UNIVERSITI PUTRA MALAYSIA

EFFECTS OF BROKEN RICE AND TARO ROOT AS SOURCES OF STARCH ON THE PHYSICAL PROPERTIES AND MICROSTRUCTURE OF EXTRUDED FISH FEED

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By

CLEMENT ROY DE CRUZ

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Master of Science

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DEDICATION

I would like to dedicate my thesis to my family members. Without whom none of my success would be possible.

Abstract of thesis was presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the Degree of Master of Science

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December 2014

Chairman: Mohd Salleh Kamarudin, PhD
Faculty: Agriculture

Currently, Malaysia has great dependency on imported starch in production of floating fish pellets. The discovery of alternative sources of starch that are locally grown would promote a sustainable aquaculture feed industry in Malaysia. This study has examined the effects of native and modified starches (broken rice and taro) and varying extrusion processing variables on the physical properties of the pelleted fish feed. In the first part of the study, the factors studied were the effects of broken rice and taro inclusion (15%, 20%, and 25%), moisture level (30%, 35%, and 40%), and die head temperature (140, 150, 160 and 170°C) on the physical properties of the extruded pellets. The three barrel zones (70, 90,100°C) and screw speed (150 rpm) of the extruder were set constant throughout the extrusion process. All diets were processed using a single screw extruder. The findings showed that increasing broken rice and taro inclusion level, moisture level and die head temperature resulted in significant improvements on the physical properties of the extruded pellets. At 25% taro and broken rice starch level, 40% moisture level and 170°C die head temperature, the extruded pellets were able to float for more than 20 minutes. Likewise, as the die temperature was elevated the taro and broken rice starch have undergone a high degree of gelatinization evidenced by pellets with increased expansion ratio and better water stability as noted in water absorption and solubility indices values. In the second part of the study, two factorial experimental design were applied to investigate the effects of modified broken rice and taro inclusion level (15, 20, and 25 %) and extrusion die head temperature (125, 140, 155 and 170°C) on the physical properties of the extruded pellets. All the blends were preconditioned to 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 set constant throughout the extrusion cooking process. The findings elucidated that changes of modified broken rice and taro inclusion level and die head temperature had significant effects on water stability and floatability of the pellets. Changing level of modified broken rice and taro inclusion level from 15% to 25% increasd expansion ratio, floatability, and reduces bulk density values. Similarly, as the die temperature was elevated, the extruded pellets had higher expansion ratio, lower bulk density, higher floatability values and better water stability. The pellets extruded using modified broken rice and taro were very durable with fines produced at less than 1% for all treatments.

Moreover, extruded pellets produced from 15% modified broken rice and taro inclusion level and 170°C die head temperature had high floatability values which were 100.00% and 93.33%, respectively. In conclusion, low inclusion of modified broken rice and taro starch could be used to manufacture high quality floating pellets with a very minimum optimization.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

KESAN SUMBER KANJI DARIPADA BERAS HANCUR DAN KELADI KEATAS SIFAT FIZIKAL DAN MIKROSTRUKTUR UNTIL YANG TELAH DIEKSTRUSI

Oleh

CLEMENT ROY DE CRUZ

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Pada masa kini, Malaysia secara keseluruhannya bergantung kepada kanji yang diimport untuk pengeluaran until makanan ikan terapung. Penemuan sumber kanji tempatan yang alternatif akan menggalakkan industri pengeluaran makanan akuakultur yang mampan di Malaysia. Kajian ini telah meneliti kesan kanji asli dan terubah (beras hancur dan keladi) dan pembolehubah proses ekstrusi ke atas sifat fizikal until makanan ikan. Di bahagian pertama kajian, faktor yang telah diuji adalah kesan kandungan beras hancur dan keladi (15, 20, dan 25%), kandungan kelembapan (30, 35 dan 40%) dan suhu *die head* (140, 150, 160 dan 170°C) ke atas sifat fizikal until yang telah melalui proses ekstrusi. Ketiga-tiga zon suhu (70, 90, dan 100°C) dan kelajuan skru (150 rpm) telah dimalarkan pada sepanjang proses ekstrusi. Semua diet melalui proses tersebut dengan ekstruder satu skrew. Keputusan kajian menunjukkan bahawa peningkatan kandungan beras hancur dan keladi, kandungan kelembapan dan suhu *die head* menyebabkan perbaikan yang ketara ke atas sifat fizikal until yang telah diekstrusi. Pada 25% kandungan beras hancur dan keladi, 40% kandungan kelembapan dan 170°C suhu *die head*, until yang telah dihasilkan boleh terapung lebih daripada 20 minit. Begitu juga, apabila suhu *die head* dinaikan, kanji keladi dan beras hancur melalui proses penggelatinan yang tinggi dan menghasilkan until yang lebih kembang dan stabil dalam air seperti yang tercatat dalam bacaan indeks penyerapan air dan kelarutan. Di bahagian kedua kajian ini, reka bentuk kajian dua faktorial telah dijalankan untuk mengkaji kesan kandungan kanji beras hancur dan keladi yang telah terubah (15, 20, dan 25 %) dan suhu *die head* (125, 140, 155 dan 170°C) terhadap sifat fizikal until yang telah diekstrusi. Semua campuran telah ditambahkan dengan air sehingga kandungan kelembapan 40%, justeru diproses dengan menggunakan ekstruder satu skrew. Ketiga-tiga zon profil suhu (70, 90, dan 100 °C) dan kelajuan skru (150 rpm) ekstruder telah dimalarkan di sepanjang proses ekstrusi. Hasil kajian menunjukkan bahawa perubahan kandungan kanji terubah bagi beras hancur dan keladi dan suhu *die head* mempunyai kesan yang ketara terhadap kestabilan air dan keterapungan until. Peningkatan kandungan kanji beras hancur dan keladi terubah dari 15% kepada 25% telah juga menyebabkan peningkatan nisbah pengembangan, keapungan dan menurunkan kepadatan pukal. Begitu juga, apabila suhu *die head* dinaikkan, until yang terhasil mempunyai nisbah pengembangan yang tinggi, kepadatan pukal yang rendah, serta peningkatan keapungan dan kestabilan air yang lebih baik. Semua until yang terhasil daripada ekstrusi menggunakan kanji terubah beras hancur dan keladi

mempunyai durabiliti yang sangat tinggi dengan peratus habuk kurang daripada 1% bagi kesemua eksperimen. Selain itu, until yang terhasil pada suhu *die head* 170°C daripada kandungan 15% kanji terubah beras hancur dan keladi mempunyai nilai keapungan yang tinggi, iaitu 100.00% dan 93.33%. Secara keseluruhannya, kanji terubah beras hancur dan keladi boleh digunakan untuk menghasilkan until terapung yang berkualiti tinggi dengan pengoptimuman yang sangat minimum dan kandungan yang rendah.

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I certify that a Thesis Examination Committee has met on 4 December 2014 to conduct the final examination of Clement Roy De Cruz on his thesis entitled "Effects of Broken Rice and Taro Root as Sources of Starch on the Physical Properties and Microstructure of Extruded Fish Feed" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfillment of the requirements for the degree of Master of Science. The members of Supervisory Committee are as follows:

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ANOVA	Analysis of variance
BD	Bulk density
CA	California
cm	Centimeter
Co.	Cooperation
db	Dry basis
DDGS	Distillers dried grains with solubles
ER	Expansion ratio
F	Floatability
g	Gram
kcal	Kilocalorie
kg	Kilogram
kJ	Kilojoule
L	Liter
mt	Million tonnes
ml	Milliliter
mm	Millimeter
MC	Moisture content
Nm	Torque
NJ	New Jersey
PDI	Pellet durability index
PG	Pregelatinized
RPM	Rounds per minute
SV	Sinking velocity
SEM	Scanning electron microscope
SME	Specific mechanical energy
t	Tonnes
UK	United Kingdom
UPM	Universiti Putra Malaysia
USA	United States of America
V	Virginia
WAI	Water absorption index
WSI	Water solubility index
µm	Micron
^{0}C	Degree Celsius
%	Percentage
<	Less than
>	More than

CHAPTER 1

GENERAL INTRODUCTION

Aquaculture is one of the most important industries in Malaysia with an annual value of RM2.76 billion (DOF, 2012). Aquaculture products such as fish and shrimp are important sources of protein for the nation. During the past decade, the production of aquaculture in Malaysia has tremendously grown from 165,119 tonnes in 2002 to 287,076 tonnes in 2012 with an average annual growth of 7.4%. This makes aquaculture industry as the fastest growing agriculture sector in Malaysia. The world average annual aquaculture growth is at 6.5% (FAO, 2011a).

The rapid growth of aquaculture production must be supported with the corresponding increase demand of aquafeeds. The feed produced must comply with the specific nutritional requirements of the cultured species such as protein content, carbohydrate, lipid, vitamins and minerals (Kaushik, 1998). It was estimated that local feed millers in Malaysia produce approximately 216,826 tonnes of aquafeeds mainly for shrimp and fish in the year 2013 (DOF, 2013).

The word extrude means to form any material with a desirable cross section by forcing it through a die. Extrusion is referred to a process of extruding. Extrusion is widely used in the aquafeed industry because it offers many advantages such as energy savings, high and continuous production, flexibility and controllability, and very minimal effluent during processing (Riaz et al., 2009). The equipment used in extrusion processing is called extruder. In general, there are two types of extruder which are single screw and twin screw extruder. A twin screw extruder has more control of the extruded product due to its flexible design and control of shear. It is also usually used for more complex diet formulation with high fat content. High fat content material cannot be process in single screw extruder because the fat decreases the shear that hinders the energy transformation into heat for cooking (Guy, 2001).

Starch is essential in the manufacturing of extruded pellets due to its binding and expanding properties (Horn & Bronikowski, 1979). It is a biopolymer and has a very unique structure which consists of amylose and amylopectin (Brouillet-Fourmann et al., 2003). These two macromolecules, amylose (linear polymer) and amylopectin (branched polymer) are assembled together to form a semi-crystalline starch granule which the exact size and shape of the granules are varied according to different type of starch (Burrell, 2003). Starch is abundant in many indigenous crops such as corn, wheat, rice, sago, tapioca, potato and yam. Starch gelatinization happens during extrusion and it is an important process because it has impact on the quality and expansion of the pellets (Colonna et al., 1989 ; Gomez & Aguilera, 1984). Furthermore, starch type, particle size and processing conditions determine the amount of starch gelatinization during extrusion cooking (Rokey & Plattner, 2003).

The starch production from cereal is about 2050 million m.t. and from tubers and roots is approximately 679 million m.t. (Tester & Karkalas, 2001). Corn, tapioca, and wheat starch are rampantly used in the aquafeed industry to produce extruded pellets (Kannadhason et al., 2009; Glencross et al., 2012). Incidentally, starches are also widely used in many other industries. In recent years, starch is also utilised as feedstock for ethanol production (Bothast and Schlicher, 2005; Kumar and Reisel, 2011). Approximately 0.18 million m.t., 0.23 million m.t., and 0.18 million m.t. for maize, wheat, and cassava starch, respectively were imported to Malaysia in year 2011 (FAO, 2011b). Whereas, only 6.81 thousand m.t., 55.00 thousand m.t., and 81.00 m.t. for maize, wheat, and cassava starch, respectively were exported from Malaysia in the same year (FAO, 2011b). The high dependency on imported starches in production of extruded aquafeed may not be ideal for sustainable aquaculture in Malaysia. The high demand of starches implies a desperate need to discover an alternative source of starch that can be locally produced in large volumes. Malaysia produces about 2.6 million m.t of rice in 2013 (FAO, 2013) and during the process from removal of the paddy husk to polishing, many of the broken rice are isolated (Elaine et al., 2004). Broken rice could be used as a new alternative source of starch since it has never been reported by any researchers on its function in producing extruded floating pellets. Similarly, cassava, potatoes, tapioca, yams and taro can be easily grown and produced in Malaysia (FAO, 2013). Furthermore, the potential of taro to be used as a source of starch in production of aquafeed and floating pellets is yet to be discovered.

Another great challenge in aquafeed production is manufacturing high quality pellets with acceptable durability and water stability (Rokey & Plattner, 2003). Some of the major characteristics that will affect the quality of the fish pellets are pellet size, shape, durability, bulk density, water absorption and solubility, resiliency, buoyancy, and chewiness (Kazamzadeh, 1989). Manufacturing fish floating pellets through extrusion is a challenge and time consuming because it requires optimization and the effects of feed ingredients and processing parameters need to be studied in detail. It is crucial to understand the relationship between the ingredients, processing parameters, and equipment design and operation to develop new and quality fish pellets (Hashimoto & Grossman, 2003). Starch modification could be a new insight to develop high quality fish pellets through extrusion with minimum optimization.

The objectives of this study were:

1. To evaluate the effects of broken rice (*Oryza sativa*, Linn) and taro (*Colocasia esculenta*) and extrusion process variables on the physical properties of extruded floating pellets.
2. To evaluate the effects of modified broken rice (*Oryza sativa*, Linn) and taro (*Colocasia esculenta*) and extrusion process variables on the physical properties of extruded floating pellets.

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