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Storage Oxidation Stability of Crude Palm Oil with some Traditional Nigerian Spices.

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Abstract
Background: *Natural preservatives can be extracted from spices and applied to palm oil to extend their storage life. The antioxidative properties of certain spices can be utilized in palm and other vegetable oils when applied as solvent extracts, powders, grits, emulsions, etc. Free fatty acids and peroxide value are commonly used as indices for monitoring the oxidation stability of stored vegetable oils. There was no study on the oxidative stability effects of the three selected Nigerian spices. We carried out this study to determine the antioxidant effects of M. myristica, M. tenuifolia and A. danielli in comparison to alpha-tocopherol on palm oil stored at room temperature for 24 weeks.*
Materials and Methods: *In this study, crude palm oil samples mixed with 200ppm of the grits (0.5mm) and n-hexane extract from each of the three spices were stored for twenty four weeks at room temperature, while the palm oil samples with and without the addition of α-tocopherol were used respectively as the control samples. The crude palm oil was analyzed for moisture content, relative density, free fatty acid, peroxide value, iodine value and saponification number before the commencement of the storage studies. The stored palm oil samples were analyzed for free fatty acid and peroxide values once every two weeks to determine the effectiveness of the spices (the grit and extract) as antioxidants.*
Results: *The moisture content, relative density, free fatty acid, peroxide value, iodine value and saponification number of the crude palm oil samples before storage were 1.078 %, 0.899, 0.80%, 0.23 m/Eq/kg, 0.80%, 58.11 g I_2/100g, and 32.59 mgKOH/g. After the twenty-fourth week, the crude palm oil samples stabilized with spice grits and n-hexane extracts and alpha-tocopherol had significantly reduced FFA () and PV() compared to the samples without treatment. The n-hexane extracts had a higher oxidative stability on the oil than grits from the spices.*
Conclusion: *Monodora tenuifolia and Monodora myristica had better antioxidant performance than alpha-tocopherol. Monodora tenuifolia, Monodora myristica and Aframomum danielli imparted oxidative stability on stored crude palm oil.*
Keywords: *Palm Oil, Free fatty acid, Peroxide value, Antioxidant, M. myristica, A. danielli, M. tenuifolia*

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I. Introduction

Palm oil is a product extracted from the fleshy part of the fruits of the oil palm (*Elaeis guineensis*) [1]. Palm oil is different from palm kernel oil (PKO) which is obtained from the kernels inside the hard shell of the palm fruit. The palm oil tree thrives in the tropics and can be seen globally in such regions in Africa, Asia and South America [2] with an outstanding output of 4.1 tonnes of oil per hectare yearly, making it the most productive oil-producing plant [2]. Premium oil quality is maintained by harvesting the fruits at optimal ripeness, protective raw material handling and proper oil extraction procedures [3]. Palm oil is used in either its' crude or refined state. The refining and fractionation process yield Refine, Bleached and Deodorized (RBD) palm oil, palm olein and palm stearin. The various products of palm oil have an enormous and growing global market value with 85% applications in food processing and the remaining applications in the oleo chemical industry, polyoly and polyurethane industry and in the manufacture of grease, insecticide, printing ink and bio fuel [4]. The importance of dietary palm oil became even more obvious with the realization that the saturated fatty acid of palm oil is similar to oleic acid in having no adverse effects on serum lipid and cholesterol profile [5]. Dietary palm oil also contributes carotenoids and vitamin E in the diet which are helpful in protection and prevention against chronic degenerative diseases [6, 7, 8] and the inhibition of cholesterol synthesis [9].

Palm oil is made up of glycerides and minor components such as carotenoids, tocopherols, etc [4, 10]. The carotenoids and tocopherols contribute to the oil's characteristic colour and relative oxidative stability,

respectively [11]. The 50% saturated fatty acids composition of palm oil also contributes to its' relatively storage stability [12]. Palm oil, despite being relatively stable, becomes rancid with time through the unsaturated fatty acid fraction. Rancidity depletes the sensorial and nutritive attributes of palm oil, reduces its economic value and causes the accumulation of free radicals. Free radicals initiate degenerative and carcinogenic disease conditions in the body. Oxidative stability of vegetable oil is a measure of the length of time taken for oxidative deterioration to commence [13] and can be measured using peroxide and free fatty acid values determination, p-anisidine test [14, 15, 16].

Oxidative stability of palm oil during storage can be enhanced with the addition of antioxidants. Natural antioxidants are currently being favoured as GRAS (Generally Regarded As Safe) due to their easy assimilation in the body and potential source of additional bioactive components in the diet [17]. Natural antioxidants contain phenolics, flavonoids, etc. [18] which act similarly as synthetic antioxidants [19, 20]. The excellent oxidative stability potential of spices as natural antioxidants has been shown in several studies [17, 21, 22, 23] where they are added as aqueous or organic extracts, powder, capsules, emulsions or whole forms [11, 17, 24].

The *M. myristica, A. danielli* and *M. tenuifolia* are tropical trees that grow in the wild [25]. Both *M. tenuifolia* and *M. myristica* are orchid flower trees belonging to the Family, Annonaceae and genus, *Monodora* with species name, *tenuifolia* and *myristica* respectively. Both seeds are oblong and ovoid in shape, however, *M. myristica* is bigger and about 2cm long and 1.5cm wide with a smooth and thick seed coat when dried, while *M. tenuifolia* is about 2.5cm long and 1.5 cm wide with rough, thin seed coat when dried. *M. myristica* bears a common name, African nutmeg and known locally as *ehuru, ariwo* and *awerewa* by the Igbo, Hausa and Yoruba speaking tribes of Nigeria. *M. tenuifolia* is also commonly known as African nutmeg but locally identified as *Ehuru ohia*, *ehinawosin* and *Uyenghen* by the Igbo, Yoruba and Ijaw tribes of Nigeria. *A. danielli* is a tropical tree with the common name, Bastered melegueta and known in Igbo tribe of Southern Nigeria as *urima*. It belongs to the family, Zingiberaceae [26]. The seeds of the three trees are aromatic and primarily used in Nigeria as spices in the preparation of several traditional dishes [25, 27] and sometimes as alternative medicine for several ailments [25, 27] and as insect repellant [28]. The oxidative stability of *M. tenufolia*, *M. myristica* and *A. danielli* has been established [28, 29, 30, 31, 32], but the comparative storage oxidative stability effect of their grits and extracts have not been shown in palm oil. This study investigated the oxidative stability potentials of the n-hexane extracts and grits of *M. myristica, A. danielli* and *M. tenuifolia* in comparison to alpha-tocopherol in palm oil stored at room temperature.

II. Materials And Methods

2.1 Materials

The three spices, *Monodora myristica* (African nutmeg, *ehuru*), *Aframomum danielli* (*Urima*) and *Monodora tenuifolia* (*Efi*) were purchased in their dried forms without any pest infestation or damage from the local retailers at a local market, Eke Onunwa in Owerri, Imo State, Nigeria. Fresh palm oil fruits were purchased from a farmer at Atta, Ikeduru LGA, Imo State, immediately after harvest. The alpha-tocopherol (Vitamin E) (100 IU) capsules were bought from a pharmacy shop to ascertain its food grade status. Identification of the nomenclature of each spice, *Monodora myristica*, *Aframomum danielli* and *Monodora tenuifolia* (Plate. 1), was done at the Taxonomy Unit of the Department of Botany, University of Nigeria, Nsukka.

2.2 Sample Preparation

2.2.1 Preparation of crude palm oil

Cleaned, fresh and ripe palm fruits (2kg) were boiled, pounded and the oil extracted by manual pressing. The oil was heated at 100^0C for 10 minutes to remove residual moisture; cooled and filtered to remove impurities. The crude palm oil was stored in an amber bottle glass container and stored at room temperature until required.

2.2.2 Preparation of spice grits.

A hundred grams, each of cleaned *Monodora myristica*, *Aframomum danielli* and *Monodora tenuifolia* seeds was sterilized with 50 mls methanol each and air-dryed for 30 minutes to remove residual methanol. The seeds of *Monodora tenuifolia* and *Monodora myristica* were then respectively toasted in a preheated oven at 177^0C for 15 minutes and dehulled to remove the seed coats. *A. danielli* having thin seed coat did not require toasting and dehulling. The prepared seeds were each milled in a hammer mill and passed through a No 32-mesh sieve to yield their respective grits of 0.5mm particle size.

Plate 1: A= *Monodora tenuifolia*; B = *Monodora myristica;* C = *Aframomum danielli*

2.2.3 Preparation of Spice extracts.

About 20g each of the flour of *M. myristica*, *A. danielli* and *M. tenuifolia*, were respectively placed in the soxhlet extractor unit. The extraction with n-hexane was carried out at 40^0C for 12 hours [33]. The flat-bottomed flask containing the spice extract was heated at 40^0C for 10 minutes and kept uncovered at room temperature for 1 hour to remove residual n-hexane.

2.3 Experimental Design

The crude palm oil was divided into eight portions with each sample containing 100g of palm oil. Sample labeled PO served as the first control: blank crude palm oil without any treatment while sample labeled PVE contained 0.02g (200ppm) alpha-tocopherol (Vitamin E) [34]. Samples labeled PMMg, PADg and PMTg contained 0.02g of the grits of *Monodora myristica*, *Aframomum danielli* and *Monodora tenuifolia* respectively. Samples labeled PMMe, PADe and PMTe contained 0.02g of the n-hexane extracts of *Monodora myristica*, *Aframomum danielli* and *Monodora tenuifolia* repectively. Each mixture was prepared in duplicates. All the samples were kept in the carefully labeled and covered plastic bottles. Initial FFA and Peroxide values of the samples were determined before storage at 28^0C. Also measured were moisture content, relative density, saponification number and iodine value.

The crude palm oil samples were tested for rancidity after the fourth and eighth week of storage and afterwards, every two weeks, until the twenty fourth week using free fatty acid (FFA) and peroxide value (PV) indicators.

2.4 Relative Density Determination

Relative density of the crude palm oil samples was determined [35]. The relative density bottle (Mw_1) was filled with distilled water and gently covered with the lid, the outside walls of the bottle was cleaned and weighed (Mw_2). The same procedure was conducted for the oil and relative density calculated thus:

$$Relative\ density = \frac{MO_1 - MO_2}{MW_2 - MW_1}$$

Where Mo_1= Mass of relative density bottle used for oil; Mo_2= Mass of relative density bottle and oil; Mw_1 = Mass of relative density bottle used for water; Mw_2 = Mass of relative density and water.

2.5 Moisture Content Determination

Moisture content value of the crude palm oil sample was determined using 5g of the sample [35]. Moisture content was calculated as: $\%\ Moisture\ content = \frac{W3-W_2}{W_2-W_1} \times 100$

Where, W_1 = Weight of porcelain dish; W_2 = Weight of empty porcelain dish + sample before drying; W_3 = Weight of porcelain dish + constant weight of dried sample.

2.6 Iodine Value Determination

Iodine value of the crude palm oil samples were determined [36]. An accurate value of oil, 0.5 g, was weighed into a 500 ml stoppered conical flask, dissolved in 10 ml chloroform and 25 ml of Wij's iodine solution added. The conical flask was sealed by moistening the stopper with a little of 10% solution of potassium iodide. The conical flask was kept in the dark for 30 minutes and afterwards, 10 ml 15% potassium

iodide and 100 ml water were added. The mixture was titrated with 0.1N Sodium thiosulphate, using 1-2ml of 1% starch solution as indicator until the blue-black colour was completely discharged.. A blank determination was also conducted without the oil. Iodine value was calculated as below:

$$Iodine\ Value, \text{g } I_2/100\text{g} = \frac{(X-Y)\times N\times 12.69}{W}$$

Where X= Volume in ml of approximately 0.1N thiosulphate solution required for the blank, Y= Volume of ml of approximately 0.1N thiosulphate solution required for the test sample, W=Weight in grammes of sample, N= normality of thiosulphate solution, 12.69 = molecular weight of Iodine.

2.7 Saponification value Determination

Saponification value of the crude palm oil samples were determined [36]. Two grams (2g) of palm oil sample was weighed into 300ml flask. Twenty-five mls (25ml) of 0.5N alchoholic Potassium hydroxide solution was added into the flask. and heated to become colourless. The mixture was cooled and titrated with 0.5N HCl until the pink color just disappeared using 0.5ml of 1% phenolphthalein solution as indicator. The titre value was recorded as X. A blank test was also determined.

$$Saponification\ value \text{ (mg KOH per g of sample)} = \frac{\text{X}-\text{Y x N x } 56.1}{W}$$

Where: X= ml, of approximately 0.5N HCl in test sample (ml); Y= ml. of approximately 0.5N HCl in blank (ml); N=normality of acid (mmol/ml); 56.1 =Molecular weight of KOH (mg/mmol) and W= weight of sample in g.

2.8 Free Fatty Acid Determination

Free fatty acid values of the crude palm oils were determined [36]. Five (5g) of crude palm oil was weighed into a 250 ml Erlenmeyer flask, dissolved in 50ml of 95% ethanol and brought to boiling point. While it was still over 70^0C, it was neutralized with 0.1N potassium hydroxide (KOH) using phenolphthalein indicator. It was then titrated with occasional shaking using 0.5 N ethanolic until the colour of the indicator changed. The end point was noted when the addition of a single drop of 0.1N KOH produced a permanent pink which persisted for at least 15sec. The value was calculated using equation 1.

$$\%\ Free\ fatty\ acid = \frac{25.6 \times \text{a} \times \text{N}}{P}$$

Where: a = number of ml of the ethanolic KOH solution used (ml); N = exact normality of the ethanolic KOH solution used (mol/1000ml); p = weight of sample in g; 25.6= molecular weight of palmitic acid (g/mol) (Molecular weight for oleic acid and lauric acid are 28.2 and 20.0 respectively).

2.9 Peroxide Value Determination

Peroxide value determination was carried out on the crude palm oil samples [36]. Two (2g) of crude palm oil was weighed into a 250 ml glass-stoppered Erlenmeyer flasks, 30 ml of acetic acid-chloroform solution (2 volume glacial acetic acid and 1 volume chloroform) was added and the solution was swirled to allow dissolution. 1g of potassium iodide was added. The solution was left to stand for a minute with occasional shaking and 30 ml of distilled water was added. The solution was slowly titrated with 0.01 N sodium thiosulfate solution and 0.5ml of 1% starch indicator, with vigorous shaking until the yellow color just disappeared. The volume of the titrant used was noted. A blank determination without the oil was carried out and the volume used was noted. Iodine value was calculated as:

$$Peroxide\ Value\ (mEq/kg\ of\ sample) = \frac{\text{T} \times \text{N} \times 1000}{W}$$

Where: T = titre (ml), N= Normality of $Na_2S_2O_3$ (mEq/ml), W = Weight of sample (g); 1000 = Conversion of units (g/kg).

2.10 Statistical Analysis

All determinations carried out were done in duplicates. Data generated were subjected to statistical analysis using SPSS 20 statistical software package. Analysis of variance (ANOVA) procedure was used to analyze the data statistically. Means were separated using the Fisher's Least Significant Difference.

III. Results And Discussion

Some of the physicochemical properties of the freshly expressed crude palm oil are presented in Table 1. The free fatty acid (FFA) (%) values of the freshly extracted crude palm oil sample just before treatment and storage was 0.80%. The FFA value was within the quality standard of 3.3% for vegetable oils [1] and comparable to the value, 2.12% obtained in palm oil [37]. FFA is an indication of raw material quality, quality

of the production process and the final product [38]. When their value exceeds a certain limit, it indicates low product quality [39]. FFA value in crude vegetable oil indicates how much the oil should be refined to remove the free fatty acids.

The peroxide value of the freshly extracted crude palm oil sample was 0.23mEq/kg, lower than the peroxide value standard of 20mEq/kg in palm oils [1] and 2.6mEq/kg reported [40]. It is defined as the quantity of peroxides in milliequivalents (mEq) for each kilogram of sample. Peroxides in palm oil are formed as preliminary products of lipid oxidation, whereby low values signify either the beginning or advanced stage of oxidation [16]. It indicates the level of oxidation of oil where values above 20 mEq/kg suggest badly degraded oil. A freshly and well refined palm oil should have a peroxide value of zero.

The iodine value of the freshly expressed crude palm oil was 58.11gI_2/100g. Iodine value is the quantity of iodine by weight absorbed by 100g of oil and is a standard for determining the amount of double bonds in an oil sample and also a measure of the susceptibility of a vegetable oil to oxidation. More iodine is absorbed as the degree of double bonds in the oil increases [42, 43]. It also measures the degree of oxidation since the double bonds and iodine value decreases as oxidation progresses [43]. The iodine value obtained was close to the recommended range of 50-55gI_2/100g for crude palm oil [1].

The moisture content (1.078%) of the freshly expressed oil sample was a little higher than the quality standard of 0.29% or less in vegetable oils [41]. Moisture content determines product quality. High moisture content in vegetable oil increases hydrolytic rancidity and FFA values [43]. A positive correlation was found between moisture content and free fatty acid [45].

The oil had a saponification number of 32.59mgKOH/g which is inversely related to the average molecular weight of the fatty acids in the oil. Palm oil with saponification number of 200mg KOH/g have low molecular weight fatty acids [46]. The relative density of the crude palm oil was 0.899. This is closely related to the FAO values of 0.891-0.899 for palm oil [1].

Table 1: Physicochemical properties of the fresh crude palm oil samples before treatment and storage

Physicochemical Properties	Palm oil samples
Free fatty acid value(%)	0.80±0.0566
Peroxide value(mEq/kg)	0.23±0.04
Iodine value (g I_2/100g)	58.11±0.0028
Moisture content (%)	1.078±0.9
Relative density	0.899±0.003
Saponification number (mgKOH/g)	32.59±0.18

The results in Fig. 1 indicates that *M. tenuifolia* extracts had the greatest effect in reducing percentage Free Fatty Acid in the crude palm oil samples (3.95%) more than α-tocopherol (4.56%) and *M. tenuifolia* grits (7.85%) at the end of the twenty four weeks room temperature storage. The highest FFA value (7.99%) was recorded in the untreated crude palm oil. All the *M. tenuifolia*-treated samples exceeded the 3.3% recommended FFA standard by the 24th week, the untreated samples being the first at the 12th week and the samples treated with *M. tenuifolia* being the last at the 22nd week. *M. tenuifolia* extract was shown to have total phenolic content of 1171.52 mg/100 [48] and a demonstrated antioxidant activity in nitric oxide induced lipid peroxidation [31].

The results in Fig. 2 show the % FFA trend in ascending order to be Palm oil +*M. myristica* extract (3.95%), Palm oil + α-tocopherol (4.56%), Palm oil + *M. myristica* grits (6.84%) and palm oil (7.99%), all differences being significant. All the samples exceeded the 3.3% recommended FFA standard by the 24th week, the untreated samples being the first at the 12th week and α-tocopherol treated samples being the last at the 22nd week. Flavonoid-rich fraction of *M. myristica* had phenolic content of 478.32 mg/100 g [48] and a lowering effect on peroxide value in stored soyabean oil [49]. From Fig. 3, α-tocopherol reduced % FFA in crude palm oil stored at room temperature (4.56%) compared to the *A.danielli* extracts (4.81%) and grits (6.08%) and the untreated crude palm oil sample (7.99%). *A.danielli* reduced acidity of lipids extracted from biscuits more than α-tocopherol and rosemary extract [50]. Antioxidative effect of *A.danielli* could be attributed to the phenolics found in the spice [30].

From the results in Fig. 4 comparing the storage oxidative stability of all the spices with α-tocopherol in crude palm oil, at the 24th week, % FFA was lowest in crude palm oil stabilized with *M. tenuifolia* and *M. myristica* extracts (3.95%) and highest in the untreated crude palm oil (7.99%) . The antioxidant and antimicrobial effects of spice extracts at a concentration of 200ppm and above in crude palm oil was reported [47]. All the crude palm oil stabilized with spice extracts had lower FFA values than the crude palm oil stabilized with spice grits. This might be explained by the fact that the active antioxidant polyphenols in spices are more concentrated in the extract fraction [26].

From Fig. 5, the storage oxidative stability performance of α-tocopherol in lowering peroxide value in the stored crude palm oil at the 24th week (7.90 meq/kg) was comparable to *M. tenuifolia* grits (8.03 meq/kg), less than *M. tenuifolia* extact (4.73 meq/kg), but better than untreated palm oil (11.00 meq/kg). All the samples

were within the recommended standard at the 24th week, lower than the values 26meq/kg, obtained for crude palm oil stored for 6 months at 26-32 °C under natural light. The results shown in Fig. 6 indicate that *M. myristica* extracts and grits lowered peroxide value in the stored crude palm oil at the 24th week (3.88 and 7.27 meq/kg repectively), better than α-tocopherol (7.90 meq/kg) and untreated crude palm oil (11.00 meq/kg). From the results in Fig 7, it can be deduced that, α-tocopherol had better storage oxidative stability effect by lowering the peroxide value of crude palm oil samples (7.90 meq/kg) better than the extracts (8.20 meq/kg) and grits (9.96 meq/kg) of *A.danielli* in crude palm oil and untreated crude palm oil (11.00 meq/kg). In an earlier study, *A.danielli* had better performance than α-tocopherol in reducing the peroxide value of palm and soya bean oils stored at 63^0C for 28 days [51].

Comparing the performance of all the spices with α-tocopherol on peroxide value reduction of crude palm oil stored at room temperature for 24 weeks, it can be deduced from Fig. 8 that *M. myristica* extract had the best performance, while the untreated crude palm oil had the highest peroxide value. *M. tenuifolia* and *M. myristica* extracts performed better than alpha-tocopherol (Vitamin E) in reducing the peroxide value of the crude palm oil samples during the storage period. Antioxidant property of the two spices' extract have been reported [31, 28]. This may be attributed to the rich flavonoid (a potent polyphenolic antioxidant) composition of *M. tenuifoli* and *M. monodora* [32]. In addition, about fifty-three different types of phenolics have been identified in the seeds of *M. myristica* and *M. tenuifolia*, with *M. myristica* having higher total phenolic content than *M. tenuifolia*. It has been shown that there is a positive relationship between the oxidative stability of spices and their total phenolics content, suggesting that the antioxidant activity in these spices is largely due to the presence of phenolic components [48].

The Peroxide values of all the crude palm oil samples were within the recommended quality standard of 20mEq/kg [1] at the end of the twenty-fourth (24th) week storage period. This is comparable to the peroxide value observed in crude palm oil stored at 26-32 °C which was above 26meq/kg after the 6-month storage period [52]. The peroxide values may however, signify the beginning or intermediate stage of oxidation, as primary or secondary breakdown products of oxidation [16].The results recorded for the PV of crude palm oil samples are similar to those previously reported [53]. It was reported that fresh oils usually have peroxide values below 10mEq/kg especially at the early months of storage [53]. A rancid taste often begins to be noticeable when the peroxide value is between 20 and 40mEq/kg [16]. The crude palm oil samples stabilized with spice extracts had lower peroxide value than the crude palm oil samples stabilized with spice grits. This could be explained by the fact that the potent polyphenols are more concentrated in the extracted fraction of the spices than in the grits forms. Extraction ensures maximum available anti-oxidants from plant materials [26].

IV. Conclusion

From the results obtained in this study, a conclusion can be drawn that raw material handling and proper oil extraction procedures are important in reducing moisture content, iodine value, free fatty acid and peroxide values of freshly extracted crude palm oil. These are important factors for shelf life stability of the oil. *M. myristica, M. tenuifolia* and *A. danielli* at a concentration of 200 ppm, had oxidative stability effects on crude palm oil by reducing free fatty acid value and peroxide value in the oil during storage with significant differences from the control (unstabilized crude palm oil) samples. The extracts of *M. myristica, M. tenuifolia* were comparable to alpha-tocopherol (Vitamin E) and in some cases, had better performance in reducing free fatty acid and peroxide values of crude palm oil stored at room temperature. Solvent extraction increased the oxidative stability effect of the spices on the crude palm oil samples, as the oil samples with added spice extracts had lower peroxide value and FFA than those with added spice grits. Generally, both the spice grits and extracts had oxidative stability effects on the crude palm oil samples and can be used to delay the onset of FFA and peroxide value development in the oil during storage.

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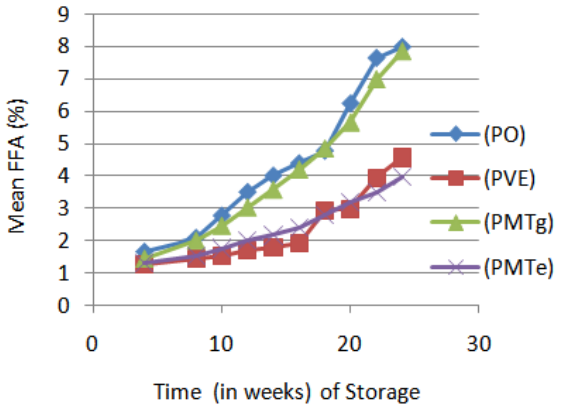

Fig 1: Oxidative stability effect of *M. tenuifolia* grits and extracts on the Free fatty acid (FFA) (%) of crude palm oil during 24 weeks storage at room temperature.

PO =Control 1(Crude palm oil); **PVE**=Control 2(Palm oil and α-tocopherol **PMTg**= Crude palm oil + *M. tenuifolia* grits; **PMTe**= Crude palm oil + *M. tenuifolia* extract

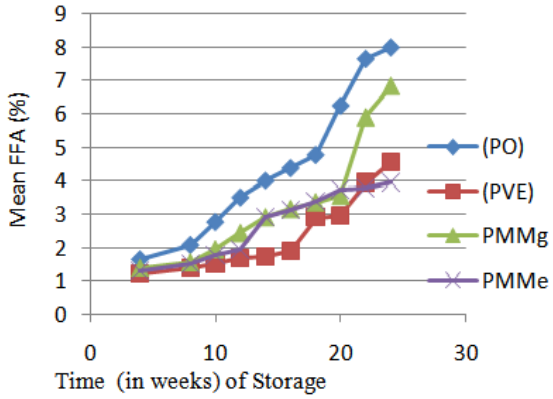

Fig 2: Oxidative stability effect of *M. Myristica* grits and extracts on the Free fatty acid (FFA) (%) of crude palm oil during 24 weeks storage at room temperature.

PO =Control 1(Crude palm oil); **PVE**=Control 2(Palm oil and α-tocopherol: **PMMg**= Crude palm oil + *M. myristica*

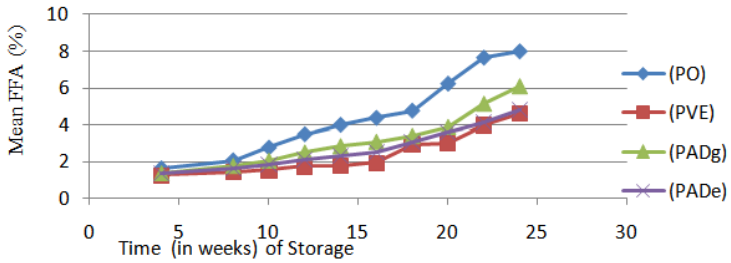

Fig 3: Oxidative stability effect of *A. danielli* grits and extracts on the Free fatty acid (FFA) (%) of crude palm oil during 24 weeks storage at room temperature.

PO =Control 1(Crude palm oil); **PVE**=Control 2(Palm oil and α-tocopherol); **PADg** = Crude Palm oil + *A. danielli* grit; **PADe**= Crude palm oil + *A. danielli* extract;

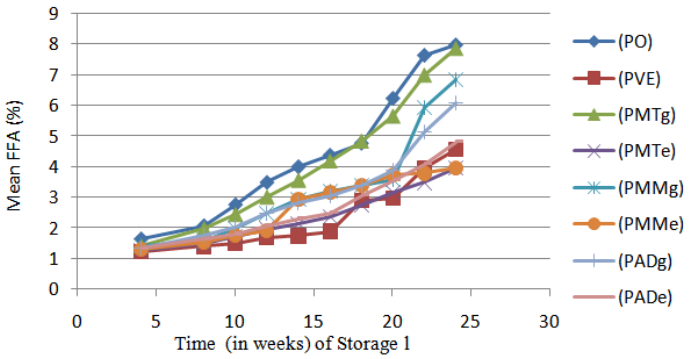

Fig 4: Oxidative stability effect of the grits and extracts of selected Nigerian spices on the Free fatty acid (FFA) (%) of crude palm oil during 24 weeks storage.

PO =Control 1(Crude palm oil); **PVE**=Control 2(Palm oil and α-tocopherol; **PMTg**= Crude palm oil + *M. tenuifolia* grits; **PMTe**= Crude palm oil + *M. tenuifolia* extract; **PADg** = Crude Palm oil + *A. danielli* grit; **PADe**= Crude palm oil + *A. danielli* extract; **PMMg**= Crude palm oil + *M.*

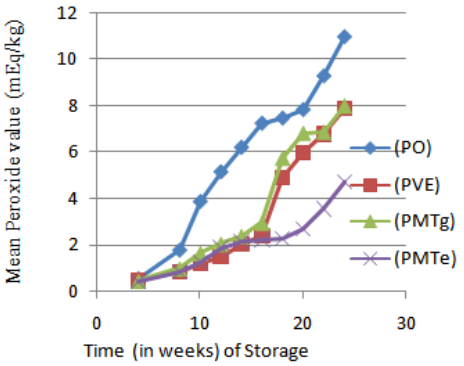

Fig 5: Oxidative stability effect of the grits and extracts of *M. tenuifolia* on the Peroxide value (mEq/kg) of crude palm oil during 24 weeks storage at room temperature.

PO=Control 1(Crude palm oil); **PVE**=Control 2(Palm oil and α-tocopherol; **PMTg**= Crude palm oil + *M. tenuifolia* grits; **PMTe**= Crude palm oil + *M. tenuifolia* extract

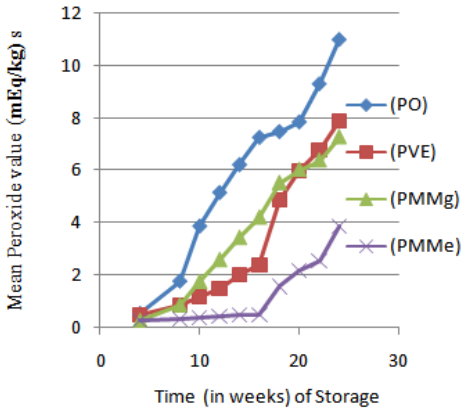

Fig 6: Oxidative stability effect of the grits and extracts of *M. monodora* on the Peroxide value (mEq/kg) of crude palm oil during 24 weeks storage.

PO =Control 1(Crude palm oil); **PVE**=Control 2(Palm oil and α-tocopherol); **PMMg**= Crude palm oil + *M. myristica* grits; **PMMe** = Crude palm oil + *M. myristica* extract

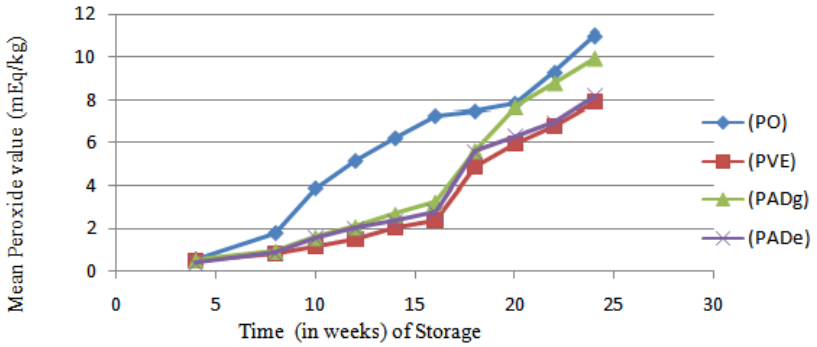

Fig 7: Oxidative stability effect of the grits and extracts of *A. danielli* on the Peroxide value (mEq/kg) of crude palm oil during 24 weeks storage.

PO=Control 1(Crude palm oil); **PVE**=Control 2(Palm oil and α-tocopherol); **PADg**= Crude Palm oil + *A. danielli* grit; **PADe**= Crude palm oil + *A. danielli* extract;

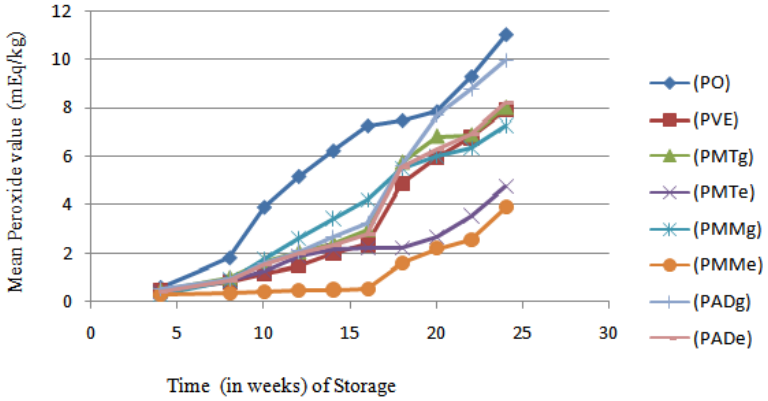

Fig 8: Oxidative stability effect of the grits and extracts of selected Nigerian spices on the Peroxide value (mEq/kg) of crude palm oil during 24 weeks storage.

PO =Control 1(Crude palm oil); **PVE**=Control 2(Palm oil and α-tocopherol); **PMMg**= Crude palm oil + *M. myristica* grits;**PMMe** = Crude palm oil + *M. myristica* extract

Nwagbo, Comfort Chinenye, et. al. "Storage Oxidation Stability of Crude Palm Oil with some Traditional Nigerian Spices." *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)*, 14(8), (2020): pp 01-09.