Agriculture and Food Sciences Research
Vol. 7, No. 1, 89-96, 2020
ISSN(E) 2411-6653/ ISSN(P) 2518-0193
DOI: 10.20448/journal.512.2020.71.89.96

Physicochemical and Antioxidant Properties of Oils Used by Local Fried Food Vendors in D/Line-Port Harcourt, Rivers State

Emelike, N.J.T[1]
Ujong A. E.[2]✉
Achinewu, S. C.[3]


(✉ Corresponding Author)

[1,2,3]*Department of Food Science and Technology, Rivers State University, NkpoluOroworukwo, Port Harcourt, Rivers State, Nigeria.*
[1]*Email: njtemelike@yahoo.com Tel: +2349027308371*
[2]*Email: animityekpo@gmail.com Tel: +2347013700574*
[3]*Email: achinewhu@yahoo.com Tel: +2348064619108*

Abstract

Frying initiates different physical and chemical changes which can cause degradation of oil and quality of the fried food. This study was conducted to investigate and monitor the physicochemical and antioxidant properties of frying oils used by local fried food vendors in D/line-port Harcourt, Rivers State. A total of five frying oils were collected randomly during frying operations from the study area and analyzed at weekly intervals (3 weeks) for physicochemical and antioxidant properties. The results showed that all the frying oils collected were above the permissible limit for free fatty acid and saponfication value while peroxide values were within the Codex regulatory limit after three weeks of collection. The results also revealed a decrease in iodine values of the frying oils except for oil samples collected from Agudama Street and Railway close. Moisture content of all the frying oils was below the 0.3% maximum limit while smoke points were not in line with the recommended standard as all the oils had smoke points <170^{o}C even up to the third week of collection. Increased usage of the oils during frying also resulted to a decrease in total phenolic content except for frying oil collected from Kaduna Street while a reverse was observed for total flavonoid content. The degradation in the quality of oils used by local fried food vendors in D/line, Port Harcourt during frying operations is an important health issue which could cause damaging health effects due to the toxic substances produced.

Keywords: Antioxidant, Physicochemical, Oil, Frying, D/line, Collection.

Citation | Emelike, N.J.T; Ujong A. E; Achinewu, S. C (2020). Physicochemical and Antioxidant Properties of Oils Used by Local Fried Food Vendors in D/Line-Port Harcourt, Rivers State. Agriculture and Food Sciences Research, 7(1): 89-96.
History:
Received: 18 March 2020
Revised: 22 April 2020
Accepted: 25 May 2020
Published: 15 June 2020

Publisher: Asian Online Journal Publishing Group

Acknowledgement: All authors contributed to the conception and design of the study.
Funding: This study received no specific financial support.
Competing Interests: The authors declare that they have no conflict of interests.
Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study was reported; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained.
Ethical: This study follows all ethical practices during writing.

Contents

Contribution of this paper to the literature
This study contributes to literature by evaluating the level of degradation in the quality of frying oils used by local fried food vendors in D/line, Port Harcourt during frying operations.

1. Introduction

Frying is one of the most common and longstanding culinary techniques used for preparation of foods throughout the world. It involves submerging the food in hot, liquid fat at high temperature of 150°C-190°C [1]. During this process, the fried food absorbs some amount of oil and as a result, certain proportions of degraded products from the oil are accumulated by the fried food [2].

Frying also initiates different physical and chemical changes which results in extensive degradation. The frying process is also open to atmospheric oxygen and high temperature which can however cause degradation in the oil leading to unpleasant odour and flavor [3]. Several studies have shown that continuous use of vegetable oils for frying results in degradation which affects the physical and chemical properties of the oil quality Idun-Acquah, et al. [4]. Codex Alimentarius Commission/FAO/WHO Food Standards [5] Reported that frequent frying of vegetable oils leads to deterioration and lipid oxidation results in the formation of peroxides which are responsible for primary oxidation in the oil [6]. Degradation of vegetable oils during frying result in loss of nutritive value and causes damaging health effects due to the toxic substances produced [6]. According to Codex Alimentarius Commission/FAO/WHO Food Standards [5] continuous deep fat frying decreases the unsaturated fatty acids of oil and increases foaming, colour, viscosity, density, specific heat and free fatty acid contents.

There has been an increase in the consumption of street fried foods in Port Harcourt metropolis resulting from high demand for such foods and the changing lifestyle and growth in the number of working women. Food items that are often cooked by frying include yam, potato, fish, meat, plantain etc. Quality control measures are lacking specifically as related to the quality of oil used by these fried foods street vendors in frying. Most of them use vegetable cooking oil numerous times for frying before discarding so as to reduce cost. The frying oil is also infrequently discarded, with these vendors instead simply adding more as oil is absorbed by the fried food [7]. According to Flores, et al. [8] this practice decreases the rate of hydrolytic alterations and therefore mask or slow down this type of deterioration. Mensah and Obeng [9] Reported that vegetable oils for cooking are to be used 3-6 times before being discarded as waste; however most of these fried food vendors use these oils even more than the supposed number of times. Some use the oils for frying until the colour changes to dark while others use it until the flavor of the product is unacceptable. Good [10] Also reported that repeated usage of vegetable oil for frying lowers the smoke point which makes the oil to smoke on heating at a lower temperature.

The consumption of repeatedly heated vegetable oil during frying has been linked with increasing the risk of developing atherosclerosis, total serum lipid and low density lipoprotein (LDL) levels [11, 12]. There is need to investigate the effect of repeated frying on the quality of oils used by these fried food vendors in order to provide basic data and knowledge of the quality of oils used for frying. Therefore, this study was aimed at determining the physicochemical and antioxidant of vegetable oils used by local fried food vendors in D/line, Port Harcourt, Rivers State.

2. Materials and Methods

2.1. Sample Collection

A total of five (5) oil samples (100 ml each) were collected at weekly intervals for period of three weeks from five Streets, all situated in D/line, Port Harcourt. The streets covered were Agudama, Emekuku, Kaduna, Wogu, and Railway close. These oil samples were repeatedly used vegetable oils collected during frying operations. Fresh unused branded oil (Kings refined vegetable oil) and unbranded (local vegetable oil) were also collected and used as control samples. The oil samples were transported to the biochemistry laboratory of the Department of Food Science and Technology, Rivers State University for analysis within 1 hr after collection and checked for physicochemical and antioxidant properties. All chemicals used for this study were of analytical grade and obtained from the department of Food Science and Technology laboratory, Rivers State University, Port Harcourt.

2.2. Methods

2.2.1. Physico-Chemical Analysis

Iodine value, peroxide value, free fatty acid content, saponfication value, smoke point and moisture content of the oils collected were all determined using the AOCS method [13].

2.2.2. Antioxidant Analysis

2.2.2.1. The Total Phenolic Content

Total phenolic of the oils was determined by the Folin–Ciocalteu reagent (FCR) according to the procedure reported by Emelike, et al. [14]. The oil sample (0.3 ml) was weighed into a conical flask and 3.0ml of Folin–Ciocalteu reagent added into it. After 5min, 6% sodium carbonate (3.0 ml) was added and the mixture allowed standing at room temperature for 90mins. The absorbance of the mixture was measured at 725nm using uv/vis Spectrophotometer (USA). The total phenolic content was calculated from the calibration curve and the results were expressed as mg of gallic acid equivalent per gram of oil (mgGAE/g oil).

2.2.2.2. Total Flavonoid Content

Total flavonoid content was determined using the method of Boham and Kocipai-Abyazan [15]. The oil samples (0.5 ml) was weighed into a conical flask and 20 ml of 80% aqueous methanol added and shake using orbital shaker for 3 hrs. This was followed by filtering using Whatman filter paper thereafter the filterate was transferred into a moisture can and evaporated for 1 hr at 105°C, cooled and weighed.

2.2.3. Statistical Analysis

All analysis was performed in duplicate and data was subjected to analysis of variance (ANOVA) using SPSS Version 23 for windows (IBM Corporation, New York, USA) according to the method of Wahua [16]. Variability within the means was separated by using Duncan Multiple Range test (DMRT) which was defined at ($p<0.05$).

3. Results and Discussion

3.1. Physicochemical Properties of the Frying Oils

3.1.2. Free Fatty acid Composition

The result of free fatty acid values (%) of the frying oils collected is shown in Figure 1. The chief composition of oils is fatty acids and the degree of unsaturation is the very first factor influencing the oxidative stability of frying oils. In this study, the lowest FFA of 0.01% and 0.03% was recorded in samples collected at week 1 from Wogu and Kaduna street respectively with no significant difference ($p<0.05$) from each other. The highest FFA of 6.90% was recorded in oil samples collected from Wogu Street at week 3. An increase in the FFA was observed after third week of collection for Railway Street (1.46-2.92%), Kaduna Street (0.03-1.02%), Wogu Street (0.01-6.90%) and Emekuku Street (2.34-3.77%) while that Agudama Street decreased from 2.78-1.01%.

Oil samples collected from Wogu and Kaduna Street at first week as well as the branded oil used as control had FFA values (0.01-0.33%) within the maximum permissible FFA of 0.3% for edible oils while others were above the range. At week 2 and 3, all the frying oils (except for branded) collected had FFA values above the specification. A study conducted by Idun-Acquah, et al. [4] also revealed similar results with %FFA ranging from 0.62-2.41% after 5 days of frying. The differences observed in the FFA values of the frying oils are a consequence of new oil added during frying process which dilutes these values. Blending of vegetable oils alter their fatty acid profiles [17] and can steeply retard oxidation of oils during frying. Idun-Acquah, et al. [4] Also stated that deviation in the FFA values may be attributed to the high temperatures attained by the oil as well as the water from the fresh food product causing the natural fatty acids in the oil to get hydrolyzed into free fatty. According to Emelike, et al. [14], low moisture in oil decreases the fatty acid content while high moisture leads to its increase. Increase in FFA from this study can also be attributed to thermal and oxidative decomposition resulting to breakdown of long carbon chains into shorter chains. Free fatty acids are also formed as a result of the cleavage and oxidation of double bonds to form carbonyl compounds at elevated temperature heating Lalas [18]. McWilliams [19] Reported that the release of free fatty acid results to the formation of acreolin and smoking of the oil. Acreolin is visible as bluish and acrid smoke and its vapour may cause eye, nasal and respiratory tract irritations in low level exposure. Acreolin also induces the respiratory, ocular and gastrointestinal irritations by inducing the release of peptides in nerve terminals innervating these systems [20]. Therefore, the oils collected at the second and third week may contain some amount of acreolin since their FFA exceeded the maximum specification.

This study agrees well with other studies that the FFA content of oils increases with the number of frying cycles [21] as well as with the frying time [22]. According to Thomas [23], smoke point of oils depends greatly on free fatty acid. The more FFA an oil contains, the quicker it will breakdown and start smoking. This result also indicates that smoke points of the frying oils will be very low.

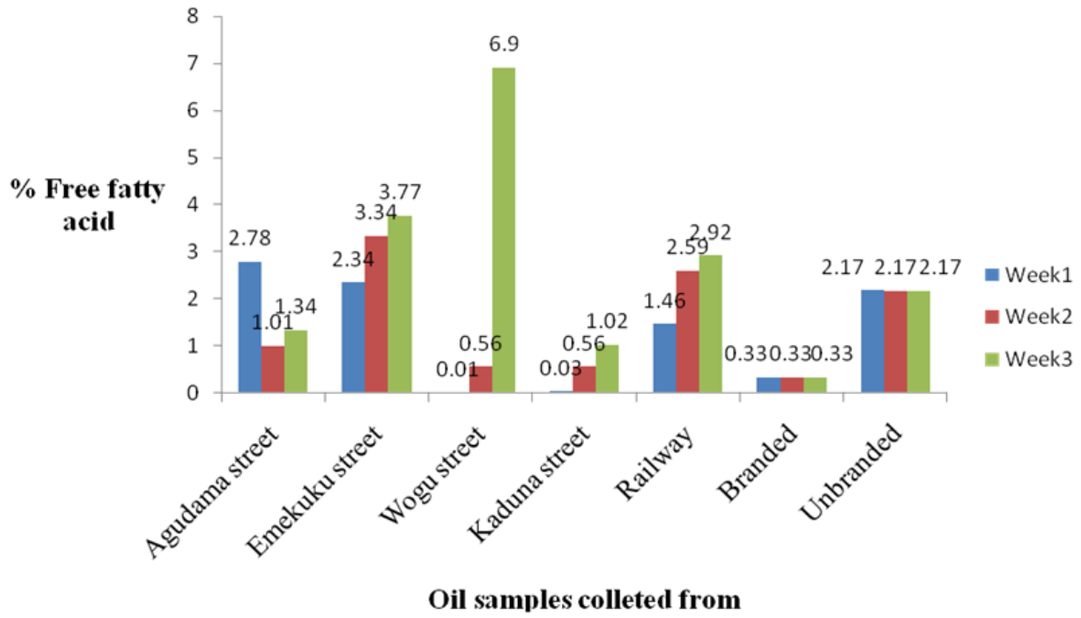

Figure-1. Free fatty acid values (%) of the oils collected at weekly intervals.

3.1.3. Peroxide Value of Frying Oils

The result of the peroxide values of frying oils is shown in Figure 2. For all the samples collected at week 1, the unbranded oil used as control had the highest peroxide value (PV) of 9.47meqO_2/kg while the lowest PV of 0.80meqO_2/kg was observed for the branded vegetable oil used as control. The PV of the oils were significantly ($p<0.05$) different from each other for all the weeks. It was observed that samples collected from Agudama, Emekuku and Wogu streets had decreasing PV of 7.79-2.20meqO_2/kg, 5.79-2.29meqO_2/kg and 6.57-3.90meqO_2/kg after the 3 weeks of collection while all other samples (except the controls) increased. The decrease in PV of these frying oils may be that the oils were changed to fresh oils at point of collection at week 2 and 3. The increase in the PV of the other samples following frying is because of the oxidation of carbon atoms adjacent to the double bonds in the triacylglyceride structure leading to the formation of hydroperoxides. PV is a useful biomarker of the preliminary stages of rancidity occurring under mild conditions and the freshness of the lipid matrix thus the

greater the PV, the faster the oxidation of the oil occurring [24]. The observed increase in PV during heating of oils has been reported by other authors [25, 26]. A study conducted by Idun-Acquah, et al. [4] obtained PV ranging 10.00-25.250 meq O2/kg after 5 days of frying. They reported the deviations of PV from the standard value to be due to the continuous exposure of the oil to light, high temperatures and atmospheric oxygen, which reacts with the oil to form peroxides. According to Codex regulatory, oils to be utilized in deep frying should have a codex regulatory maximum PV of 10meqO_2/kg [27]. In this study, PVs increased but all the oils were still concordant with the maximum codex standard.

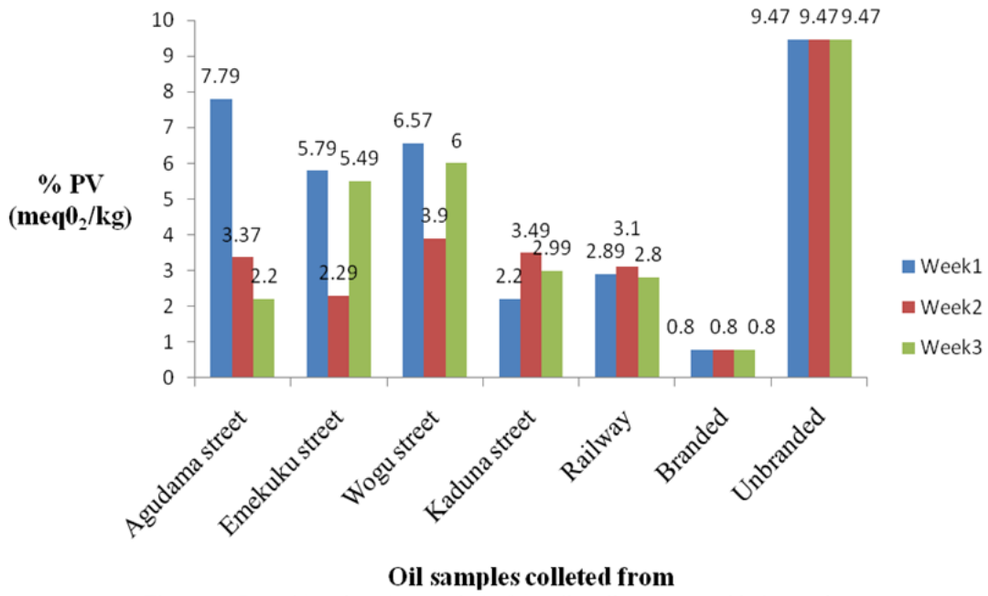

Figure-2. Peroxide values (meq0_2/kg) of the oils collected at weekly intervals.

3.1.4. Iodine Value of Frying Oils

The result of the iodine values of the frying oils collected and analyzed is presented in Figure 3. Iodine value (IV) is chemically the mass of iodine in grams that is consumed by 100gram of a chemical substance by mass as oleic acid. Iodine value is often used to determine the amount of unsaturation in fatty acids. The higher the iodine index, the faster is the tendency of oil oxidation during heating at elevated temperatures as in deep frying [28]. The maximum iodine value observed was the control (branded) sample with 44.69gI_2 while the control (unbranded) sample had the least IV with gI_2. IV for all the oil samples at weekly intervals were significantly ($p<0.05$) different from one another. Samples collected from Agudama and Railway Streets showed an increase in the IV after three weeks of collection and this could probably be due to a change in the used oil to fresh oil or the addition of fresh oil into the used oil in the frying medium. On the other hand, oil samples collected from Emekuku, Wogu and Kaduna streets showed a decrement in IV. The observed decrement of the iodine value is concordant with the decrement in double bonds attributed to oxidation and thermal decomposition and has been reported by Omara and Kigenyi [29]. Chebet, et al. [30] Reported that a decrease in iodine value is an indication of deterioration in the vegetable oils. Iodine value is of major interest in regard to oxidative stability of oils after frying of food. It is therefore established from the study that the decrease in the iodine value of the oils after frying shows relatively higher oxidation.

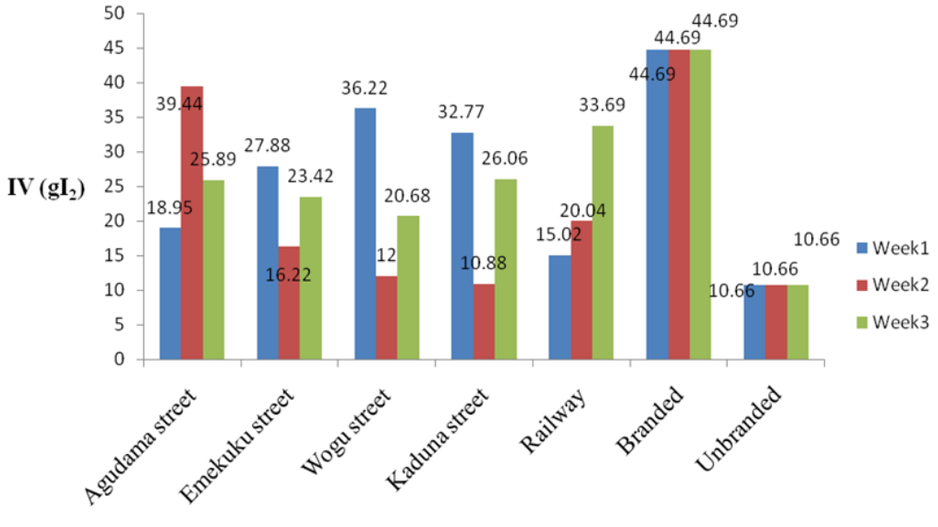

Figure-3. Iodine values (gI_2) of the oils collected at weekly intervals.

3.1.5. Saponification Value of Frying Oils

Result of the saponification values of the frying oils collected is shown in Figure 4. Saponification value (SV) is used to determine the saponification number of a fat or oil which is an index of the average molecular weight of the triaclyglceride in the sample. Saponification number is a very important factor in soap production. From the results

obtained, the reference sample (unbranded oil) and samples collected from railway at second week had SV within the standard 196-206mgKOH/g of oil by National Standardization body [31]. There was an increase in the saponification values of all the oils (except for samples collected from Wogu and Railway) even after second and third weeks of collection with values ranging between 238.99-353.37mgKOH/g, 231.13-360.96mgKOH/g, and 208.27-293.89mgKOH/g for samples collected from Agudama, Emekuku and Kaduna Streets, respectively. This increase above the specification for vegetable oils indicates that the oil to be discarded after frying can be used for soap production. This result correlates with the findings of Alajtal, et al. [32] who reported an increase in the saponification values of sunflower, corn and olive oils after frying from 21.09-22.44mgKOH/g, 19.41-21.15mgKOH/g and 21.54-22.27mgKOH/g oil respectively.

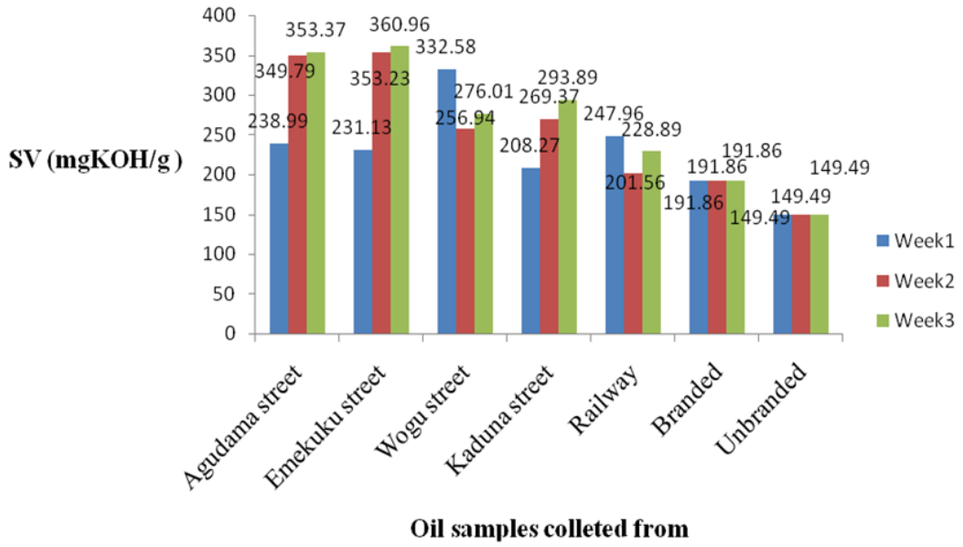

Figure-4. Saponification values (mgKOH/g) of the frying oils collected at weekly intervals.

3.1.6. Smoke Point of Frying Oils

Result of the smoke points of the frying oils collected is presented in Figure 5. The smoke point is the temperature at which a fat or oil produces a continuous wisp of smoke when heated. The maximum smoke point observed was for the reference samples (170°C and 160°C for branded and unbranded vegetable oils respectively). At week 1, the smoke point of all the frying oils ranged between 123-155°C, week 2, 130-165°C and week 3, 110-150°C. A decline in the smoke point of frying oils collected from Agudama, Emekuku and Wogu Street for all the three weeks studied. For Kaduna and Railway, an increase was observed only at week 2, following this was a decrease. This was consistent with the findings of Choudhary and Grover [33] that a decrease in smoke point was observed after first, second and third frying of rice bran oil blends. According to Sarwar, et al. [34] the smoke point of cooking oil must be at least 170°C. The findings of the present study were not in line with this statement as all the frying oil samples collected (except for the branded control) had smoke point <170°C even up to the third week of collection. This may be due to the level of impurities in the oil from the frying process.

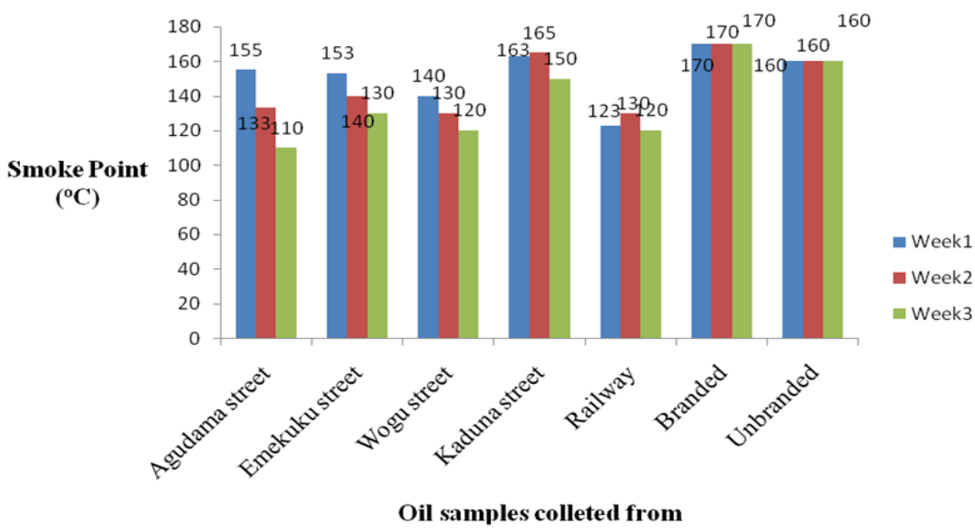

Figure-5. Smoke points (°C) of the frying oils collected at weekly intervals.

3.1.7. Moisture Content of Frying Oils

Result of the moisture content of the frying oils collected is shown in Figure 6. For all the samples collected at week 1, the moisture content of the frying oils were found to be in the range of 0.13-0.20% with samples collected from Agudama street recording lowest while samples from Railway and the unbranded sample were highest. After three weeks of collection, the moisture was found to be in a range of 0.10-0.20% with frying oils from railway recording lowest and unbranded samples recording highest. However, there was no significant ($p>0.05$) difference in the moisture content of the frying oils studied. The frying oils collected had values below the 0.2% maximal limit for volatile matters at 105°C in oil and fats [35].

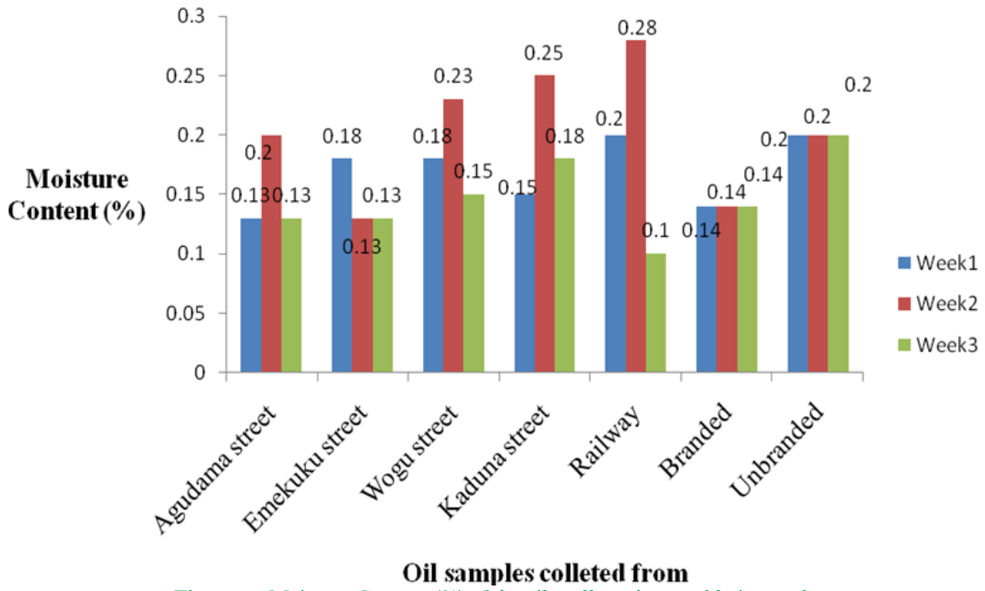

Figure-6. Moisture Content (%) of the oils collected at weekly intervals.

3.2. Antioxidant Properties of the Frying Oils

3.2.1. Total Phenolic Content (TPC)

Result of the total phenolic content of the frying oils collected is presented in Figure 7. Total phenolic content of the frying oils at week 1, 2 and 3 ranged from 0.01-0.37mgGAE/g, 0.02-0.37mgGAE/g and 0.00-0.37mgGAE/g, respectively. There was a decrease in the TPC of frying oils collected from Agudama, Worgu, Emekuku and Railway Streets at 3rd week of collection while those from Kaduna recorded an increase. Total phenolic content of control (branded oil) was significantly higher ($p<0.05$) than all other frying oils while total phenolic content of unbranded oil did not differ with oil collected from Kaduna at 3rd week of collection and from Railway, Emekuku and Agudama at first week of collection. The decrease in total phenolic content of oil during frying operations is as a result of the exposure of the frying oil to high temperature and long time during deep frying. The total phenolic content of the oils are close to that of Güzel, et al. [36] for vegetable oils in Turkey (0.133-1.596mgGAE/ml). The results are higher than that of Xuan, et al. [37] for commercial vegetable edible oils marketed in Japan (1.76-39.16mgGAE/g). Results presented here are in correlation with that of Gómez-Alonso, et al. [38] where the reduction of antioxidant activity of olive oil correlated well with the number of deep-frying cycles. Phenolics are known for their role in the oxidative stability of oils. Their presence may also prevent deterioration of oils through quenching of radical reactions responsible for rancidity [39, 40].

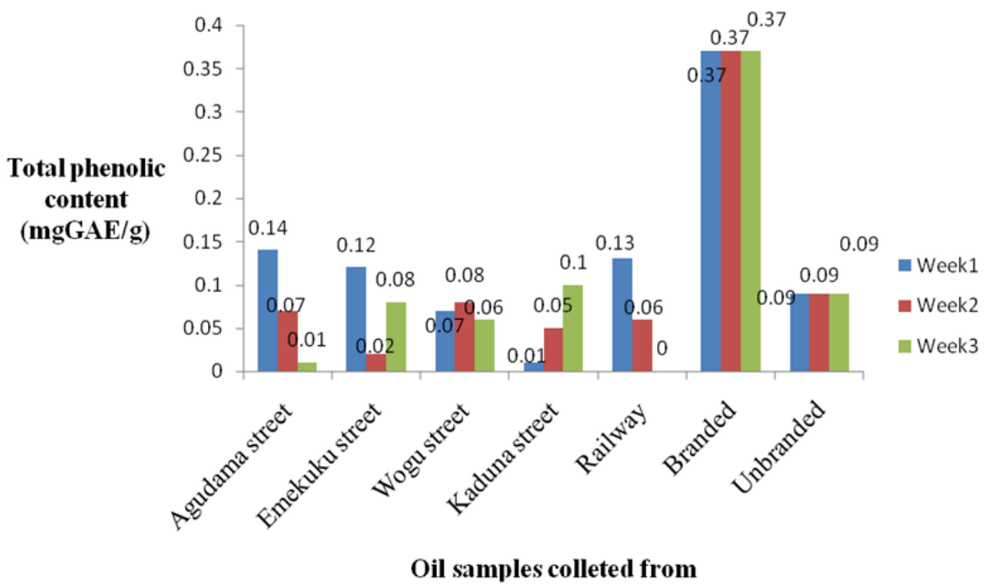

Figure-7. Total phenolic content (mgGAE/g) of the oils collected at weekly interval.

3.2.2. Flavonoid Content of the Oils

Result of the flavonoid content of the frying oils collected is shown in Figure 8. Initial flavonoid content of the frying oils collected ranged from 0.77-2.20% with oil collected from Wogu Street observed to be the lowest while the branded oil was highest. At week 2 and 3, oils collected from Agudama and Kaduna streets were lowest in flavonoid content. Flavonoid content of branded oil was significantly higher ($p<0.05$) than the frying oils collected while at week 3, it showed no significant difference ($p>0.05$) except for oil collected from Kaduna street and unbranded oil. Flavonoids are known for their antioxidant, anti-inflammatory, anti-atherosclerotic and anti-carcinogenic properties [41]. They are among antioxidant defensive systems protecting vegetable oils against oxidative damage.

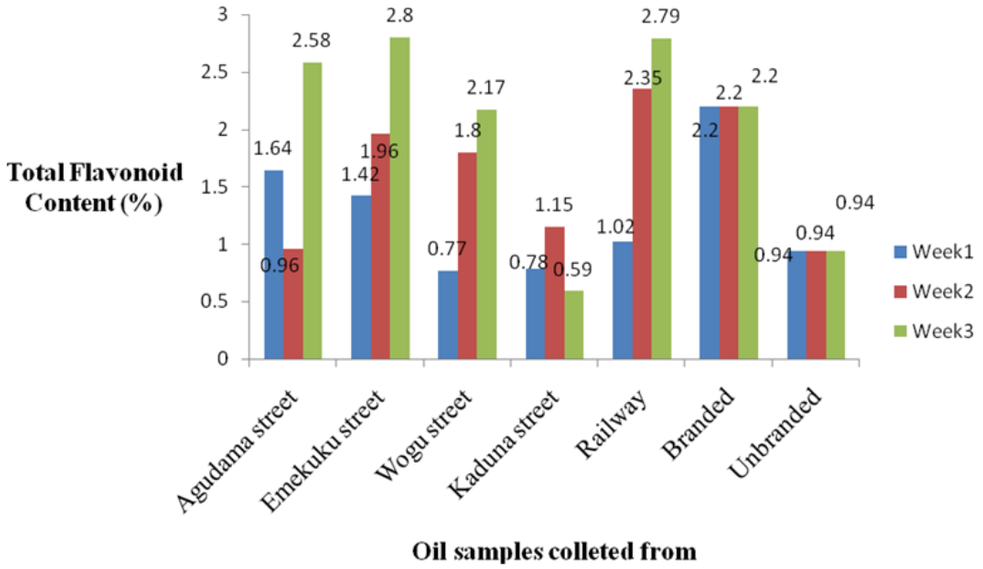

Figure-8. Flavonoid content (%) of the oils collected at weekly interval.

4. Conclusion

The study results showed degradation in the physicochemical and antioxidant properties of the vegetable cooking oil after repetitive use of frying. All oil samples collected at first week from Wogu and Kaduna Streets were within an acceptable range for percentage free fatty acid and as the weeks progressed, they were above the permissible limit. There was also an increase in peroxide value of some oils while others showed a decrease, however all the frying oils collected were within the Codex regulatory limit. All the oils collected showed a decrease in Iodine value except for samples collected from Agudama and Railway close while increase in saponification value above the specification for the oils was observed. Smoke point of the oils not in line with standard limits even up to third week of collection while moisture content was below the 0.3% maximum limit. Total phenolic content of the oils were relatively low and this decreased as collection weeks progressed except for oils from Kaduna Street while a reverse was observed for flavonoid content. This study therefore shows the level of degradation in the quality of oils used by these fried food vendors during frying operations. Safety measure should therefore be put in place as these degradations in oil quality could cause damaging health effects due to the toxic substances produced. Degraded oils are not suitable for human consumption but can be used for alternate uses including biodiesel and soap production.

References

[1] F. A. Rehab and A. M. El Anany, "Physicochemical studies on sunflower oil blended with cold pressed tiger nut oil during deep frying process," *Grasas Y Aceites*, vol. 63, pp. 455-465, 2012. Available at: https://doi.org/10.3989/gya.057612.

[2] J. Marcano, Y. La Rosa, and N. Salinas, "Influence of the deep fat frying process on the lipid profile of the fat contained in the French type fried potato using palm olein," *Grasas y Aceites*, vol. 61, pp. 24-29, 2010.

[3] E. O. Ngozi, O. H. Giwa, B. K. Adeoye, I. F. Ani, N. C. Ajuzie, and T. I. Olutayo, "Quality effect of repetitive use of frying oil by street food vendors on quality of the oil," *Nigerian Journal of Nutritional Sciences*, vol. 40, pp. 73-78, 2019.

[4] N. Idun-Acquah, Y. O. George, and M. Ebenezer, "Repetitive use of vegetable cooking oil and effects on physico-chemical properties–Case of frying with redfish (Lutjanus fulgens)," *Science and Technology*, vol. 6, pp. 8-14, 2016.

[5] Codex Alimentarius Commission/FAO/WHO Food Standards, *Codex standards for named vegetable oils*: CODEX STAN 210. CX-STAN 210-1999, 2000.

[6] N. Gotoh and W. Shun, "The importance of peroxide value in assessing food quality and food safety," *Journal of the American Oil Chemists Society*, vol. 83, pp. 473-474, 2006. Available at: https://doi.org/10.1007/s11746-006-1229-4.

[7] N. J. T. Emelike, A. E. Ujong, and S. C. Achinewu, "Knowledge and practice of local fried food vendors in D/line, Port Harcourt, Rivers State regarding the quality of oils used for frying," *Research Journal of Food Science and Quality Control*, vol. 6, pp. 32-43, 2020.

[8] M. Flores, L. Meyer, S. Orellana, C. Saravia, C. Galdames, and M. C. Perez-Camino, "Quality of lipid fractions in deep-fried foods from street vendors in Chile," *Journal of Food Quality*, vol. 2018, pp. 1-8, 2018. Available at: https://doi.org/10.1155/2018/7878439.

[9] E. Mensah and G. Y. Obeng, "Assessment and projection of waste vegetable oils from hotels for biodiesel feedstock and CO2 savings in Ghana," *International Journal of Engineering Research and Science and Technology*, vol. 2, pp. 1-12, 2013.

[10] J. Good, "Healthiest cooking oil chart with smoke points, baseline of health foundation. Retrieved from https://www.jonbarron.org/article/healthiest-cooking-oil-chart-smokepoints," 2012.

[11] A. Lapointe, C. Charles, and L. Simone, "Effects of dietary factors on oxidation of low-density lipoprotein particles," *The Journal of Nutritional Biochemistry*, vol. 17, pp. 645-658, 2006.

[12] C. Garrido-Polonio, M. C. Garcia-Linares, M. T. Garcia-Arias, S. Lopez-Varela, H. R. Garcia-Katragadda, S. S. A. Fullana, and A. A. Carbonell-Barrachina, "Emissions of volatile aldehydes from heated cooking oils," *Food Chemistry*, vol. 120, pp. 59-65, 2009.

[13] AOCS, *Official methods and recommended practices*, 6th ed. Champaign: American Oil Chemists' Society, 2009.

[14] N. Emelike, M. Akusu, and A. Ujong, "Antioxidant and physicochemical properties of oil extracted from cashew (Anacardium occidentale L) kernels," *International Journal of Food Science and Nutrition*, vol. 2, pp. 122-128, 2017.

[15] B. Boham and R. Kocipai-Abyazan, "Flavonoids and condensed tannins from leaves of Hawaiian Vaccinium vaticulatum and V. calycinium," *Pacific Science*, vol. 48, pp. 458-463, 1974.

[16] T. A. T. Wahua, *Applied statistics for scientific studies*. Aba, Nigeria: African Link Press, 1999.

[17] H. Mamat, I. N. Aini, M. Said, and R. Jamaludin, "Physicochemical characteristics of palm oil and sunflower oil blends fractionated at different temperatures," *Food Chemistry*, vol. 91, pp. 731-736, 2005. Available at: https://doi.org/10.1016/j.foodchem.2004.06.045.

[18] S. Lalas, *Quality of frying oil. In: S. Sahin, S.G. Sumnu, editors. Advances in deep-fat frying of foods*. Boca Raton: CRC Press, 2009.

[19] M. McWilliams, *Nutrition and dietetics*, 8th ed. Singapore: Pearson Education Inc, 2007.

[20] O. Faroon, N. Roney, J. Taylor, A. Ashizawa, M. Lumpkin, and D. Plewak, "Acrolein health effects," *Toxicology and Industrial Health*, vol. 24, pp. 447-490, 2008.

[21] J. Chung, J. Lee, and E. Choe, "Oxidative stability of soybean and sesame oil mixture during frying of flour dough," *Journal of Food Science*, vol. 69, pp. 574-578, 2004. Available at: https://doi.org/10.1111/j.1365-2621.2004.tb13652.x.
[22] G. Mazza and H. Qi, "Effect of after-cooking darkening inhibitors on stability of frying oil and quality of french fries," *Journal of the American Oil Chemists Society*, vol. 69, pp. 847-853, 1992. Available at: https://doi.org/10.1007/bf02636331.
[23] A. T. Thomas, *Fats and fatty oils. Ulmann's encyclopedia of industrial chemistry*. Wenheim: Wiley-VCH, 2002.
[24] S. Sulthana and D. Sen, "Studies on deep fat frying-changes during heating of oil," *Journal of Food Science and Technology, India*, vol. 16, pp. 208-213, 1979.
[25] J.-M. Park and J.-M. Kim, "Monitoring of used frying oils and frying times for frying chicken Nuggets using peroxide value and acid value," *Korean Journal for Food Science of Animal Resources*, vol. 36, pp. 612-616, 2016. Available at: https://doi.org/10.5851/kosfa.2016.36.5.612.
[26] A. Serjouie, C. P. Tan, H. Mirhosseini, and Y. Che Man, "Effect of vegetable-based oil blends on physicochemical properties of oils during deep-fat frying," *American Journal of Food Technology*, vol. 5, pp. 310-323, 2010. Available at: https://doi.org/10.3923/ajft.2010.310.323.
[27] D. G. Atinafu and B. Bedemo, "Estimation of total free fatty acid and cholesterol content in some commercial edible oils in Ethiopia, Bahir DAR," *J Cereals Oil Seeds*, vol. 2, pp. 71-76, 2011.
[28] G. Otunola, G. Adebayo, and O. Olufemi, "Evaluation of some physicochemical parameters of selected brands of vegetable oils sold in llorin metropolis," *International Journal of Physical Sciences*, vol. 4, pp. 327-329, 2009.
[29] T. Omara and E. Kigenyi, "Effects of continuous deep fat frying on the physical and chemical properties of assorted brands of cooking oils sold in Metropolitan Kampala," *Asian Journal of Applied Chemistry Research*, vol. 3, pp. 1-13, 2019. Available at: https://doi.org/10.9734/ajacr/2019/v3i230086.
[30] J. Chebet, T. Kinyanjui, and P. K. Cheplogoi, "Impact of frying on iodine value of vegetable oils before and after deep frying in different types of food in Kenya," *J. Sci. Innov. Res*, vol. 5, pp. 193-196, 2016.
[31] S. Iiyas, "Peroxide and saponification value to some packaging of palm oil after frying repeatedly," *International Journal of PharmaTech Research*, vol. 9, pp. 560-564, 2016.
[32] A. I. Alajtal, F. E. Sherami, and M. A. Elbagermi, "Acid, peroxide, ester and saponification values of some vegetable oils before and after frying," *American Association for Science and Technology*, vol. 4, pp. 43-47, 2018.
[33] M. Choudhary and K. Grover, "Effect of deep-fat frying on physicochemical properties of rice bran oil blends," *Journal of Nursing and Health Science*, vol. 1, pp. 1-10, 2013.
[34] A. Sarwar, S. Vunguturi, and A. Ferdose, "A study on smoke point and peroxide values of different widely used edible oils," *International Journal of Engineering Technology Science and Research*, vol. 3, pp. 271-273, 2016.
[35] Codex Alimentarius Commission/FAO/WHO, *Food standards. Standard for named vegetable oils*: CODEX-STAN 210, Ed. FAO/WHO, 2011.
[36] S. Güzel, E. N. Herken, and O. Erel, "Total antioxidant capacity and total phenol contents of Turkish edible oils," *Academic Food*, vol. 7, pp. 13-17, 2009.
[37] T. D. Xuan, G. Gangqiang, T. N. Minh, T. N. Quy, and T. D. Khanh, "An overview of chemical profiles, antioxidant and antimicrobial activities of commercial vegetable edible oils marketed in Japan," *Foods*, vol. 7, p. 21, 2018. Available at: https://doi.org/10.3390/foods7020021.
[38] S. Gómez-Alonso, G. Fregapane, M. D. Salvador, and M. H. Gordon, "Changes in phenolic composition and antioxidant activity of virgin olive oil during frying," *Journal of Agricultural and Food Chemistry*, vol. 51, pp. 667-672, 2003. Available at: https://doi.org/10.1021/jf025932w.
[39] A. Siger, M. Nogala-Kalucka, and E. Lampart-Szczapa, "The content and antioxidant activity of phenolic compounds in cold-pressed plant oils," *Journal of food lipids*, vol. 15, pp. 137-149, 2008. Available at: https://doi.org/10.1111/j.1745-4522.2007.00107.x.
[40] A. Koski, S. Pekkarinen, A. Hopia, K. Wähälä, and M. Heinonen, "Processing of rapeseed oil: Effects on sinapic acid derivative content and oxidative stability," *European Food Research and Technology*, vol. 217, pp. 110-114, 2003. Available at: https://doi.org/10.1007/s00217-003-0721-4.
[41] K. S. Mala and A. E. Kurian, "Nutritional composition and antioxidant activity of pumpkin wastes," *International Journal of Pharmaceutical, Chemical and Biological Sciences*, vol. 6, pp. 336-344, 2016.