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Effects of Frying Yam Slices on the Physiochemical Properties of *Elaeis guineensis* (Palm) and *Glycine max* (Soya bean) Oils

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Abstract
Deterioration of oil quality during deep-frying is the area the authors want to investigate. Most street food vendors in Nigeria reuse oil repeatedly for frying even at the point of its degradation. This could be attributed to either poor income earn or lack of awareness that frying is an agent of oil degradation. The palm and soya bean oils were separately heated at 140°C for twelve (12) hours. 100 g of yam slices was added and fried in the respective oil for 30 minutes. At the end of each cycle (2 hours), 50 mL of each fried oils was fetched and allowed to cool at ambient temperature. The results of the analyses showed changes in the physicochemical properties of the palm and soya bean oils. Moisture content of the oils at a point increased suggesting the exchange of oil with water. Acid value for palm oil was 5.88mg KOH/g but soya bean oil has 2.86 mg KOH/g. Free fatty acid value for palm and soya bean oils was 2.84mg NaOH/g and 16.64mg NaOH/g, respectively. While palm oil iodine value reduced up to 10 g/100g, soya bean oil was reduced to 18 g/100. The respective peroxide value for palm and soya bean oils was 16.64 and 14.96 meq/kg. Palm oil has a saponification value of 203.31mg KOH/g whereas soya bean oil was 195.21mg KOH/g. Changes in these parameters were attributed to hydrolysis of oils as well as its primary and secondary oxidations. The results however showed deterioration in both fried oil. Hence it worthwhile for food vendors to avoid reuse of oil that has spoiled for frying purposes.

Keywords: Frying, palm oil, soya bean oil, acid value, iodine value, free fatty acid value, peroxide value, saponification value

1. Introduction

Heating is the most widely used technique in food preparation both at homes and industries. The prolonged use of edible oils for this purpose has a significant effect on the physical and chemical properties of oils as well as the cooked or fried foods [1,2]. Edible oils are sources of energy, and contain lipids, proteins and fatty acids. They are composed of tocopherol, phenolic, phytosterol (hydrophilic antioxidants) that assist in the metabolism of fat-soluble vitamins. Edible oils also contain omega-3 and omega-6 essential fatty acids, which the human body cannot produce. They are capable of adding flavour and colour to foods during frying process [2-4].

Frying is an adaptable means of cooking which involves heat distribution as a medium to the food. The process is very important because it added flavour and taste to the fried foods [5,6]. The process involved subjecting food into hot oil at temperatures of about 140°C and above. During this process certain amount of products from the oil are

broken down by a number of changes like thermal oxidation, hydrolysis and polymerization. Consequently, flavour and texture of compounds present in cooking oil got deteriorated. Besides, the quality of fried food is also affected due to the fact the food itself is subjected to chemical and physical transformation at certain temperatures, which can result to diverse health effects [7]. Research reports had shown that prolong subjection of oil to heat during frying at high temperatures in the presence of air and water would led to the production of harmful constituents like aldehyde, ketone, trans-fatty acid, and polycyclic aromatic hydrocarbons due to triglyceride oxidation. Zhao Chen (2023) reported that frying can lead to the formation of acrylamide, a toxic carcinogenic compound. In addition, frying can also cause a wide spectrum of toxic effects such as neurotoxic and genotoxic. According to the literature, acrylamide is formed when foods rich in carbohydrates (potatoes) are heated at high temperatures. Moreover, fried foods contain high calories, saturated fat, and sodium, which can lead to weight increase, high blood pressure, and other related ill health issues. It was also established that consuming a diet that is highly fried prompt heart disease, diabetes and other chronic diseases [7-10]. Furthermore, Sunita et al. (2023) also reported that organ damage is correlated to the time of heating oil. The longer the oil is heated, the more danger it poses to the kidney, liver and heart. In another scenario, Oke et al. (2017) had it that there is simultaneous exchange of heat, moisture and oil between food and heating medium. This implies that by-products (fatty acids) of the frying oil are also transferred into the product as well [11]. The physicochemical changes occurring at high temperatures in the frying process and deterioration of fried oil as a result of compounds formed has also been reported. Report has it that deep frying tends to maximize foaming, colour, viscosity, density, polymeric and polar compounds as well as free fatty acid composition [12].

Aside from the negative effects one can derive from frying vegetable oils, frying still maintains some merits. During the process, the oil into which food is immersed acts as a heat transferring medium that has a preservative thermal destructive action against microbes and enzymes and reduces water activity on the food surfaces [6]. Although many research scholars had reports on the effects of heat on physicochemical properties taking place in the frying oils; yet there is lack of literature on the effects of frying yam slices on physicochemical parameters of *Elaeis guineensis* oil and *Glycine max* oil as a function of time. Hence, the study aims to assess the physicochemical degradation of frying palm and soya bean oils at varying time intervals.

2. Materials and Methods

Reagents

Sodium hydroxide, starch indicator, hydrochloric acid, starch solution, alcoholic potassium hydroxide, chloroform, petroleum ether, phenolphthalein indicator, iodine monochloride, sodium thiosulfate, potassium iodide, potassium hydroxide, ethanol and glacial acetic acid. All the reagents and chemicals were of analytical grade and purchased from Merck, QualiKems, Paradise Scientific Company, Dhaka and Bangladesh.

Samples collection

Soya bean oil was bought at Togoa Supermarket high level in Makurdi, while freshly processed palm oil was obtained from Guma Local Government Area of Benue State. The researchers have chosen these sources of oils to avoid adulteration. The oils were stored at ambient temperature prior to analyses.

Frying process

The frying process was carried out for a period of twelve (12) hours; two hours per cycle to give a total of six cycles. One liter (1 L) each of the oil was placed separately in a frying pot heated up to 140 °C. Then 100 g of yam slices were submerged in the respective oil and fried for 30 minutes. This was done for two hours. At the end of each cycle (2 hours), 50 mL of the frying oil was fetched and allowed to cool at ambient temperature. The parameters of each oil sample were determined. The raw oil samples were used as control.

Determination of Moisture Content (MC)

The moisture content of oil samples before and after heating was determined using the method; Association of Official Analytical Chemists (AOAC, 2004). 15 g of each oil sample was weighed into separate weighed dried crucible. The samples were dried to constant weights in an oven at 105 °C, cooled in desiccators and weighed until two consecutive weights were obtained. The percentage of moisture content was calculated as follows:

$$M.C = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Where, W_2 = Weight of sample + crucible, W_3 = Weight after drying, W^1 = Weight of the empty crucible.

Determination of Acid Value (AV)

Acid values of both raw and fried oil were determined using the International Organization of Standardization (1996) method. 2 g of each oil sample was mixed with 10 mL ethanol, followed by two drops of phenolphthalein. The mixture was boiled for five minutes and then titrated with 0.1 N potassium hydroxide solution till a pale pink colour was obtained. The acid value was calculated using the following equation.

$$\text{Acid value} = \frac{\text{Titre} \times \text{N of KOH} \times 56.1}{\text{weight of the sample (g)}} \times 100$$

Determination of Free Fatty acid (FFA)

Free fatty acids of both the raw and fried oils were determined by titrating with alcoholic solution of the oil in an aqueous solution of sodium hydroxide using phenolphthalein indicator. The free fatty acid concentration was determined by adapting the method used by Aletor et al (1990). Approximately 10 g of each of the oil was poured into separate conical flask. 50 mL of alcohol ether mixture in equal volume was added and warmed on laboratory hotplate stirrer to obtain a homogeneous mixture. 1 mL of phenolphthalein indicator was then added and titrated with 0.1 N NaOH until a fairly pink endpoint was obtained.

$$\text{FFA} = \frac{\text{Titre (mL)of NaOH} \times \text{N of NaOH} \times 28.2}{\text{weight of the sample (g)}}$$

Where, FFA = Free fatty acid

Measurement of Iodine Value (IV)

The iodine values of both raw and cooked oil were determined using Wijs method (2003). A mixture of 25 mL Wijs solution (iodine solution) and 10 mL of chloroform was added to 0.30 g of each oil sample. The mixture was allowed to stand for 30 minutes in the dark cupboard. About 20 mL of 10 % potassium iodide was added to the mixture followed by 3 drops of starch indicator. The solution was titrated with 0.1 N sodium thiosulphate solution until a colourless endpoint (S) was obtained. A blank (B) titration was also carried out and the iodine value was calculated according to the following equation:

$$\text{Iodine Value} = \frac{(\text{B} - \text{S}) \times \text{N} \times 12.69}{\text{w}}$$

Where, B = blank titre value; S = sample titre value; N = normality of $Na_2S_2O_3$; w = weight of sample.

Determination of Peroxide Value (PV)

Peroxide values of both raw and fried oil were determined using AOAC method (2003). 10 g of each oil sample was weighed into a separate conical flask, followed by the addition of 30.0 mL mixture of glacial acetic acid and chloroform (3:2). 0.5 mL of 1 % starch indicator solution was added to the resultant solution. The flask was corked and allowed to stand for 1 minute. 30 mL of distilled water was added and the solution was titrated with 0.01 N sodium thiosulphate solution until the black colour turns white.

$$\text{Peroxide value} = \frac{\text{V} \times \text{N} \times 1000}{\text{W}}$$

Where, W = weight of sample, V= volume of the titration

Measurement of Saponification Value (SV)

The saponification values for both raw and fried oil were determined using the Association of Official Analytical Chemists (AOAC, 2003). 4 g of each oil sample was weighed into 250 mL conical flask and 50 mL of alcoholic potassium hydroxide was added. The mixture was thoroughly mixed and heated at temperature between 60 and 70 oC for one hour. The hot mixture was titrated with 0.5 N HCl using 2 drops of 1 % phenolphthalein indicator until a colourless endpoint (S) was obtained. A blank titration (B) was also carried to out determine the saponification value. The value was calculated using the following formula:

$$\text{SaponificationValue} = \frac{(\text{B} - \text{S}) \times \text{N of HCl} \times 56.1}{\text{wieghtofthe sample (g)}}$$

Where, B = HCl (mL) for blank, S = HCl (mL) for sample

3. Results and Discussion

The physicochemical properties such as moisture content, acid value, free fatty acid, iodine value, peroxide value and saponification value of oil samples before frying (ambient temperature) and after frying were analyzed and the results tabulated in Table 1 and 2.

Moisture content

The estimation of moisture content in raw palm oil was above the standard set by WHO (0.29 %), and was higher compared to soya bean oil (Table 2). The high moisture content could be attributed to differences in the extraction method as well as inadequate processing treatment during processing. In Nigeria most of the palm oil is produced by traditional method which involves warm water-oil mixture [13]. Palm oil extracted from wet mixture method may usually have high moisture content as results of Table 1 portraits. High moisture content has a negative impact on the quality of oils in terms of shelf life. This property can also increase the release of free fatty acids in the course of oil frying [2,6]. In Table 1and 2, it was noticed that both moisture content of the oils first decreased; increased and then decreased again. Increased in the content in this regard suggested the outflow of moisture and absorption of oil in fried yam slices; the consequent of heat energy transferred [6].

Table 1: Variation in physicochemical properties of palm oil

Frying Time (h)	Palm oil					
	M.C	**AV**	**FFV**	**IV**	**PV**	**SV**
0•	1.40±0.18	0.87±0.02	2.20±.20.31	18.20 ±.06	7.28±0.16	200.30±2.12
2	0.85±0.42	4.45±0.02	2.25±0.02	13.74±0.04	8.41±0.01	201.31±1.36
4	0.71±0.01	4.86±0.04	2.45±0.02	12.72±0.03	8.65±0.02	201.64±0.17
6	0.80±0.01	5.29±0.02	2.65±0.02	11.81±0.02	9.25±0.01	202.06±0.10
8	0.60±0.03	5.48±0.04	2.72±0.01	11.42±0.04	9.38±0.01	202.64±0.92
10	0.49±0.01	5.67±0.02	2.78±0.00	10.68±0.02	12.68±0.02	203.22±0.48
12	0.37±0.01	5.88±0.02	2.84±0.02	10.06±0.01	16.64±0.08	203.31±1.57

Key: M.C = Moisture content (%), AV = Acid value (mgKOH/g), FFA = free fatty acid (mgNaOH/g), IV = Iodine value (g/100 g), PV = Peroxide value (meq/kg), SV = Saponification value (mgKOH/g), 0• = Control

Table 2: Variation in physicochemical properties of soya bean oil

Frying Time (h)	Soya bean oil					
	M.C	**AV**	**FFV**	**IV**	**PV**	**SV**
0•	0.30±0.15	0.87±0.15	0.56±0.46	30.2 ± 0.3	5.70±0.12	191.20±7.68
2	0.20±0.01	1.69±0.03	0.64±0.01	26.47±0.06	6.04±0.05	191.50±0.06
4	0.30±0.01	1.88±0.01	0.71±0.01	25.83±0.03	6.81±0.02	192.02±0.06
6	0.26±0.01	2.08±0.01	0.79±0.02	24.54±0.08	8.29±0.06	192.38±0.01
8	0.22±0.02	2.27±0.02	0.82±0.03	22.67±0.04	10.35±0.05	192.90±0.01

10	0.18±0.01	2.38±0.01	0.90±0.02	19.50±0.04	11.62±0.01	193.38±0.08
12	0.12±0.01	2.66±0.01	0.97±0.02	18.36±0.01	14.96±0.04	195.21±0.02

Key: M.C = Moisture content (%), AV = Acid value (mgKOH/g), FFA = free fatty acid (mgNaOH/g), IV = Iodine value (g/100 g), PV = Peroxide value (meq/kg), SV = Saponification value (mgKOH/g), 0• = Control

Acid Value and Free Fatty Acid Content

Acid value is a measure used to express the amount of free fatty acid present in oils. The value is also used as an indication of the condition for edible oil. It therefore means the number of free fatty acid varies directly as the number of acid value [1]. In this research, we found that the acid value produced from fried yam slices using palm and soya bean oils increased to the maximum of 5.88 mg KOH/g and 2.86 mg KOH/g, respectively; after the 6 hour cycle. The acid value for the palm oil is above the value set by Standard Organization of Nigeria (SON) (≤ 0.6 mgKOH/g) as shown in Table 1 and 2. The progressive increased in acid value is attributed to hydrolysis of the oil. This chemical reaction is initiated by water, steam and oxygen molecules. When ester linkage in triacylglycerol is attack by weak electrophile (water), mono- and diacylglycerols, glycerol and free fatty acids are produced. In general, immersion of moist food in heated oil, lead to the hydrolysis of triacylglycerol to yield free fatty acids and glycerol; therefore, increasing acidity and free fatty acids of the fried oil [14].

Iodine value

Iodine value is used to characterize the degree of unsaturation of fats and oils. The higher the iodine values the more rapid the oil tends to be oxidized, hence the greater the unsaturation [15]. Changes in the iodine value of the two-frying media before and after twelfth (12) consecutive hours of frying were shown in Table 1 and 2, respectively. It was observed that the estimated IV of soya bean oil before frying has higher degree of unsaturation (IV = 30.2 g/100 g) compared to palm oil (IV = 18.20 g/100 g), hence the former oxidized rapidly than the later. At the end of the 12 hours of frying, iodine value for palm and soya bean oils decreased to 10 and 18, respectively. The reduction in IV can be attributed to the destruction of unsaturation or double bonds either by oxidation or polymerization reaction. The decreased in IV with time of frying could also be attributed to the alteration taking place in fatty acids with frying period [16,17]. The highest decreased in IV was observed in soybean oil at the end of 12 hour of frying yam slices. This could be probably due to differences in the specific heat capacities of the two edible oil samples [18]. The result obtained is in consistent with the study made on deep fat frying of food chips by Navin et al. (2010) and Josphine et al. (2016).

Peroxide value

PV tells the degree of rancidity in oils. The results obtained showed that the peroxide value for the two oil samples increased as frying time increased. It ranged from 7.28 meq/kg (for the control) to 16.64 meq/kg with average value of 11.92 meq/kg for the fried palm oil sample; and 5.70-14.96 meq/kg with a mean value 10.33 meq/kg for soya bean oil. The peroxide values for the two oils depicted higher value than the stipulated standard value set by FAO, SON and WHO (10 mEq/kg). A raised in peroxide value signifies more yield of peroxides as frying time increases due to primary oxidation of oil. This chemical reaction is attributed to the presence of moisture and repeated heating that give rise to increase in rate of oxidation of poly unsaturated fatty acids, hence increased in peroxide value. A similar reaction such as secondary oxidation of hydroperoxides which can occur at high temperatures lead to secondary decomposition products: alcohols, carbonyls and acids [6,14,19,20]. Our finding also agreed with other similar studies which shows that oil used to fry foods has higher peroxide value than the value for standard limit [16,19,21]. Moreover, the PV at the end of 6 hours cycle of palm oil used for this study has higher value compared to soya bean oil, the consequent of moisture couple with atmospheric oxidation reaction [22]. Hence palm oil has more moisture content than soya bean oil.

Saponification value

Saponification value is used as an indicator for molecular weights of the triglycerides in the oil. A low saponification value denotes long chain fatty acid with high molecular weight triglyceride of oil; whereas a high SV indicates triacylglycerols with short chain fatty acid. The low value could also suggested that the oil may not be too good for shampoos, soap or oil-based ice cream production [7,16]. Table 1 and 2, portrayed variations in the

saponification value of the oils from 0 to 12 hours. The saponification values at 0 hour (control) of the oils were 200.20 mgKOH/g and 191.20 mgKOH/g for palm oil and soya bean oil, respectively. The SV estimated for this study falls within the range as documented by Aremu et al. (2015), [23]. From the tables it can be observed that the amount of SV increases in both oils. The increased may be due to the production of more secondary oxidation products (carbonyl compounds) due to transformation of primary oxidation products. The increase in the SV showed that the oil has degraded and should probably be utilized for soap making, else discarded [7,16]. We also noticed that palm oil has low iodine value but high saponification value. This result agreed with the literature which established that oil with high saponification value has low iodine value and hence may be used to produce good quality soap [24]. Since palm oil has high SV of 203 mgKOH/g at end of heating period, and the value is within the standard (185-205 mgKOH/g) as reported by Abdulkadir and Jimoh (2013), [25]; it is therefore recommended for soap making.

4. Conclusion

The research to evaluate the effects of frying yam slices on physicochemical properties of locally made and commercial vegetable oils using standard methods; showed changes in the physicochemical parameters of the oil samples during frying process. The results showed general increased in the acid, peroxide, free fatty acid and saponification values of the oils but a decreased in iodine value when analyzed from zero (0) hour to twelfth (12) hours. We also observed that frying affects the quality of cooking oils. It is therefore advisable not to re-use vegetable oils repeatedly for a long period as this can impacts off-flavour of fried foods and impose dangerous ill health issues to consumers. All food vendors and other consumers should discard fried edible oils when there is alteration in colour. We recommended that vegetable oils producers should properly refined their produce during processing to minimize the amount of moisture content as this reduced shelf life of oils over storage period. More so, chemical reaction such as hydrolysis that leads to the breakdown of triacylglycerol to yield free fatty acids and glycerol, initiated by the presence of water is avoided.

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Conflict of Interest

Regarding the publication of this paper, the authors declare no conflicts of interest.

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