UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF EXTRUDED PUFFED CORN-FISH SNACK FROM SILVER CARP (Hypophthalmicthys molitrix)

HAMIDREZA SHAHMOHAMMADI

FSTM 2013 21
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HAMIDREZA SHAHMOHAMMADI

DOCTOR OF PHILOSOPHY

UNIVERSITI PUTRA MALAYSIA,
2013
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DEVELOPMENT OF EXTRUDED PUFFED CORN-FISH SNACK
FROM SILVER CARP (Hypophthalmicthys molitrix)

By

HAMIDREZA SHAHMOHAMMADI

Thesis Submitted to the School of Graduated Studies, Universiti Putra
Malaysia, in Fulfillment of the Requirement for the Degree of Doctor of
Philosophy

June 2013
DEDICATION

To my loving family whose never ending support and encouragement helped me to believe in myself and discover that I can accomplish anything with such self-belief.
Abstract of thesis presented to the senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

DEVELOPMENT OF EXTRUDED PUFFED CORN-FISH SNACK FROM SILVER CARP (Hypophthalmicthys molitrix)

By

HAMIDREZA SHAHMOHAMMADI

June 2013

Chairman: Professor Jamilah Bt. Bakar, PhD

Faculty: Food Science and Technology

Corn-based snacks are generally well accepted but low in protein content due to the limited protein–based ingredient incorporated in the formulations. This is because the common extrusion technology used to produce the snack is basically developed for starch-based dough formulation. Incorporating fish protein in the formulation could result in several problems relating to extrusion condition, textural properties and the stability of the snack itself. Therefore, in order to overcome these constraints, the present study was aimed at developing a nutritious puffed corn-fish snack by (i) enhancing the nutrition value and texture of the snack (ii) optimizing the extrusion conditions for enhanced textural properties (iii) and evaluating the storage stability of the developed snack. Extruded puffed corn-fish snack was produced from corn grits containing 0 to 30% of Silver carp (Hypophthalmicthys molitrix). This was followed by
optimizing the composition of the snack using Response Surface Methodology. The optimum formulation was obtained at 85% corn and 15% fish. Improvement of textural characteristics of the puffed corn-fish snack was studied by nucleating materials (calcium carbonate, magnesium silicate, sodium bicarbonate and bran) which were incorporated at 1 to 2% for the first three nucleating agents and at 5 and 10% for bran. The results showed that all nucleating agents significantly enhanced the texture of the puffed snack except for bran. Among the four studied nucleating agents, magnesium silicate at 0.5% was the best texture modifier. Microstructure of the puffed corn-fish snack, which was examined by Scanning Electron Microscope showed that the air cell diameter in the snack which containing 0.5% of magnesium silicate was reduced 7.32 times while the number of cells per unit area was increased 4.76 times compared to the control. In order to optimize the extrusion conditions, RSM experimental design was performed. The optimum extrusion condition was determined to be at 116°C, 1107 g/min feed rate and 148 rpm screw speed. Storage stability of the developed snack both unseasoned and seasoned packed in Biaxillary Poly Propylene films were studied over a storage period of 30 weeks. Microbial conditions were evaluated at 0, 15 and 30 weeks of storage while chemical and sensory parameters were carried out at six weeks intervals for 30 weeks. It is concluded that the shelf-stable, nutritious crispy puffed corn-fish snack containing 15% fish, 84.5% corn and 0.5% magnesium silicate (w/w)
can be produced, packed under air atmosphere conditions with metalized BOPP and well accepted for a storage period of 28 weeks.
Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PEMBENTUKKAN SNEK JAGUNG-IKAN DARIPADA IKAN KAP PERAK (HYPOPHTHALMICHTHYS MOLITRIX) DENGAN MENGGUNAKAN TEKNIK PENYEMPITAN.

Oleh

HAMIDREZA SHAHMOHAMMADI

Jun 2013

Pengerusi: Professor Jamilah Bt. Bakar, PhD

Fakulti: Sains dan Teknologi Makanan

Snek berasaskan jagung secara umumnya diterima baik tetapi kandungannya yang rendah protein disebabkan oleh bahan-bahan terhad yang berasaskan protein telah ditambah dalam formulanya. Ini semua adalah kerana teknologi penonjolan yang biasa digunakan untuk menghasilkan snek adalah secara asasnya dibangunkan untuk formula doh yang berasaskan kanji. Mencampurkan protein ikan dalam formula tersebut menyebabkan beberapa masalah yang berkaitan dengan keadaan penonjolan, sifat tekstual dan kestabilan snek itu sendiri. Oleh yang sedemikian, dalam usaha mengatasi kekangan ini, kajian ini bertujuan untuk membangunkan snek jagung –ikan yang berkhasiat dengan (i) meningkatkan nilai nutrisi dan tekstur snek (ii) mengoptimumkan proses
penonjolan untuk memperbaiki sifat tekstur (iii) dan menilai kestabilan bagi penyimpanan snek yang telah dibangunkan tersebut. Snek jagung-ikan yang penuh khasiat telah dihasilkan daripada tepung jagung mengandungi 0 hingga 30% isi ikan kap perak (Hypophthalmicthys molitrix). Ini diikuti pula dengan mengoptimumkan komposis snek menggunakan Metodologi Respon Permukaan. Formula optimum telah diperoleh pada 85% jagung dan 15% ikan. Penambahbaikan bagi karekteristik tekstur bagi snek penuh jagung-ikan telah dikaji dengan penukleusan bahan (kalsium karbonat, magnesium silikat, sodium bikarbonat dan bran) yang mana telah dicampurkan pada 1 hingga 2% untuk 3 agen penukleusan yang pertama dan pada 5 dan 10% bagi bran. Dapatan ini menunjukkan yang kesemua agen penukleusan secara signifikannya memperbaiki tekstur bagi snek yang penuh kecuali kepada bran. Di kalangan emapat agen penukleusan yang dikaji, magnesium silikat pada 0.5% adalah pengubah tekstur yang terbaik. Struktur mikro bagi snek jagung-ikan yang penuh yang telah dikaji dengan Mikroskop Elektron Scanning menunjukkan yang diameter udara sel yang mengandungi 0.5% magnesium silikat telah dikerangkan sebanyak 7.32 kali ganda manakala bilangan sel per unit telah bertambah 4.76 kali ganda berbanding dengan pengawalan. Dalam usaha untuk mengoptimumkan keadaan penonjolan, rekabentuk eksperimen RSM telah dijalankan. Keadaan penonjolan yang optimum telah ditetapkan pada 116ºC, 1107 g/min kadar suapan dan 148 rpm kelajuan skru. Kestabilan penyimpanan
bagi snek yang dibangunkan bagi kedua-dua tidak berperisan dan berperisan dibungkus dalam filem berbesikan Biaxillary Poly Propylene telah dikaji bagi tempoh penyimpanan selama 30 minggu. Keadaan bermikrob telah dinilai pada minggu 0, 15 dan 30 bagi penyimpanan manakala parameter berkimia dan bersensor telah dijalankan pada interval enam minggu bagi 30 minggu. Ianya dapat disimpulkan yang snek jagung-ikan penuh khasiat rangup tahan simpan mengandungi 15% ikan, 84.5% jagung dan 0.5% magnesium silikat (w/w) boleh dihasilkan dipedakan dibawah keadaan atmosfera yang berbesikan BOPP dan diterima baik bagi tempoh penyimpanan bagi 28 minggu.
ACKNOWLEDGEMENTS

First of all I would like to thank the Almighty ALLAH for his perpetual assistance. I also pray that God Subahanahu wa Ta’ala bless this work and make it useful for humanity.

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I would like to acknowledge the snack manufacturing company “Golfam Talaei Alborz” for providing all materials and machinery required for conducting the study. My sincere thanks are also due to its investment in commercializing the finding of the study under the brand name of “Puffish”.

Finally, I would like to express my appreciations to all those who have contributed towards the success of this research in so many ways, big and small.
APPROVAL
DECLARATION

I declare that the thesis is my original work except for quotations and citation, which have been duly acknowledged. I also declare that it has not been previously or currently submitted for any other degree at Universiti Putra Malaysia or any other institutions.

HAMIDREZA SHAHMOHAMMADI

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<td>ANOVA</td>
<td>Analysis of variance</td>
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<tr>
<td>Ave.</td>
<td>Average</td>
</tr>
<tr>
<td>$a_w$</td>
<td>Water activity</td>
</tr>
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<td>BD</td>
<td>Bulk Density</td>
</tr>
<tr>
<td>BOPP</td>
<td>Biaxillary-Oriented Poly Propylene</td>
</tr>
<tr>
<td>CC</td>
<td>Calcium carbonate ($\text{CaCO}_3$)</td>
</tr>
<tr>
<td>cc</td>
<td>Cubic centimeter</td>
</tr>
<tr>
<td>CCD</td>
<td>central composite cubic design</td>
</tr>
<tr>
<td>cfu/g</td>
<td>colony forming units per gram</td>
</tr>
<tr>
<td>CON</td>
<td>Control</td>
</tr>
<tr>
<td>$^\circ\text{C}$</td>
<td>Degrees centigrade</td>
</tr>
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<td>D</td>
<td>Diameter</td>
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<td>ER</td>
<td>Expansion ratio</td>
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<td>FAO</td>
<td>Food and Agriculture Organization</td>
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<td>FFA</td>
<td>Free Fatty Acid</td>
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<tr>
<td>FO</td>
<td>Fish Odour</td>
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<tr>
<td>FR</td>
<td>Feed rate</td>
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<td>IFRO</td>
<td>Iranian Fisheries Research Organization</td>
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ISIRI Institute of Standards and Industrial Research of Iran

kg Kilo gram
L Length
LD Linear distance
M Molar
MAP Modified atmosphere packaging
MDA Malondialdehyde
Meq Milliequivalent
MF Maximum Force
mg Milligram
min Minutes
mL Milliliter
mm Millimeter
MS Magnesium Silicate (MgSio$_3$)
N Normality
N$_2$ Nitrogen
NB Sodium bicarbonate or sodium hydrogen carbonate (NaHCO$_3$)
NFPRC National Fish Processing Research Center
No. Number
OA Overall acceptability
OPP No-metalized Biaxillary-Oriented Poly Propylene
OTR Oxygen transmission rate
p  Probability
PC  Peaks count
PV  Peroxide value
R^2  Coefficient of determination
RH  Relative humidity
rpm  Revolution per minute
RSM  Response surface methodology
SC  Sensory crispness
SD  Standard deviation
SS  Screw speed
ST  Sensory texture
TBA  Thiobarbituric acid
T  Temperature
TVB-N  Total volatile basic nitrogen
UPM  University Putra Malaysia
W  Weight
WB  Wheat bran
µm  Micrometer
CHAPTER 1

INTRODUCTION

1.1 Background of the study

Extrusion cooking has been shown to be the most efficient technology, in which we can break down raw food ingredients to a well cooked and pre-digested form. This process can increase storage stability from a few weeks to 9-12 months and the product can be consumed in a convenient, ready-to-eat form by the final consumer (Kazemzadeh, 2011). Classic extruded foods and snacks composed of cereals, starches, sugars and oils are believed to be low nutrient-dense food with wide range of consumers, particularly children and young people. They are known as "junk food" due to their high fat and carbohydrate and low protein content (Nurtama & Sulistyani, 1997). However, the global snack food market has developed remarkably in recent years and is expected to reach US$334.7 billion by 2015. Nowadays the market demand for more nutritious snacks is rising considerably. Therefore, there is an increasing trend for some animal proteins to be mixed with grains to produce a complex matrix, using extrusion technology that would meet the needs of the new market demand (Jose, 2012).
Fish species are known to provide high content of important constituents for the human diet such as nutritional and readily-digestible proteins, lipid-soluble vitamins, microelements and polyunsaturated fatty acids (Friedman, 1996). However, it is not a major part of the diet for most Middle-Eastern people. Besides, in the seafood industry, 30-80% of the fish catch, depending on species, is not utilized for human consumption. Extrusion technology can provide a method to utilize fish muscle recovered from underutilized fish (Choudhury & Gogoi, 1996). Restructuring the fish proteins together with a carbohydrate matrix using extrusion technology, can result in a valuable ready-to-eat food that adds value to an underutilized fish species such as silver carp. Extrusion is the best method to eliminate anti nutritional factors. Furthermore this treatment is the most effective method to improve protein and starch digestibility (Alonso, Aguirre, & Marzo, 2000).

Its beneficiaries would be consumers, producers as well as suppliers. The combination of carbohydrates and fish proteins is excellent from the nutritional point of view (SR18, 2005). By combining complementary proteins, the overall quality of the protein as well as its digestibility will be increased. However, to bring this idea to fruition following problems need to be considered.
1.2 Problems statement

I. Cereal extruded snacks are high-calorie and low-protein food.

II. Silver carp (*Hypophthalmicthys molitrix*) is cultured in abundance but it is under-utilized. In spite of having white flesh muscle advantage and the potential of providing a good source of nutritious foodstuff, its abundance of tiny bones makes it unpopular for filleting and direct consumption particularly when the fish are small (less than 1kg).

III. Since extrusion processes are normally designed for starch-based snacks, incorporation of fish muscle in extrusion feed could be problematic from different points of view e.g. technical, consumer acceptability and quality attributes.

IV. The incorporation of minced fish as an ingredient of extruded puffed snack may affect the storage stability of the product.

Therefore, the present research was aimed at developing an extruded puffed corn-fish product with the following hypothesis and objectives.
1.3 Hypothesis

I. Extrusion technology can be used to produce a nutritious extruded puffed corn-fish snack with an acceptable combination of corn and minced fish (silver carp).

II. Nucleating agents such as inorganic salts are able to enhance the texture of the puffed corn-fish snack by compensating the negative effect of high moisture content of minced fish.

III. Formulated snacks should have an acceptable storage stability due to its low $a_w$ and low moisture.

Therefore the objectives of the study are as below:
1.4 Objectives

I. To develop an acceptable formulation for extrusion process and optimizing the fish content of the puffed corn-fish snack.

II. To determine the effects of nucleating substances on the texture of the extruded corn-fish puffed snack, in order to enhance the texture, as well as determine a suitable additive and its proper level.

III. To study the effects of process conditions on textural properties and to optimize feed rate, screw speed and barrel temperature of the developed puffed corn-fish snack.

IV. To investigate quality changes during storage, determining storage stability and evaluating the effects of fish incorporation and packaging conditions on storage stability.
1.5 Overall research flow diagram

Formulation and optimization of the fish content in the extrusion feed
(Chapter 3)

Texture improvement of the formulated snack by nucleating agents
(Chapter 4)

Determination of the proper level of incorporation of the selected nucleating agent to enhance the texture
(Chapter 4)

Identification of the effects of the extrusion feed rate, barrel temperature and screw speed on the physical properties of the developed snack and determining the best extrusion conditions
(Chapter 5)

Evaluation of the storage stability of the developed snack using chemical, biochemical and sensory analyses
(Chapter 6)
REFERENCES


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Mix Texturized by Extrusion Cooking. LWT - Food Science and Technology, 29(5-6), 526-535.


