



UNIVERSITI PUTRA MALAYSIA

**EFFECTS OF COOKING MEDIUM AND BATTER FORMULATION ON QUALITY
ATTRIBUTES OF FRIED FISH FILLETS**

YAZDAN MORADI

FSTM 2008 8



**EFFECTS OF COOKING MEDIUM AND BATTER FORMULATION ON
QUALITY ATTRIBUTES OF FRIED FISH FILLETS**

By

YAZDAN MORADI

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfilment of the Requirements for the Degree of Doctor of Philosophy**

December 2008



DEDICTED TO MY BELOVED FAMILY



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Doctor of Philosophy

**EFFECTS OF COOKING MEDIUM AND BATTER FORMULATION ON
QUALITY ATTRIBUTES OF FRIED FISH FILLETS**

By

YAZDAN MORADI

December 2008

Chairman : Professor Jamilah Bakar, PhD

Faculty : Food Science and Technology

Fried breaded fish fillets are consumed for their unique flavor and textural characteristics which are contributed by the preparation and the breading process. However, the cooking process can cause detrimental changes to the highly valued lipid characteristics of the fish lipid. Therefore, this study was carried out with the objectives of evaluating the changes that could be brought upon by the presence of breading materials, preparation process (pre-frying and pre-drying) and the cooking methods on the desired quality attributes of the breaded fish fillets. The effects of resistant starches on the quality attributes of the breaded fillets were also evaluated. The breaded and non-breaded black pomfret (*Parastromateus niger*) fillets were



deep-fried in sunflower oil and palm olein and evaluated for the physico-chemical properties such as fat content, moisture loss, texture and color changes. The frying process significantly ($P < 0.05$) changed the fat and moisture content in the fillets. The presence of breading materials decreased significantly ($P < 0.05$) the moisture loss and the fat uptake. However, the lipid compositions were observed to change significantly. The n-3/n-6 ratios were decreased in all fried samples. The palm olein fried samples had significantly ($P < 0.05$) higher n-3/n-6 ratio than the sunflower oil fried samples. Breaded fillets were also pre-fried prior to frozen storage to evaluate the effect of pre-frying on the lipid profile of the samples. The pre-frying treatments resulted in the decrease of the saturated fatty acids concentration and an increase of the monounsaturated fatty acids for all samples. The polyunsaturated fatty acids content was found to increase in the sunflower oil fried samples and decreased in the palm olein fried ones. The effects of three final cooking methods on the quality attributes of breaded fillets were also determined. Among the three methods, oven cooking had the least changes in the parameters evaluated. The concentration of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) in the oven cooked samples was about two times higher than the samples cooked by other methods. Oven cooking methods also showed lower thermal oxidation and higher n-3/n-6 ratio than the other two cooking methods. The highest and lowest values of hardness in the final product were observed for those fried and microwaved, respectively. Pre-drying before frying of breaded fillets affected the moisture content, the fat content and the hardness of the final product significantly ($P < 0.05$). A positive correlation ($r = 0.90$) between the pre-drying time and moisture content, and between pre-drying time and



hardness ($r = 0.96$), and a negative correlation between the pre-drying time and the fat uptake ($r = -0.78$) were found. The incorporation of the resistant starches in the batter formulation affected all trends of moisture and fat migration in and out of the breaded materials. The moisture content increased while the fat content decreased significantly ($P < 0.05$) in all breaded samples containing resistant starches as compared to the control. A significant ($P < 0.05$) increase in hardness and crispiness of the samples containing resistant starches were also observed.



Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

Kesan medium penggorengan, teknik pra-pengeringan dan formulasi adunan pada kualiti isi ikan bersalut

Oleh

YAZDAN MORADI

Disember 2008

Pengerusi: Prof. Jamilah Bakar, PhD
Fakulti: Sains Makanan dan Teknologi

Isi ikan bersalut yang telah digoreng, dimakan kerana keunikan pada sifat citarasa teksturnya yang dipengaruhi oleh kaedah pemprosesan dan penyalutannya. Namun begitu, proses memasak boleh menyebabkan perubahan yang tidak diingini pada sifat lipid ikan. Oleh itu, objektif kajian ini adalah untuk menilai perubahan yang disebabkan oleh bahan penyalut, cara pemprosesan (pra-penggorengan dan pra-pengeringan) dan kaedah memasak ke atas kualiti isi ikan bersalut. Kesan kanji berentang (resistant starch) pada kualiti isi ikan bersalut juga dinilai. Isi ikan bawal hitam (*Parastromateus niger*) bersalut dan tidak bersalut digoreng dengan minyak bunga matahari dan minyak olein kelapa sawit dinilai untuk sifat fiziko-kimia seperti



kandungan lemak, kehilangan air, tekstur dan perubahan warna. Proses penggorengan menunjukkan perubahan ketara ($P < 0.05$) pada kandungan lemak dan kelembapan isi ikan. Dengan adanya bahan penyalutan, penyerapan lemak dan kehilangan air ($P < 0.05$) adalah ketara. Namun begitu, komposisi lemak telahpun berubah dengan ketara. Nisbah n-3/n-6 telah menurun dalam kesemua sampel yang digoreng. Sampel yang digoreng dalam minyak kelapa sawit mempunyai nisbah n-3/n-6 yang lebih tinggi daripada sampel yang digoreng di dalam minyak bunga matahari. Isi ikan bersalut yang di pra-goreng sebelum disejukkan dinilai untuk kesan pra-penggorengan keatas profil lemak sampel. Rawatan pra-penggorengan mengurangkan asid lemak tepu dan meningkatkan asid lemak tak-tepu bagi semua sampel. Asid lemak tak-tepu didapati meningkat dalam sampel yang digoreng dengan minyak bunga matahari dan berkurangan dalam sampel yang digoreng dengan minyak isirong kelapa sawit. Kesan tiga kaedah memasak pada kualiti isi ikan bersalut juga dikaji. Diantara ketiga-tiga kaedah tersebut, memasak dengan ketuhar menunjukkan perubahan yang paling kecil pada parameter yang dikaji. Kepekatan asid *eicosapentaenoic* (EPA) dan asid *docosahexaenoic* (DHA) dalam sampel yang dimasak dengan ketuhar adalah dua kali ganda lebih tinggi berbanding dengan sampel yang dimasak dengan kaedah lain. Kaedah memasak dengan ketuhar menunjukkan pengoksidaan therma dan nisbah n-3/n-6 yang tinggi berbanding dengan dua kaedah memasak yang lain. Nilai kekerasan adalah tertinggi pada sampel yang digoreng dan terendah pada sampel yang dimasak dengan ketuhar gelombang mikro. Kaedah pra-pengeringan sebelum isi ikan bersalut digoreng dengan ketara mempengaruhi kandungan lemak dan kekerasan produk terakhir dengan ketara ($P < 0.05$). Korelasi positif ($r = 0.90$) diantara masa pra-

pengeringan dan kandungan air, dan diantara masa pra-pengeringan dengan kekerasan ($r = 0.96$) manakala korelasi negatif diantara masa pra-pengeringan dan penyerapan lemak ($r = - 0.78$) telah deperolehi. Penggunaan kanji rentangan di dalam formulasi *batter* memberi kesan ke atas tren perpindahan air dan lemak di dalam dan diluar bahan salutan. Kandungan air meningkat manakala kandungan lemak berkurangan ($P < 0.05$) dengan ketara pada sampel bersalut yang mengandungi kanji rentangan berbanding dengan kawalan. Peningkatan yang ketara pada kekerasan dan kerangupan bagi sampel yang mengandungi kanji rentangan juga diperhatikan.



ACKNOWLEDGEMENTS

All praise and thanks for Almighty Allah who has given me all the best during all stages of my study. I would like to start by expressing my deepest gratitude, appreciation and thanks to Professor Dr. Jamilah Bakar for her kind supervision, assistance and encouragement during the preparation of this thesis. I also thank members of my supervisory committee, Professor Dr. Yaakob Che Man and Associate Professor Dr. Sharifah Kharidah for their advice, constructive comments and support.

I would like also to acknowledge the financial support provided by the Ministry of Jihad Keshavarzi and Ministry of Science, Research and Technology of Islamic Republic of Iran for this study.

My sincere gratitude also goes to the technicians; Mr. Mohammd Soib in the engineering lab, Mr. Razali Othman in the processing lab, Mr. Azman and Mrs. Lina in the biochemistry lab, Mr. Ho from Institute Bioscience and En. Dzulkifly from Halal Products Research Institute.



I certify that an Examination Committee met on 05 / 12 / 2008 to conduct the final examination of Yazdan Moradi on his PhD degree of Food Technology thesis entitled “Effects of cooking medium and batter formulation on quality of fried fish fillets” in accordance with Universiti Pertanian Malaysia (higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

BADLISHA SHAM BAHARI, PhD

Associate Professor
Faculty of Food Science and Technology
Universiti Putra Malaysia
(Chairman)

SUHAILA MOHAMED, PhD

Professor
Faculty of Food Science and Technology
Universiti Putra Malaysia
(Internal Examiner)

TAN CHIN PING, PhD

Associate Professor
Faculty of Food Science and Technology
Universiti Putra Malaysia
(Internal Examiner)

OSMAN HASSAN, PhD

Professor
Faculty Science and Technology
Universiti Kebangsaan Malaysia
(External Examiner)

HASANAH MOHD. GHAZALI, Ph.D.

Professor/ Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:



This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Jamilah Bakar, PhD

Professor
Faculty of Food Science and Technology
Universiti Putra Malaysia
(Chairman)

Yaakob Bin Che Man, PhD

Professor
Faculty of Food Science and Technology
Universiti Putra Malaysia
(Member)

Sharifah Kharidah Syed Muhammad, PhD

Associate Professor
Faculty of Food Science and Technology
Universiti Putra Malaysia
(Member)

HASANAH MOHD. GHAZALI, Ph.D.

Professor/ Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 12 February 2009



DECLARATION

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

YAZDAN MORADI

Date: 22 / 12 / 2008



TABLE OF CONTENTS

	Page
DEDICATION	ii
ABSTRACT	iii
ABSTRAK	vi
ACKNOWLEDGEMENTS	ix
APPROVAL	x
DECLARATION	xii
LIST OF TABLES	xviii
LIST OF FIGURES	xx
LIST OF APPENDICES	xxiii
LIST OF ABBREVIATIONS	xxv
CHAPTER	
I GENERAL INTRODUCTION	1
II LITERATURE REVIEW	7
Benefits of fish in human diet	7
Fish body structure and composition	9
Fish lipid composition and characteristics	13
Effects of cooking methods on fish lipid characteristics	21
Effects of frying on fish lipid	21
Effects of microwave and oven cooking on fish lipid	24
Effects of other cooking methods on fish lipid	25
Thermal oxidation index for fish lipid	26
Deep-fat frying technology	26
Process of deep-fat frying	26
Oil uptake during deep-fat frying	30
Methods of reduction of oil uptake in food during fat-frying	35
Frying oil and quality of fried foods	43
Microwave cooking	48
Batter and breading food technology	49
Quality of battered and breaded Foods	52
Effects of ingredients on quality of battered and breaded foods	55
Effects of cooking methods on quality of battered and breaded foods	70



III	EFFECT OF BREADING ON LIPID CHARACTERISTICS OF THE BLACK POMFRET (<i>Parastromateus niger</i>) FILLETS DURING DEEP-FAT FRYING IN SUNFLOWER AND PALM OLEIN	73
	Introduction	73
	Materials and methods	74
	Materials	74
	Fish	74
	Frying oils	75
	Breeding materials	75
	Experimental design	76
	Methods	78
	Fillet breading procedure	78
	Deep-fat frying	78
	Total fat determination	79
	Moisture content determination	79
	Fatty acid determination	79
	Lipid extraction	79
	Preparation of the fatty acid methyl ester	80
	Gas chromatography analysis of fatty acid methyl ester	80
	Scanning electron microscopy	81
	Sample preparation	81
	Electron microscopy observation	82
	Frying oil viscosity determination	82
	Statistical analysis	82
	Results and discussion	83
	Fat and moisture content in raw and fried samples	83
	Fatty acid compositions in raw and fried samples	87
	PUFA/SFA and n-3/n-6 ratio of raw and fried samples	93
	Scanning electron microscopy of raw and fried samples	94
	Conclusion	98
IV	EFFECT OF DIFFERENT FINAL COOKING METHODS ON THE PHYSICO-CHEMICAL PROPERTIES OF THE PRE-FRIED BREADED BLACK POMFRET (<i>Parastromateus niger</i>) FILLETS	99
	Introduction	99
	Materials and methods	101
	Materials	101
	Fish	101
	Frying oils	101
	Breeding materials	101



Experimental design	102
Methods	104
Fillet breading procedure	104
Pre-frying	104
Final cooking methods	104
Fat, moisture and fatty acid determination	105
Thermal oxidation determination	105
Texture profile measurement	105
Color measurement	108
Statistical analysis	108
Results and discussion	109
Fat and moisture content of the pre-fried and final cooked breaded fillets	109
Fatty acid composition of pre-fried and final cooked breaded fillets	111
Fatty acid composition of pre-fried breaded fillets	111
Fatty acid composition of final cooked breaded fillets	112
Effects of final cooking methods on the n-3/n-6 ratio of breaded fillets	115
Thermal oxidation of the pre-fried and final cooked of breaded fillets	116
Texture profile of the pre-fried and final cooked of breaded fillets	117
Effects of different final cooking methods on the color of breaded fillets	123
Conclusion	125
V	
EFFECT OF PRE-DRYING ON QUALITY OF BREADED BLACK POMFRET(<i>Parastromateus niger</i>) FILLETS	127
Introduction	127
Materials and methods	129
Materials	129
Fish	129
Frying oil	129
Breading materials	129
Experimental design	129
Methods	132
Fillet breading procedure	132
Pre-drying	132
Pre-frying	132
Final cooking	132
Fat content determination	133



	Moisture content determination	133
	Color measurement	133
	Texture profile measurement	133
	Statistical analysis	133
	Results and discussion	134
	Effects of pre-drying on the fat and moisture content of the breaded fillets	134
	Effects of pre-drying on the texture profile of breaded fillets	139
	Effects of pre-drying on the color of the breaded fillets	147
	Conclusion	150
VI	EFFECT OF RESISTANT STARCH ON BATTER PROPERTIES AND QUALITY ATTRIBUTES OF BREADED BLACK POMFRET (<i>Parastromateus niger</i>) FILLETS	151
	Introduction	151
	Materials and methods	154
	Materials	154
	Fish	154
	Frying oils	154
	Breading materials	154
	Experimental design	155
	Methods	157
	Preparation of different batter formulations	157
	Fillet breading procedure	158
	Pre-frying	158
	Final cooking	158
	Determination the water retention capacity of the batter	158
	Fat content determination	159
	Moisture content determination	159
	Determination the viscoelastic properties of batter	159
	Color measurement	160
	Texture profile measurement	160
	Scanning electron microscopy	160
	Statistical analysis	161
	Results and discussion	161
	Water retention capacity of different batter formulations	161
	Effects of RS on the fat and moisture content of the breaded fillets	162
	Effects of RS on viscoelastic properties of the different batter formulations	167
	Effects of RS on the texture profile of the breaded fillets	173
	Effects of RS on the color of the breaded fillets	180

	Microstructure of the surface of the breeding materials	182
	Microstructure of cross section the of the breeding materials	182
	Microstructure of the cross section of fish muscle	183
	Conclusion	190
VII	SUMMARY, CONCLUSION AND RECOMMENDATIONS	191
	Summary and conclusion	191
	Recommendations	193
	REFERNCES	195
	APPENDICES	213
	BIODATA OF THE STUDENT	229



LIST OF TABLES

Table		Page
2.1	Principal constituents of fish muscle	10
2.2	Chemical composition of the fillets of various fish species	12
2.3	Lipid content in three tilapia species in different seasons	13
2.4	Lipid composition of different fish species	17
2.5	Major fatty acid composition of different fish species	19
2.6	Proximate analysis of black pomfret fillets	21
2.7	Typical mean water and oil content of selected fried foods	31
2.8	Fatty acid profiles of different types of sunflower oil	46
2.9	Fatty acid composition of different fractions of palm oil	47
2.10	Concentration and function ability of ingredients used in batter formulation	51
3.1	Fat and moisture content of raw and fried samples	87
3.2	Correlations between moisture loss and fat uptake in raw and fried samples	87
3.3	Fatty acid composition of raw and fried non-breaded, and breaded removed of fish muscle	89
3.4	Fatty acid compositions of raw and fried breaded fillets	90
3.5	Fatty acid composition of cooking sunflower oil and palm olein	92
4.1	Effects of different final cooking on the fat and moisture content of breaded fillets	110



4.2	Effects of different final cooking on the fatty acid composition of samples	114
4.3	Effects of different final cooking on the texture profile of breaded fillets	119
4.4	Effects of different final cooking on color of breaded fillets	124
5.1	Effects of pre-drying on the fat and the moisture content of final cooked breaded fillets	137
5.2	Effects of pre-drying on the texture profile of final cooked breaded fillets	140
5.3	Effects of pre-drying on the color of the final cooked breaded fillets	149
6.1	Composition of different batter formulations	157
6.2	The effects of resistant starch incorporation on the moisture content of final cooked breaded fillets	165
6.3	The effects of resistant starch incorporation on the fat content of final cooked breaded fillets	166
6.4	Temperature gelatinization and storage modulus values of the batters during heating process	173
6.5	Effects of resistant starch on the texture profile of final cooked breaded fillets	176
6.6	Effects of resistant starch on the color of final cooked breaded fillets	181



LIST OF FIGURES

Figure		Page
2.1	World fisheries production and human consumption	8
2.2	Per capita food fishery supply	9
2.3	Black pomfret (<i>Parastromateus niger</i>)	20
2.4	Deep-fat frying process	27
2.5	Four basic situations for penetration of oil during frying	34
2.6	Conceptual diagram illustrating the effect of edible films on moisture and fat transfer during deep-fat frying of starchy products	39
2.7	Microstructure of fried ribbon samples	42
3.1	Flowchart of experimental design	77
3.2	Micrographs of raw and fried of un-breaded fillets	96
3.3	Micrographs of the surface of the raw and fried of breading Materials	97
4.1	Flowchart of experimental design	103
4.2	An example of texture profile curve of the fried breaded fillet	107
4.3	Effect of final cooking methods on n-3/n-6 ratio of breaded fillets	115
4.4	Effects of final cooking methods on the thermal oxidation of breaded fillets	116
4.5	Compression of texture profile of different final cooked samples	120
4.6	Effects of final cooking methods on the count peaks of the breaded fillets	122
4.7	Effects of final cooking methods on linear distance of the breaded fillets	122
5.1	Flowchart of experimental design	131



5.2	Correlation between pre-drying and moisture content of final cooked breaded fillets	138
5.3	Correlation between pre-drying and fat content of final cooked breaded fillets	138
5.4	Correlation between pre-drying and hardness of the final cooked breaded fillets	141
5.5	Correlation between pre-drying and adhesiveness of the final cooked breaded fillets	142
5.6	Examples of texture profile curves of pre-dried samples (pre-fried in sunflower oil)	144
5.7	Examples of texture profile curves of pre-dried samples (pre-fried in palm olein)	145
5.8	Correlation between pre-drying and peak counts of the final cooked breaded fillets	146
5.9	Correlation between pre-drying and linear distance of the final cooked breaded fillets	146
6.1	Flowchart of experimental design	156
6.2	Effect of resistant starch concentration on water retention capacity of the batter	162
6.3	Effect of incorporation of Hi-maize 1043 on the storage and loss modulus of batter during heating process	170
6.4	Effect of incorporation of Fibersym 70 on the storage and loss modulus of the batter during heating process	171
6.5	Effect of resistant starch concentration on the peaks count of the final cooked breaded fillets	177
6.6	Effects of resistant starch concentration on linear distance of the final cooked breaded fillets	177
6.7	Texture profile curve of breaded fillets with different resistant starch concentration (pre-fried in palm olein)	178
6.8	Texture profile curve of breaded fillets with different resistant starch concentration (pre-fried in sunflower oil)	179



6.9	Micrographs of the surface of the breading materials different samples pre-fried in palm olein	184
6.10	Micrographs of the surface of the breading materials pre-fried in sunflower oil	185
6.11	Micrographs of the cross section of the breading materials pre-fried in palm olein	186
6.12	Micrographs of the cross section of the breaded materials pre-fried in sunflower oil	187
6.13	Micrographs of the cross section of the fish muscle pre-fried in palm olein	188
6.14	Micrographs of the cross section of the fish muscle pre-fried in sunflower oil	189



LIST OF APPENDICES

APPENDIX		Page
A1	Fatty acid composition of the raw breeding materials	213
B1	Effects of pre-frying on the fatty acid composition	214
B2	Two way Analysis of variance results for frying oils and final cooking methods for fat, moisture and fatty acid composition of breaded fillets	215
B3	Two way Analysis of variance results for frying oil and cooking methods on the texture and color of the breaded fillets	216
B4	Effect of cooking methods on the peak counts and the linear distance of breaded fillets	217
C1	Analysis of variance two way results for effects of pre-drying on the fat, moisture, texture and color of the breaded fillets	218
C2	Effects of pre-drying on the peak counts and the linear distance of the breaded fillets	219
D1	Properties of resistant starch (HI-MAIZE 1043)	220
D2	Properties of resistant starch (Fibersym 70)	221
D3	Correlation between resistant starch concentration and water retention capacity of the batter	222
D4	Effect of resistant starch in water retention capacity of the batter	223
D5	P values of Analysis of variance for effects of frying mediums, resistant starches types and concentrations on the fat and moisture content of breaded fillets	224
D6	Correlation between resistant starch concentration, fat and moisture content of the breaded fillets	225
D7	Values of storage and loss modulus of the different batter formulations	226



D8	P values of Analysis of variance for effects frying mediums resistant starches types and concentration on the texture and color of breaded fillets	227
D9	Effect of resistant starch on the peak counts and the linear distance of breaded fillets	228

