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Effects of extruder die temperature on the physical properties of extruded fish pellets containing taro and broken rice starch

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ABSTRACT

A study was conducted to investigate the effects of starch source (taro and broken rice) and extrusion die temperature (125, 140, 155 and 170 °C) on the physical properties of extruded pellets. The blends containing taro or broken rice starch were extruded using a single screw extruder and the three zones of the barrel temperature profile were set constant at 70, 90 and 100 °C. Moisture content, expansion ratio, bulk density, floatability, pellet durability index, water absorption and solubility indices were extensively analysed. The results elucidated significant effects on the physical properties of the extruded pellets during the increase of die temperature and also change of starch source from taro to broken rice. The highest ER, PDI, WAI was noted in the fish diet containing broken rice starch compared to diet containing taro starch. Increase of die temperature from 125 to 170 °C has significant effects on physical properties of the extruded pellets containing taro and broken rice starch. The MC, ER, F, PDI and WAI values significant increased by 7.0, 3.5, 103.6, 0.1 and 13.5%, respectively, as the die temperature was increased from 125 to 170 °C. In contrast, there was a significant decrease in BD and WSI values by 9.4 and 12.2%, respectively, as the die temperature elevated from 125 to 170 °C.

1. Introduction

Extrusion is a high temperature and short time (HTST) food and feed processing technique widely used in several industries. Harper (1979) explained that extrusion cooking can be best described as a process of moistened starchy and proteinaceous materials are cooked and worked into viscous, plastic-like dough. During extrusion cooking the raw ingredients may undergo many chemical and structural changes such as protein denaturation, starch gelatinization and complex formation between amylose and lipid (Ilo and Berghofer, 1999). Furthermore, extrusion cooking is a very complicated process that product quality is highly variable depending on the type of extruder, screw speed and configuration, temperature profile on the barrel, die profile, feed rate and feed moisture (Mercier, 1977; Chinnaswamy and Hanna, 1988).

Commercial starches are primarily used in producing fish pellets in which are usually obtained from corn, tapioca, wheat, potato and sago (Chinnaswamy and Hanna, 1988; Govindasamy et al., 1995; Huber and Riaz, 2000; Shankar et al., 2008; Xie et al., 2009; Umar et al., 2013; Sarawong et al., 2014). Starch is known as an important ingredient in extrusion for its

Abbreviations: MC, moisture content; ER, expansion ratio; BD, bulk density; F, floatability; PDI, pellet durability index; WAI, water absorption index; WSI, water solubility index; SEM, scanning electron microscope.

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Table 1
Nutrient composition of taro and broken rice starch (g/kg as fed basis).

Dietary component	Taro flour	Broken rice flour
Dry matter	890.0	881.0
Crude protein	58.0	75.3
Crude lipid	7.9	15.0
Ash	39.0	25.0
Starch	768.1	758.7
Gross energy (kJ/g)	15.5	15.9

binding capabilities as well as expansion of the extrudates (Horn and Bronikowski, 1979). Starch undergoes gelatinization and melting process at high temperature which results changes in physicochemical properties of the pellet (Mercier, 1977; Davidson et al., 1984). Two of the major challenges that fish feed industry facing for a profitable feed production is feed formulation and processing (Kazamzadeh, 1989). Since certain amount starch is required in feed formulation to produce floating pellets (Rolfe et al., 2001; Kannadhason et al., 2009; Glencross et al., 2012), the inflated price of corn starch (Bothast and Schlicher, 2005; Luchansky and Monks, 2009) have impact on the cost of producing aquafeed. Currently, more than 17,000 million gallons of ethanol are produced from grain and sugar crops for the transportation sector (RFA, 2008). The versatility of starches causes price inflation and implies a need to discover new suitable source of starch. Identification of new potential source of starch would reduce the cost of feed development and promote a sustainable aquaculture feed industry.

Taro (*Colocasia esculenta*) is an important starchy staple food with a dietary role similar to yam and cassava in many regions of the world including West Africa and Indies, Asia, Caribbean, Pacific and Polynesian Islands and South America. The estimated annual world taro production is 10 million metric tonnes (m.t.), where Asia contributed 2.2 million m.t. (FAO, 2012). Taro has been reported to have high starch content with small granules that is highly digestible in the gastrointestinal human tract (Sefa-Dedeh and Agyr-Sackey, 2004). Although taro is known for its nutritional and health benefits, these tubers suffers 30% loss during storage as a consequence of their high moisture content, sustained metabolism, and microbial attack (Agbor-Egbe, 1991). Taro is mainly consumed in fresh state and large scale industrial processing into dehydrated food is still uncommon. These issues can be resolved by making taro to non-perishable food item thorough processing into flour and finding its new food application. Likewise, rice is the staple food source for countries like Malaysia which is also a producer (Tey and Radam, 2011). Removal of the paddy husk gives brown rice and polishing to remove the bran and germ results white rice (Elaine et al., 2004). Milled rice with lower percentage of broken rice has greater economic value. The broken rice is isolated and usually sold at a lower price to be used in various processing products (Saleh and Meullenet, 2013).

Fortunately, high starch content in taro and broken rice may be suitable to be used as a replacement for corn, wheat, and tapioca starch in producing extruded fish pellets. The main objectives of this work were to investigate (1) the potential of taro (*C. esculenta*) and broken rice (*Oryza sativa*, Linn) as an alternative starch source in producing high quality floating pellets and (2) determining the effects of starch source and extrusion die temperature on the physical quality of the extruded fish pellets.

2. Materials and methods

2.1. Taro and broken rice starch preparation

Fresh taro corms (*C. esculenta*) and broken rice rice (*O. sativa*, Linn) used in the present study was bought from the local market at Malaysia. Taro corms were washed thoroughly and peeled with a knife. The peeled taro corms were cut into slices (2 cm thickness), steamed (99 ± 2 °C, 10 min) and cooled to room temperature. The cooled slices of taro were oven dried in an electric convection oven (60 °C, 48 h). The dried taro and broken rice were ground and sieved through a 200 μm sieve to obtain starch. The nutrient composition of both starch were analysed (Table 1).

2.2. Raw ingredients and sample preparation

The isonitrogenous and isocaloric diets (300 g/kg net protein and 14.65 kJ/g, respectively) were formulated cointaning taro and broken rice starch (Table 2). For each blends, the ingredients were finely ground and mixed using a dough mixer. At the same time, water was added consistently in order to achieve targeted moisture of 400 g/kg wet basis. All treatments were triplicated. The blends were sealed in polyethylene bags and stored overnight under air condition room for moisture stabilization.

2.3. Extrusion

Approximately 1 kg blends for each replicate were extruded to pellets using a single-screw extruder (Brabender KE19; Brabender GmbH, Germany). The extruder has a barrel length and diameter 420 mm and 19 mm, respectively, with at length to diameter (L/D) ratio of 22:1. A uniform pitch screw L/D ratio of 25:1 was used. The maximum screw torque was 150 N m