Traditional and Semi-Mechanized Palm Oil Processing in South-Eastern Nigeria and its Application in Food

Enyi Chukwunwike UCHENNA[1], Philippa Chinyere OJIMELUKWE[2], Chinasa OKORIE-HUMPHREY[3], Clara Obiageri OGBEDEAGU[4]

[1,4] Department of Food Science and Technology, University of Agriculture and Environmental Science Umuagwo, Imo State, NIGERIA

[2,3] Department of Food Science and Technology, Michael Okpara University of Agriculture Umudike, P.M.B 7267 Umuahia, Abia State, NIGERIA

[1]https://orcid.org/0000-0003-1114-7721, [2]https://orcid.org/0000-0002-0263-0597
[3]https://orcid.org/0000-0003-2455-0122, [4]https://orcid.org/0009-0007-9886-0998

Corresponding author: nnasedo@gmail.com

Research Article	**ABSTRACT**
	This study is aimed to provide a detailed overview on the traditional and semi-mechanized, method of extraction of red palm oil from South – Eastern Nigeria and its applications in food. The study was undertaken in Udi Local Government Area of Enugu State and Umuahia North Local Government Area of Abia State both in South-Eastern part of Nigeria. One village each from these Local Government Areas was selected and four processors each from the villages in the study area were selected, interviewed and observed for processing practices. The processing stages involved harvesting, bunch reception of harvested fruits, fruit removal, bunch sterilization, digestion of the sterilized fruit, extraction of palm oil, clarification of oil and oil storage. These processes help to retain β-carotene and vitamin E in red palm oil. The unique solid content profile of palm oil, its perfect oxidative stability, high nutritional value and competitive price makes palm oil as one of the most utilized oils by food manufacturers and consumers in the region. The oil yield from the traditional processing method ranged from 15.50 - 15.70%, while that of semi mechanized processing method ranged from 20.40 - 20.70%. This study has revealed that semi mechanized method of palm oil processing had a higher oil yield when compared to the traditional method.
To Cite :	

INTRODUCTION

Oil palm has diverse uses along with other commonly used oil producing plants. It is known to grown very well in areas of tropical and subtropical regions (Izah and Ohimain, 2016). Palm oil is obtained from oil palm fruit and is one of the most important utilized vegetable oils (Andoh et al., 2019). Palm oil has high consumption

rate as well economic value in Nigeria due to it nutritional benefits and application which goes beyond food (Ohimain and Izah, 2015; Ndidi et al., 2020). Nigeria is among the major producers of the oil, which is gotten from flesh mesocarp of the palm fruit and has contributed tremendously to Nigerians diet (Biodun et al., 2020). The application of palm oil is dependent on its quality which is associated with the processing methods. Three methods of oil palm processing exist: These include traditional method which is mainly manual, semi-mechanized and mechanized methods. Oil palm processors are predominantly traditional processors which are up to 80% (Ohimain et al., 2013), semi-mechanized processors are 16% while mechanized processors are 4% (Ohimain and Izah, 2013). Traditional processors use manual equipments for their processing. The use of these manual equipments greatly affects their processing thereby leading to maintaining poor level of hygienic practices in the processing area. These have greatly affected the quality of crude palm oil (Ohimain and Izah, 2014). There are similarities between semi-mechanized and traditional processors which are up to 50%. Traditionally, sterilization and digestion involved in palm oil milling processes is done to enhance mechanical oil extraction. However, this method has gone passed its limit, which is being shown from the reduced oil extraction rates over the years. Enzymatic biotechnology has been introduced which has a significant breakthrough in the palm oil industry and has shown to overcoming the challenges encountered in traditional method of processing (Oils & Fats International Magazine, 2018). Enzymes can effectively break down plant cell walls, thereby helping oil release and subsequently extraction efficiency. With effective break down of palm fruit cell walls, enzyme enhances oil extraction without affecting the quality of crude palm oil. Most palm oil companies are practicing enzymatic biotechnology method of processing which has resulted in an increase in oil production. This breakthrough has not only ensured improved efficiency, but also reduced the industry's environmental footprint linked to use of land, an important development towards sustainable practices (Silvamany, 2021). In the mechanized methods fresh fruit bunch delivered to the palm oil mill undergo quality check for ripeness and quality standards before being loaded into cages for processing. These cages are transported into a horizontal sterilizer and steamed at a temperature of 143°C and 3 bar gauge pressure for up to 90 minutes, in a process known as sterilization. This procedure inhibits the action of hydrolytic enzymes, makes the separation of individual fruits from bunches very easy and prepares the nuts for further processing by decreasing kernel breakage during pressing and nut cracking, (Foong et al., 2919).

Pre-processing operations like injuries to fruits during transportation, enzymatic activities during fermentation before to threshing, clarification and as, well as storage are the main processing activities which have an affects on the quality of the palm oil regardless of the processing methods adopted (Ohimain and Izah, 2014). Fresh fruit

bunches must be allowed to be fully ripened before harvesting and taken to the factory for processing in other to obtain high oil yield. In 2018, Ministry of Agriculture stated that fresh fruit bunch should be processed within 24 hours of harvesting. There are various factors which delay processing of harvested fruits within 24 hours or even 2 – 3 days. These factors include transportation from place of harvest to place of processing, delay to meet the capacity required before processing and damage to palm oil milling equipments. Oxidation and hydrolysis causes changes in fatty acid composition thereby leading to oil rancidity (Ali et al., 2015).

Most constituents of palm oil include Palmitic acid methyl ester (31.5%) and oleic acid methyl ester (31.5%) (Ogundare et al., 2019). Different oils have unique fatty acids profile. Free fatty acid (FFA) has been used to determine palm oil quality (Lim et al., 2020). There are so many health benefits of palm oil due to its functional properties (Olafisoye et al., 2017). There has been negative report on the quality of industrial processed crude palm oil available in many Nigerian markets (Odoh et al., 2017). Inadequate handling and negligence of best processing practices have led to poor quality of processed palm oil which has adverse effect on the oil quality and also human health (Ngangjoh et al., 2020). Contamination as a result of poor processing (Enyi and Ojimelukwe, 2021), improper storage practices and adulteration of processed palm oil affect the qualities of palm oil thereby posing as a great challenge to the growth of oil palm industry in, many African countries like Nigeria (Aphiar and Raphael, 2019). Palm oil serves different varieties of purposes as edible oil in different food products, as well as households and foodstuff factories. Palm oil is been used in manufacturing of different food products like cooking oils, margarines, shortenings, confectioneries and other food applications (Madubuike et al., 2015). Minor components such as vitamin E (tocopherols and tocotrienols), aliphatic hydrocarbons, carotenoids, glycolipids, terpenes, sterols and phospholipids are present in unrefined palm oil at nearly 1%. Due to their physiological properties, carotenoids and vitamin E are the major important minor components present in oil (Goh et al., 2015). Palm oil provides essential fatty acids which include linoleic and arachidonic acids and it is an important food source to man as it serves as nutritional and industrial purposes (Goudoum et al., 2015). The purpose of this research was to investigate current processing methods for palm fruits in South-Eastern Nigeria.

MATERIALS and METHODS

Study Area

The study was done in Udi Local Government Area of Enugu State and Umuahia North Local Government Area of Abia State both in South-Eastern part of Nigeria. The indigenes of these areas are majorly oil palm processors into palm oil mostly for

their household uses and for commercial purposes. A purposeful study was carried out targeting a community that predominantly undertakes traditional processing in Enugu State and a community that predominantly undertakes semi-mechanized processing in Abia State.
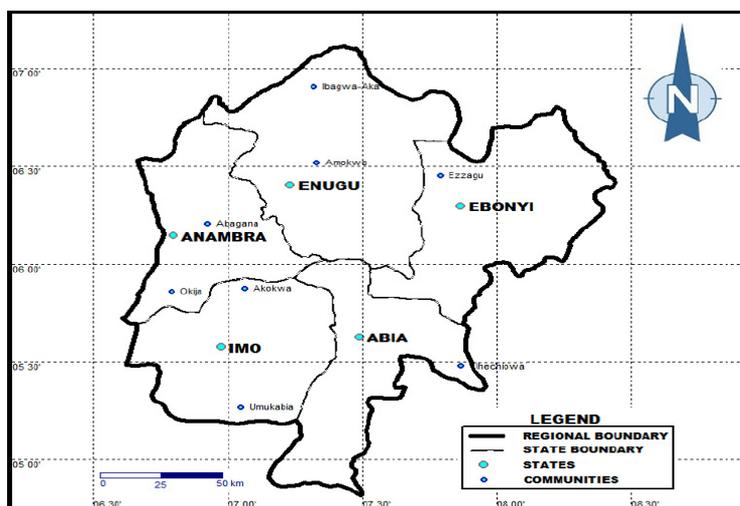

Figure 1. Map of Southeastern Nigeria (study area

Sampling Size and Sampling Procedures

This study adopted a multistage sampling procedure. The first stage was the selection of Udi and Umuahia North Local Government Areas in Enugu and Abia States respectively. The second stage was selection of (1) village each from the Local Government Areas based on predominance in processing of palm fruits to palm oil. These villages were Affa in Udi Local Government Area of Enugu State with mostly traditional processors and Ibeku in Umuahia North Local Government Area of Abia State with mostly semi-mechanized processors. The third stage consists of a random selection of 4 processors each from each of the selected villages in the study area. A questionnaire was shared to collect data about processing methods. The processing of palm oil was directly monitored.

Determination of Oil Yield

Oil yield was determined on-site. The oil yield in percentage for 50 kg of the fresh fruits was calculated using the formula below:

$$\%Y = \frac{Me}{Mm} \, x \, \frac{100}{1}$$

Where: Y = oil yield

Me = mass of oil extracted (kg)

Mm = mass of whole fresh fruit used (kg)

Data Analysis

Mean and standard deviation was carried out using SPSS version 22.0. The data obtained for oil yield were represented using bar chart.

RESULTS and DISCUSSION

About 80% of the palm oil processed in Nigeria is produced by low income farmers (Edelman et al., 2013). Processing and marketing of palm oil involve economic activities such as transportation to processing site, sorting and grading, processing and storage. The use advanced method of processing is highly encouraged as it ensures high oil yield with better quality. The major actors in palm oil processing are the workforce and progress or challenges of palm oil processing rely on how the workforce is effectively utilized.

Bunch Harvesting

Harvesting of palm fruit bunches was mostly done by skilled farmers who were experienced in climbing palm trees. They are been hired by the owners of the oil palm once the fruit is ripped and they are paid to cut the fruit and allow it to fall freely on the ground. These palm trees are been inspected often for ripe bunches as over-ripped fruits produce low quantity palm oil. Harvesting is done during the season of harvest and the method of harvest practiced in these study areas are by men climbing the tree with a rope tie around their waist to aid climbing and as well guide them from falling off the tree and harvesting the fruit in bunch with a cutlass. Adeniyi et al. (2014) reported that large set of equipments are needed for producing palm oil. These equipments range from manual or traditional mechanisms to advanced automated machinery. They further stated that even duo machine type or methods of palm oil processing may vary; there are basic steps for palm oil production. First step taken is in production of palm oil is the harvesting of fruit bunches. Figure 2 below clearly showed how fruit harvesting processes in South-Eastern part of Nigeria.

Bunch Reception and Threshing (removal of Fruit from the Bunches)

Freshly harvested fruits are received to the mill as intact bunches or loose fruit. The fresh harvested bunches are been packed in heaps and covered with jute bags and allowed to stay for up to 2 – 3 days to enable the fruit to loosen up prior to threshing. Processed palm oil quality is majorly relied on the quality of bunches received from the field. There are on-field challenges that affect the composition and as well the palm oil final quality. These factors include: agronomic, genetics, environmental, harvesting technique adopted, age of the tree, handling and transportation of the fruits. Small-scale processors have challenges managing these factors which ultimately affect the quality of processed palm oil. There are control measures in

place over harvesting method as well as post-harvest transport and handling of palm fruit bunches.

Fruit bunches are been threshed with an axe or cutlass after loosening on the bare ground and they are mostly performed by men because of their man power, although women sometime participate in threshing. The fresh fruit bunch consist of a mini bunches which are embedded on a main stem. Manual threshing is commonly adopted in these areas, and it is done by cutting the mini bunch from the bunch stem with an axe or machete before separating the fruit from the main bunch with hand. Some local villagers work in these factory sites as labourers using this as their main source of income. Figure 2 below shows how the fruit bunch is being threshed and separated in Udi and Umuahia North Local Government Area.

Figure 2. showing (a) harvesting of oil palm fruit bunch (b) harvested bunches (c) threshingand (d) fruit separation

Sieving and Boiling of Fruits

After threshing of the fruits, the level of dirt mixed with the fruits is reduced by sieving prior to boiling. This is achieved with the use of locally fabricated mesh wires made with palm fronds and it is mostly done by women and children. After sieving, the nuts are packed into metallic drums and firstly covered with a jute bag to retain heat and minimize the loss of vapour from the top before covering with a metallic cover and boiled in water. Fire woods and palm fruit fibers gotten from the waste of palm oil extraction are used to light the fire. Boiling is one of the main operations in the processing of palm fruits. This is mostly done to soften the fruits prior to digestion and to inhibit enzymes, activity, conditioning of nuts and coagulation of proteins (Chaw and Ma, 2007). Figure 3 below showed how the fruit is being boiled in these Local Government Areas of study.

Fruit Digestion and Oil Extraction

These stages involve digestion of the cooked fruits for easy extraction of oil from the fiber. This includes crushing and pressing of the heat-softened mesocarp from fruit nuts. In Udi, Local Government Area of Enugu State Nigeria, fruit digestion is mostly done in traditional way while semi-mechanized method is adopted in Umuahia-North Local Government Area. Traditional processing methods involve two methods of fruit digestion and they include: use of wooden or concrete made mortars with a wooden pestle to pound the cooked fruits and foot trampling or matching the cooked fruits in canoes or specially constructed wooden troughs. The village local method of extracting palm oil in Udi, Local Government Area requires the use of water to wash the pounded fruit mash and hand pressing to remove fibre and nuts from the oil/water mixture. A basket or a vessel with fine opened holes in the bottom is used to filter out fibre and nuts. In semi-mechanized method from Umuahia-North Local Government Area, the machine is constructed so that the motorized hydraulic digester and press system are constructed in such a way that the digestion and pressing is done by a single machine. According to Enyi and Ojimelukwe (2021) the quality of these oils is dependent on their processing methods. Figure 3 below showed how these operations are carried out in Udi Local Government Area of Enugu State and Umuahia North Local Government Area of Abia State both in Nigeria.

Figure 3. Palm oil processing:(A) boiling of fruit (B), traditional fruit digestion by mashing with the feet (C),traditional oil filtration (D), semi-mechanized fruit digestion (E), and semi-mechanized oil separation

Clarificmation and Oil Filtration

Clarification is done after releasing of the oil from the fruit and it is the last important operation in palm oil processing. The oil is transferred to a metallic container and heated before filtering to remove impurities. In the wet extraction process, as seen in the traditional method of processing, additional steps are required to make sure that moisture in the mixture is removed. This is achieved by heating the oil in a clarifying pot. This process drives excess moisture out of the oil and allows any trace of impurity to sediment prior filtration. After this operation, the oil is checked for appropriate moisture and fat content before storage. The kernels are separated from the fibre after oil extraction and it is mostly done by the women. The dried fibre is mostly used to make fire while the kernels are either sold out to industries for further processing or the shell being cracked open, and the nuts taken. The nuts serve different purposes as some take it with roasted corn and can be used for palm kernel oil extraction.

Figure 4. Showing last phase of processing: (A) Oil clarification (B) Oil filtration (C), Separation of kernel from the fibre at Umuahia North Abia State Nigeria

Palm Oil Yield

Figures 5 below showed the graphs of oil yield from traditional processing method in Udi LGA of Enugu State and semi mechanized processing method in Umuahia North LGA of Abia State. The oil yield from the traditional processing method ranged from 15.50 - 15.70%, while that of semi mechanized processing method

ranged from 20.40 - 20.70%. Semi mechanized method had a higher recovery rate because of the methods adopted to loosen the matrix of the fruit tissues to allow fat extraction. According to Ruswanto et al. (2019) several factors which include method of harvesting, processing method adopted, state of fresh fruit Bunch (FFB) from the period of harvesting to postharvest processes in the factory, ripeness of the palm fruit prior to harvesting and transportation time of the harvested fruit from the farm to the factory influence palm oil yield

Table 1. Oil yield from traditional and semi-mechanized processing methods from Udi and Umuahia North LGA in Nigeria

Processors		Udi Lga (Enugu State)	Umuahia North Lga (Abia State)
First processor	Mean	15.4800	20.6967
	N	3	3
	Std. Deviation	.07211	.00577
Second processor	Mean	15.6300	20.4833
	N	3	3
	Std. Deviation	.01000	.00577
Third processor	Mean	15.6967	20.4000
	N	3	3
	Std. Deviation	.00577	0.00000
Fourth processor	Mean	15.6733	20.6433
	N	3	3
	Std. Deviation	.00577	.00577
Total	Mean	15.6200	20.5558
	N	12	12
	Std. Deviation	.09342	.12479

Values are mean±Standard deviation of triplicate determinations.

According to Owolarafe et al. (2007) digestion is a process of reducing the size of the palm fruit thereby allowing the rupturing of oil cells to release oil. Proper digestion of the fruits as seen in semi mechanized method of processing ensure homogenous mash free from undigested fruits, which gives maximum oil yield. The degree at which the fruit is digested is determined by the extent of exposure of the fruit to mashing (Owolarafe et al., 2002). The number of fruits in a given bunch, production of large number of female species, the size of each fruit which is affected by the environment, the mesocarp /kernel and finally the fruit/bunch ratio is been affected by the yield of the oil palm.
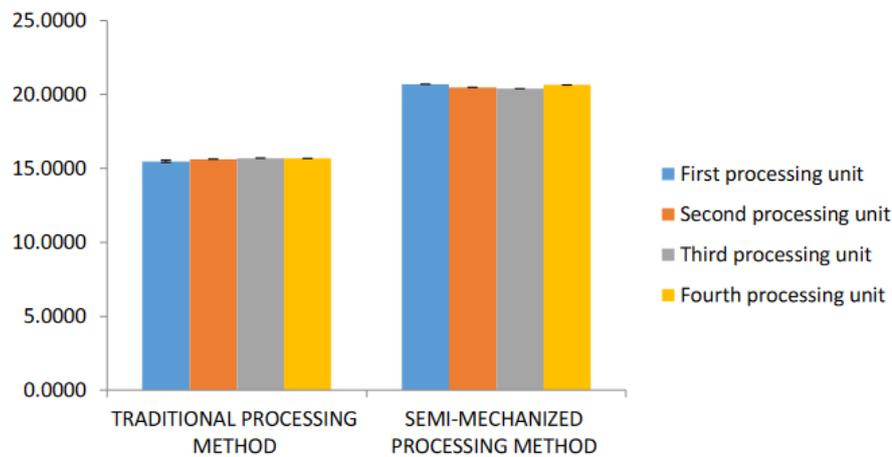
Figure 5. Oil yield from traditional and semi-mechanized processing methods from Udi and Umuahia North LGA in Nigeria

Palm Oil Storage and Preservation

Plastic materials are commonly used for the storage of palm oil in these locations. Heavier clear glass bottles and Lacquered cans were said to be used in the past. Palm oil are been advised to be stored in the dark to reduce the rate of hydrolytic and oxidative deterioration of palm oil. Enyi and Ojimelukwe (2021) observed that processing methods and storage period have adverse effects on the palm oil quality. Therefore, palm oil requires proper handling to prevent quality deterioration. Many studies have been carried out on the different factors affecting the quality of oil during storage. Previous researches have proven that light, oxygen, moisture, and as well heat affect the quality of oil and that light facilitates the rate of deterioration of oils (Egbuna et al., 2013). For this reason, oil should be preserved away from open and direct sunlight and stored in lacquered metal can or stored in an amber and green glass bottles rather than clear plastic bottles. Polyethylene film is not a good packaging material. Therefore, should be avoided. Processed palm oil is been stored in a storage tank prior to dispatch from the factory in commercial mills. The oil is advised to be maintained at a temperature of 50°C by the application of hot water or low-pressure steam-heating coils to avoid solidification and fractionation. The storage tank should be constructed with a suitable protective coating to prevent iron contamination (Ataga et al., 1993). Small- scale processors have no storage methods in place. They store processed oil in used plastic or petroleum drums at room temperature.

Food Uses of Palm Oil in Southeastern Nigeria

Frying and Cooking

Palm oil is extensively used for cooking in Southeastern Nigeria. When it is used for frying, the food is dipped in heated oil at an elevated temperature. Various undesirable reactions take place during the use of this oil for frying which causes its deterioration. These include thermal oxidation, hydrolysis, and polymerization (Setyawan et al., 2013). Palm oil is majorly used in frying than any other food application, for performance and economic reasons as it is widely known as ideal and heavy-duty frying oil (Nallusamy, 2006).

Selection of frying medium should be well considered in frying procedures as the quality of the fried foods and also consumer's health are greatly affected. There are different frying media which include Vegetable oils, animal fats or a combination of both. There are important attributes to be considered while selecting the frying medium suitable for deep-frying. These include the quality of the fats/oils to withstand the high temperature of deep frying and also stable against the oxidation and polymerization. The oil must contain a high resistance to oxidation and gumming, low rate of darkening and foaming, low level of free fatty acid rise, smoking and melting point and good fatty acid composition (Nor Aini and Miskandar, 2007).

Products obtained from frying in palm oil include potato and yam chips, French fries, doughnuts, diet, plantain, meats, and fish. Currently in Southeastern Nigeria, palm oil is among the most significant type of product which is widely used in homes as cooking oil. It is used in preparing all kinds of foods such as soups, porridge yam, beans and other locally prepared foods.

Baked Products and Blending

Palm olein and palm stearin are products obtained from red palm oil which could be used in place of margarine as a result of their compositions of fatty acids likely colors and textures for the product. They are used in cakes, bread, cookies, pastries and other bakery products. A study by Harianti showed that red palm oil could be used to produce high antioxidant cake products (Harianti et al., 2018). In the food industries, the nutritional quality of a particular food product, the functional properties and oxidation stability of the frying oil can be improved by blending palm oil with other edible oil. To produce new specific frying oils, two or more oils with varying characteristics, such as fatty acid chain length and/or patterns of unsaturation can be blended (Tiwari et al., 2014).

The trend which is to modify the vegetable oil in the frying industry is done in other to enhance the oxidation stability, nutritional and functional properties, and technical

performance of the frying oil (O'Brien, 2010; De Leonardis and Macciola, 2012). The blended oils share the same nutritional and functional properties which is dependent on the blend ratio. It is very paramount that the blended oils are within the stipulated food laws and guidelines and also meet consumers' expectations. The aim of blending oils could be for commercial, functional, technical, nutritional purposes depending on the reason for application. Blending is majorly practiced within this geographical area because it does not increase processing cost.

Making Ice Cream, Mayonnaise and Infant Formula

Butterfat used in ice-cream formulation has been replaced using palm oil as it is economical and readily available. Palm oil is now widely used in ice-cream formulation, due to their physical characteristics which helps to produce ice-cream with good texture, mouth feel and stability especially during storage. According to Isa et al. (2009), 5%, 8% and 10% of red palm olein have been combined with non-milk fat solids in ice creams production and have recorded higher scores in color, taste and texture. Palm oil can be blended with other vegetable oils like soya oil for mayonnaise and salad dressing. Apart from the favourable price of palm oil above other liquid vegetable oils, the high content of vitamin E as reported by Enyi and Ojimelukwe (2021), a natural antioxidant in palm oil, would give it an added advantage when compared with other vegetable oil as vitamin E would improve the oxidative stability of the products. Palm oil has been widely used in Southeastern Nigeria as complementary food formulation when blended with other vegetable oils. It was found that palm oil contains about 10% - 15% palmitic acid which helps in the high digestibility of the products containing palm oil.

CONCLUSION

Nigeria is among the largest producers of palm oil in the world. Palm oil processing is a common practice in Southeastern Nigeria. Both men and women participate actively in the processing for commercialization and household consumption. The traditional and semi-mechanized processing methods are mostly adopted in Southeastern Nigeria. Smallholders use manual or traditional equipment for processing, and they are the major players. Palm oil can be applied in many foods such as cooking/frying oil, fat spreads, ice cream, salad and mayonnaise dressing, health supplements, and so many others. It is applied in many foods as it is readily availability with fair prices, natural oxidative stability, high nutritional value, and antioxidant properties. The yield of oil palm in Southeastern part of Nigeria is relatively high, and if the sector is properly managed, it has the ability to reduce the rate of unemployment in the area.

REFERENCES

Adeniyi OR, Ogunsola GO, Oluwusi D., 2014. Methods of Palm Oil Processing in Ogun State, Nigeria: A Resource Use Efficiency Assessment. American International Journal of Contemporary, Research, 4(8): 173-179.

Ali FS, Shamsudin R, Yunus R., 2015. The Effect of Storage Time of Chopped Oil Palm Fruit Bunches on the Palm Oil Quality. Agric Agric Sci Procedia [Internet]. 2: 165–72.

Andoh SS, Nuutinen T, Mingle C, Roussey M., 2019. Qualitative analysis of Sudan IV in edible palm oil. Journal of the European Optical Society, 15(1): 1-5. https://doi.org/10.1186/s41476-019-0117-0.

Aphiar AE, Raphael NI., 2019. Quality Assessment of Physicochemical Properties of Palm Oil From Different Palm Oil Mills In Isoko , Delta State. International Journal of Innovative Research and Advanced Studies, 6(6): 31–35.

Ataga DO, Ilechie CO, Omoti U., 1993. Small Scale Palm Oil Processing Technology in Nigeria. Paper Presented to BUROTROP-AFOPDA. Seminar on Small and Medium Scale Palm and Coconut Technologies, Accra, Ghana. pp. 77-89.

Biodun MB, Akinlabi ET, Okokpujie IP, Fayomi OSI., 2020. An overview of palm oil production processing in Nigeria: A case study of Ilashe, Nigeria. International Conference on Engineering for Sustainable World (ICESW 2020), 1107 (2021) 012134. https://doi:10.1088/1757-899X/1107/1/012134.

Chaw MC, Ma AN., 2007. Processing of fresh palm fruits using microwaves. International Microwave Institute, 40(3): 165-173.

Edelman M, Oya C, Borras SM., 2013. Global Land Grabs: Historical processes, Theoretical and Methodological Implication, and current Trajectories. Third World

Quarterly, 34(9): 1517-1531.

Enyi CU, Ojimelukwe PC., 2021. Processing Methods and Storage Period Affect the Quality of Palm Oil. Carpathian Journal of Food Science and Technology, 13(4): 192-210. https://doi.org/10.34302/crpjfst/2021.1 3.4.15.

Foong SZY, Andiappan V, Tan R, Ng DKS., 2019. Optimization and analysis for palm oil mill operations via input-output optimization model. EDP Sciences, 206: 1-6. https://doi.org/10.1051/matecconf/201926802006.

Goh SH, Choo YM, Ong ASH., 2015. Minor Constituents of palm oil. Journal of the American Oil Chemists' Society, 62: 237-240. https://doi.org/10.1007/BF02541384.

Goudoum A, Makambeu NA, Abdou BA, Mbofung CM., 2015. Some physicochemical characteristics and storage stability of crude palm oils (Elaeisguineensis Jacq). American Journal of Food Science and Technology, 3(4): 97-102.

Harianti R, Marliyati S, Rimbawan R, Sukandar D., 2018. Development of high antioxidant red palm oil cake as a potential functional food. Jurnal Gizi dan Pangan, 13: 63-70.

Isa WRA, Idris NA, Rahman IA., 2009. Physical properties of red palm-based ice cream. In Oil Palm Bulletin, Malaysia, pp. 18-24.

Izah SC, Ohimain EI., 2016. The opportunities and weakness of Nigerian oil palm industry. Biotechnological Research, 2(1): 33–43.

Lim K, Pan K, Yu Z, Xiao RH., 2020. Pattern recognition based on machine learning Identifies oil adulteration and edible oil mixtures. Nature Communications, 11(1). https://doi.org/10.1038/s41467-020-19137-6.

Madubuike PC, Ezigbo I J, Ekpe IO, Onukwube SI., 2015. Evaluation of the quality and level of adulteration of palm oil obtained from different locations in Enugu Metropolis, Nigeria. International Journal of Multidisciplinary Sciences and Engineering, 6(6): 23-26.

Nallusamy S., 2006. The role of palm oil in the snack food industry. Paper presented at The International Palm Oil Trade Fair and Seminar. 21-24 November 2006, Kuala Lumpur, Malaysia.

Ngangjoh AS, Tatanja NA, Ejoh AR., 2020. Spoilage and microbial quality of crude palm Oil from the North-west Region of Cameroon. African Journal of Food Science, 14(9): 304-312. https://doi.org/10.5897/ajfs2020.1993.

Ndidi N, Tamuno-boma O, Udiomine Brantley A, Tamunomiebam EI., 2020. Toxicological Effects of Sudan III Azo Dye in Palm Oil on Liver Enzyme and Non Enzyme Markers of Albino Rat. International Journal of Nutrition and Food Sciences,

9(4): 104-111. https://doi.org/10.11648/j.ijnfs.20200904.12.

Odoh CK, Amapu TY, Orjiakor IP, Martins PE, Seibai BT, Akpi UK, Ugwu CS, Lerum NI, Nwankwegu AS., 2017. Assessment of mold contamination and physicochemical properties of crude palm oil sold in Jos, Nigeria. Food Science and Nutrition, 5(2): 310-316. https://doi.org/10.1002/fsn3.393.

Ogundare FO, Adekola FM, Oladosu IA., 2019. Compositions and photon mass Attenuation coefficients of diesel, kerosene, palm and groundnut oils. Fuel, 255: 115697. https://doi.org/10.1016/j.fuel.2019.115697.

Ohimain EI, Izah SC., 2013. Gaseous Emissions from a semi-mechanized oil palm Processing mill in Bayelsa State, Nigeria. Continental Journal of Water, Air and Soil Pollution, 4(1): 15-25.

Ohimain EI, Izah SC., 2014. Energy self-sufficiency of smallholder oil palm processing In, Nigeria. Renewable Energy, 63: 426-431.

Ohimain EI, Izah SC., 2015. Physicochemical characteristics and microbial population of palm oil sold in major markets in yenagoa metropolis, bayelsa states, Nigeria. Journal of Environmental Treatment Techniques, 3(3): 143-147.

Ohimain EI, Izah, SC, Obieze FA., 2013. Materialmass balance of smallholder oil palm processing in the Niger Delta, Nigeria. Advance Journal of Food Science and Technology, 5(3): 289-294.

Oils & Fats International Magazine. 2018. Available from: https://www.ofimagazine.com/content-images/news/Enzymes.pdf

Olafisoye OB, Oguntibeju OO, Osibote OA., 2017. Trace elements and radionuclides in Palm oil, soil, water, and leaves from oil palm plantations: A review. Critical Reviews in Food Science and Nutrition, 57(7): 1295-1315. https://doi.org/10.1080/10408398.2014.886032.

Owolarafe OK, Olabige MT, Faborode MO., 2007. Macrostructural characterisation of palm fruit at different processing conditions. Journal of Food Engineering, 79: 31-36.

Owolarafe OK, Faborode MO, Ajibola OO., 2002. Comparative evaluation of the digester-screw andhand-operated hydraulic press for oil palm fruit processing. Journal of Food Engineering, 52: 249-255.

Ruswanto A, Ramelan AH, Praseptiangga D, Partha IBB., 2019. Palm oil yield potency on different level of ripening and storage time based on fruits percentage and fresh fruit bunches. International Conference on Food and Bio-Industry, 443(2020): 012005. https://doi.org/10.1088/1755-1315/443/1/012005.

Setyawan AD, Sugiyarto S, Susilowati A., 2013. Physical, physical chemistries,

chemical, and sensorial characteristics of the several fruits and vegetables chips produced by low temperature of vacuum frying machine. Nusantara Bioscience, 5: 86-103.

Silvamany H., 2021. Engineering Solutions for the Palm Mill of the Future: Increasing Extraction Rate and Sustainability through Biotechnology. Malaysia, United Kingdown: IOP Conference Series: Materials Science and Engineering, 2021. https://doi.org/10.1088/1757-899X/1195/1/012061.

Tiwari MR, Tiwari KK, Toliwal D., 2014. Studies on thermal stability of palm–sesame oil blends during deep fat frying. Journal of Scientific & Industrial Research, 73: 153-156.