UNIVERSITI PUTRA MALAYSIA

Effects of Cooking and Chill-Reheating on Lipid and Flavor Characteristics of *Scomberomorous commerson* and *Scomberomorous guttatus*

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By

ESHAGH ZAKIPOOR RAHIMABADI

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

January 2008

ESPECIALLY DEDICATED TO MY BELOVED FAMILY

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

Effects of Cooking and Chill-Reheating on Lipid and Flavor Characteristics of *S. commerson* and *S. guttatus*

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January 2008

Chairman: Professor Jamilah Bt. Bakar, PhD

Faculty : Food Science and Technology

The cook-chill-reheating of foods are becoming more important in the catering industry today. However, reports on the potential changes on the nutrients such as lipid characteristics are negligible. Therefore, the objectives of the study were to determine the effect of cook-chill-reheating on the lipid characteristics, fatty acid composition and also flavor characteristics of the fish fillets. The lipid content, chemical characteristics i.e. free fatty acid (FFA), peroxide value (PV), iodine value (IV) and Thiobarbituric acid value (TBA), fatty acid composition, flavor profile, phospholipids and triglycerides content were determined in the raw and cooked and chilled-reheated samples. The sequential effect of cook-chill-reheating on the lipid and flavor characteristics in 'Tenggiri batang' (*Scomberomorous commerson* Lacepede, 1800) and 'Tenggiri papan' (*S. guttatus* Bloch and Schneider, 1801) fillets were studied. Cooked samples (by microwave, grilling, steaming and shallow fat frying) were chilled (4 ± 2 ºC) and then reheated using a microwave oven after 2 days. A two months frozen (-18 ºC) storage of

raw material was studied to evaluate the effects of frozen storage on lipid characteristics prior to cooking. One and two way analysis of variance test (ANOVA) were used to analyze the effect of cooking by the afore mentioned methods and the two way ANOVA was used to analyze the effect of chill-reheating on the cooked samples. Principle components analysis (PCA) was used for visualizing and reducing the data. The lipid characteristics did not change significantly during the first two weeks of frozen storage. Cooking and reheating by the different methods significantly ($P<0.05$) changed the FFA, PV and TBA content in both fish. The initial lipid content of *S. commerson* (2.3%), significantly changed to 4.0, 2.6, 3.6 and 4.8 % after microwave cooking, grilling, steaming and shallow fat frying; and for *S. guttatus* the initial lipid content of 6.0% changed to 7.0, 10.5, 5.4 and 10.3 %, respectively. Significant increase in lipid content were observed in steamed samples after reheating in both fish, and in grilled and fried samples of *S. commerson*. Both cooking and chilling-reheating affected ($P<0.05$) the fatty acid composition. Higher concentrations of C16:0, C18:1 n-9 c and C18:2 n-6 c were observed in shallow fat fried samples. Frying significantly increased the amount of n-6 FAs in both fish. Reheating caused a slight increase in the amount of SFA / PUFA and also the n-6/ n-3 ratio in all cooked samples. The C22:6/C16:0 ratio decreased in all cooked and reheated samples. Alkanes-alkenes were the major group of volatile compounds of raw samples in both fish. Cooking generated new compounds and increased the concentration of volatile component from 72.8 to 111.1, 74.3, 112.2 and 92.4 µg/kg for *S. commerson* and from 63.6 to 67.4, 77.80, 65.8 and 67.1 µg/kg for *S. guttatus* after microwave cooking, grilling, steaming and frying, respectively. Reheating also caused changes in the number and the concentration of the

volatile compounds. In *S. commerson*, only shallow fat frying significantly increased the TG content. In *S. guttatus* there were no significant changes in the triglycerides and phospholipids content in the cooked samples. Slight increase in the amount of TG content was detected in all cooked samples of *S. commerson* during chill-reheating. The TG content of microwave cooked and steamed samples of *S. guttatus*, slightly decreased after chill-reheating.

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

Kesan Memasak dan Disejuk-Dipanaskan Semula Ke Atas Ciri Lemak dan Rasa *S. commerson* dan *S. guttatus*

ESHAGH ZAKIPOOR RAHIMABADI

January 2008

Pengerusi : Professor Jamilah Bt. Bakar, PhD

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Masak-disejuk-dipanaskan semula makanan kini semakin penting di dalam industri katering. Namun begitu, tiada laporan tentang perubahan permakanan makanan seperti ciri lemak didapati. Oleh yang demikian, objektif kajian ini adalah untuk menentukan kesan masak-disejuk-dipanaskan semula pada ciri lemak, komposisi asid lemak dan juga rasa filet ikan. Kandungan lemak, sifat kimia seperti asid lemak bebas (FFA), nilai peroksida (PV), nilai iodin (IV) dan nilai asid tiobarbituric (TBA), komposisi asid lemak, profil rasa, fosfolipid dan trigliserid telah ditentukan untuk sampel mentah dan yang dimasak, disejuk dan dipanaskan semula. Kesan daripada masak-disejuk-dipanaskan semula ke atas lemak dan ciri rasa dalam isi ikan 'Tenggiri batang' (*Scomberomorous commerson* Lacepede, 1800) dan 'Tenggiri papan' (*S. guttatus* Bloch and Schneider, 1801) telah dikaji. Sampel yang dimasak (dengan menggunakan ketuhar gelombang mikro, dipanggang, dikukus dan digoreng di dalam minyak cetek) telah disejukkan pada suhu (4 ± 2 ºC) dan kemudian dipanaskan semula menggunakan

ketuhar gelombang mikro selepas 2 hari. Bahan mentah yang disejukbeku (-18 ºC) disimpan selama 2 bulan telah dikaji untuk menilai kesan penyimpanan sejukbeku ke atas sifat lemak sebelum dimasak. Data dianalisis dengan menggunakan (ANOVA) satu dan dua hala digunakan untuk menentukan kesan memasak dan kesan disejuk-dipanaskan semula ke atas sample yang telah dimasak, masing-masing. Analisis komponen principal (PCA) digunakan untuk memaparkan dan menrumuskan data. Ciri lemak tidak berubah sepanjang dua minggu yang pertama ketika penyimpanan sejukbeku. Memasak dan pemanasan semula dengan keadah yang berbeza mengubah kandungan FFA, PV and TBA pada kedua-dua ikan tersebut dengan ketara (P<0.05). Kandungan asal lemak pada *S. commerson* (2.3%), berubah secara ketara kepada 4.0, 2.6, 3.6 and 4.8 % selepas dimasak dengan ketuhar gelombang mikro, dipanggang, dikukus dan digoreng di dalam minyak cetek; untuk *S. guttatus*, kandungan lemak asal sebanyak 6.0% berubah kepada 7.0, 10.5, 5.4 and 10.3 %, masing-masing. Peningkatan ketara terhadap kandungan lemak dalam sampel yang dikukus selepas dipanaskan semula bagi kedua jenis ikan, dan pada sampel *S. commerson* yang dipanggang dan digoreng. Memasak dan menyejukpanaskan semula memberi kesan (P<0.05) terhadap komposisi asid lemak. Kepekatan yang lebih tinggi bagi C16:0, C18:1 n-9 c and C18:2 n-6 c diperhatikan pada sample yang digoreng di dalam minyak cetek. Penggorengan meningkatkan dengan ketara bagi kandungan n-6 Fas di dalam kedua jenis ikan. Pemanasan semula menyebabkan peningkatan yang sedikit di dalam kandungan SFA / PUFA dan juga bagi nisbah n-6/ n-3 pada semua sampel. Nisbah C22:6/C16:0 berkurangan di dalam semua sampel yang dimasak dan dipanaskan semula. Alkana-alkena merupakan antara kumpulan utama daripada komponen yang meruap di dalam

sampel ikan mentah bagi kedua jenis ikan. Memasak menghasilkan sebatian baru dan meningkatkan kandungan sebatian dari 72.8 kepada 111.1, 74.3, 112.2 dan 92.4 µg/kg untuk *S. commerson* dan dari 63.6 kepada 67.4, 77.8, 65.8 dan 67.1 µg/kg untuk *S. guttatus* selepas dimasak dengan ketuhar gelombang mikro, dipanggang, dikukus dan digoreng di dalam minyak cetek. Pemanasan semula juga menyebabkan perubahan pada jumlah kepekatan sebatian mudah meruap. Di dalam *S. commerson*, hanya penggorengan di dalam minyak cetek meningkatkan kandungan TG. Bagi *S. guttatus* pula, tiada perubahan dalam kandungan TG dan fosfolipid dalam sampel yang dimasak. Sedikit peningkatan dalam kandungan TG dikesan dalam semua sampel yang dimasak dan disejuk-dipanaskan semula bagi *S. commerson.* Bagi *S. guttatus*, kandungan TG bagi sampel yang dimasak dengan ketuhar gelombang mikro dan dikukus pula berkurangan sedikit selepas disejuk-dipanaskan semula.

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I certify that an Examination committee met on 4th JAN 2008 to conduct the final examination of Eshagh Zakipoor Rehimabadi on his Doctor of Philosophy thesis entitled "Effects of Cooking and Chill-Reheating on Lipid and Flavor Characteristics of *Scomberomorous commerson* and *Scomberomorous guttatus*" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and University Pertanian Malaysia (Higher Degree) Regulation 1981. The committee recommends that the candidate be awarded the relevant degree. Members of Examination Committee are as follows:

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

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Date: 21 February 2008

DECLARATION

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

Eshagh Zakipoor Rahimabadi

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Date: 08/01/2008

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LIST OF ABBREVIATIONS

ALA	Alpha Linolenic Acid
Abs	Absorbance
ANOVA	Analysis of Variance
C-C	Carbon Bond
CCR	Cook-Chill-Reheat
cm	Centimeter
DHA	Docosahexaenoic Acid
EPA	Eicosapentaenoic Acid
FA	Fatty Acid
FAME	Fatty Acid Methyl Ester
FAO	Food and Agriculture Organization
FFA	Free Fatty Acid
FID	Flame Ionization Detector
g	Gram
GC	Gas Chromatography
GC-MS	Gas Chromatograph Mass Spectrometry
GLA	Gamma Linolenic Acid
GLC	Gas- Liquid Chromatography
h	Hour
HPLC	High Performance Liquid Chromatography
HUFA	High Unsaturated Fatty Acid

id	Internal Diameter
kg	Kilogram
KI	Iodide Potassium
LA	Linoleic Acid
L^{o}	Alkyl Radical
LOO^{o}	Peroxyl Radical
LOOH	Hydroperoxides
LPC	Lysophosphatidyl Choline
M	Molar
m	Meter
meq	Milliequivalents
min	Minute
mg	Milligram
MHZ	Mega Hertz
ml	Milliliter
mm	Millimeter
MRP	Maillard Reaction Products
MUFA	Monounsaturated Fatty Acid
N	Normal
n-6	Omega-6
NO.	Number
NPN	Non Protein Nitrogen
^{o}C	degree centigrade
^{o}OH	Hydroxyl Radical

-OOH	Hydroperoxide
PC	Phosphatidyl Choline
PCA	Principal Component Analysis
PE	Phosphatidyl Ethanolamine
PI	Phosphatidyl Inositol
PL	Phospholipids
PS	Phosphatidyl Serine
PUFA	Polyunsaturated Fatty Acid
PV	Peroxide Value
R^2	Coefficient of Determination
RI	Refractometer Index
rpm	Revolutions per minute
SDE	Simultaneous Distillation- Solvent Extraction
SPE	Sphingomyelin
TAG	Triglyceride
TBA	Thiobarbituric Acid
TCA	Thichloroacetic Acid
µl	Microliter
µm	Micrometer
Vol	Volume
WHO	World Health Organization
WOF	Warmed-Over Flavor

CHAPTER I

GENERAL INTRODUCTION

Seafood is an excellent source of high-quality protein and many nutrients. The effect of fish lipid on coronary heart disease, stroke, kidney disorders, arthritis, diabetes, arrhythmias, hypertension and cancer are well established (Pepping, 1999; Von Schacky *et al*., 1999; Daviglus *et al*., 1997; and Christensen *et al*., 1996). These benefits are related to fish lipid composition. Fish lipids are characterized by long chain fatty acids and a high degree of saturation with multiple double bonds (Jittrepotch *et al*., 2006). It possesses some essential fatty acids such as EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid) and other polyunsaturated fatty acids of the n-6 and n-3 configurations that are essential for body and can not be synthesized by humans. However, lipid content and fatty acid composition in fish vary from species to species, age, sex and diet (Sigurgisladóttir and Pálmadóttir, 1993). In addition to these biological factors, processing also affects lipid composition (Aubourg, 1999 and Hoffman *et al*., 1994). Thus, the beneficial effects of the fish lipid may be affected during any form of handling such as cooling, freezing, cooking and reheating which may happen during food processing.

Heat is generally applied to food for cooking purposes to enhance the flavor, taste and to increase the shelf life (García-Arias *et al*., 2003). During cooking, chemical and physical changes take place that are highly related to lipid content and composition of