African Journal of Integrated Knowledge and Technology Vol. 4 No. 1 June 2024
Print ISSN: 2814-2802 e-ISSN: 3027-0553 www.ajikt.org

PHYSICO-CHEMICAL QUALITIES OF RED PALM OIL AS AFFECTED BY MEDIA pH

Emmanuel N. Okoronkwo[1], Loretta N. Eke[1], Esther A. Ayodele[1], Nnenne U. Umennakenyi[1], Josephine N. Egege[1] and Ikenna L. Mmadubuike[2]

[1]Department of Food Technology, Akanu Ibiam Federal Polytechnic, Unwana.
[2]Deparment of food Science and Technology, Imo State University, Owerri.
Corresponding author: enokoronkwo@gmail.com

Abstract

Water is an indispensable medium in food processing and the quality of water used in processing foods especially its pH can exert significant influence on the behaviour and properties of the food system. This work is an investigation on the effects of pH of water used in the processing of palm fruits on the physico-chemical qualities of the resulting oil. Palm fruits (*Elaeis guineensis*) were processed into edible red oil using water of different pH values (pH 3.5, 5.5, 7, 9.5, 11.5 and control). The resulting fresh oils were immediately subjected to physico-chemical analysis following standard procedures. The results showed that the pH of the oil samples ranged from 6.35-6.80; the iodine value of the samples ranged from 37.29mgI_2/g-63.40mgI_2/g; peroxide value ranged from 6.42mEq/kg/KOH-15.58mEq/kg/KOH; the specific gravity of the oil samples ranged from 0.91-0.93 while the saponification value of the oil samples ranged from 177.75mg/KOH/g - 236.36mg/KOH/g. The viscosity of the oil samples at (35^{o}C) ranged from 134.45mPas-205.04mPas and the free fatty acid ranged from 4.44%-6.84%; There were significant differences at $P<0.05$ for each of these physico-chemical qualities except in the specific gravity of the oil samples. Oil samples processed in acidic media (pH<7) were seen to have high viscosity and saponification properties whereas samples processed in alkaline media (pH> 7) were seen to be higher in iodine value but low in free fatty acid content and peroxide values. This work therefore reveals that the pH of water used in processing palm fruits can influence the physico-chemical qualities of the resulting palm oil. The quality of water especially its pH used in processing palm fruits should be identified as this work has revealed that media of both acidic and alkaline pH has both desirable effects and limitations in the quality of the resulting oil.

Keywords: pH quality of water, Palm fruits, Physico-chemical qualities, red palm oil.

Introduction

The importance of red palm oil to the national economy of Nigeria cannot be over emphasized; it ranges from being an essential ingredient in foods for human consumption, to being an article of commerce, source of employment, income to farmers and the nation and raw materials for industries. Red palm oil is an edible vegetable oil obtained from the fruit of oil palm (*Elaeis guineensis*). It has been reported to contain a balanced fatty acid composition comprising 50% saturated fatty acids, 40% monounsaturated fatty acid components, and 10% polyunsaturated fatty acids, making it one of the most versatile vegetable oils for foods and industrial applications (Nwakodo *et al.*, 2019). Palm oil production has been a major segment of the local economy of the rural population at both cottage and industrial levels, thereby increasing its utility in many parts of Nigeria (Ihenetu *et al*., 2018). However, in Nigeria, red palm oil obtained for both domestic and industrial uses is still primarily produced by farmers who adopt different processing methods (traditional and mechanized) that vary from one locality to another. Regardless of the processing method, the palm fruits are sterilized by boiling or steaming using water to soften and hydrate the oil-rich mesocarp before digestion and extraction of the oil. Thus, water is an indispensable medium in the processing of palm fruits for its edible oil.

Numerous studies have been carried out on the factors affecting yield, physico-chemical qualities and storage stability of palm oil but there is paucity of information on the effects of media pH on the physico-chemical properties of palm oil. Studies on the effect of pre-processing factors on oil quality such as variety, climate and weather conditions, soil quality and fertility and pest and disease management have been reported by Zulkiply *et al*., 2017; Tan *et al*., 2019; Kumar *et al*., 2018; Suhaimi *et al*., 2019. In the same way, the effect of processing factors such as extraction methods, refining process and bleaching and degumming on the quality of palm oil have been well documented (Gunstone *et al*., 2017; Decker *et al*., 2018; and Lopez *et al*., 2019), and post-processing factors such as temperature and humidity, container quality and cleanliness and transportation duration and conditions and their effect on palm oil have been extensively reported by Tan *et al*., 2019; Siew *et al* ., 2018; Kumar *et al*., 2018. Incidentally, as important as water is in the processing of palm fruits into edible oil, there has been little or no documented works on how water quality especially its pH affects the quality of oil obtained. Observations have shown that processors both at the cottage and industrial levels use any available water without a conscious effort to identify its qualities especially its pH. A childhood experience while growing up in the village could be recalled in which a certain unlettered neighbour processed his palm fruits using stagnant/ muddy water from dug-out wells and run-off sources, whereas in our home, we used portable water in processing palm fruits. Ironically, this unlettered neighbour was always producing more palm oil for the same quantity of palm fruits than we that used cleaner water. This observation apparently suggested that there is something about the quality of water which can affect the production and quality of palm oil.

pH is the level of acidity or alkalinity in a given media in relation to a pH scale of 1-14 with 7 being neutral. It is an intrinsic property of every organic matter and it affects the physical and chemical functionality of any given food system (Wujie, *et al*., 2011). Since pH can be affected by chemicals in the environment or medium, it is expressed in "logarithmic units" of $[H^+]$ in the medium. Each number represents a 10-fold change in the acidity/alkalinity of the medium.

Considering that triglycerides make up 95% of palm oils, and consist of different units of fatty acid chains, the significance of interactions of these organic acids with the pH of the processing media cannot be overlooked in the quality of the final product. Earlier work by Wujie, *et al*. (2011) demonstrated how pH of water interacts with the food system during processing and Kumar *et al*. (2017) clearly demonstrated how pH affects the saponification values of oils.

Physico-chemical qualities of palm oil are common physical and chemical parameters which are used to characterize the quality of red palm oil and which largely determines its domestic and industrial applications. They include among others free fatty acid, peroxide value, iodine value, saponification value, pH, specific gravity and viscosity. An investigation into the pH quality of water used in the processing of palm fruits on the physico-chemical qualities of the resulting oil could advance the palm oil industry. Besides, optimizing pH quality of water used in the processing of palm fruits is essential for ensuring optimal quality of the resulting red palm oil. Moreover, many processors usually store palm oil during its peak seasons in speculation of price appreciation before sales and during this period physical and chemical deterioration of the oil usually occurs.

Identifying the physico-chemical qualities of the freshly processed oil can also reveal how the pH of the water used for its processing affects the stability of the red palm oil during storage. There is a need, therefore, to investigate the effect of pH quality of water used in the processing of palm fruit on the physico-chemical qualities of the resulting red palm oil.

Materials and Methods

Sourcing and preliminary processing operations

Freshly harvested palm fruits bunches were used in this work and they were sourced from an oil palm plantation in Afikpo North local Government Area of Ebonyi State. The palm fruit bunches were carefully transported to the processing site by ensuring very minimal injuries to the fruits. They were dissected into spikelet using sharp machetes. The spikelets were covered with jute materials and allowed to be conditioned for 2 days. The palm fruits were picked off the spikelet, sorted and then randomly distributed and mixed together to ensure uniform representation of all varieties and qualities in the lot. They were then washed with portable water and allowed to drain before further processing.

The pH of water used for the treatment of the palm fruits was achieved by adjusting the pH of distilled water with natural acidifiers and alkalinisers.

Processing of Palm Fruits into Red Palm Oil

The sorted and washed palm fruits were divided into six portions of equal mass and each portion was sterilized by boiling in water of a known pH quality for 60mins in order to soften and hydrate the oil-rich mesocarp. The different water pH qualities used in the sterilization of the palm fruits were 3.5, 5.5, 7, 9.5, 11.5 and water of an unknown pH to serve as the control. This range of pH values (3.5-11.5) selected for the treatments was based on the natural pH range of most food systems. The choice of mid-points in-between two values was to accommodate extremes of pH since this work is a novel work and all possible outcomes were being envisaged. The sterilized oil palm fruits were quickly transferred to a mechanized digester powered by a 200G petrol engine and allowed to be digested until the nuts were visibly separated from the fibre mash. The digested materials were scooped out and placed into an oil press for the extraction of the red palm oil. The screw press was worked to express as much red palm oil as possible from the digested material. The expressed red palm oil mixture was dried/ evaporated by boiling off the water content in an open pot. The evaporation process was assumed to be completed when there were no more water bubbling or foaming in the pot. The pot was brought down and allowed to cool in a slanting position in other to enhance clarification of the red palm oil content. The cooled red palm oil was then carefully decanted into a container through a funnel fitted with filter cloth and taking care not to allow any residues/debris into the product. The recovered red palm oil was bottled for further analysis.

The flow chat for the processing of palm fruits into edible red palm oil is as shown in Figure 1 below.

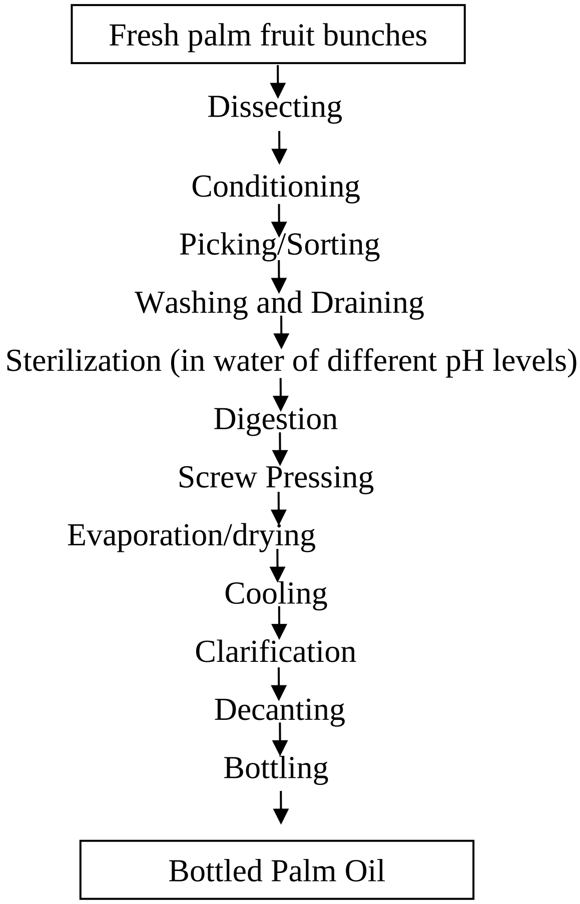

Figure 1: The processing of Oil Palm Fruits into edible Palm Oil

Physico-Chemical Analysis of Palm Oil Samples

The freshly processed palm oil samples were subjected to physico-chemical analysis following standard procedures. The American Oil Chemists Society (AOCS 2012) method was used in determination of Iodine value, specific gravity, saponification value, free fatty acid and peroxide value. pH of oil samples was determined by direct reading using a portable pH meter: model name - Water Quality Tester Z9909SP. Each oil sample was poured into a beaker at room temperature and the pH meter was dipped into it and allowed to read and stabilize before the readings were taken which was in the scale of 1-14 according to the [H^+] scale (Nguyen, T. A. *et al*., 2020) while viscosity of the samples was determined by direct reading of a digital viscometer (model NDJ5S) at 35°C. Each oil sample was placed into the culvert and the electronic probe of the viscometer which works as a sensor was positioned and switched on. The turning of the probe on the samples generated a torque which was electronically translated as viscosity in mPas (x10^6Pas). All measurements were done in duplicates and the mean readings were taken.

Statistical Analysis

Data generated from the physico-chemical analysis of the oil samples were subjected to One-Way Analysis of Variance (ANOVA) using the Statistical Package for Social Sciences (SPSS) software version 25 for windows and means separated using Duncan's test at 95% confidence level.

Results and Discussion

Table 1 below shows the physico-chemical qualities of red palm oil samples processed using water of different pH qualities.

Table 1: Physico-Chemical Qualities of Palm Oil Samples Processed in Water of Different pH Levels

SAMPLES	pH	IV (mgI_2/g)	PV (MEq/kgKOH)	SG	SV (mgKOH/g)	VISCOSITY (MPas)	FFA %
S03	6.45^b	41.0072^d	15.5897^a	0.93^a	212.7898^c	205,034.33^a	5.2396^b
S05	6.60^b	47.8517^b	11.1996^b	0.92^a	225.4769^b	149,367.67^c	4.7910^c
S07	6.60^b	43.0501^d	6.4249^d	0.91^a	236.3654^a	157,467.67^b	6.8495^a
S09	6.50^b	63.4045^a	12.7755^b	0.91^a	196.7873^d	133,951.50^d	4.6687^c
S11	6.80^a	37.2908^e	8.1041^c	0.91^a	193.3740^d	160,351.00^b	4.7427^c
CON	6.35^c	45.3201^c	9.2084^c	0.91^a	177.7598^e	134,451.00^d	4.4357^c

Values are means of duplicates. Means with the same superscript in the same column are not significantly different ($p<0.05$) from one another.

Key
S03= palm oil processed using water pH of 3.5
S05= palm oil processed using water pH of 5.5
S07= palm oil processed using water pH of 7
S09= palm oil processed using water pH of 9.5
S11= palm oil processed using water pH of 11.5
CON= palm oil processed using water of unknown pH
PV= Peroxide value
FFA= Free fatty acid
IV= Iodine value
SV= Saponification value
SG= Specific gravity

Print ISSN: 2814-2802 e-ISSN: 3027-0553 www.ajikt.org

Discussion

pH: This is the degree of acidity or alkalinity of a substance. It tells the level of free hydrogen ion $[H^+]$ or free hydroxyl ion $[OH^+]$ in a given system. The pH value of all the samples was found to be within the range of 6.35-6.80. These pH values are within the pH range of 5-7 as recommended by SON (2000) for edible oils showing that the pH range of the oil samples is within the acceptable culinary range. Moreover, this result shows that despite the wide variations in the pH of the water used for their processing, the resulting oils were within a very narrow pH range of 6.35-6.80 implying that palm fruits have a natural buffering ability. The narrow pH range of the oil also suggests that the palm fruits used in the processing of the oil were at optimal ripeness since over-ripe, bruised or fermented palm fruits give rise to products with high acid value due to high FFA content (Tan *et al*., 2019). Work by Gungshik J. R. *et al*., (2023) reported a pH range of 3.99-4.15 which was very acidic and hence said not to be recommended for consumption. Besides, oils with low pH are said to be very low at oxidative stability during storage.

Iodine Value (IV): This is used to determine the degree of unsaturation in lipids and triglycerides. The IV of the samples ranged from 37.29mg/100gI_2 – 63.40mg/100gI_2, with some of the samples (S05 and CON) falling within the standard range of 45 mg/100gI_2 – 53mg/100gI_2 as recommended by SON (2000) and NIS (1992). However, the range of values obtained in this work is higher than the 33.40mg/100gI_2 reported by Akinyeye *et al*., (2011). Investigation has revealed that the iodine values of oil are also indicative of the type of fatty acids that make up the triglyceride molecules in the oil thus the iodine value of oil affects its physical state. The more the level of unsaturation the oil has the more likelihood of the oil to be free flowing at room temperature (Gunstone, 2006). However, vegetable oils with relatively low degree of unsaturation are less prone to oxidation and spoilage during storage. The differences in the iodine values obtained in this work shows that the pH of the medium significantly impacted on the chemical structure of the resulting oils since IV has to do with the presence of double bonds in the fatty acid chains.

Peroxide Value (PV): The PV is an indicator of the level of lipid peroxidation or oxidative degradation. It is a measure of the readiness to deteriorate. The PV for the red palm oil processed with water of different pH as presented in table 1 above shows that the values obtained for the PV ranged from 6.42mEq/kg - 15.58mEq/kg with the palm oil processed with water of pH of 7 having the lowest PV and palm oil processed with water of pH of 3.5 having the highest PV. Samples S07, S11 and CON fell within the range of 0-10mEq/kg given by Standard Organisation of Nigeria (SON 2000) while samples S03, S05 and S09 though higher than SON (2000) and Nigeria Industrial Standards (NIS 1992) recommendation, were much lower than values of 40mEq/kg and above as reported by Enyoh *et al*., (2017). The high PV of sample S03 could be due to the fact that acidic conditions could promote oxidation reactions during the processing of palm fruits into oil, leading to the formation of peroxides and other oxidative products while the low value of 6.42mEq/kg recorded by S07 could be as a result of the neutral pH of the media. This result implies that for a low PV in palm oil, water of pH 7 and above should be used during processing as lower pH values may lead to oil products with high PV which could initiate oxidative instability during storage

Specific Gravity (SG): This is a term used to define the weight or density of a liquid as compared to the density of an equal volume of water at a specified temperature. The values obtained for SG of the oil samples ranged from 0.91-0.93 and these values are around the range of 0.89-0.92 obtained by Enyoh *et al*., (2017). This implies that variation in the pH of the water used for the processing of palm fruit had little or no effect on the SG of the resulting oils. The SG of substances is closely associated with their level of purity. The narrow range of SG of the oil samples obtained in this work suggests that the samples have little or no impurities possibly due to the quality of materials used in their processing. Low levels of impurities in oils enhance their oxidative stability during storage.

Saponification Value (SV): This is an indication of the molecular weights of triglycerides of oils. High SV indicates high proportion of low molecular weight fatty acids since SV is inversely proportional to the average molecular mass of fatty acid (Mohammed *et al.*, 2017). The SV obtained ranged from 177.75mgKOH/g to 236.36mgKOH/g. The control had the lowest SV while the Palm fruit processed with water of pH of 7 had the highest SV. Only one sample (S09) fell within the recommended range of 195-205mgKOH/g for palm oil as recommended by (SON 2000; NIS 1992). The value of the samples processed using acidic medium is close to the 222.90mgKOH/g reported by Akinyeye *et al.*, (2011), but all the samples had a higher SV than the 140.00mgKOH/g reported by Birnin-Yauri *et al.*, (2011). The result of this work suggests that using water of higher pH qualities (alkaline media) in processing palm fruits had higher hydrolysing effects on the triglycerides in the palm oil whereas water of lower pH values being acidic had less hydrolysing effect on the triglycerides in the palm oil. This suggests that processors who targets high SV in their palm oil may consider using water of lower pH values to process their palm fruits. Oils with high saponification properties are more desirable for soap making purposes because it gives more yield of soap per unit of reagents used.

Viscosity: The viscosity of the oil samples ranged from 133.95mPas-205.04mPas. There was significant difference ($P < 0.05$) among the oil samples. Sample S03 processed in water of pH of 3.5 had the highest viscosity value of 205.04mPas while sample S09 processed in water of pH 9.5 had the lowest value of 133.95mPas. Viscosity of the oil samples seemed to reduce with increasing pH of the processing media. However, the range of values obtained in this work were much higher than that reported by Fasina *et al.*, (2008) who reported viscosity values of 46.29mPas and 38.63mPas for olive oil and soybean oil respectively at 35^{o}C. The variations in the viscosity of the palm oil samples processed in water of different pH as obtained in this work suggests that the pH of the medium might have interacted with the intramolecular forces of the triglycerides in the oil samples because viscosity is a function of how the molecules in a fluid resist flow over one another. Viscosity of oil is associated with the chain length of fatty acids in the oil sample. Triglycerides made up of more long chain fatty acids tend to be more vicious than those comprising of short or medium chain fatty acids. The longer the chain length of the constituent fatty acids, the more the likelihood of a higher viscosity of the oil at the given temperature. The trend of viscosity in the oil samples as obtained in this work seemed to indicate that processing palm fruits in media of acidic pH results in palm oil of high viscosity.

Free Fatty Acid (FFA) Content of Oil Samples: This is the fraction of fatty acid that is not bound to glycerol in the form of triglycerides and is also a measure of its acid value. The FFA obtained in this work ranged from 4.44% - 6.84% with sample S07 processed with water of neutral pH having the highest FFA value. These values obtained are a bit higher than SON 2000 recommended maximum value of 3.5% but much lower than the range of 10.38% -18.80% obtained by Enyoh *et al.*, (2017). The narrow range of the FFA values obtained in this work shows that variations in the pH of the water used in processing the palm fruits did not have much effect in the aspect of FFA content of the resulting oils. This could also imply that the palm fruits used for this work were of good quality and were at proper ripeness stage. In Hasibuan, *et al.*, 2021, it was demonstrated that the stage of ripeness of palm fruits and other pre-processing factors affects the level of FFA in the resulting oil. Ordinarily, the level of FFA is one of the critical indicators of quality in fats and oils as all forms of oxidative instabilities whether physically or chemically induced result in higher levels of FFA in a given oil sample. (Hadi *et al*., 2019). Indeed, the FFA is a very strong indicator of oil quality in many ramifications because all forms of oil deterioration almost always manifest in form of high FFA levels in the oil. The trend of values of FFA as obtained in this work showed that lower values of FFA were obtained with samples processed using water of alkaline pH (pH > 7). This simply suggests that processing palm fruits with water of alkaline pH could enhance the reduction of FFA in palm oil and which will definitely improve the stability of the oil during storage.

Conclusion

Palm fruits were processed into edible red palm oil after sterilizing in water of different pH qualities. The resulting red palm oils were then analysed for some of their physico-chemical qualities following standard procedures. Results showed that oil samples processed in water of different pH qualities were significantly different in their pH, Iodine value, peroxide value, saponification value and free fatty acid contents except in their specific gravities. Palm fruits processed in acidic media (pH < 7) were seen to have higher saponification and viscosity values which is desirable for most industrial applications. On the other hand, oils processed in alkaline media (pH > 7) were seen to have higher iodine but lower free fatty acid and peroxide values which are very desirable for most culinary applications and storage stability of oils. It was also discovered that physico-chemical properties of oil samples processed in media of neutral pH (pH 7) were not as pronounced as those processed in the extremes of the pH scale. The findings of this work can be very useful in policy making and quality control for the palm oil industry. The quality of water especially its pH used in processing palm fruits should be identified as this work has revealed that media of both acidic and alkaline pH has both desirable effects and limitations in the quality of palm oil. More investigation can also be carried out on the effect of media pH on the yield and storage stability of palm oil

References

Akinyeye R.O., Adeyeye, E.I., Fasakin, O. & Agboola A., (2011) Physico-chemical properties and anti-nutritional factors of palm fruit products (*Elaeis guineensis jacq*.) from Ekiti State, Nigeria. *Electronic Journal of Environmental Agriculture and Food Chemistry*, 10(5).

American Oil Chemist’s Society AOCS (2012). Official Methods and Recommended Practice of the American Oil Chemical Society 5th Ed. Champan.

Birnin-Yauri, U.A & Garba, S. (2011). Comparative Studies on some physicochemical properties of baobab, vegetable, peanut and palmoils. *Nigerian Journal of Basic and Applied Science*, 19,64-67.

Decker, E. A., Akoh, C. C. & Wilkes, R. S. (2018) Role of pH in Lipid Oxidation and Antioxidant Activity. *Annual Review of Food Science and Technology*. https://www.doi.org/10.1146/annurev-food-030117-012643

Enyoh, E.C., Enyoh, C. & Amaobi, C.E (2017). Quality Assessment of Palm Oil from Different Palm Oil Local Factories in Imo State, Nigeria. Department Of Food Technology, School of Industrial And Applied Sci., 88(2),152-167

Fasina O.O. & Colley Z., (2008) Viscosity and specific Heat of Vegetable Oils as a function of Temperature: 35^{o}C to 180^{o}C. *International Journal of Food Properties*, 11(4):738-746

Gunshik, J.R., Ibrahim, M., Onyemowo, O.A. & Rabiat, L.A. (2023). Comparative Analysis of the Physico-Chemical Properties and Trace Metal content of Palm oil, from selected markets in Jos South and Jos North LGA, Plateau State, Nigeria. *National Journal for Clinical Research.* 28(2) 2023, 100-111. https://doi.org/10.10.4314/njcr.v28i1.3

Gunstone, F. D., Harwood, J. L. & Dijkstra, A. J. (2017). Palm Oil: Production, Processing, and Applications. In vegetable Oils in Food Technology (2nd ed.), pp. 257-276. Wiley-Blackwell. https://www.doi.org/10.1007/978-3-319-55119-0 12

Gunstone F. D (2006). *Vegetable Oil in Food Technology: Composition, Properties and Uses.* Blackwell Publishing.

Hadi, M. A., Zulkifli, R. & Latif, M. T. (2019). The Influence of Palm Oil Milling Processes on Residual Oil and By- Products Quality. *Journal of Oil Palm Research*, 31 (3), 440-451.

Hasibuan, R., Siregar, M. E. & Harahap, N. (2021). The Impact of Fruit Maturity on Palm Oil Quality. *Journal of Oil Palm Research*, 33(2), 285-297.

Ihenetu S.C., Enyoh C.E., Uzoigwe A.D. & Ubah O.G (2018) Biophysical Characterization of Palm Oil Mill Effluent from Adapalm, Imo State Nigeria. *Journal of Environmental Studies*, 4(1), p. 4.

Kumar, V., Sharma, A. & Kumar, A. (2018). Factors affecting the Quality of Palm Oil: A Review, *Journal of Food Science and Technology*, 55(4), 1220-1228. https://www.doi.org/10.1007/s13394-018-0285-3

Lopez, A., Pateiro, M. & Bermudez, J. (2019). Shelf-life extension of Palm Oil through Processing and Storage Optimization. Foods,8(2), 53. DOI:10.3390/foods8020053

Mohammed, B., Nofrizal, A., Lollie, A. & Pancawaraswati, P. (2017). Characteristics of Fresh Fruit Bunch Yield and the Physico-Chemical Qualities of Palm Oil during Storage in North Sumatra, Indonesia. *Indonesia Journal of Chemistry*, 17(2):182-190.

Nigeria Industrial Standard (NIS, 1992). Standards for Edible Vegetable Oil, Pg 5-12

Nwakodo, C.S, Udensi E. A. & Chukwu, M. N. (2018). Effect of processing methods and storage time on physical characteristics of palm oil. *Research Journal of Food Science and Nutrition*, 3(5):65-73.

Siew, W. L. Tan, C. P., & Lai, O. M. (2018). Moisture Content and Palm Oil Quality. *Journal of Food Science*,83(5), S1448-S1456. DOI:10.1111/1750-3841.14341

Standard Organisation of Nigeria (SON, 2000). *Standards for Edible Refined Palm Oil and Its Processed Form* pp. 2-5.

Suhaimi, N.S., Yusoff, M.M., & Abdullah, S. (2019). Effects of pest and disease management practices on palm oil quality. *Journal of Oil Palm Research*, 31(2), 161-172

Tan, C. H., Yusoff, M. M. & How, H. W. (2019). Storage conditions and Palm Oil Quality: A Review. *Journal of Food Chemistry*, 275, 731-738. https://www.doi.org/10.1016/J.foodchem.2019.02.044

Print ISSN: 2814-2802 e-ISSN: 3027-0553 www.ajikt.org

Wujie, Zhufie & Zujing (2011). The Influence of Water Quality on Food Quality and the Treatment of Water for Food Processing. *Procedia Environmental Sciences,* 10, pp. 2671-2676.

Zulkiply, S. N et al., (2017). Effects of Harvesting Technique on Palm Oil Quality. *Scientia Horticulturae*, 217, 241-248. https://www.doi.org/10.1016/*J.scienta*.2017.02.042.