EFFECTS OF REPEATED DEEP FRYING ON REFRACTIVE INDEX AND PEROXIDE VALUE OF SELECTED VEGETABLE OILS

Awuchi Chinaza Godswill[1], Ikechukwu O. Amagwula[2], Igwe S. Victory[3] and Allan Isiaga Gonzaga[4]

Department of Food Science and Technology, Federal University of Technology, Owerri, Imo State, Nigeria.
Department of Physical Sciences, Kampala International University, Kampala, Uganda.

Email address: awuchi.chinaza@kiu.ac.ug, awuchichinaza@gmail.com (Awuchi), ikechukwuamagwula1@gmail.com (Amagwula), victoryigwe@gmail.com (Igwe), isiagiallan@gmail.com (Allan)



ABSTRACT

The peroxide values and refractive indices of palm olein, sesame oil and sunflower oil were evaluated before deep frying. The vegetable oils were used to frying white Irish potato chips in three batches, with the peroxide value and the refractive indices of the oils determined after every stage of deep frying. Results of the study show that both refractive index and peroxide value of the vegetable oils largely vary with deep frying. The findings show that refractive index and peroxide value of sesame palm and sunflower do increase on frying, though not in a linear fashion. The refractive index of palm oil increased from 1.4653 to 1.4655 after frying the three consecutive batches; the RI of sunflower oil increased from 1.4722 to 1.4724 respectively. There was no significant change in the refractive index of sesame oil. The peroxide values of palm oil increased from 1.9948mEq/kg to 9.3020mEq/kg after three consecutive deep frying. The value of peroxide of sunflower oil raised from 10.6359 mEq/kg to 19.3101 mEq/kg while that of sesame increased from the initial 3.9914 mEq/kg to 11.9555 mEq/kg on frying the second batch and finally reduced to 11.3095 mEq/kg after frying the third batch of Irish potato chips. Tables 3 and 4 show the relationship between refractive index and peroxide value of the vegetable oil. These findings indicate that repeated deep frying leads to corresponding rancidity and spontaneous deterioration of the vegetable oil.

Keywords: Refractive Index, Peroxide Value, Vegetable oil, Palm olein, Sesame oil, Sunflower oil

1.0. INTRODUCTION

Vegetable oils are a popular cooking medium in many parts of the world. Despite problems related to the intake of excessive calories and health concerns regarding the ingestion of trans-fatty acids, the flavor and texture of fried food continue to be greatly appreciated. Refractive index and peroxide value are some of a very long list of parameters, physical and chemical respectively, carried out on oils to verify their quality and degree of rancidity. One of the easiest and time efficient foods is the fries. These are relatively easy and convenient to prepare. Deep frying is the most common cooking method of preparing fried snacks such as potato chips, cassava chips, fish balls, chicken, among others. Deep frying is mainly done by cooking the food material at about 180°C – by dipping the largest percent of it in fully heated oil. Various food products such as potato chips, chicken patties, are prepared at large scale by this frying process. Fried food is considered to be tastier than non-fried. Being unpropitious area cooking oil used for frying is usually heated repeatedly. Anytime one cooks food; it runs the risk of creating heat-induced damage; frying with vegetable oils are among the most susceptible phenomena. The cooking oils one chooses to cook with must be stable enough to resist the rigors of chemical changes when heated to high temperatures.

One of the ways cooking oils can inflict damage is by converting our good cholesterol into bad cholesterol—by oxidizing it (Goswami *et al*, 2015). The aroma and taste or flavor present in deep-fried foods makes the food more enticing and appetizing for consumption. Worldwide, the major concern with cooking oil is the level of cholesterol in form of LDL which is associated with cardiovascular disease and blockage of arteries but there are several equally dangerous concerns which are yet to receive the necessary attention. Such concerns include the dangers of prolonged use, reuse of cooking oil. From the point when the cooking oil is introduced the heated frying pan, subsequent physical and chemical changes to the oil are initiated which at higher temperatures lead to other changes.

Cooking oil of plant and animal origin or synthetic fat is used in frying, baking, and other types of cooking. It is also used in food preparation and flavoring not involving heat, such as salad dressings and bread dips, also termed edible oil. Cooking oils are liquid, although some oils that contain a high amount of saturated fat, such as coconut oil, palm oil, and palm kernel oil, are solid at room temperature. Most cooking oils on the market are harvested from plants species that include olive, maize, sunflower and many other species. Different types of cooking oil include olive oil, soybean oil, palm oil, sunflower oil, corn oil, groundnut oil, safflower oil, peanut oil, sesame oil, and other vegetable oils, as well as animal-based oils like butter and lard. Most refined cooking oils on the market are fortified with vitamin A with the main aim of supply where it is deficient; other companies fortify cooking oil with vitamin E.

In most African countries like Uganda, Nigeria, Zimbabwe, etc., vegetable oil market is dominated by palm oil, sunflower oil, sesame oil, groundnut oil, etc., largely, due to their affordability. Sunflower oil, though not very expensive, is mainly consumed by the medium income earners. Currently, struggling for its way onto the market is sesame oil which is relatively not cost effective because of the availability of few sesame processing industries. The other relatively affordable type of cooking oil on the market is corn oil, which is yet to gain popularity, while very good oils like olive oil, avocado oil are extremely priced. When preparing a meal, one may use whatever oil is easiest to reach for which in most cases palm oil and groundnut oil-related products are available at any times and relatively more affordable, and the most widely used by the deep frying industries. Every oil has a smoke point or a temperature at which smoke forms and the oil's chemical compositions and structure break down, releasing free radicals, degrading nutrients, and producing a rancid flavor, which alters some of the physical and chemical properties of the oil. Oil degradation can also cause food to absorb too much oil and become greasy. As for flavor, too-high heat destroys aromatic compounds in oils (Gorin, 2016).

The deep frying sector worldwide has a sounding contribution to the growth of income for those who depend on it. Consequently, it is the fastest source of quick fries for those who have no time to enjoy the kitchen fever. How long cooking oil should be used remains a matter subjected to research and debate; also the consequences of ingestion of such foods prepared using cooking oil which has been reused several times need enough attention. Only after that can a fruitful campaign against the over reuse of edible cooking oil be achieved.

Determining and comparing various physiochemical properties of oil before and after frying gives relevant information on the change in cooking oil quality which can be used to determine its rate and range of degradation. That way possible health complications related to such degradation can be stressed out. This study set out to identify the changes in refractive indices and peroxide values of selected vegetable oil so as to identify which one amongst them would be recommended for deep frying purpose.

Both heat and mass transfer change the physicochemical properties of the cooking oils. As heating proceeds, volatile and nonvolatile compounds are formed. Some of these are desirable as they give the food a tasty flavor while others are undesirable whereby besides causing off-flavors they can be poisonous, leading to food poisoning. Refractive index increases with the increase in the amount of conjugated fatty acids whilst peroxide values vary with the concentration of primary oxidation products. But both ultimately are used to detect deterioration in terms of rancidity. Rancidity is usually noticeable as a foul smell in food and also within the oil itself. Refractive index increases with increase in oxidation same as peroxide value. Rancid oil will bare a PV between 30mEq/kg and 40mEq/kg.

The findings of the study bare the significances relative to the respective categories of people. To the policy makers and planners, the findings of the study will give an informed basis to address issues related to repeated use of vegetable oil during frying to ensure the health of the populace is not put at risk. The findings of the study are crucial as they can help to identify the best choice of cooking oil to use in deep frying activities based on the change in the peroxide values and RI. The findings of the study will provide literature in the future to researchers who will wish to carry out studies in fields related areas. The finding of the study will provide scientific-based deductions to the concerned parties and interest groups on mass sensitization.

2.0. MATERIALS AND METHODS

2.1. Sample collection and preparation

Refined palm olein, sesame oil, and sunflower oil, as well as Irish potato samples, were obtained from commercial markets in Kampala. Potatoes were sliced in closely equal chips in terms of size (about 6 mm thickness). Each of the oil was used to fry three batches of chips, and samples for analysis collected after every batch. The deep frying was carried out in a 1000 ml stainless steel saucepan. The research was carried out at Uganda Industrial Research Institute, Jinja, Kampala.

2.2. Reagents and chemicals

The chemicals used were obtained from Uganda Industrial Research Institute and these were glacial acetic acid (CH_3COOH), chloroform (CH_3Cl), sodium thiosulphate ($Na_2S_2O_3$), and potassium iodide (KI) all of which were of HPLC grade. Acetic acid was mixed with chloroform in the ratio of 2:1 respectively. 0.1N sodium thiosulphate was prepared by adding 28.4g of $Na_2S_2O_3.7H_2O$ to distilled water in a 1000 ml volumetric flask.

2.3. Determination of refractive indices of the oils

The refractive index (RI) was determined using Abbe 60 Refractometer as described by the AOAC. Method (AOAC, 2000). A double-prism was opened by means of the screw head and few drops of oil were placed on the prism. The prism was closed firmly by tightening the screw head. The prism was closed, tightened firmly with the screw-head and allowed to stand for 1 minute after which the determination of RI was done. The refractometer was cleaned between readings by wiping off the oil with a smooth tissue paper; the prism was regularly cleaned with petroleum ether and then allowed to dry by use of a clean tissue. The process was repeated twice.

2.4. Determination of Peroxide Value of the oils

The experimentations were done according to Uganda Industrial Research Institute's UIRI/MET/FTOIL/08. A given weight (5.0g) of the samples was weighed with an allowance of ± 0.05g as error into 250ml glass stoppered Erlenmeyer flasks and the weights recorded. By graduated cylinders, 30 ml of the acetic acid – chloroform solution were added. The flasks were swirled until the samples were completely dissolved. Using 1 ml Mohr pipettes, 0.5 ml of saturated potassium iodide solution were added. The flasks were stoppered and the contents of the flasks were shaken for exactly one minute then the flasks were placed in a dark place for 1 minute. By graduated cylinders, 30 ml of distilled water were added, the flasks stoppered and shaken vigorously to liberate the iodine from the chloroform layer.

Burettes were filled with 0.1N sodium thiosulphate. 1 ml of the starch indicator was added to every flask and titration with the thiosulphate done until the blue-grey color disappeared in every flask. Also, a blank titration was carried out with everything except the oil samples.

The peroxide values were calculated from the formula below:

$$\text{Peroxide Value (PV)} = \frac{(S-B)\times N \times 1000}{weight\ of\ sample}$$

S – Volume of thiosulphate used in the titration of the sample
B – Volume of thiosulphate used in the titration of the blank.
N – Normality of sodium thiosulphate
To ensure the stability of results, three replicates of every sample were analyzed.

2.5. Statistical analysis

Triplicate of each sample for both parameters was analyzed using statistical analysis system. The analysis of variance (ANOVA) was performed to examine the significance of all the results in the parameters measured. The difference between the means was determined using the Least Significant Difference at a confidence level of 95%.

3.0. RESULTS AN DISCUSSION

3.1 Refractive indices of the oil samples

Table 1: The mean values of RI of the oils before and after every frying batch.

Frying turn	Palm olein	Sunflower oil	Sesame oil
0.0	$1.4653^{a} \pm 0.0002$	$1.4722^{a} \pm 0.0002$	1.4722 ± 0.0003
1st	$1.4654^{b} \pm 0.0002$	$1.4724^{b} \pm 0.0003$	1.4723 ± 0.0002
2nd	$1.4655^{c} \pm 0.0001$	$1.4724^{b} \pm 0.0002$	1.4723 ± 0.0002
3rd	$1.4655^{c} \pm 0.0002$	$1.4725^{c} \pm 0.0002$	1.4722 ± 0.0002
LSD	0.0001	0.0001	NSD

Means with a superscript‘a,b,c’ in columns are significantly different at $p \leq 0.05$ within the columns.

Key

1. 0.0 - Before Frying
2. 1st – After frying the first batch of chips
3. 2nd – After frying the second batch of chips
4. 3rd - After frying the third bath of chips
5. NSD – No significant difference

Results in Table 1 show that the refractive index of the oils increased with that of palm oil going from the initial 1.4653 of the original oil to 1.4655 on frying of the final potato chips batch, sunflower oil's refractive index increased from 1.4722 of the original cooking oil to 1.4725 after frying the third batch. There is a significant difference ($p \leq 0.05$) in the mean values of RI of palm olein and sunflower oil. The refractive index of sesame oil, on the other hand, shows negligible variation between 1.4722 and 1.4723 from the initial refractive index. There is no significant difference in the mean values of RI of sesame oil after repeated frying. All of the oils recorded a standard deviation of 0.0002 as indicated in the table of results. The results obtained are in agreement with the work of Arya *et al*. (1969), and Ruben Meerman (2009). The changes in the refractive indices were statistically significant at ($p \leq 0.05$) for palm oil which registered a p-value of 0.0098 and sunflower oil for which the p-value was 0.0035. At that particular significant level that is ($p \leq 0.05$), the change in the refractive index of sesame oil was not significant as its recorded p-value was 0.085 which is higher than 0.05.

Refractive Index is the ratio of light in a vacuum to its velocity in a specified medium. Refractive Index is can be used as an objective method for evaluation of rancidity in edible oils and fats (Arya *et al*, 1969). Continuous increase in the RI of the oil due to repeated frying batches indicates that deep frying increases rancidity of the oil. This means that repeated frying using same vegetable oil should be discouraged.

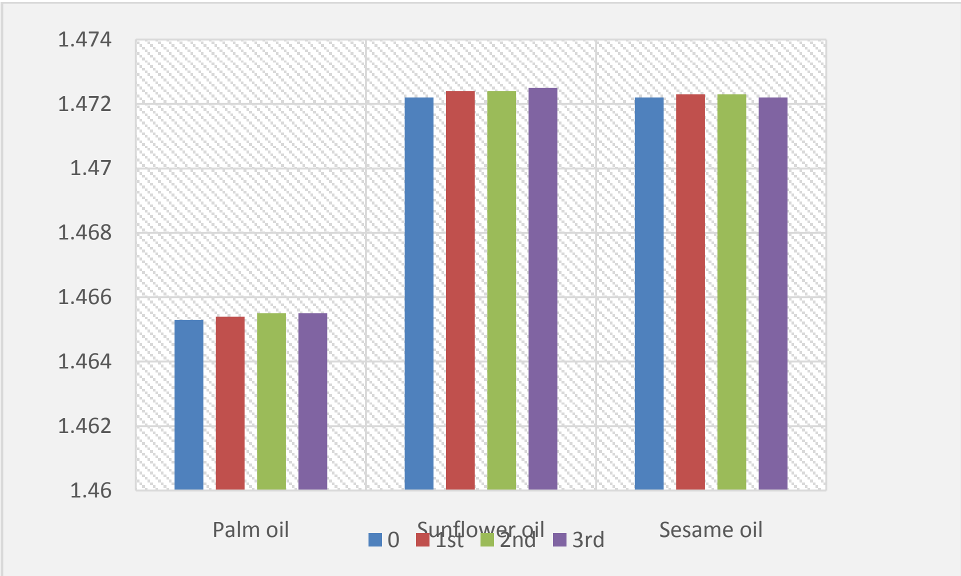

Figure 1: Mean Refractive Index of the oils.

3.2. Peroxide values of the oils

Table 2: Average Peroxide Values (PV) of the Oils

Frying turn	Palm olein mEq/kg	Sunflower oil mEq/kg	Sesame oil mEq/kg
0.0	$1.9948^{c} \pm 3.2500$	$10.6359^{c} \pm 3.9460$	$3.9914^{c} \pm 2.9920$
1st	$7.3107^{b} \pm 3.1339$	$11.2874^{c} \pm 3.7392$	$7.3025^{b} \pm 3.2111$
2nd	$7.3130^{b} \pm 3.1637$	$13.9632^{b} \pm 2.8560$	$11.9555^{a} \pm 3.7201$
3rd	$9.3020^{a} \pm 3.3011$	$19.3101^{a} \pm 3.1456$	$11.3095^{a} \pm 3.2642$
LSD	1.3475	1.6573	1.8315

Means with the same superscript do not differ significantly at $p \leq 0.05$ within the.
Means with different superscripts differ significantly at $p \leq 0.05$.

Key

1. 0.0 - Before Frying
2. 1st – After frying the first batch of chips
3. 2nd – After frying the second batch of chips
4. 3rd - After frying the third bath of chips

Results in Table 2 show the results of peroxide value of the oils and indicated a general increase in the mean values of the oils, with the peroxide value of palm olein increasing from 1.9948 mEq/kg (before frying) to 9.3020mEq/kg after the final frying. PV of fresh oils are usually less than 10 milliequivalents/kg; when the peroxide value is between 30 and 40 milliequivalents/kg, a rancid taste is usually perceptible. On the average, the PV of sunflower oil increased from the initial 10.6359 mEq/kg to finally 19.3101mEq/kg after frying the third batch of potato chips, whilst that of sesame oil ascended from 3.9914 mEq/kg of the initial oil to finally 11.3095 mEq/kg on the third frying turn. In all the three types of cooking oil, the changes in peroxide value were significant at the significant level of $p \leq 0.05$, with the p-value of palm oil being 0.001 while sunflower oil had a p-value of 0.004. Sesame recorded 0.003.

The peroxide value is defined as the amount of peroxide oxygen per 1 kilogram of fat or oil (Chakrabarty M., 2003). Detection of peroxide gives the initial evidence of rancidity in unsaturated fats and oils. Other methods are available, but peroxidevalue is the most widely used. It gives a measure of the extent to which an oil sample has undergone primary oxidation, the extent of secondary oxidation may be determined from the p-anisidine test (Chakrabarty M., 2003). The PV tells the amount of iodine in a given oil, which indicates the degree of rancidity**.**

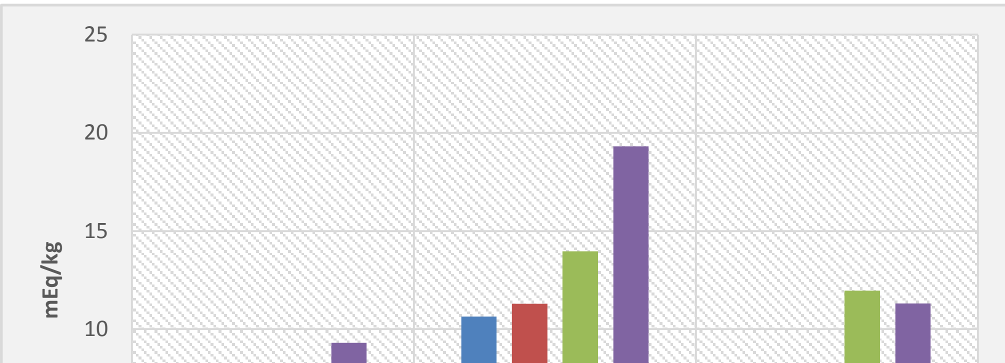

Figure 2: Mean Peroxide Values of the oils

3.3. Correlation of RI and PV of the Oil

The results of the correlation of RI and PV of the vegetable oil are shown in Table 3.

Table 3: The correlation of RI and PV of the vegetable oil are shown in Table 3.

Control Variables			RIPO	RISUNFO	RISO	PVPO	PVSUNFO	PVSO
-none-[a]	RIPO	Correlation	1.000	.899	.302	.904	.780	.995**
	RISUNFO	Correlation	.899	1.000	.229	.997**	.795	.852
	RISO	Correlation	.302	.229	1.000	.306	-.343	.307
	PVPO	Correlation	.904	.997**	.306	1.000	.749	.859
	PVSUNFO	Correlation	.780	.795	-.343	.749	1.000	.757
	PVSO	Correlation	.995**	.852	.307	.859	.757	1.000
PVPO & PVSUNFO & PVSO	RIPO	Correlation	1.000					
	RISUNFO	Correlation		1.000				
	RISO	Correlation			1.000			

**. Correlation is significant at 0.01 level

a. Cells contain zero-order (Pearson) correlations.

RIPO = Refractive Index of Palm Olein, RISO = Refractive Index of Sesame Oil, RISUNFO = Refractive Index of Sunflower Oil, PVPO = Peroxide Value of Palm Olein, PVSO = Peroxide Value of Sesame Oil, PVSUNFO = Peroxide Value of Sunflower Oil

Table 3 shows moderate to high degree of correlation between PV and RI of the vegetable oils. The higher the PV, the higher the level of correlation. This shows that the relationship between the values of refractive index and the peroxide value is significant.

3.4. Regression of Refractive Index and Peroxide Value of the Oil

Table 4 shows the results of the regression of refractive index on peroxide value of the oil.

Tables 4 - 6: regression of refractive index on peroxide value of the oil.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.904[a]	.818	.727	.00005

a. Predictors: (Constant), PVPO

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.795[a]	.632	.447	.00009

a. Predictors: (Constant), PVSUNFO

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.307[a]	.094	-.359	.00007

a. Predictors: (Constant), PVSO

Mean R = 0.667 Mean R square = 0.514

RIPO = Refractive Index of Palm Olein, RISO = Refractive Index of Sesame Oil, RISUNFO = Refractive Index of Sunflower Oil, PVPO = Peroxide Value of Palm Olein, PVSO = Peroxide Value of Sesame Oil, PVSUNFO = Peroxide Value of Sunflower Oil

The results of the regression of refractive index on peroxide value of the vegetable oils are shown in Table 4. The mean values of R and R square are 0.667 and 0.514 respectively. This shows that the over 66.70% of the variation in refractive indices of the vegetable oil may be due to the variation in peroxide value values. The R square value indicated that over 51.4% variation in the refractive index of the vegetable oil is due to the peroxide values.

3.5. Further Discussion

3.5.1. Refractive index

Table 1 shows the refractive index of palm olein, sunflower and sesame oils. There is a general increase in the index of refraction of these oils which may be due to the increase in the levels of conjugated fatty acids as a result of thermal degradation during the frying process. The increase in the number of conjugated acids also conveys an increase in the level of autoxidation. The refractive index during heating of oil increases as more conjugated acids are formed (Chakrabarty, 2003). In optics, the refractive index or index of refraction n of an optical medium is a dimensionless number that describes how light, or any other radiation, propagates through that medium. Refractive index is an important optical parameter to analyze the light rays traversing through materials medium (Anwesa *et al*, 2015). It is the ratio of velocity of light in vacuum to the velocity of light in the oil or fat; more generally, it expresses the ratio between the sine of angle of incidence to the sine of angle of refraction when a ray of light of known wavelength (usually 589.3 nm, the mean of D lines of Sodium) passes from air into the oil or fat. Refractive index varies with temperature and wavelength. Optics is a branch of physics which deals with the study of light. But in the chemistry of oil, it indicates the possible chances of rancidity development in oil. Higher the refractive index higher is the chances of spoilage due to oxidation. Refractive index is a basic value that relates molecular weight, fatty acid, chain length, the degree of unsaturation and degree of conjugation.

A mathematical relationship exists between refractive index and iodine value.

$$\text{Refractive Index at } 25^{o}\text{C} = 1.45765 + 0.0001164 \times \text{Iodine Value}$$

Temperature changes affect the results obtained, the refractive index decreases with increase in temperature but otherwise increases with the length of the carbon chains and with the number of double bonds present in the fatty acids. A reverse relationship used to calculate the iodine value when the refractive index is known is

$$\text{Iodine Value} = 8661.723 \times \text{Refractive Index at } 25^{o}\text{C} - 12626.174$$

Refractive index is used as a rapid control for the determination of the product endpoint of hydrogenation reactions (Richard D., 2008).

3.5.2. Peroxide value

Heating of oil causes the increase of the index of peroxide at the beginning of cooking to a maximum value and then there is a decrease. Oils that are more unsaturated are oxidized more quickly than less unsaturated oils (Parker *et al.*, 2003). From the peroxide value results, there is a general increase in the level of hydroperoxides for all the three oils that are palm, sunflower and sesame oils. Furthermore, the lipid hydroperoxides radical is formed when the heated oil is kept at room temperature and reused again in frying. The decrease in the peroxide value of sesame oil on the third frying turn is explained by the further oxidation of the peroxides to secondary oxidation compounds such as aldehydes, ketones which nonlinear variance in the peroxide value of oils was also evident in Emhemmed*et al,* 2016. Oxidation of lipids is a major cause of their deterioration, and hydroperoxides formed by the reaction between oxygen and the unsaturated fatty acids are the primary products of this reaction. Hydroperoxides have neither flavor nor odor but break down rapidly to form aldehydes, which have a strong disagreeable flavor and odor. The peroxide concentration, usually expressed as peroxide value, is a measure of oxidation or rancidity in its early stages (Richard D., 2008). Detection of peroxide gives the initial evidence of rancidity in unsaturated fats and oils. Oxidation at the early stages is termed as primary oxidation. The double bonds present in fats and oils play a role in autoxidation. Oils with a higher degree of unsaturation are most susceptible to autoxidation. The best test for autoxidation is a determination of peroxide value.

Peroxide value is the amount of peroxide oxygen per 1 kilogram of fat or oil and is traditionally measured in milliequivalents per kilogram of oil or fat. The peroxide is determined by measuring the amount of iodine liberated by potassium iodide on reacting with the peroxide from the oil or fat.

$$2KI + H_2O + HOOH \rightarrow HOH + 2KOH + I_2$$

The base produced is taken up by the excess of the acetic acid present. The iodine liberated from the reaction is titrated with sodium thiosulphate.

$$2S_2O_3{}^{2-} + I_2 \rightarrow S_2O_4{}^{2-} + 2I^-$$

The acidic condition that is excess acetic acid prevents the formation of hypoiodite which would interfere with the reaction. The indicator used is a starch solution where amylase forms a blue to a black solution with iodine and is colorless where iodine is titrated.

4.1. CONCLUSION

During frying, in addition to thermal induced molecular reorientation, there is an exchange of constituents between oil and the foodstuff leading to chemical reactions. This is usually aided by heat transfer taking place between the media. The refractive index of sesame oil, on the other hand, shows negligible variation between 1.4722 and 1.4723 from the initial refractive index. There is no significant difference in the mean values of RI of sesame oil after repeated frying. Refractive index and peroxide value measurements indicated the extent to which the oil has degraded. The study shows an increase in both PV and RI of the cooking oil on repeated frying. There is a significant difference ($p \leq 0.05$) in the mean values of RI of palm olein and sunflower oil. The results of correlation and regression show that the peroxide values of the oil have a moderate impact on the refractive index of the oil. The average PV of sunflower oil increased from the initial 10.6359 mEq/kg to finally 19.3101 mEq/kg after frying the third batch of potato chips, whilst that of sesame oil ascended from 3.9914 mEq/kg of the initial oil to finally 11.3095 mEq/kg on the third frying turn. This certainly should raise alarm to each and every one because the key to a good life starts with a healthy body. The texture of the food may not be affected by rancidity. This deteriorative condition is highly associated with health complications such as cellular damage. Rancid oils cause digestive distress including deprivation of the body's vitamins B and E. other implications include accelerated aging, raised cholesterol levels, obesity. Other compounds of the oxidation are carcinogenic. During frying, vegetable oils should be discarded after first use.

REFERENCES

1. Allison Kociuruba (2011): Our Favorite Ways to Cook Potatoes [Blog] Available from https://www.wholefoodsmarket.com/blog/whole-story/our-favorite-ways-cook-potatoes; Retrieved on March 7, 2018
2. Amy Gorin (2016): Which Cooking Oil is Really Best for Your Health? [Blog] Available from https://www.huffpost.com/us/entry/9113228 Retrieved on February 21, 2018

3. Anwesa S., J. P. Pandey, Anupama S., Lakshmi T., Anil K. (2015): A Novel Method of Using Refractive Index as A Tool for Finding the Quality of Aqueous Enzymatic Extracted Algae Oil; Pelagia Research Library ISSN: 0976-8610 CODEN (USA): AASRFC
4. AOAC (2000): Official Methods of Analysis of the Association of Official Agricultural Chemists, 14th ed. Washington, D.C.
5. Araya A, Prabhat K (2010): Heat and Mass Transfer in Deep Frying of Pumpkin, Sweet Potato and Taro (Journal) Available from https://www.ncbi.nlm.nih.gov/pmc/articles/PM3551148/ Retrieved on March 6, 2018
6. Arya S.S., Srirama R, and Vijayaraghavan P.K (1969). Refractive index as an objective method for evaluation of rancidity in edible oils and fats. *Journal of the American Oil Chemists' Society,* 46(1): 28 – 30.
7. Bordin K, et al (2013): Changes in Food Caused by Deep Fat Frying—A Review. [Online] Available from https://www.ncbi.nlm.nih.gov/m/pubmed/2416963 Retrieved on March 4, 2018
8. Carmen M. Dobarganes, ND: Oils & Fats, Formation of New Compounds During Frying- General Observation [online] Available from https://www.lipidlibrary.aocs.org/OilsFats/Content.cfm?ItemNumber=39209
9. Chakrabarty M. M., 2003. Chemistry and Technology Of Oils And Fats. *Allied Publishers Pvt. Ltd*, viii + 752. ISBN: 81-7764-495-5.
10. David B. Min, ND: Food Lipids: Chemistry, Nutrition, And Biotechnology, Third Edition; Chemistry Of Frying Oils; Page 189
11. Emhemmed A. A., Jalal A. I., Abdulgader S. H, ND: Effect of Heat Processing and Storage on Characteristic and Stability of Some Edible Oils. Published by 6th Int'l Conference on Agriculture and Biological Sciences in 2016. Page 106 https://doi/10.15242/IIE.A1216008
12. Eunice Liu(2015): Fair Food: The Science Of Deep-Frying [Online] Available From https://scienceandforoducla.wordpress.com/2015/08/25/fair-food-deep-frying/ Retrieved on March 6, 2018
13. Frankel E. N. (2005): Lipid Oxidation (The Oily Press, Bridgewater, UK)
14. Goswami G, Rajni B, Mahipat S. R (2015): Oxidation Of Cooking Oils Due To Repeated Frying And Human Health [Research] Department Of Applied Sciences, University Of Delhi
15. Kaleem A., Sana A., Mehwish H., et al (2015): Investigating Changes and Effect of Peroxide Values of Cooking Oils Subject to Light and Heat. FUU AST J. BIOL., 5(2): 191-196
16. M. M. Chakrabarty (2003): Chemistry and Technology of Oils & Fats: Fat-Based Coating Products. Page 650
17. Mordor Intelligence (2018): Global Potato Chips Market-Growth Forecast (2018-2023) [Online] Available from https://www.modorintelligence.com/industry-repots/pota-chips-market. Retrieved on March 7, 2018
18. Moreira R, Palau J. and Sun X. (1995): Simultaneous Heat And Mass Transfer During The Deep Fat Frying Of Tortilla Chips. J Food Proc. Eng. 18:307

19. Parker, T.D., Adams, D.A., Zhou, K., Harris, M.,and Yu, L. (2003). "Fatty acid Composition And Oxidative Stability Of Cold-Pressed Edible Seed Oils," *J Food Sci* 68: 1240–3.
20. Richard D. O'Brien (2008): Fats and Oils: Formulating and Processing for Application, Third Edition. Pages 212, 213, 219, 220
21. Ruben Meerman (2009). Teacher Demonstration 27 The Invisible Bowl. *ABC Science Online*, 1 – 2. *www.abc.net.au/science/surfingscientist/pdf/teachdemo27.pd*
22. The Essential Chemical Industry, ND: Edible Fats and Oils [Online] Last Amended On March 18, 2013; Available from https//www.essentialchemicalindustry.org/materials-and-applications/edible-fats-and-oils.html Retrieved on March 7, 2018
23. Uday, Rekha, Pushpa (1997): Studies on Deep Fat Fried Snacks From Some Cereals And Legumes [Research Articles] Volume 76, Issue 3. Page 377
24. UIRI Chemistry Laboratories (2010): Determination of Peroxide Value in Fats and Oils. UIRI/MET/FTOIL/08 First Edition, Issue No. 1

APPENDIX

Table A1: Data of refractive index of palm oil

Replicate	Before frying	1st frying	2nd frying	3rd frying
1	1.4653	1.4654	1.4655	1.4655

2	1.465	1.4653	1.4656	1.4657
3	1.4652	1.4656	1.4655	1.4657

Table A2: Data of refractive index of sunflower oil

Replicate	Before Frying	1st Frying	2nd Frying	3rd Frying
1	1.4722	1.4724	1.4724	1.4725
2	1.4721	1.4726	1.4725	1.4727
3	1.4721	1.4723	1.4726	1.4727

Table A3: Data of refractive index of sesame oil

Replicate	before frying	1st frying	2nd frying	3rd frying
1	1.4722	1.4723	1.4723	1.4722
2	1.4721	1.4725	1.4726	1.4726
3	1.4721	1.4724	1.4726	1.4727

Table A4: Data of peroxide value of palm oil

Replicate	before frying	1st frying	2nd frying	3rd frying
1	1.9952	5.994	7.985	7.9656
2	1.9908	7.9759	5.9836	11.9465
3	1.9985	7.9623	7.9703	7.9939

Table A5: Data of peroxide value of sunflower oil

Replicate	before frying	1st frying	2nd frying	3rd frying
1	9.9701	11.9522	11.9808	17.9928
2	9.98	11.9355	13.9609	21.9855
3	11.9577	9.9745	15.948	17.9519

Table A6: Data of peroxide value of sesame oil

Replicate	before frying	1st frying	2nd frying	3rd frying
1	3.995	5.9946	13.9634	13.9603
2	3.9857	7.9521	11.9358	7.9855
3	3.9934	7.9608	9.9673	11.9827

The experiments were carried out at Uganda Industrial Research Institute on 26th February 2018.

The analysis of variance was done using Microsoft Excel 2017 for all the data to assess their significance with the choice of ANOVA: Single Factor.