UNIVERSITI PUTRA MALAYSIA

EFFECTS OF DIFFERENT FRYING METHODS, FRYING CONDITIONS AND PRE-TREATMENTS ON FORMATION OF ALDEHYDES IN FRENCH FRIES

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By

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

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DEDICATION

This thesis is dedicated to my beloved father, mother and siblings who are always giving me their unlimited support, love, patience and understanding throughout this journey.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Science

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September 2016

Chairman : Associate Professor Seyed Hamed Mirhosseini, PhD
Faculty : Food Science and Technology

Aldehydes are the decomposed compounds formed by the thermal decomposition and oxidation of cooking oil during frying. The formation of such oxidation compounds in the frying oil is one of the most critical concerns for consumers. In most cases, they are known as unhealthy compounds, which cause many health issues (such as cardiovascular diseases) in the human. This study aimed to investigate the effects of different frying methods (i.e. deep fat frying, microwave frying and air frying), conditions (time and temperature) and pre-treatments (i.e. blanching, freezing and drying) on the formation and reduction of different aldehydes in frying oil and French fries. The results showed that the main detected aldehydes were decanal, 2-decenal, 2, 4-decadienal, hexanal, 2-heptenal and nonanal. Both frying methods and conditions significantly ($p<0.05$) affected the type and content of aldehydes formed in the oil and French fries during frying. Total aldehyde content was considerably increased by increasing frying time and temperature. The significant changes in aldehyde content during frying were significantly related to the changes in peroxide value (PV), anisidine value (AV), totox value (TV), free fatty acid (FFA) and iodine value (IV). The application of the deep frying and air frying resulted in the formation of the highest and the lowest aldehyde content in the frying oil and French fries. The deep-fried samples showed the highest concentration of hexanal (14.2 ppm), 2-heptenal (3.1 ppm), nonanal (1.4 ppm), 2 decenal (2.2 ppm) and 2, 4-decadienal (4.3 ppm); while air-fried samples showed the lowest concentration in hexanal (0.6 ppm), 2-decenal (0.3 ppm) and 2, 4-decadienal (0.2 ppm).

The results revealed that the pre-treatments of potato also significantly ($p<0.05$) influenced the formation and reduction of aldehydes in the oil during frying. Among all applied pre-treatments, the drying resulted in the lowest concentration of aldehydes (ppm) namely hexanal, 2-heptenal, nonanal and decanal. Meanwhile, the blanching followed by freezing resulted in the formation of the highest aldehyde content. This

might be explained by the significant effect of such pre-treatments on the moistutre content. In fact, the moisture content of potato significantly affected the formation rate and content of aldehydes in French fries and oil. This might be because the samples containing higher moisture contents are more susceptible against hydrolysis and oxidation, resulting in the formation of higher aldehyde content.

It was concluded that the selection the proper frying method and condition can significantly affect the type and content of aldehydes during frying. The current study revealed that the deep frying and air frying were the least and most desirable frying method among all applied methods. The current study highly recommended to apply drying process in order to reduce moisture content and making healthier French fries with lower level of aldehyde content.

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

KESAN PEBEZAAN KAEDAH PENGGORENGAN, KEADAAN PENGGORENGAN DAN PRA- RAWATAN DALAM PEMBENTUKAN ALDEHID DALAM UBI KENTANG GORENG

Oleh

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Pengerusi : Profesor Madya Seyed Hamed Mirhosseini, PhD
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Aldehid adalah sebatian yang reput dibentuk oleh penguraian terma dan pengoksidaan minyak masak semasa menggoreng. Pembentukan sebatian pengoksidaan seperti dalam minyak menggoreng adalah salah satu kebimbangan yang paling penting kepada pengguna. Dalam kebanyakan kes, mereka dikenali sebagai sebatian yang tidak sihat, yang menyebabkan pelbagai isu-isu kesihatan (seperti penyakit kardiovaskular) dalam badan manusia. Kajian ini bertujuan untuk mengkaji kesan kaedah penggorengan yang berbeza (penggorengan yang mendalam, penggorengan gelombang mikro dan penggorengan udara), keadaan (masa dan suhu) dan pra-rawatan (iaitu pengceluran, pembekuan dan pengeringan) mengenai pembentukan dan pengurangan aldehid yang berbeza dalam minyak masak dan kentang goreng. Hasil kajian menunjukkan bahawa aldehid utama yang dikesan adalah decanal, 2-decenal, 2,4-decadienal, hexanal, 2-heptenal dan nonanal. Kedua-dua kaedah penggorengan dan perbezaan ketara ($p < 0.05$) memberi kesan kepada jenis dan kandungan aldehid yang terbentuk dalam minyak menggoreng dan kentang goreng semasa penggorengan. Jumlah kandungan aldehid telah jauh meningkat dengan peningkatkan masa dan suhu menggoreng. Perubahan ketara dalam kandungan aldehid semasa menggoreng ialah perubahan dalam nilai peroksida (PV), nilai anisidin (AV), nilai totox (TV), asid lemak bebas (FFA) dan nilai iodin (IV). Penggunaan penggorengan dalam dan penggorengan udara menyebabkan pembentukan aldehid yang paling tinggi dan kandungan aldehid yang paling rendah dalam minyak menggoreng dan ubi kentang goreng. Sampel peggorengan mendalam menunjukkan kepekatan tertinggi hexanal (14.2 ppm), 2-heptenal (3.1 ppm), nonanal (1.4 ppm), 2 decenal (2.2 ppm) dan 2,4-decadienal (4.3 ppm); manakala sampel penggorengan udara menunjukkan kepekatan yang paling rendah dalam hexanal (0.6 ppm), 2-decenal (0.3 ppm) dan 2, 4-decadienal (0.2 ppm).

Hasil kajian menunjukkan bahawa pra-rawatan ubi kentang juga menunjukkan perbezaan yang ketara ($p < 0.05$) yang mempengaruhi pembentukan dan pengurangan aldehid dalam minyak semasa menggoreng. Antara semua pra-rawatan digunakan, pengeringan menyebabkan kepekatan yang paling rendah aldehid (ppm) seperti hexanal, 2-heptenal, nonanal dan decanal. Sementara itu, pengceluran diikuti dengan pembekuan yang menyebabkan pembentukan kandungan aldehid tertinggi. Ini mungkin dapat dijelaskan oleh kesan yang ketara pra-rawatan terhadap kandungan kelembapan. Malah, kandungan lembapan kentang ketara dipengaruhi kadar pembentukan dan kandungan aldehid dalam kentang goreng dan minyak. Ini mungkin kerana sampel yang mengandungi kandungan lembapan yang lebih tinggi adalah lebih mudah terdedah terhadap hidrolisis dan pengoksidaan, menyebabkan pembentukan kandungan aldehid yang lebih tinggi.

Kesimpulannya bahawa pemilihan kaedah dan keadaan menggoreng yang betul boleh menjejaskan jenis dan kandungan aldehid semasa menggoreng. Kajian ini mendedahkan bahawa penggorengan dalam dan penggorengan udara adalah kaedah menggoreng paling lemah dan paling wajar dikalangan semua kaedah digunakan. Kajian ini amat disyorkan menggunakan proses pengeringan untuk mengurangkan kandungan kelembapan dan membuat kentang goreng lebih sihat untuk dimakan dengan kandungan aldehid lebih rendah.

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I certify that a Thesis Examination Committee has met on 5 September 2016 to conduct the final examination of Adilah binti Zakaria on her thesis entitled "Effects of Different Frying Methods, Frying Conditions and Pre-Treatments on Formation of Aldehydes in French Fries" 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 was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBEREVIATIONS

AOCS	American oil chemist society
AV	Anisidine value
FAME	Fatty Acid Methyl Ester
FFA	Free Fatty Acid
IV	Iodine Value
Min	Minutes
PO	Palm oil
PORIM	Palm Oil Research Institute Malaysia
PV	Peroxide Value

CHAPTER 1

INTRODUCTION

Frying is one of the oldest and popular cooking methods practiced in Malaysia. The food industry, especially the fast food restaurants widely use frying as the most common method in their food products. As stated in Euromonitor (2014), the fast food industry showed increasing market value in Malaysia from US$ 995.7 million (2008) to US$ 1415.4 million (2012). Between the year 2008 and 2012, the fast food market recorded a compound annual growth rate (CAGR) of 9.2 % which is the second highest annual growth rate for consumer food service sector including 100 % home delivery or take away. Notably, the French fries is one of the most popular fast food in Malaysia and also worldwide.

However, frying also had been studied can cause several issues in both frying oil and fried foods especially after long and frequent heating at high temperature. This is because during frying, oils and fats are undergoing several series of reaction such as oxidation, hydrolysis and polymerization after subjected to oxygen, water and high temperature (Alizadeh et al., 2016). Besides that, heating process accelerates the oxidative rancidity of frying oil, resulting in the formation of peroxide, hydroperoxides, free radicals, short and medium chain aldehydes and many other oxidized compounds. The type and content of such oxidized compounds and degree of oxidative rancidity depend on many factors such as frying type and condition.

There are several factors that influenced oxidation process of edible oils such as light or heat, presence of oxygen, fatty acid proportion and minor compounds (pigments, metals, phospholipids, free fatty acids, thermally oxidized compounds, antioxidants, monoacylglycerol and diacylglycerols). These past years, many studies had been carried out to help improving the oxidative stabilities of oils by investigating the effects of these factors (Choe & Min, 2006). Meanwhile, hydrolysis occurs when water, steam, and oxygen presence during frying that causes several chemical reactions occurred in the frying oil and food. The high amount of water can accelerate the hydrolysis process by contact of frying oil with the aqueous phase of food. A weak nucleophile, water, attacks the ester linkage of triacylglycerols and form monoacylglycerol, diacylglycerols, glycerol, and free fatty acids. The high amount of water in the food being fry hydrolyzed frying oil rapidly and degrade the quality of the oil.

The thermal oxidation of unsaturated fatty acids mainly contributes to the thermal degradation of vegetable oils among constituent fatty acids. At high temperature, the primary oxidation product, hydroperoxides are not stable and cause it not accumulate in frying oil. However, hydroperoxides are spontaneously decomposed into secondary oxidation products like volatile compounds and polymers. The examples of volatile compounds produced by thermal oxidation include aldehydes, ketones, alcohols, acids, esters, and hydrocarbons. These volatile compounds give

desirable and undesirable flavours when oils subjected to high temperature (Endo et al., 2013).

The identification of these compounds is important because there are a few of them are toxic and can be associated with several diseases such as cancer, Alzheimer, and Parkinson (Guillen & Goicoechea, 2008). But, the most important decomposition product among volatile compounds is aldehydes because they are mostly presence in frying oil (Rao, 2010). Furthermore, aldehyde emissions from edible oils at frying temperature also gain a lot of interest because they contaminate the atmosphere and can be inhaled, and also, they can either be ingested directly with the oil or incorporated into fried food. Besides that, it also stated that unsaturated aldehydes such as alkenals and alkadienals showed more severe toxicity than alkanals (Meacher & Menzel, 1999; Rao et al., 2010).

Deep-fat frying is a process of cooking through immersion of foods in hot frying oil. It is a common unit operation worldwide used in food preparation. There are various physical and chemical changes take place during this process (Fullana & Sidhu, 2004). Besides that, there are new method of frying that had extensively introduced nowadays such as microwave frying and air frying. Microwave frying is a cooking process by conversion of electromagnetic field energy to thermal energy, which arises in the field by polar water molecules in food (Mahmoud et al., 2009). Air frying is a new way of frying by emulsion containing oil droplets in the flow of hot air. It takes place in the chamber where the product is continuously in motion to promote the relationship between the product and a simple homogeneous external emulsion (Arafat, 2014).

French fries are a popular snack food made from potatoes (*solonum tuberosum*). Potatoes are grown in approximately 80% of all countries worldwide and the worldwide production exceeds 300 million tons per year. This in turn promotes the growth in the production of potatoes products especially potato chips around the world (Pedreschi et al., 2005; Intake, 2009). However, although it gives good taste and aroma, it causes health problems due to high calorie, cholesterol intake and other diseases. Recently, the consumer becomes more health cautious and demand specifically for less dense, low-calorie and low cholesterol foods (Division, 2012).

Deep fat frying had been used extensively nowadays because of acceptable organoleptic properties formed after frying. However, deep fat frying can cause various health issues to the consumer because of aldehyde formation during frying. So, the application of other frying method was required to study effect of frying method on formation of aldehydes. Besides that, the study of quantification of aldehydes present in oil is also scarce although analysis of p-anisidine value had been carried out in the past few decades. In addition, study of quantification of aldehydes in palm oil especially in Malaysia also scarce.

The main objectives of this study were:

1. To investigate the effects of different frying methods (i.e. deep fat frying, microwave frying and air frying) and conditions on the formation of different aldehydes in frying oil and French fries.
2. To investigate the effects of different pre-treatments (i.e. drying, blanching and freezing) of French fries on formation and reduction of aldehydes during frying.

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