.1.

[c] Mineral (mg/kg complete feed): KCl, 900; KI, 0.4; $CaHPO_4 \cdot 2H_2O$, 5000; NaCl, 400; $CuSO_4 \cdot 5H_2O$, 30; $ZnSO_4 \cdot 7H_2O$, 40; $CoSO_4$, 2; $FeSO_4 \cdot 7H_2O$, 20; $MnSO_4 \cdot H_2O$, 30; $CaCo_3$, 2100; MgOH, 1200; Na_2SeO_3, 0.3.

[d] Mazola sunflower oil.

by Nuttanan et al. (1995) has found sago starch as a good tablet binder compared to various commercial binders such as maize starch, tapioca starch, pregelatinized starches and polyvinylpyrrolidone. Sago starch can prolong the disintegration process by 19.3 min as compared to about 5 min for above mentioned samples (Singhal et al., 2008). Therefore, this study was conducted to evaluate the potential and performance of tapioca and sago starches in the production of an extruded Malaysian mahseer (*Tor tamborides*) diet. In addition, the effects of sago–tapioca starch ratio and moisture level of the feed mixture prior to extrusion on the physical properties of mahseer extruded diet were investigated.

2. Materials and methods

2.1. Test diets

Five mahseer diets (350 g/kg protein and 18.8 kJ/g gross energy) were formulated to contain 200 g/kg starch at five tapioca–sago starch ratios (Table 1). Before the extrusion, water was added to the diets to 200, 300 and 400 g/kg total moisture. Each treatment in this 5 × 3 factorial experiment was triplicated. Fishmeal, soybean, rice bran and corn meal were ground using a laboratory grinder. For each diet, all the ingredients except for the vegetable oil were mixed. Water was added consistently in order to achieve the target feed moisture content. The mixtures were then placed in sealed polyethylene bags and kept overnight at room temperature for moisture stabilization.

2.2. Extrusion

Approximately 1 kg of pellets was produced for each replicate. All replicate diets were randomly extruded using a laboratory scale stand-alone single-screw extruder with a throughput of 5 kg/h (Brabender KE19; Brabender Gmbh, Germany). The extruder had a barrel length and barrel diameter of 420 mm and 19 mm, respectively with a length to diameter ratio of 22:1. A uniform pitch screw with a length to diameter ratio of 25 was used in the experiment. The maximum screw torque was 150 Nm and the compression ratio achieved inside the barrel was 3:1. The barrel zone was heated electrically with heating/cooling jacket. The barrel temperature profile was set at 80–100–120 °C while the die temperature was set at 160 °C. The extruder was operated at a preset feeder, screw and 4-bladed cutter speeds of 40, 120, and 300 rpm, respectively. The die had a diameter of 3 mm and pressure of 8.0–10.0 MPa.

Extrudates were oven-dried at 45 °C for less than 24 h. The oil was then sprayed over the dried extrudates. After that, 1 g of each replicate diet was placed inside the drying chamber of an infrared moisture-determination balance (AD-4715; A&D Weighing Co., Milpitas, CA, USA) and its moisture content was recorded. Finally, the physical properties of extrudates of each replicate were measured as described in Section 2.3.

2.3. Physical properties analysis

Each replicate diet was poured into a 1000 ml cylinder in order to measure the weight of 1000 ml diet. Bulk density (BD) was then reported as g/l (Sørensen, 2007). Floatability of each replicate diet was tested using 100 ml beakers. The characteristics of 10 pellets (floated or sunk) were noted after 20 min. Water stability (WS) was measured as the ratio of the pellets retained on a wire mesh screen after immersion of 3–4 g of each replicate diet in 100 ml water for 20 min and oven-drying at 105 °C for 24 h to whole pellets at the start (Lim and Cuzon, 1994). For measuring durability, 100 g of each