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Evaluation of the Physicochemical Properties of Re-used Frying Oils Treated with Natural Antioxidating Materials; Onion, Ginger, Turmeric and Carrot

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Abstract: This studyevaluated the physicochemical properties of re-used frying oils treated with natural antioxidating materials; onion, ginger, turmericand carrot.Yam chips of 300g was fried in 1.5 liters of oil in five (5) different oil systems at temperatures between 160 to 190^{0}C for 30 days at three-days interval; Samples A: oil without plant material, B: oil plus 50g onions (O), C: oil plus 50g ginger (G), D: oil plus 50g turmeric (T), and E: oil plus 50g carrot (C). The oil samples (100ml) were collected in amber bottles after every frying round and topped to theoriginal volume with fresh oils. The physicochemical properties of the oil samplesweredetermined and the data obtained were analyzed using Analysis of variance (ANOVA) from the Statistical Package for Social Sciences (SPSS) version 25.The result obtained from the physicochemical propertiesof samples A to E showed that there was no significant ($p>0.05$) effect on the acid value (1.12 to 1.85 mgKOH/g), peroxide value (3.3 to 10.2 mEq/kg), specific gravity (0.92 to 0.96 g/ml), refractive index (1.47 to 1.55), viscosity (0.03 to 0.4 mp), flash point (277 to 399^{0}C), smoke point (180 to 260^{0}C) and fire point (326 to 470^{0}C) of the oil systems while free fatty acid (0.16 to 0.26 %), saponification value (101.18 to 110.83 mgKOH/g), iodine value (18.40 to 161.80gI2/100g)and melting point (11 to 18.2^{0}C) were statistically significant ($p<0.05$). All the oil systems maintained their initial colours of amber yellow for samples A, B, C,E, while sample D has a golden yellow colour which was as a result of higher curcumin in turmeric.The plant materials showed potentials in reduction of lipid oxidations of re-used frying oil.

Keywords:re-used frying oil, lipid oxidation, natural antioxidants, plant materials, physicochemical

I. Introduction

Frying is one of the oldest and quickest methods of food preparation used by man especially the ancient Egyptians in the sixth century BC (Elham, 2008). It is one of the popular and convenient methods of food preparation used both at homes and commercial places due to its specific and desirable effects on the sensory properties (flavor, colour, taste, crispiness) of foods which make them more desirable and acceptable (St. Angelo*et al.*,1996). Frying is generally referred to as one of the processes or methods of cooking foods which is achieved in hot oil or fat at high temperatures between 160-190°C (Boskou*et al.*, 2006). Frying can be achieved by complete immersion of foods in fat or oil (deep frying), placing foods on pan half covered with fat or oil (shallow frying), or without any addition of fat or oil or by using only the oil that comes out directly from the food products to fry the food (dry frying) (Merry, 2015). Due to high temperatures involved in frying, in addition to exposure of the oil to atmospheric oxygen and moisture, a lot of deteriorative processes such as hydrolysis, lipid oxidation and thermal alteration occur which on the other hand produce numerous compounds including phytosterol oxidation products which may adversely affect consumers' health, shelf-life and nutritional quality of the product being fried (Ramadan *et al*., 2006).

Lipid oxidation is referred to as uncontrolled oxidative degradation of lipids initiated by free radical reactions between fatty acids and oxygen, resulting to rancidity and deterioration (Elham, 2008). Lipid oxidation is an important chemical reaction between unsaturated lipids and active oxygen species (Min and Boff, 2002). The overall stages of lipid oxidation consist of three steps; initiation, propagation and termination (Raharjo and Sofos, 1993). According to Akram *et al*. (2012), lipid oxidation has been seen as one of the major causes of food quality deterioration, off-odours and off-flavours development, reduction of shelf-life, alteration of texture and colour of foods as well as reduction in nutritional value of food item.

However, among all the methods used in controlling lipid oxidation, the use of antioxidants has been the most effective method (Alam*et al.*, 2012).Antioxidants are chemical substances which are usedto control the activities of free-radicals during lipid oxidation, thereby improving the oxidative stability of fats and oils.Free radicals are highly reactive chemical species that contain one or more unpaired electrons (Cutson*et al.*, 1995). Natural antioxidants are sub – group of antioxidants found in food (plant and

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animal sources) without much processing (Hurrell, 2003). Natural antioxidants have become an indispensable group of food additives in food industries due to their distinctive features of increasing the shelf life of food products without being detrimental to health (Alam*et al.*, 2012).The main objective of this research work was to evaluate thephysicochemical properties of re-used frying oils treated with natural antioxidating materials; onion (*Allium cepa L.*), ginger (*Zingiber officinale*), turmeric (*Curcuma longa*) and carrot (*Dascus carota L*)

II. Materials And Method

2.1Materials

All plant materials; yam tubers (*Dioscorea esculanta*),tumeric, ginger, carrot, onion and vegetable oil (kings' oil brand) were purchased from *Ekeukwu* Owerri Market in Imo State. A mechanical yam slicer was used for yam slicing and an electric deep fryer (Model No XJ-10302) was used for the frying process.

2.2Methods

2.2.1Frying experiment

Deep-frying of yam chips with vegetable oil was done using the method as described by Alireza *et al.* (2010). Yam tubers were peeled and sliced to a thickness of 2 mm and cut into desired chips using a mechanical slicer. The chips were washed and drained in a sieve before weighing into 200 g batch for frying. The samples were added to the respective oil when the temperature of the oil reaches 60 ^{0}C. Frying of yam chips was done between 160 to 190 ^{0}C, every 3 days (morning) intervals for a period of 30days. The electric frying machine was left uncovered during the frying period. At the end of the frying, the electric fryer was switched off and the temperature was allowed to drop to ambient temperature. Oil samples for analysis (100 ml) was collected in amber bottles and then stored for analysis.

2.3Physicochemical properties of oil samples

2.3.1Acid value (AV)

Free fatty acid was determined using the method described in Food Safety and Standards Authority of India lab manual 2 (FSSAI, 2015). Ethyl alcohol was prepared by adding 95% alcohol to phenolphthalein indicator. Phenolphthalein indicator solution was also prepared by dissolving 1g of phenolphthalein in 100 ml of ethyl alcohol. 1g of oil sample was accurately weighed in a 250 ml conical flask and 50 ml to 100 ml of freshly neutralized hot ethyl alcohol was added and about 1 ml of phenolphthalein indicator solution was also added. The mixture was boiled for about five minutes and titrated while hot against standard alkali solution shaking vigorously until a pink color persisted for 15 seconds. Acid is calculated thus;

$$\text{Acid value} = \frac{5.61 \times V \times N}{W} \quad (1)$$

V = Volume in ml of standard potassium hydroxide or sodium hydroxide used

N = Normality of the potassium hydroxide solution or Sodium hydroxide solution

W = Weight in g of the sample

Note: Acid value is also expressed as percentage free fatty acid calculated as oleic acid

2.3.2Iodine value (IV)

Iodine value was measured according to the method described by (William and Vida, 2015). Wiji's reagent was prepared by dissolving 8g of iodine trichloride in 200 ml glacial acetic acid and 9 g of iodine in 300 ml carbon tetrachloride. The two solutions were mixed together and diluted to 1000 ml with glacial acetic acid. 1g of oil sample was weighed into a 500mL volumetric flask. 15 ml of carbon tetrachloride was added to the sample and swirled to ensure that the sample is completely dissolved. 25 ml of Wiji's solution was then dispensed into the flask containing the sample using a pipette. The flask was stoppered and swirled to ensure complete mixing. The sample was then placed in the dark for 30 minutes at room temperature. The flask was removed from storage and 20mL of 10% potassium iodide (KI) solution added, followed by 150 ml of distilled water. The mixture was titrated with 0.1 N thiosulphate ($Na_2S_2O_3$) solution, adding gradually and with constant and vigorous shaking until the yellow colour. A 1.5ml of starch indicator solution was added and the titration was continued until the blue colour disappeared. A blank determination was conducted simultaneously.

$$\text{Iodine Value} = \frac{1.269 \times N \times (V_2 - V_1)}{W} \quad (2)$$

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Where;

N = Normality of thiosulphate solution,

V_1 = Volume of thiosulphate solution used in test

V_2 = Volume of thiosulphate solution used in blank

W = Weight of sample

2.3.3Saponification value (SV)

The saponification value was measured according to the method described byUzoma *et al*.(2002). A 1g of the oil sample was weighed into a volumetric flask. Then 25 ml of 1.0 N alcoholic KOH was pipetted and allowed to stand in the mixture for about 1 minute. The mixture was allowed to boil gently under a reflux condenser for 45 minutes with swirling at frequent intervals. The excess alkali was determined while the solution was still hot by titrating with 0.5 N hydrochloric acid (HCl) using 1 ml of phenolphthalein indicator until the pink colour disappeared. A blank determination was conducted simultaneously on the sample with the same quantity of potassium hydroxide solution under the same condition.

$$\text{Saponification value} = \frac{28.05 \times (V_2 - V_1)}{W} \quad (3)$$

Where;

V_1= volume of HCl used in the test, (ml)

V_2 = volume of HCl used in the blank, (ml)

W = weight of sample, (g)

2.3.4Free Fatty Acid (FFA)

Free fatty acid was determined using the method described in Food Safety and Standards Authority of India lab manual 2 (FSSAI, 2015). Ethyl alcohol was prepared by adding 95% alcohol to phenolphthalein indicator. Phenolphthalein indicator solution was also prepared by dissolving 1g of phenolphthalein in 100 ml of ethyl alcohol. 1g of oil sample was accurately weighed in a 250 ml conical flask and 50 ml to 100 ml of freshly neutralised hot ethyl alcohol was added and about 1 ml of phenolphthalein indicator solution was also added. The mixture was boiled for about five minutes and titrated while hot against standard alkali solution shaking vigorously until a pink colour persisted for 15 seconds. Free fatty acid is calculated thus;

$$\text{Free fatty acid (FFA) in percentage weight (as oleic acid)} = \frac{2.82 \times N \times V}{W} \quad (4)$$

Where;

V = Volume in ml of standard potassium hydroxide or sodium hydroxide used

N = Normality of the potassium hydroxide solution or Sodium hydroxide solution

W = Weight in g of the sample

2.3.5Peroxide Value (PV)

This was determined using the method described in (Uzoma *et al*., 2002; Awuchi, *et al*., 2018). Reagent preparation was carried out by mixing 3 parts by volume of glacial acetic acid, reagent grade, with 2 parts by volume of chloroform U.S.P. grade. Potassium iodide solution was prepared by adding saturated solution of KI, A.C.S grade, in recently boiled distilled water and stored in the dark. It was tested daily by adding 2 drops of starch solution to 0.5ml of the potassium iodide solution in 30ml of acetic acid-chloroform solution. 0.1N accurately standardized solution of sodium thiosulfate was prepared by accurately pipetting 100ml of the 0.1 N solution into 1000ml volumetric flask and diluted with recently boiled distilled water. 1.0% of soluble starch was dissolve in distilled water to form the starch indicator solution. 1g of the sample was weighed into a 250 ml glass stopper Erlenmeyer flask and then, 30ml of acetic acid-chloroform solution was added. The flask was swirled until the sample was dissolved in the solution. 0.5ml of saturated potassium iodide was added using Mohr type measuring pipette. The solution was allowed to stand for exactly 1 minute with occasional shaking and then 30ml of distilled water was added. The solution was titrated with gradual addition of 0.1 N Sodium thiosulfate by constant and vigorous shaking until the yellow colour almost disappeared. 0.5 ml of starch indicator was added and the titration continued with constant and vigorous shaking of the flask in order to liberate all the iodine from the chloroform layer. Drops of thiosulfate were added until the blue colour disappeared. The

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blank titration of the reagents was carried out daily with 0.1ml of the 0.1N sodium thiosulfate solution. Peroxide value is calculated as;

$$\text{Peroxide value} = \frac{(S-B)\times N\times 1000}{W} \quad (5)$$

Where;

B= Titration of blank

S= Titration of sample

N= Normality of sodium thiosulfate solution

W= Weight of sample

2.3.6Specific Gravity (SG)

The specific gravity was determined according to the method described in Food Safety and Standards Authority of India lab manual 2 (FSSAI, 2015). A dry pycnometer was filled with the prepared sample in such a manner to prevent entrapment of air bubbles after removing the cap of the side arm. A stopper was inserted and then it was immersed in water bath at 30 ^{0}C and held for 30 minutes. Any oil spillage out of the capillary opening was carefully wiped out. The bottle was removed from the bath, cleaned and thoroughly dried. The cap of the side arm was removed and quickly weighed ensuring that the temperature does not fall below 30 ^{0}C.

$$\text{Specific gravity at 30 } ^0\text{C} = \frac{A-B}{C-B} \quad (6)$$

Where;

A = weight in gram of specific gravity bottle with oil at 30^{0}C

B = weight in gram of specific gravity bottle at 30^{0}C

C = weight in gram of specific gravity bottle with water at 30^{0}C

2.3.7Refractive Index (RI)

Refractive index was determined according to the method described in Food Safety and Standards Authority of India lab manual 2 (FSSAI, 2015). A few drops of the filtered dry sample were placed on a glass prism. Water was sprayed on the surface of the instrument in order to unify the temperature of the instrument with that of the sample. The prism was closed and allowed to stand for 2 minutes. The instrument and lighting were adjusted to obtain the most distinct reading possible in order to determine the refractive index. A clean tissue paper was used to wipe off oil on the refractometer between readings. The glass prism was also cleaned regularly with petroleum ether on clean tissue paper and then allowed to dry. The process was done in duplicate.

2.3.8Flash Point (FP)

Flash point was determined according to the method described in Food Safety and Standards Authority of India lab manual 2 (FSSAI, 2015). All parts of the cup and its accessories were thoroughly cleaned and dried before starting the test, making sure that any solvent which had been used to clean the apparatus was removed. The tester was supported on a level steady table. The cup was filled with the oil sample to be tested up to the level indicated by the filling mark. The lid was placed on the cup and properly engaged the heating devices. The thermometer was inserted and the test flame was lit and adjusted to 4.0 mm in diameter. The sample was heated so that the temperature increase was about 5 to 6 ^{0}C per min. During the heating, the stirring device was turned from one to two revolutions per second. The test flame was applied when the temperature of the sample is a whole number not higher than 17 ^{0}C below the flash point at every 5 ^{0}C rise in temperature, stirring was stopped and the test flame applied by opening the device which controls the shutter and lowers the test flame into the shutter opening for about 0.5 second and quickly returned to the raised position. As soon as the test flame had been returned to the raised position, stirring was resumed. The flash point is the temperature indicated by the thermometer at the time of the flame application that causes a distinct flash in the interior of the cup.

2.3.9Melting Point (MP)

Melting point was determined using the method described in Food Safety and Standards Authority of India lab manual 2 (FSSAI, 2015). The sample was melted and filtered through a filter paper to remove any impurities and last traces of moisture. The dry

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sample was thoroughly mixed. A capillary tube was inserted into the molten sample, so that a column of the sample, about 10 mm long, was sucked into the tube. 3 of such clean capillary tubes were dipped into the liquid sample completely so that the sample rises about 10 mm high in the tubes. It was chilled at once by holding the ends of the tubes that contain the sample against a piece of ice until the fat solidifies. The tube was placed in a small beaker and held in a refrigerator at 4^0C to 10 ^{0}C for 16 hours. The tube was removed from the refrigerator and attached with a rubber band to the thermometer bulb, so that the lower end of the capillary tube and the thermometer bulb are at the same level. The thermometer was suspended in 600 ml beaker of clear distilled water. The bottom of thermometer was immersed in the water to the immersion mark. Water was taken at 10 ^{0}C in the 'Thiele' tube and the thermometer with the capillary tube containing the sample of oil was immersed into it. The temperature was gradually increased by heating at the side-tube of the Thiel Tube at the rate of 2 ^{0}C per min, till the temperature reaches 25 ^{0}C, and thereafter at the rate of 0.5 ^{0}C per min. The temperature of the water when the sample column begins to rise in the capillary tube was noted. Report of the average of two such separate determinations was given as melting point.

2.3.10Smoking Point (SP)

Smoking point was determined using the method described in AOCS Official Method Cc 9a-48 2012 (De Alzaa*et al*., 2018; Shashikant, 2020). A test portion of each oil sample was filled into a cup, and heated until a continuous bluish smoke appeared. *Each measurement was twice*.

2.3.11Fire Point (FP)

Fire point was determined according to the method described in Food Safety and Standards Authority of India lab manual 2 (FSSAI, 2015;Shashikant, 2020). All parts of the cup and its accessories were thoroughly cleaned and dried before starting the test, making sure that any solvent which had been used to clean the apparatus was removed. The tester was supported on a level steady table. The cup was filled with the oil sample to be tested up to the level indicated by the filling mark. The lid was placed on the cup and properly engaged the heating devices. The thermometer was inserted and the test flame was lit and adjusted to 4.0 mm in diameter. The sample was heated so that the temperature increase was about 5 to 6 ^{0}C per min. During the heating, the stirring device was turned from one to two revolutions per second. The test flame was applied when the temperature of the sample is a whole number not higher than 17 ^{0}C below the flash point at every 5 ^{0}C rise in temperature, stirring was stopped and the test flame applied by opening the device which controls the shutter and lowers the test flame into the shutter opening for about 0.5 second and quickly returned to the raised position. As soon as the test flame had been returned to the raised position, stirring was resumed. The flash point is the temperature indicated by the thermometer at the time of the flame application that causes a distinct flash in the interior of the cup. The heating is continued after every 10 ^{0}C rise in temperature; the oil vapours are tested for fire points. The temperature at which the experimenting oil catches fire at least 5 seconds was recorded as its fire point.

2.3.12Viscosity

Viscosity was determined using the method described by American Society for Test and Material ASTM D 2270 (Ioana, 2014).The oil viscosity was determined with calibrated Schott Ubbelohde-type viscometers at temperatures 40 and 100^0C. The viscometer was placed in a temperature-controlled vessel equipped with a thermostat which maintained the temperature with an accuracy of ±0.1. The temperature error in viscosity determination was less than 0.5 %. Density and temperature were measured using a 25^0C pycnometer immersed in a temperature – controlled circulating water bath. The viscosity values at each temperature were determined by multiplying the measured flow time on the oil through the viscometer capillary with a calibration constant.

2.3.13Colour

Colour was determined by using the method described in Food Safety and Standards Authority of India lab manual 2 (FSSAI, 2015). Making sure that the sample was absolutely clear and free from turbidity, the glass cell of desired size was cleaned with carbon tetrachloride and allowed to dry. It was filled with the oil sample and placed in position in the tintometer. The colour was matched with sliding red, yellow and blue colours. The colour of the oil was reported in terms of Lovibond units as follows: -

Colour reading = (aY + 5bR) or (aY + 10bR) (7)

Where;

a = sum total of the various yellow slides (Y) used

b = sum total of the various red (R) slides used

Y + 5R = the mode of expressing the colour of light-coloured oils

Y + 10 R =for the dark-coloured oils

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III.Results And Discussion

3.1Physicochemical properties of frying oil treated with natural antioxidating materials

3.1.1Acid value

The acid value is seen as a measure of the quantity of fatty acids which have been liberated by hydrolysis of glycerides due to the actions of moisture, temperature and or lipolytic enzyme lipase during frying (FSSAI, 2015). The results of the acid values obtained in this work for the oil systems A, B, C, D, and E is contained in Figure 1. The table shows that at the end of the frying period (D_{27}) the acid values of the oil systems A, B and C increased from 1.18mg/g to 1.51mg/g, 1.12mg/g to 1.78mg/g and 1.15mg/g to 1.17mg/g while those of D and E decreased from 1.24mg/g to 1.22mg/g and from 1.21mg/g to 1.20mg/g. However, there were no significant differences among the acid values of the different oil systems indicating that the onion, ginger, turmeric and carrot added to the oil systems did not have much effect in controlling the acid values of the oils. The acid values obtained for the oil systems were higher than the FAO/WHO standard value (0.6 mg KOH/g) with a p-value of 0.341at ($p \leq 0.05$) including the control (A) (normal vegetable oil).

3.1.2Free fatty acid

Free fatty acid parameter is often used for assessment of the suitability of frying oils for human consumption and a value of 2% is defined as the limit for oil rejection (Matthaus, 2006). Thus, lipid oxidation and oil deterioration increase with increase in free fatty acid composition (Bhuiyan*et al.*, 2016). The results of the free fatty acid values of the oil systems are shown in Figure 2. The FFA for oil system A (control) and B (onion) at the end of the frying period (D_{27}) increased from 0.17mg/g to 0.22mg/g and 0.16mg/g to 0.26mg/g respectively suggesting that the onion added into oil system B had no positive effect in retarding oxidation of the oil system rather even increased the FFA of the oil. This could be associated to the higher water content in onion (85% onion, 80% ginger, 80% turmeric, and 70% carrot) Ahmad *et al*, (2012), which could have increased the water in the frying oil during frying and subsequent storage before reuse thus making it more prone to oxidation.

However, the FFA values of C (ginger), D (turmeric) and E (carrot) maintained the same values of 0.17mg/g, 0.18mg/g and 0.17mg/g which were their initial FFA values on D_o indicating the effects of these materials in retarding the production of FFA during repeated oil frying. However, the FFA values of all the oil systems conform to the Codex Alimentarius International Food Standard of 0.3% (CODEX ALIMENTARIUS, 2021) and the maximum permissible standard of Standard Organization of Nigeria (3.5mg /g oil) (SON, 2000).

3.1.3Saponification value

The knowledge of the saponification value of an oil sample helps in the quality assessment of the oil as oxidation of oil increases with increase in saponification value. Additionally, fats/oil with high saponification number or value is best for industrial purpose such as soap production and this adversely affects human health (De Alzaa*et al.*, 2018). The results of the saponification value of the oil systems are presented in Figure 3. The saponification value for oil system A (control), B (onion) and C (ginger) increased from 102.30mgKOH/g oil to 107.50mgKOH/g oil, 101.18mgKOH/g oil to 110.42mgKOH/g oil and 101.82mgKOH/g oil to 102.12mgKOH/g oil respectively suggesting that the onion and ginger added into oil system B and C had no positive effect in retarding oxidation of the oil system rather the helped in increasing the saponification value of the oil systems at the end of the frying period.

This could also be attributed to the reduction in chain length of the fatty acid characterized by the presence of high concentration of low molecular weight of free fatty acid in their triglycerides as a result of the high temperature which breaks down the oil into free fatty acid and glycerol leading to oil deterioration and oxidation (John *et al.*, 2021). On the other hand, the saponification value of D (turmeric) and E (carrot) decreased from 103.31mgKOH/g oil to 103.07mgKOH/g oil and 102.83mgKOH/g oil to 102.75mgKOH/g oil respectively indicating that these plant materials (turmeric and carrot) are effective in the reduction and control of the saponification value of oil during repeated frying as oil with high saponification is not healthy for human consumption rather better for industrial use (De Alzaa, *et al*., 2018). The reduction in saponification value could be associated with activities of the antioxidants in the plant materials which facilitates the increase in the molecular weight of the fatty acids in the glycerides (Mengistie*et al.*, 2018). However, these values were below the FAO/WHO specified standard for refined vegetable oil (194-202).

3.1.4Iodine value

Iodine value or number could be used to quantify the amount of double bond present in the oil which reflects the susceptibility of oil to oxidation (Uzomah*et al.*, 2002). The result of the iodine value of the oil systems are shown in Figure 4. The iodine results of all the oil systems at the end of the treatment period (D_{27}) A (control), B (onion), C (ginger), D (turmeric), and E (carrot)

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decreased from 109.77gI_2/100g oil to 38.07 gI_2/100g oil, 69.79 gI_2/100g oil to 65. 23 gI_2/100g oil, 77.09 gI_2/100g oil to 66.73 gI_2/100g oil, 46.95 gI_2/100g oil to 34.26 gI_2/100g oil and 90.10 gI_2/100g oil to 25.05gI_2/100g oil respectively. Oil system A, D and E have tremendous decrease while oil systems B (onion) and C (ginger) decreased slowly. The highest decrease in iodine value as observed in oil systems A, D, and E respectively indicates that the added turmeric and carrot have no significant in the control of the iodine value of the oil systems as a result of a decrease in double bonds or greater degree of unsaturation leading to oxidative rancidity (Alireza *et al*., 2010).

3.1.5Peroxide value

Peroxide value (PV) is one of the methods used for determining the amount of hydroperoxides which is the initial lipid oxidation products (John *et al*., 2021). The results of the peroxide value of the oil systems are presented in Figure 5. The results of the peroxide value of all the oil systems A, B, C, D, and E at the end of the frying period (D_{27}) increased from 3.7 mEq/kg to 5.0 mEq/kg, 3.8 mEq/kg to 7.0 mEq/kg, 4.0 mEq/kg to 8.2 mEq/kg, 4.0 mEq/kg to 9.0 mEq/kg and 4.1 mEq/kg to 5.1 mEq/kg respectively indicating that these plant materials have no significant effect in the reduction of the peroxide value of oil during re-usage.

The result further revealed that the increase in peroxide value could be as a result of the decomposition of peroxides that are formed during primary oxidation, breakage and saturation of bonds or decrease in unsaturation due to high temperature used during frying, leading to reduction in oil quality, rancidity as well as lipid oxidation (John *et al*., 2021). However, these values conformed to the FAO/WHO standard value (10 milli-Equivalent of active oxygen/kg oil) (NAFDAC, 2019;Alimentarius, 2021).

3.1.6Specific gravity

Specific gravity signifies heaviness of fats and oil compared to that of water. The specific gravity of unsaturated glycerides is higher than the corresponding saturated ones (West and Rousseau, 2016). The results of the specific gravity of the oil systems are shown in Figure 6. The specific gravity results of all the oil systems A, B, C, D, and E at the end of the frying period (D_{27}) increased from 0.92 g/ml to 0.95 g/ml, 0.92 g/ml to 0.94 g/ml, 0.92 g/ml to 0.96 g/ml, 0.92 g/ml to 0.94 g/ml and 0.92 g/ml to 0.94 g/ml respectively, indicating that these plant materials have no significant effect in the reduction of the specific gravity of oil during repeated frying process.

This increase could be as a result of increase in unsaturation and the release of particles of fragment of the plant materials in the oil systems. However, their results slightly deviated from the WHO/FAO recommended standard (0.899-0.920) (Alimentarius, 2021).

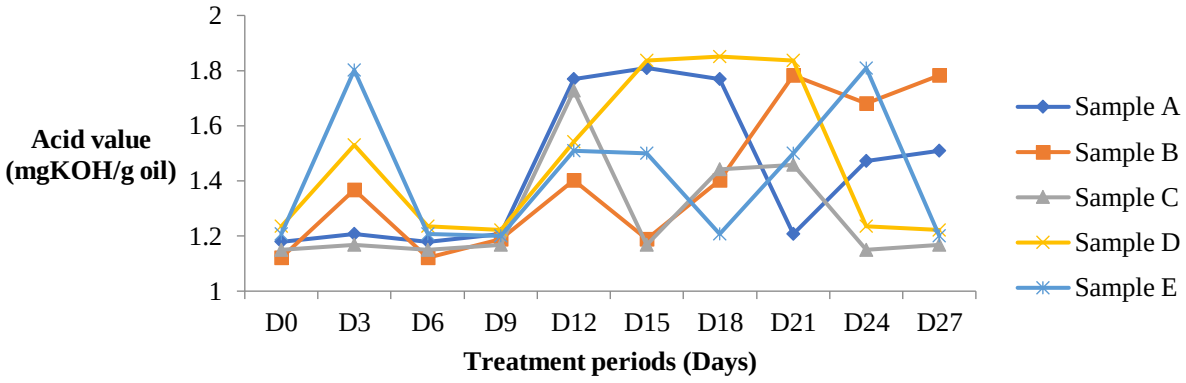

Figure 1: Result of the acid value of the different oil samples

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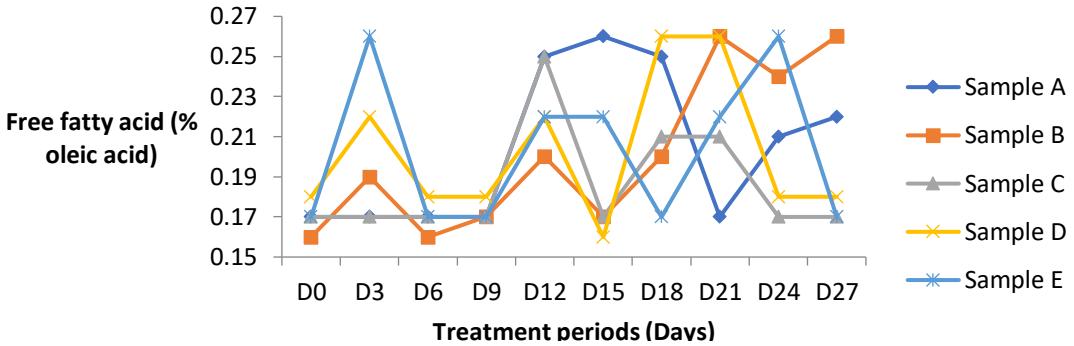

Figure 2: Result of the free fatty acid of the different oil samples

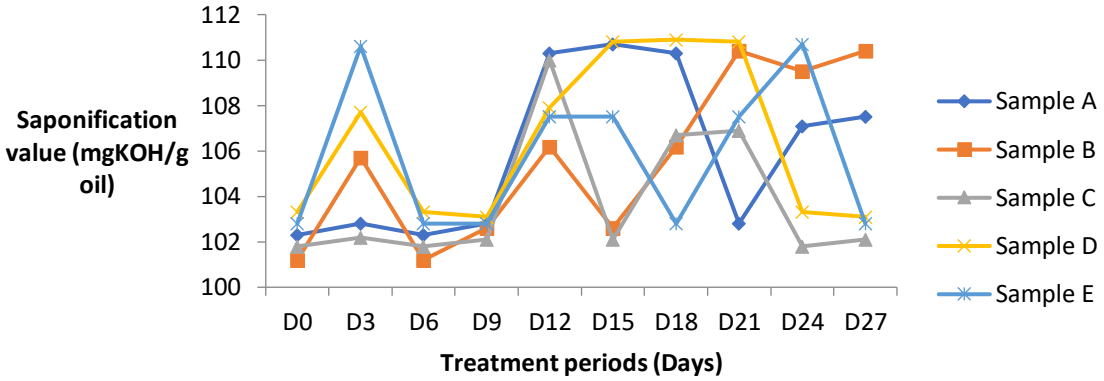

Figure 3: Result of the saponification value of the different oil samples

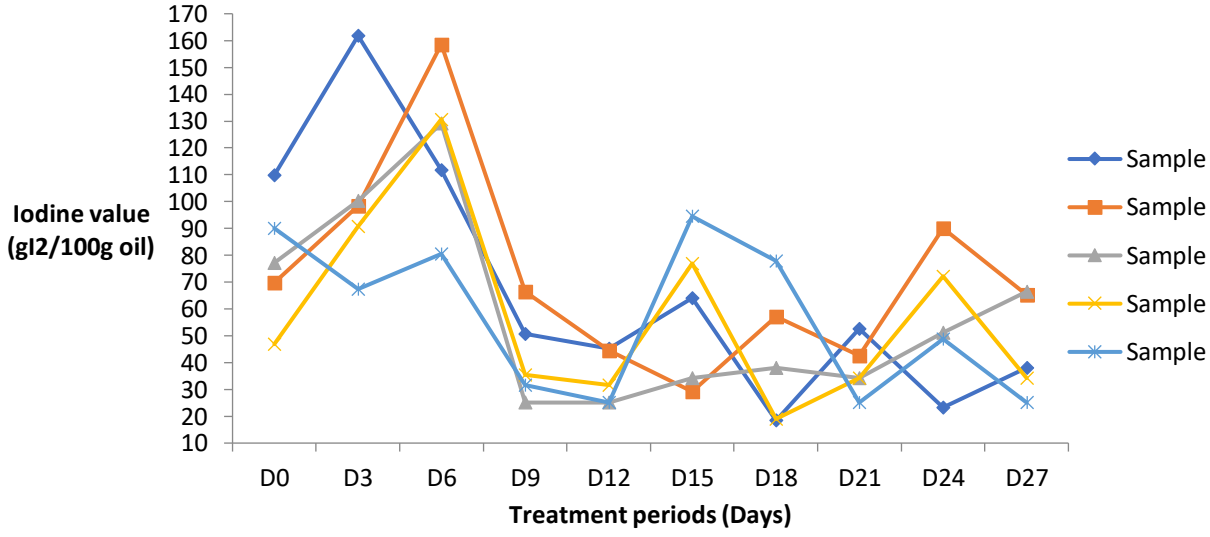

Figure 4: Result of the iodine value of the different oil samples

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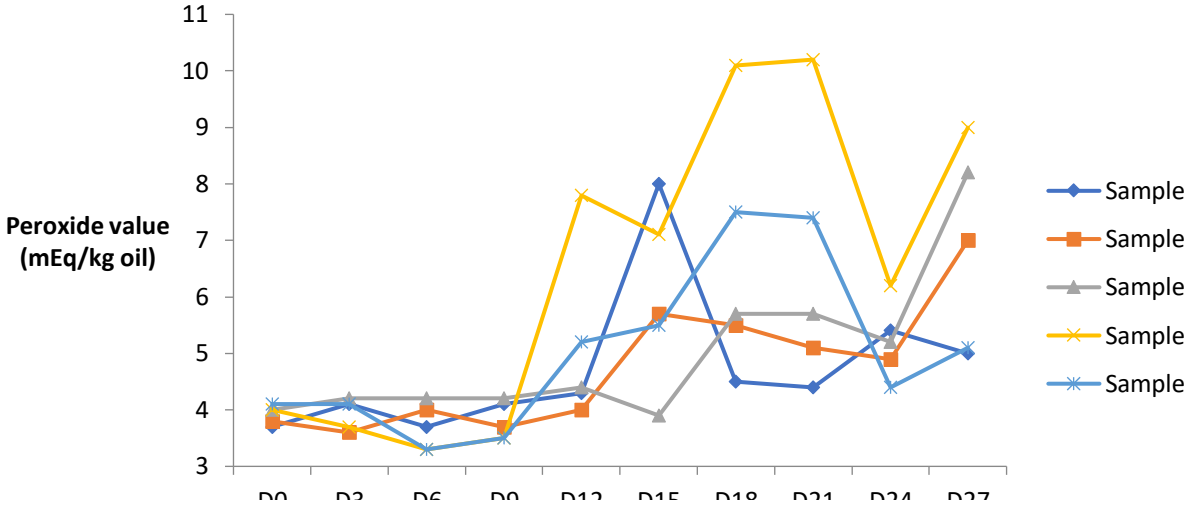

Figure 5: Result of the peroxide value of the different oil samples

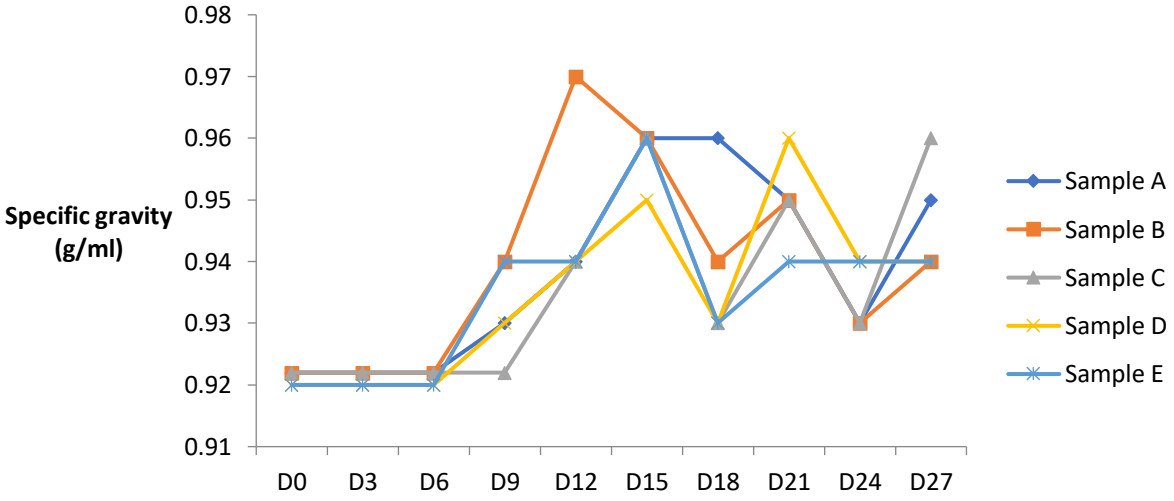

Figure 6: Result of the specific gravity of the different oil samples

3.1.7Refractive index

Refractive index is the ratio of velocity of light in vacuum to the velocity of light in the oil or fat. Refractive index varies with temperature and wavelength (William and Vida, 2015). The results of the refractive index of the oil systems are presented in Figure 7. However, sample A and C showed higher refractive index values while samples B, D, and E competed with each other (1.47 to 1.49). Oil rich in polyunsaturated fatty acids are more susceptible to rancidity than those rich in monounsaturated fatty acid. Therefore, nutritionally the plant materials in oil systems B, D, and E could be used to stabilize refractive index of frying oil as they are slightly in line with the FAO/WHO (1.466 - 1.470) permissible standard (Mengistie*et al*., 2018).

3.1.8Viscosity

Viscosity is the fundamental factor in the rheological study of liquid foods which can be expressed as the resistance of one part of the fluid with respect to the other. West and Rousseau (2016) reported that viscosity increases with increase in molecular weight and decreases as the temperature and degree of unsaturation increases. The result of the viscosity of the oil systems A, B, C, D and E are shown in Figure 8. The results shows that at the end of the frying period (D_{27}), the viscosity value of all the oil systems A, B, C, and E maintained their initial value on D0 indicating that the added plant materials have no significant difference on the

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control of oil viscosity during frying (0.04 milli poise to 0.04 milli poise) while sample D on the other hand increased from 0.03 milli poise to 0.04 milli poise suggesting that the added turmeric has a significant effect on increasing oil viscosity during repeated frying process, although the results showed no statistical significance.

3.1.9Melting point

The melting point of fat/oil is defined by the specific conditions of the method by which it is determined because it does not have a definite or sharp melting point (FSSAI, 2015). The results of the melting points of the oil systems (A, B, C, D, and E) from D_0 to D_{27} are contained in Figure 9. The melting point of oil system B, D, and E increased from 14.50 to 17.40^{0}C, 16.20to 18.10^{0}C, 14.80 to 18.20^{0}C respectively indicating that the added plant materials have no significant effect on the reduction of melting point of oil during repeated frying.

This increase in melting point could be associated with the high water content of the plant materials accompanied by their residues in the oil after frying and storage which increased their molecular weight as increase in molecular weight leads to increase in melting point (West and Rousseau, 2016). On the other hand, oil system C (ginger) reduced from 17.80to 15.80^{0}C depicting that ginger has significant effect in the control of melting point of oil during repeated frying, while sample A (control) maintained its initial value of 16.80^{0}C. Hence, the result showed that ginger can be used to control the melting point of frying oil as oil with low melting point tends to be more stable and healthier than their counterparts.

3.1.10Flash point

Flash point determines the temperature at which the oil or fat catches fire when a test flame is applied under the conditions specified for the test (FSSAI, 2015). The flash point of edible oil decreases as the oil is repeatedly heated with increase in oxidation process (Bhuiyan *et al.*, 2016).The results of the flash points of the oil systems are contained in Figure 10. The flash point of all the oil systems A, B, C, D, and E increased from 335to 365^{0}C, 300 to 385^{0}C, 316to 346^{0}C, 280 to 374^{0}C and 323 to 399^{0}Crespectively indicating that the added plant materials (onion, turmeric, and carrot) have no statistical significance in the oil systems during repeated frying, however sample C (ginger) has the lowest flash point (316to 346^{0}C) indicating its effectiveness in stabilizing the flash point of the oil system during repeated frying, making it to be in line with the NIS standard (300–350^{0}C).

3.1.11Fire point

Fire point temperature is defined as self ignition temperature (SIT). It could be affected by multiple times heating of edible oil at high temperature. (Bhuiyan *et al.*, 2016). The results of fire point obtained in this work for the oil systems A, B, C, D, and E are contained in Figure 11. The results showed that at the end of the frying period D_{27}, the fire points of all the oil systems increased from 397 to 430^{0}C, 358 to 458^{0}C, 372 to 408^{0}C, 330 to 440^{0}C, and 362to 470^{0}C respectively indicating that the added plant materials were not statistically significant on the control of fire point of frying oil during repeated frying. However, sample C (ginger) has the lowest fire point on D_{27} while sample E has the highest fire point. These results were higher than that obtained from the study of Shashikant (2020) which ranged from 313 – 378^{0}C.

3.1.12Smoking point

Smoking point is the temperature at which edible oil begins to produce smoke during heating. At this point toxic fumes and free radicals are produced (Bhuiyan *et al.*, 2016). The results of the smoke point obtained from this work for oil system A, B, C, D, and E is contained in Figure 12. The results show that at the end of the frying period D_{27}, the smoke point of all the oil systems increased from 218 to 238^{0}C, 195 to 253^{0}C, 206 to 225^{0}C, 182 to 243^{0}C, and 210to 260^{0}C respectively with samples A (control), C (ginger), and D (turmeric) being in line with the NIS standard (200 – 250) and sample E and B being slightly higher than the NIS standard. However, these results were slightly lower than that obtained by Angaye and Maduelosi(2015) for king's oil brand (268 – 271.6) on shelve indicating that the added plant materials could be used in the control and stabilization of the smoke point of oil during repeated frying, although the results of the oil systems were not statistically significant.

3.1.13 Colour

The results of the colour of the oil systems are presented in Table 1. The results at the end of the frying period (D_{27}) for all the oil systems were amber yellow indicating that the added onion, ginger and carrot had no significant effect on the colour of the frying oil systems. On the other hand, sample D has a golden yellow colour which may be associated to the yellow pigment or curcumin found in turmeric. The golden yellow color may be an attribute which made the fried yam chips to be the second in overall

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acceptability on D0 and third on D27. Hence, turmeric could be used as colour enhancer during frying especially when frying food products targeted at young children.

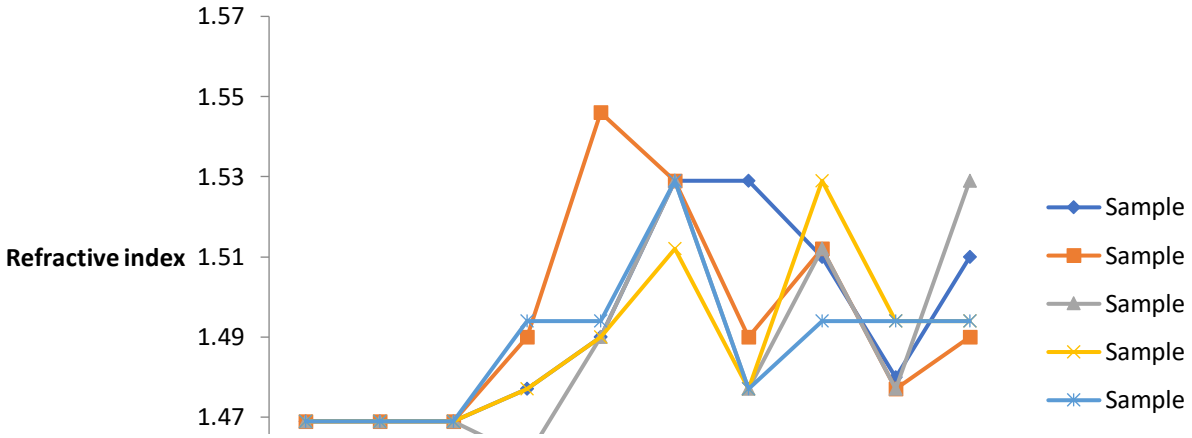

Figure 7: Result of the refractive index of the different oil samples

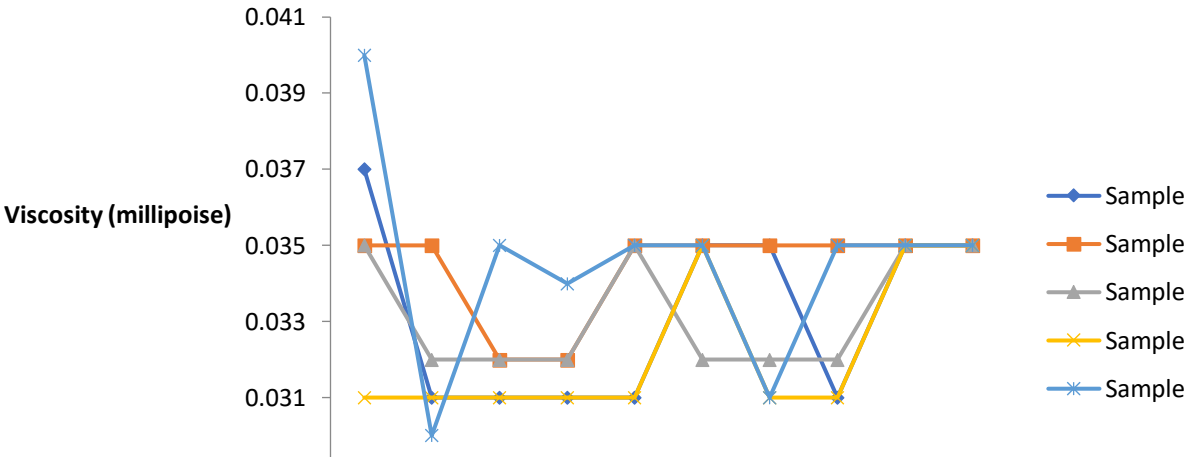

Figure 8: Result of the viscosity of the different oil samples

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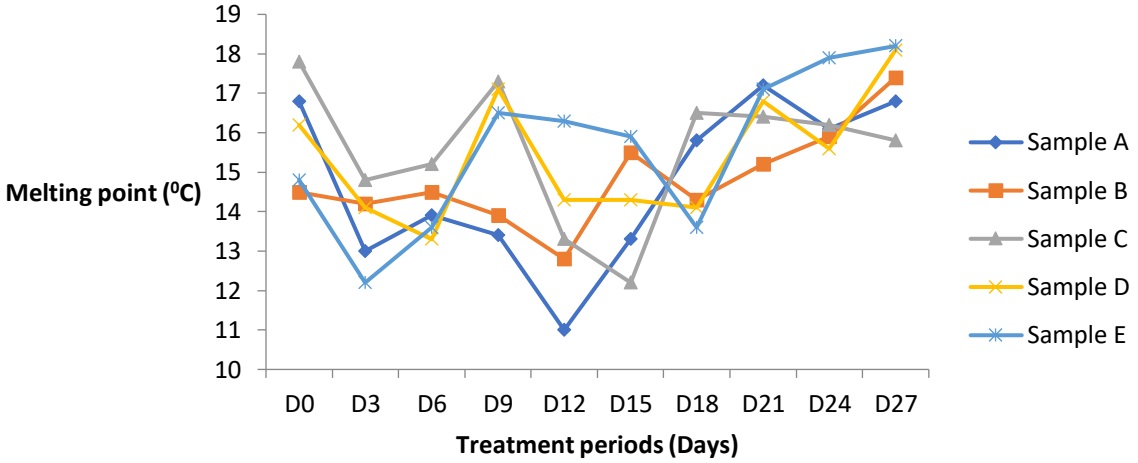

Figure 9: Result of the melting point of the different oil samples

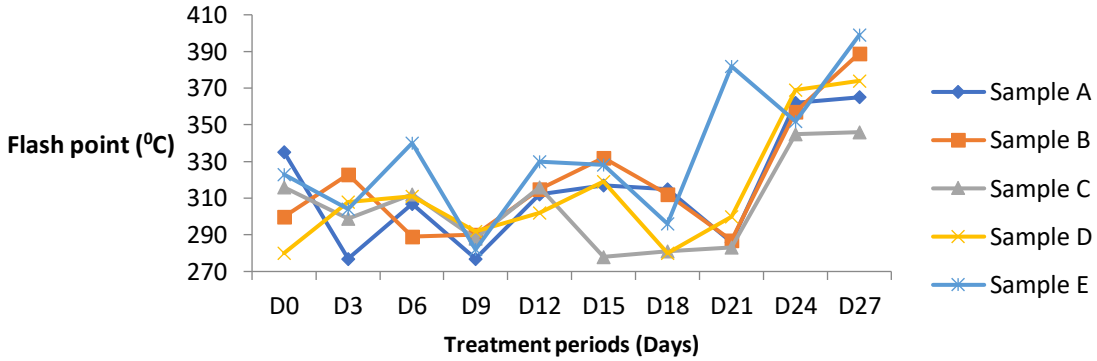

Figure 10: Result of the flash point of the different oil samples

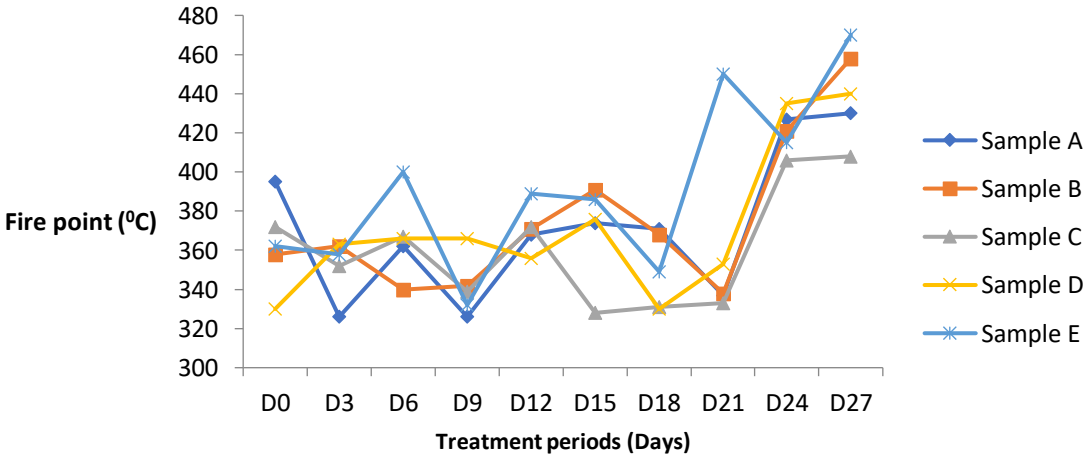

Figure 11: Result of the fire point of the different oil samples

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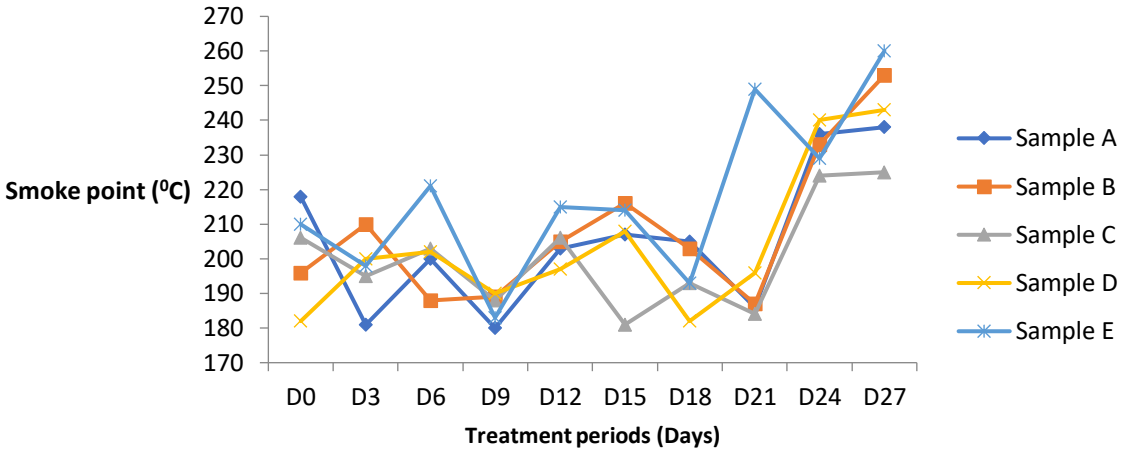

Figure 12: Result of the smoke point of the different oil samples

Table 1: Different colours of the oil samples

Treatment	Colour of oil samples				
Periods (Days)	**A**	**B**	**C**	**D**	**E**
D0	Golden yellow	Golden yellow	Golden yellow	Golden yellow	Golden yellow
D3	Amber yellow	Amber yellow	Amber yellow	Golden yellow	Amber yellow
D6	Amber yellow	Amber yellow	Amber yellow	Golden yellow	Amber yellow
D9	Pale yellow	Amber yellow	Amber yellow	Golden yellow	Amber yellow
D12	Pale yellow	Amber yellow	Amber yellow	Golden yellow	Pale yellow
D15	Amber yellow	Amber yellow	Amber yellow	Golden yellow	Amber yellow
D18	Amber yellow	Amber yellow	Amber yellow	Golden yellow	Amber yellow
D21	Amber yellow	Amber yellow	Amber yellow	Golden yellow	Amber yellow
D24	Amber yellow	Amber yellow	Amber yellow	Golden yellow	Amber yellow
D27	Amber yellow	Amber yellow	Amber yellow	Golden yellow	Amber yellow

Keys:

A = Normal vegetable oil

B = Vegetable oil with 50g onion

C = Vegetable oil with 50g ginger

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D = Vegetable oil with 50g turmeric

E = Vegetable oil with 50g carrot

IV. Conclusion

The aggravated health risk posed to consumers due to continuous re-usage of oil during frying has been of great concern as the price of oil continues to increase on daily basis. This is because the solution to this problem is very much expensive with special application skills. This therefore, necessitated investigation on the physicochemical propertiesof re-used frying oils treated withnatural antioxidating materials (onion, ginger, turmeric and carrot). There was no significant difference on the acid value, viscosity and specific gravity of the oil samples while the other physicochemical properties showed significant difference at $p \leq 0.05$. Hence, the addition of onion, ginger, turmeric and carrot into frying oil in this research work contributed to the reduction of both the iodine and saponification value as well as stabilizing the peroxide value and the flash point of the oil samples, making the oil fit for consumption and non drying at room temperature thereby, providing, a cheap, convenient and non-skill method of lipid oxidation control.

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