UNIVERSITI PUTRA MALAYSIA

OPTIMIZING PHYSICOCHEMICAL PROPERTIES OF RECYCLED COOKING PALM OIL USING PARTICLE SWARM OPTIMIZATION

ABDULMUMINI SALIHU JALO

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By

ABDULMUMINI SALIHU JALO

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

January 2016

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DEDICATIONS

I would like to dedicate this thesis to my late Brother, Abubakar Ibrahim.

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

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ABDULMUMINI SALIHU JALO

January 2016

Chair : Asnor Juraiza binti Ishak, PhD
Faculty : Engineering

The effect of frying mechanism on cooking oil produces toxic compounds which destroy the essential vitamins in the oil and increase the risks of various diseases. The inconvenient and inconsistency of evaluating techniques at hand are attributing factor of the diseases risk. The influence of the numerous variable that accelerates the properties deterioration during the frying process made it difficult to evaluate the oil quality. The aim of this work was to provide a safe and automatic means of evaluating the used oil quality. Through assessing the effect of frying mechanism on the oil properties at a spot and their significance. To established the interrelationship between the oil properties and to find the optimum effect of the frying mechanism on the oil properties.

The effect of the frying process on the oil properties is mainly influenced by frying temperature and time (cycles) as revealed in literature. The above objective is achieved using statistical tools namely, correlation, analysis of variance (ANOVA), and regression in conjunction with computational intelligent; particle swarm optimization (PSO) and genetic algorithm (GA). The effect of frying mechanism on the total polar compound, free fatty acid, pH value, viscosity, and the red color of the oil was studied, through frying of chicken meat (1±0.05kg) at regulated temperatures of (100, 150, and 200)$\pm 10^{o}C$.

The statistical analysis reveals the correlation between the oil properties were significant at $p<0.05$ and the relationship straightened with an increase in frying temperature except for the pH value and red color which decline with an increase in frying temperature. The analysis of variance portrays TPC, FFA, pH value, viscosity and red color were statistically significant at $p<0.05$ with an increase in frying cycle and straighten to $p<0.01$ at 200^{o}C frying temperature. The regression analysis reveals that the pH value, FFA, and red color are statistically significance at $p<0.01$ then viscosity at $p<0.05$ and TPC had not been significant at $p>0.05$. The optimization finding showed free fatty acid and red color had the better performance fitness of 0.0001 and 0.0019 respectively while viscosity had

the worst fitness of 0.0588. The compared results between PSO and GA algorithm shows negligible differences between their results in all the properties.

Therefore, the outcome of the study portrayed the effect frying mechanism deteriorate the oil quality, causes changes in the oil properties, and it enhances the relationship between the oil properties. The studied further reveals both PSO and GA are potential tools for evaluating the quality of the cooking oil.

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

MENGOPTIMUMKAN SIFAT FIZIKOKIMIA MINYAK MASAK KELAPA SAWIT YANG DI KITAR SEMULA MENGGUNAKAN TEKNIK PENGOPTIMUMAN PARTICLE SWARM

Oleh

ABDULMUMINI SALIHU JALO

Januari 2016

Pengerusi : Asnor Juraiza binti Ishak, PhD
Fakulti : Kejuruteraan

Kesan minyak masak keatas hasil gorengan menghasilkan sebatian toksik yang menghapuskan vitamin-vitamin yang wujud di dalam minyak dan meningkatkan risiko pelbagai penyakit. Teknik penilaian yang remeh dan tidak selaras pada masa kini menjadi faktor penyumbang kepada risiko penyakit tersebut. Pengaruh pelbagai pembolehubah yang mempercepatkan kemerosotan sifat-sifat minyak semasa proses menggoreng menyukarkan lagi penilaian kualiti minyak. Kajian ini bertujuan menghasilkan kaedah penilaian kualiti minyak terpakai yang selamat dan beroperasi secara automatik. Melalui penilaian terhadap kesan mekanisme menggoreng keatas sifat-sifat minyak pada minyak tersebut dan hubungannya. Selain itu, kajian ini juga bertujuan untuk menghasilkan hubungan antara sifat-sifat minyak serta mencari kesan optimum mekanisme menggoreng terhadap sifat-sifat minyak.

Kesan proses menggoreng terhadap sifat minyak kebanyakannya dipengaruhi oleh suhu menggoreng dan masa (pusingan) minyak digunakan sebagaimana dinyatakan di dalam literatur. Objektif di atas dicapai menggunakan alat statistik seperti korelasi, ANOVA dan regresi bersama-sama pengiraan pintar pengoptimuman kumpulan zarah (PSO) dan algoritma genetik (GA). Kesan mekanisme menggoreng ke atas keseluruhan sebatian polar, asid lemak bebas, nilai pH, kelikatan dan warna merah pada minyak telah dikaji, dengan menggoreng daging ayam (1 ± 0.05kg) pada suhu terkawal (100, 150 dan 200)$\pm10^oC$.

Analisis statistik menunjukkan korelasi antara sifat minyak pada $p<0.05$ dan hubungan itu bertambah kuat dengan peningkatan dalam suhu menggoreng kecuali untuk nilai pH dan warna merah pada minyak dimana ia berkurang dengan meningkatnya suhu menggoreng. Analisis pada varian menunjukkan TPC, FFA, nilai pH, kelikatan dan warna merah pada minyak menpunyai hubungan secara statistik pada $p<0.05$ dengan peningkatan kitaran gorengan dan kekuatan pada $p<0.01$ dan suhu menggoreng 200^oC. Analisis regresi menunjukkan bahawa

nilai pH, FFA dan warna merah pada minyak hubungan secara statistik pada $p<0.01$,manakala kelikatan pada $p<0.05$ dan TPC tidak mempunyai hubungan pada $p>0.05$. Dapatan pengoptimuman ini menunjukkan asid lemak bebas dan warna merah pada minyak masing-masing mempunyai kecergasan prestasi yang lebih baik iaitu 0.0001 dan 0.0019 manakala kelikatan memperolehi kecergasan prestasi terburuk dengan nilai 0.0588. Perbandingan keputusan antara PSO dan algoritma GA memparkan perbezaan keputusan pada semua sifat.

Oleh yang demikian, hasil dari kajian ini menunjukkan kesan mekanisme menggoreng mengurangkan kualiti minyak, menyebabkan perubahan dalam sifat minyak dan meningkatkan hubungan antara sifat-sifat minyak. Kajian ini juga turut membuktikan bahawa kedua-dua PSO dan GA merupakan alat yang berpotensi dalam menilai kualiti minyak goreng.

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I certify that a Thesis Examination Committee has met on 26 January 2016 to conduct the final examination of Abdulmumini Salihu Jalo on his thesis entitled "Optimizing Physicochemical Properties of Recycled Cooking Palm Oil using Particle Swarm Optimization" 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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Declaration by graduate student

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This is to confirm that:

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LIST OF ABBREVIATIONS

a*	Green to red spectrum
ANFIS	adaptive neuro-fuzzy inference system
ANOVA	analysis of variance
b*	blue to yellow spectrum
CCD	central composite design
CCF	central composite face
$_c$P	centipoise
^{o}C	degree celsius
FFAs	free fatty acid
FOS	food oil sensor
FOM	food oil monitor
GA	genetic algorithm
HNE	4 hydroxy-trans2 nonenal
L*	light to dark spectrum
LDIW	linear decreasing inertia weight
MRSO	multiple response surface optimization
NIR	near infrared
NMR	nuclear magnetic resonance
NaOH	sodium hydroxide
PORIM	palm oil research institute Malaysia
PSO	particle swarm optimization
POV	peroxide value
R^2	coefficient of determination
RSMs	response surface methodology
RSREG	response surface regression
TPCs	total polar compound
USA	united state of america

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CHAPTER 1

INTRODUCTION

1.1 Background

Edible oil (Triglyceride) is one of the natural sources of vitamins in our dishes, mostly produced from plants or animals and used is widely for cooking. The term triglyceride refers to three free fatty acids chemically attached to glyceride radicals. The composition of the fatty acids in an edible oil is used highly for its classification. The percentage of saturated and unsaturated free fatty acid composition attached to a glyceride portrays either it is fat or oil. Fat is usually derived from animals and usually solid at room temperature. Fat has a higher percentage of saturated fatty acid content in it; while oil, which is normally liquid at room temperature, has a higher percentage of unsaturated free fatty acid, which is either polyunsaturated or monounsaturated free fatty acid. Triglycerides that are derived from plants, such as palm oil, sunflower, corn oil and many more are normally liquid at room temperature.

Palm oil being one of the leading types of cooking oil in the world, is widely cultivated in Asia and largely produced in Malaysia. Palm oil alone has contributed to over 25% percent of the cooking oil produced in the world, and it has had a growth rate of more than 100 percent in the last ten years. However, the oil has almost an equal percentage of saturated and unsaturated free fatty acid and other advantages that have made it generally acceptable in the world. Moreover, for the purpose of this study, palm oil has been chosen because of the advantages mentioned above. Chicken meat has also been chosen for the purpose of this study being it is one of the common meats that is generally accepted by all faiths and largely consumed by more than 50% percent of the world population. In addition, deep fat frying, which is the most common method of frying chicken meat, was used for the study. Deep frying is a frying method whereby food substances are immersed fully in hot oil with a temperature range between 100 to 200^oC. The surplus advantages of the method, such as prevention of an excess escape of moisture and nutritional content of the fried food. The approach also protects the food surface from intense heat, lower cost, easier and faster to cook. The fried food has a unique color and aroma, moreover the method easier to recycled the oil for the frying process than other frying methods.

Recycling cooking oil for frying chicken meat is practiced widely in our society and common in most of the restaurants in Malaysia and other developed and developing countries. Despite the vitamins and other numerous advantages derived from oil and fried food, it has some setbacks which depend on the usage. Continuously cooking food in oil at high temperature is called Recycled frying. The process is the oldest and most common practice in our modern society today, (Saguy and Dana, 2003). The threat of recycling fried cooking oil on public health has been discussed and studied for a long time. The level of development in the world today has boosted the awareness of the health threat connected with fried food consumed in the society. Fried food is consumed largely by millions of people both in developed and developing nations. The uniqueness of its aroma, flavor,

color and palatability attract many consumers according to the satisfactory test. The complex nature of reactions taking place in the oil during frying damage the essential vitamins in the oil. The process produces toxic compounds such as NHE (4hydroxy-trans2 nonenal) and much more cytotoxic compounds that were reported to increase the risks of Parkinson's, Alzheimer, cardiovascular, stroke and various liver cancer diseases. Those compounds deteriorate the oil quality and also causes serious changes in the physicochemical properties of the oil that are commonly used for its quality evaluation, (Kanner, 2007; Guillén and Uriarte, 2012).

The sensitivity of the threat rooted in recycling frying has led to the development of numerous techniques for its quality evaluation. Standard (titration) and un-standard approaches are the most commonly used techniques today in our modern society. The ancient (Standard) approach of titration is still in practice in our modern society because it has proven to be successful for many years. The approach is widely used for evaluating many properties of oil especially free fatty acid, peroxide and iodine values and many more. The method is less attractive because of the involvement of corrosive chemicals, it is destructive, time wastage and the need for a skilled personnel to perform the evaluation. The invention of analytical approaches, such as gas chromatography, spectrophotometer rapid test kits, and many more devices draws the attention of the user from the chemical method to approaches that are free of or use fewer chemicals and are somehow faster than the ancient approach. However, despite all the achievement derived from the above techniques, they are still faced with some drawbacks which make them not largely acceptable by users.The most predominant of the setbacks are the need for a specialist to do the test the techniques are tedious, destructive and expensive. Moreover, none of the techniques has the capability of evaluating more than one property of the oil at a time or give the maximum quantity of food stuff needed to be used to declare that the oil has spoiled.

1.2 Problem Statement

The increasing awareness of health issues associated with fried food quality and the consumption of reused cooking oil has received much attention since health is life. The Standard methods of grading cooking oil quality are chemically based, the instruments and equipment used are cumbersome and large, quite inconvenient and troublesome, time-consuming, expensive, s and, moreover, need a specialist to do the test (Hirri et al., 2015). The non-standard approach used for grading the quality of recycled cooking oil are designed only to measure one particular property of the used oil. While other properties are heavily affected by high concentrated toxic compound before attainment of discarding point of other properties during the frying process (Bansal et al., 2010a; Guillén and Uriarte, 2012).

Grading quality of used frying oils at different frying stages is still a complex issue due to the numerous variable that possibly affect the nature of the oil quality. To determine the time when frying oils reach their maximum life cycle is a challenging task and the only solutions to overcome the threat of cooking oil deterioration (Weisshaar, 2014). The inconsistency of non-standard evaluation

devices on the same oil sample is worrisome (Bansal et al., 2010a; Weisshaar, 2014). The effect of frying cycles on physicochemical properties of cooking oil was widely studied to establish the relationship between the oil properties and evaluate the oil quality. However, their fewer studies in the literature that discuss the effect of frying mechanisms on the oil properties (Sunisa et al., 2011; Chen et al., 2013; Weisshaar, 2014), Moreover, some of the must important mechanisms that deteriorate the oil quality are frying temperature and frying cycles (time) (Debnath et al., 2012; Chen et al., 2013).

Once the principal mechanism (factors) that influence response is identified. The permutation and combination of best factor settings of the multivariable parameter that will result in the optimum value of the response are the multi-tasking challenge in process quality control (Pelletier et al., 2012; Hajslova et al., 2011; Vogt and Kord, 2011). The significance effect on oil properties by a slight variation of frying mechanism (frying temperature and frying cycles) must be reliability and robustly set for effective control of the frying process, avoidance of human errors and the threat to public health.

Therefore, an alternative method of evaluating recycled cooking oil that will addressed the above problems through below objective is presented.

1.3 Aims and Objectives

The aim of this thesis to optimize the effect of frying mechanism for the accurate assessment of used cooking oil using Computational Intelligent (CI) techniques such as Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) techniques for grading more than one property at a time. The specific objectives are:

(a) To correlate the physicochemical properties of recycled cooking palm oil.

(b) To design and analyze objective function based on regression model for the physicochemical properties of recycled cooking oil.

(c) To develop an optimization algorithm for the optimizing effect of frying mechanism on the physicochemical properties using particle swarm optimization and to compared the results with that of genetic-based algorithms.

1.4 Research Contributions

(a) The established correlation between the physicochemical properties of the oil is new because of the frying mechanism used. The strength of the correlation between the properties portrays the significant of the properties relationship is in chapter four. The result can be applied to the invention of new cooking oil grading sensors.

(b) The increase in the effect of frying mechanism on physicochemical properties of cooking palm oil was significant. The developed response regression functions of the properties were as a result of variation in the explanatory

variable. The regression functions goodness of fit portrays it accuracy in estimating the frying effect on the oil properties and used for evaluating the oil quality.

(c) An algorithm for effective evaluation of recycled cooking oil quality by assessing the frying effect on the oil properties at a sport was developed. The result of the algorithm reveals that the algorithm can be applied in parameter control for quality frying process, and proper evaluation of the oil quality as can be seen in chapter four.

1.5 Scope of Study

Cooking palm oil has been selected out of the numerous types of cooking oil for this study because of its availability in the country and its domination of the world market today. One meat that is accepted by all faiths (chicken meat) was used for the study. The most popular means of cooking meat in oil (deep frying) is used, and the samples were recycled once, twice and three times. One of the central composite experimental design called Central Composite Face (CCF) was used because of its excellent prediction capability and lower experimental runs was considered for the study. The tediousness of the chemical method for evaluating the oil and non-availability of some chemical restricted the study to only five properties which are Total Polar Compound (TPC), Free Fatty Acid (FFA), Viscosity, pH value and Red color. A Particle Swarm Optimization (PSO) and a Genetic Algorithm (GA) were used for optimization to overcome the setback of optimizing dual response surface function with Lagrange multiplier and others.

1.6 Thesis Organization

The next chapter, Chapter 2, describes the overview of previous techniques that are used for grading the quality of cooking oil which are similar to the one proposed in this thesis. The importance of identifying the components required for grading cooking oil. The merits, and demerits of the previous techniques at hand. In addition to reviewing literature related to the research, the chapter further reviewed the effect of frying on physicochemical properties of cooking oil and examines the potentials of statistical tools, such as correlation, analysis of variance and regression analysis. The important of experimental design and optimization design were further discuss in detail. Furthermore in the chapter detail of multivariate analysis neural network evolutionary algorithm and swarm intelligent were presented. In Chapter 3 details of the methods and materials used in this work were presented. These include the experimental design, meat preparation and frying process, data collection and statistical analysis method. The development and strategies of turning the algorithm were also detailedly presented. Then Chapter 4 presents the results of correlation between the physicochemical properties of the oil, The analysis of variance (ANOVA) of the properties, the descriptive statistics of the experimental result and regression analysis of the properties. Furthermore, the chapter also presents the algorithms result, and finally a comparison between the algorithms results. The final chapter, Chapter 5, Start with Conclusion of the research work, concludes with the overall success and achievement of the research objectives and finally ends with a recommendation for future study.

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