Statistical Analysis Investigation on Vegetable Oils Stability during Deep Frying using Selected Quality Parameters

Jamal I Daoud[1], and Mohamed E S Mirghani[2]

[1] Department of Science in Engineering, Kuliyyah (Faculty) of Engineering, International Islamic University Malaysia (IIUM), P. O. Box 10, Gombak, 50728 KL, Malaysia
[2] International Institute for Halal Research and Training (INHART), IIUM, P. O. Box 10, Gombak, 50728 KL, Malaysia

E-mail: [1] jamal58@iium.edu.my, [2] elwathig@iium.edu.my

Abstract. The frying process is complicated because of a large number of parameters involved and the interactions between them. High stability liquid oils are in great demand. The best way to decide on the fats and oils suitability for frying is to study their natural stability to oxidation. In this study, consecutive deep-fat frying was done by using potato chips in palm oil, cottonseed oil and groundnut oil at 170 ⁰C. All oils used were refined, bleached and deodorised from good quality authentic crude oils. The study was used to investigate the influence of frying time on oil quality by measuring the concentration of tocopherol content (TC), iodine value (IV), peroxide value (PV), free fatty acids (FFA) and polymer content (PC). Changes in these parameters were determined on the oil samples taken periodically during frying. A MANOVA statistical model was used for the investigations of oil quality parameters while used continuously in frying potato chips. The analysis which was implemented using XLSTAT is showing that the frying time has a significant impact on the compositions of the frying oil. A significant increase in PV, FFA and PC was observed during frying while a decrease in the concentration of TC and IV values was observed. The result concluded that refined, bleached deodorised palm oil is more stable during deep-fat frying compared to cottonseed oil followed by groundnut oil.

Keywords: Deep frying, IV, MANOVA, PV, Polymer content, Tocopherols, XLSTAT, Vegetable oils.

1. Introduction

There are direct relation and correlation between healthy food and healthy people, which are the assets of any society and nation. There was always some imbalance between the demand of human beings for food and the available amount of food, and that might happen due to lack of food or to the mismanagement or abuse by people. Nowadays, the problem is more severe and multidimensional. People sometimes and in many regions stricken by poverty and wars either they eat less than the minimum norm and required food assuming the food is healthy, the worst scenario when we see people are searching in the garbage to eat. In this study, we are trying to touch on an important issue relating to healthy food, and in particular, about deep-frying oils which are used intensively in fast food shops and outlets due to the complexity of temporary life and not having time to cook home and the fast-food restaurants are the favourite destinations for people who are studying or working.

The primary process in cooking food in fast food restaurants is deep fry activity for meat, chicken or vegetables, mainly potato. The oil varies widely in eating quality, functionality, and rate of deterioration depending on the source, processing, or formulation [1]. Now, what is deep oil (fat) frying? Deep oil (fat) frying is a cooking method that can be used to cook foods such as fried chickens, French fries, and potato chips. The process involves submerging a food in scalding oil until it reaches a safe minimum internal temperature. When the food is deep-fried properly, it will be hot and crispy on the outside and cooked safely in the centre. Deep frying is very fast and, when appropriately performed, destroys bacteria [2].

Fried food is widely used all over the world and their quality depends on the oil or fat they are fried. Qualitative (physical chemistry indices) and quantitative measurements [3] (fry-life oil or fat until disposal, oil turnover, type of oil or fat and amount and type of fried foods).

2. Qualitative indices of oils

In this study, we focused on three types of frying oils, namely, palm oil, cottonseed oil, and groundnut oil. Five physical chemistry indices were observed, namely, the concentration of tocopherol (ppm), Iodine value (WIJS), Peroxide value (meq/kg), free fatty acid (%), and polymer compounds (%). The frying time used as the independent variable affecting the number of above-mentioned nutrients of the oil. We assume that any newly used frying oil will contain maximum amounts of the above-mentioned components and then reduces gradually based on hours of frying and type of oil as will be seen in the analysis part.

3. Statistical analysis

Statistical analysis carried out in many directions and ways. We analysed the quality of each oil after maximum hours of frying, which is 20 hours. For all oils, we noticed that all (proper) nutrients are decreased to the minimum by reaching 20 hours deep frying. Virtually it is evidence of deterioration and degradation of the oil. Other analysis focused on comparing one component reduction for all three oils. Multivariate ANOVA has been used and simple regression models found for each component of the oil [4]. MANOVA is the test that analyses the relationship between several response variables and a standard set of predictors at the same time. Like ANOVA, MANOVA requires continues response variables and categorical predictors [5]. MANOVA has several advantages over doing multiple ANOVAs, one response variable at a time; these advantages are:

i) Increased power: the covariance structure of the data between the response variables can be used to test the equality of means at the same time. If the response variables are correlated, then this additional information can help detect differences too small to be detected through individual ANOVAs.

ii) Detects multivariate response patterns: the factors may affect the relationship between responses instead of affecting a single response. ANOVAs will not detect these multivariate patterns.

iii) Controls the family error rate: The chance on incorrectly rejecting the null hypothesis increases with each successive ANOVA. Doing one MANOVA to test all response variables at the same time keeps the family error rate constant and equal to the significant level alpha.

The data used in the analysis consist of five readings for every type of oil, with different time of frying ranging 0-20 hours with an interval of 2.5 hours. For cottonseed oil and groundnut oil, the data available only for range 0-15 hours.

The MANOVA has been employed on three types of oil. The results are in the table1 below:

Table 1. The summary of MANOVA is in the table below for three types of oil

	Criterion	Test statistic	Approx. F	p-value
Palm oil	Wilks'	0.000	61.452	0.000
	Lawley-Hotelling	1077.12158	703.719	0.000

	Pillai's	3.94095	14.471	0.000
Cottonseed oil	Wilks'	0.00271	11.056	0.000
	Lawley-Hotelling	128.71385	96.106	0.000
	Pillai's	1.68864	2.380	0.000
Groundnut oil	Wilks'	0.00143	13.531	0.000
	Lawley-Hotelling	161.22064	120.378	0.000
	Pillai's	2.04881	3.240	0.000

Table1 is showing that frying time is significantly affecting the components of three types of oil. All three used criterion for the above analysis is showing that the frying time was affecting all oil components. The p-value for these three criteria equal to zero confirming this result. On the other hand, the p-values for all criterion also supporting the hypothesis that there are significant differences between the chemical indices of each oil.

ANOVA has been employed on different oils to analyses the impact of frying time on the components of each oil. The results of the analyses are given in tables 2, 3, and 4.

Table 2. Summary of statistical analyses for Palm oil

Components	Regression Model	ANOVA				R^2 /R^2 adjusted
		Sum of Squares	Mean square	F cal.	p-value	
Concentration of tocopherol (ppm)	$ct = 823 - 9.17t$	157733	157733	1833.6	0.000	97.7/97.7
Iodine Value (WIJS)	$iv = 56 - 0.942t$	1663.4	1663.4	1477.4	0.000	97.2/97.1
Peroxide Value (meq/kg)	$pv = 1.53 + 0.318t$	190.18	190.18	5963.7	0.000	93.3/93.1
Free Fatty Acid (%)	$ffa = 0.0754 + 0.0139t$	0.36122	0.36122	1353.5	0.000	96.9/96.8
Polymer Compound (%)	$pc = 0.137 + 0.0801t$	12024	12024	1281.2	0.000	96.8/96.7

Abbreviations: CT= Concentration of Tocopherol; FFA = Free fatty acids; IV = iodine value; PC= Polymer compounds; PV= Peroxide value.

From Table 2, we can see that the frying time affecting all chemical indices of palm oil. The p-value and R-squared values are confirming this significant relation.

For the concentration of tocopherol, the regression model is showing that the frying time is negatively related to tocopherol concentration, the more we fry, the less we get tocopherol concentration in the oil. From the regression equation, we can conclude that the tocopherol concentration is reducing in an amount of 9.17 ppm when the frying time increases by one hour.

For Iodine, we can see from the regression model that the relation between frying time and iodine value is negative. The more we fry the less we have iodine value in the oil. The regression model is telling us that the iodine value is decreasing in a number of 0942 wijs, when the frying time is increased by one hour.

For peroxide value, the regression model shows a positive relationship between the frying time and peroxide value. The peroxide value is increasing by 0.318 (meq/kg) when the frying time is increased by one hour. The more we fry, the more we get peroxide value in the oil [6] [7].

For free fatty acid, the regression is showing a positive relation between frying time and percentage of free fatty acid. From the equation, we can see that the percentage of free fatty acid is increasing at an amount of 0.0139 when the frying time increases by one hour. For the last chemical index, the polymer compound we see from the regression model that the percentage of polymer compound is increasing in an amount of 0.0801 when the frying time increases by one hour.

Table 3. Summary of statistical analyses for Cottonseed oil

Components	Regression Model	ANOVA				R^2 /R^2 adjusted
		Sum of Squares	Mean square	F cal.	p-value	
Concentration of tocopherol (ppm)	$ct = 1096 - 9.08t$	72141	72141	5.56	0.024	14.4/11.8
Iodine Value (WIJS)	$iv = 110 - 1.92t$	3219.2	3219.2	76.35	0.000	69.8/68.9
Peroxide Value (meq/kg)	$pv = -0.571 + 0.772t$	521.91	521.91	797.99	0.000	96/95.9
Free Fatty Acid (%)	$ffa = 0.590 + 0.377t$	124.42	124.42	666.9	0.000	95.3/95.1
Polymer Compound (%)	$pc = 0.310 + 0.216t$	40.856	40.856	526.98	0.000	94.1/93.9

Abbreviations: CT= Concentration of Tocopherol; FFA = Free fatty acids; IV = iodine value; PC= Polymer compounds; PV= Peroxide value.

From the table above we can see that the frying time affecting all chemical indices of cottonseed oil. The p-values for all indices confirm this significant relation. For R-squared values, we see that the concentration of tocopherol is performing poorly, with the value ranging from 14.4 to 11.8. This means that the model needs more variable to be included, in other words, the frying time is not the only crucial variable in affecting the tocopherol concentration amount. Also for a p-value of tocopherol concentration is 0.024, which mean that it might be not significant if we choose alpha less than 0.024 [8].

For the concentration of tocopherol, the regression model is showing that the frying time is negatively related to tocopherol concentration, the more we fry, the less we get tocopherol concentration in the oil. From the regression equation, we can conclude that the tocopherol concentration is reducing in an amount of 9.08 ppm when the frying time increases by one hour.

For Iodine, we can see from the regression model that the relation between frying time and iodine value is negative. The more we fry the less we have iodine value in the oil. The regression model is telling us that the iodine value is decreasing in an amount of 1.92 wijs, when the frying time is increased by one hour.

For peroxide value, the regression model shows a positive relationship between the frying time and peroxide value. The peroxide value is increasing by 0.772 (meq/kg) when the frying time is increased by one hour. The more we fry, the more we get peroxide value in the oil [7].

For free fatty acid, the regression is showing a positive relation between frying time and percentage of free fatty acid. From the equation, we can see that the percentage of free fatty acid is increasing at an amount of 0.377 when the frying time increases by one hour. For the last chemical index, the polymer compound we see from the regression model that the percentage of polymer compound is increasing in an amount of 0.216 when the frying time increases by one hour [9].

IOP Conf. Series: Journal of Physics: Conf. Series **1489** (2020) 012027 doi:10.1088/1742-6596/1489/1/012027

Table 4. Summary of statistical analyses for Groundnut oil

Components	Regression Model	ANOVA				R^2 /R^2 adjusted
		Sum of Squares	Mean square	F cal.	p-value	
Concentration of tocopherol (ppm)	$ct = 1415 - 9.39t$	77127	77127	5.43	0.026	14.1/11.5
Iodine Value (WIJS)	$iv = 115 - 2.56t$	5740.3	5740.3	195.8	0.000	85.6/85.1
Peroxide Value (meq/kg)	$pv = -0.602 + 0.683t$	408.49	408.49	794.33	0.000	96/95.9
Free Fatty Acid (%)	$ffa = 0.056 + 0.499t$	217.95	217.95	983.96	0.000	96.8/99.7
Polymer Compound (%)	$pc = -0.215 + 0.230t$	46.159	46.159	423.43	0.000	92.8/92.9

Abbreviations: CT= Concentration of Tocopherol; FFA = Free fatty acids; IV = iodine value; PC= Polymer compounds; PV= Peroxide value.

From Table (4) above, we can see that the frying time affecting all chemical indices of groundnut oil. The p-values for all indices confirm this significant relation. For R-squared values, we see that the concentration of tocopherol is performing poorly, with the value ranging 14.1 to 11.5. This means that the model needs more variable to be included; in other words, the frying time is not the only crucial variable in affecting the tocopherol concentration amount. Also, for a p-value of tocopherol concentration is 0.026, which mean that it might be not significant if we choose alpha less than 0.026.

For the concentration of tocopherol, the regression model is showing that the frying time is negatively related to tocopherol concentration, the more we fry, the less we get tocopherol concentration in the oil. From the regression equation, we can conclude that the tocopherol concentration is reducing in an amount of 9.39 ppm when the frying time increases by one hour.

For the iodine value (IV), we can see from the regression model that the relation between frying time and iodine value is negative. The more we fry the less we have iodine value in the oil. The regression model is telling us that the iodine value is decreasing in an amount of 2.56 wijs, when the frying time is increased by one hour [6].

For peroxide value, the regression model shows a positive relationship between the frying time and peroxide value. The peroxide value is increasing by 0.683 (meq/kg) when the frying time is increased by one hour. The more we fry, the more we get peroxide value in the oil [10].

For free fatty acid, the regression is showing a positive relation between frying time and percentage of free fatty acid. From the equation, we can see that the percentage of free fatty acid is increasing at an amount of 0.499 when the frying time increases by one hour. For the last chemical index, the polymer compound we see from the regression model that the percentage of polymer compound is increasing in an amount of 0.230 when the frying time increases by one hour.

4. Conclusions

1- Frying has a direct impact on chemical indices of frying oil, and repeated fry has more impact.

2- The impact of frying time is increasing the amount of some of the chemical indices, namely tocopherol concentration and iodine value, and increasing others like peroxide value, free fatty acid, and polymer compound.

3- From the result, we can see that palm oil is showing significant dependency on frying time for all five chemical indices, whereas the cottonseed and groundnut oils not having significant dependency on frying time for tocopherol concentration.

IOP Conf. Series: Journal of Physics: Conf. Series **1489** (2020) 012027 doi:10.1088/1742-6596/1489/1/012027

5. References

[1] Rani M and Chauhan G S 1995 Effect of intermittent frying and frying medium on the quality of potato chips. *Food Chemistry* **54** 365

[2] Hashempour-Baltork F, Torbati M, Azadmard-Damirchi S. and Savage G P 2016 Vegetable oil blending: A review of physicochemical, nutritional and health effects. *Trends in Food Science and Technology* **57** 52

[3] Jaswir I, Man Y B C, and Kitts D D 2000 Use of natural antioxidants in refined palm olein during repeated deep-fat frying. *Food research international*. **33** 501

[4] Mirghani M E S, Man Y C, Jinap S Baharin, B S and Bakar J 2002 FTIR spectroscopic determination of soap in refined vegetable oils. *Journal of the American Oil Chemists' Society*. **79** 111

[5] Man Y B C and Jaswir I 2000 Effect of rosemary and sage extracts on frying performance of refined, bleached and deodorized (RBD) palm olein during deep-fat frying. *Food Chemistry*. **69** 301

[6] Che Man Y B and Mirghani M E S 2000 Rapid method for determining moisture content in crude palm oil by Fourier transform infrared spectroscopy. *Journal of the American Oil Chemists' Society* **77** 631

[7] Mirghani M E S, Man Y C, Jinap S, Baharin B S and Bakar J 2002 Rapid method for determining malondialdehyde as secondary oxidation product in palm olein system by Fourier transform infrared spectroscopy. *Phytochemical Analysis: An International Journal of Plant Chemical and Biochemical Techniques* **13** 195

[8] Kaddour A A, Grand E, Barouh N, Baréa B, Villeneuve P and Cuq B 2006 Near-infrared spectroscopy for the determination of lipid oxidation in cereal food products. *European journal of lipid science and technology* **108** 1037

[9] Mirghani M E S, Man Y C, Jinap S, Baharin B S and Bakar J 2003 Application of FTIR spectroscopy in determining sesamol in sesame seed oil *Journal of the American Oil Chemists' Society* **80** 1

[10] Yildiz G, Wehling R L and Cuppett S L 2003 Comparison of four analytical methods for the determination of peroxide value in oxidized soybean oils *Journal of the American Oil Chemists' Society* **80** 103