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Effects of extruder die head temperature and pre-gelatinized taro and broken rice flour level on physical properties of floating fish pellets

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ABSTRACT

Two experiments were conducted to investigate the effects of pre-gelatinized (PG) taro and broken rice and extruder die temperatures on the physical properties of extruded pellets. The first experiment was conducted to evaluate the effects of PG taro and extruder die head temperature (125, 140, 155 and 170 °C) and a subsequent experiment was conducted using PG broken rice instead. All the blends were preconditioned to a 40% moisture content and then extruded using a single screw extruder. The three zones of the barrel temperature profile (70, 90 and 100 °C) and screw speed (150 rpm) of the extruder were constant throughout the extrusion cooking process. The physical properties of the pellets included floatability, expansion ratio, bulk density, pellet durability, water absorption and solubility, moisture content and pellet microstructure. The findings showed in both experiments that PG taro and broken rice inclusion levels and die temperature had significant effects on most of the physical properties of the pellets except for pellet durability index. Changing the inclusion rate of PG taro and broken rice from 15 to 25% significantly increased the expansion ratio and floatability of the extruded pellets. Similarly, as the die temperature was elevated in both experiment, the floatability of the extruded pellets in diet containing PG taro and broken rice increased by 114.62% and 21.88%, respectively. It was also noted that use of PG taro and broken rice resulted in highly durable pellets in all treatments. Further, microstructure analysis of the extruded pellets revealed that using PG taro and broken rice, the surface of the extruded pellets became coarser when the die temperature was elevated from 125 to 170 °C and the PG taro and broken rice inclusion level was at 15%. In conclusion, pre-gelatinized taro and broken rice could be used to manufacture higher quality floating pellets.

1. Introduction

Over the years as the aquaculture industry rapidly grew, the focus on producing high quality fish pellets through the process of extrusion has been studied by numerous researchers (Mercier, 1977; Riaz, 1997; Aarseth et al., 2006; Sørensen et al., 2010). Extrusion is a high temperature and short time (HTST) continuous processing operation which is widely applied in the food and feed industries. Extrusion soon became the most important processing technique that is used in producing aquafeeds because it offers energy saving, product shaping, improved textural and flavour characteristics, versatility, controllability, continuous and high

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production as well as minimal effluents during processing (Riaz et al., 2009). During extrusion cooking, the moistened starchy and proteinaceous materials are subjected to high temperature, pressure and mechanical shearing forces (Harper, 1979; Chinnaswamy and Hanna, 1988) that cause many chemical and structural changes such as protein denaturation, starch gelatinization, inactivation of many food enzymes, decreased microbial counts and complex formations between amylose and lipid (Harper, 1989; Ilo and Berghofer, 1999). Larrea et al. (2005) reported that the extrusion process was also able to decrease insoluble dietary fiber and increase soluble dietary fiber.

The role of starch as a functional ingredient in extrusion cooking include its binding and expansion capabilities which are required to produce extruded pellets (Horn and Bronikowski, 1979). Starch gelatinization can be manipulated by the presence of water and heat as well as the presence or absence of shear forces which bring changes in the physicochemical properties of the pellet (Mercier, 1977). However, this often depends on the starch composition, since those with a high amylopectin causes light, elastic, and expended extrudates, whereas starch with a high amylose content leads to hard and less expanded extrudates (Mercier and Feillet, 1975). Suknark et al. (1997) reported that increased amylose from 23% to 48% in various starches increased the expansion of the extrudate. Conversely, Della Valle et al. (1997) stated that starches with high amylopectin contents have high expansion because the branch linkages are easier to pull apart during expansion of the extrudate. Glencross et al. (2012) assessed several cereal grains and starches in extruded diets for barramundi and found that triticale provided the highest expansion, tapioca gave the lowest bulk density and barley led to the highest hardness with 0% floatability.

Most of these studies examined the physical quality of the fish pellets and are limited to native starch from corn, tapioca, wheat, potato, barley, taro, broken rice and sago (Chinnaswamy and Hanna, 1988; de Cruz et al., 2015; Govindasamy et al., 1995; Huber and Riaz, 2000; Shankar et al., 2008; Sørensen et al., 2010; Glencross et al., 2012; Umar et al., 2013; Sarawong et al., 2014). Although native starches have unique properties, they lack versatility to function properly in the production of floating pellets which is likely due to various interactions with the other ingredient types (protein, fiber and lipid) and their levels but also the moisture content and extrusion processing parameters (Chevanan et al., 2008; Kannadhason et al., 2009; Chevanan et al., 2010; Ayadi et al., 2011). Due to these many complex interactions, the production of floating or sinking aquafeeds requires optimization which is time consuming (Kannadhason and Muthukumarappan, 2010). It is crucial to understand the relationship between the ingredients, processing parameters, and equipment design and operation to develop new and quality fish pellets. Therefore, starch modifications prior to extrusion may potentially minimize optimization by improving their functional properties. Pre-gelatinization is one of the simplest physical modifications of starch that easily can be processed (Sørensen et al., 2010). When processed by heat treatment, the pre-gelatinized starches have increased water absorption and solubility indices upon dispersion in cold water compared to their native forms, which may be due to various physical changes including molecular depolymerzation, irreversible granule swelling, loss of birefringence and crystallinity (Colonna et al., 1984; Freitas et al., 2004). To the best of our knowledge, few studies have investigated the effects of pre-gelatinized (PG) taro and broken rice in aquafeeds however the results have been promising. For instance, Sørensen et al. (2010) showed that gelatinized starch improved the durability of extruded pellets while Amirkolaie et al. (2006) demonstrated that gelatinized starch significantly improved the digestibility, growth and faecal removal rate for tilapia.

Native forms of taro (*Colocasia esculenta*) and broken rice (*Oryza sativa*) were found to be suitable in the production of floating extruded pellets (de Cruz et al., 2015), however, the potential of their modified forms have not yet been investigated. The aim of this study was to examine the effects of PG taro in experiment 1 and broken rice in experiment 2, inclusion rate (15, 20, and 25%) and die temperature (125, 140, 155 and 170 °C) on various physical characteristics of aquafeed pellets using a single screw extruder.

2. Material methods

2.1. Taro and broken rice flour preparation

Fresh taro corms (*Colocasia esculenta*) were purchased from a local market in Malaysia and were washed thoroughly and carefully 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 slices were ground using a laboratory scale hammer mill (Pulian International Enterprise Co. Ltd., Taiwan) and sieved through a 200 μm sieve to obtain the flour. Similarly, broken rice (*Oryza sativa*) was finely ground to flour. The nutrient composition of both flour were then analysed (Table 1).

Table 1
Nutrient composition of taro and broken rice starch (g/100 g as fed basis).

Dietary component	Flour	
	Taro	Broken rice
Dry matter	89.0	88.1
Crude Protein	5.8	7.5
Crude lipid	0.7	1.5
Ash	3.9	2.5
Starch	76.8	75.8
Gross energy (kJ/g)	15.5	15.9