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Comparative study of oxidation of three vegetable oils in Congo: Nkamba nut oil (*Ricinodendron africanum var Nkamba*), Kumu oil (*Bombax acquaticum*) and Manga peanut oil (*Arachis hypogea*).

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Abstract: *The aim in this present study was to compare the oxidation status of the three oils with knowing Kumu (Bombax aquaticum), the Nkamba nut (Ricinodendron africanum var Nkamba) and Manga peanut (Arachis hypogea), stored at room conditions for 4 years. The physical and chemical characteristics, i.e., indices values, fatty acid composition, colour, carotens and polyphenols content, thermal behavior profiles were evaluated.*
The Totox value of old oils OO, was increased for 16.4 times in Nkamba nut oil and for 4 times in Kumu and Manga oils. The amount of CT (conjugated trienes) in (OO) Nkamba nut oil was for 1683 times, in Kumu oil for 62.6 times and in Manga oil for 196.7 times. The parameter ***L*** *(lightness) went on clear along the storage. The loss of the polyphenols was ranging from 98.9%, 92%, 81.98% respectively for Nkamba nut, Kumu, Manga oils.*
Nkamba nut oil (OO) presents a slight amount of oleic acid from 22.08 to 23.51%. The trans fatty acids (OO) as elaïdic acid grew up to 8.1-12.4%. The level of linolenic acid decrease strongly for 31 times.
The thermal behavior was changed according to oxidation status.
The oxidative status was ordered as Manga < Kumu < Nkamba oils.

Key words: *Nkamba nut, Ricinodendron, africanum, oil, Manga, Arachis hypogea, Kumu (Bombax acquaticum), Physical and chemical analysis, oxidation.*

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I. Introduction

Generally, Congolese people highly appreciate the fluid oils as olive oil, soybean oil or sunflower or peanut oil. But the palm refined deodorized bleached palm oil is the more extended. Next to these conventional oils extracted from plants, grains or fruits with high lipid content; it can be noted that there are in the tropics plants with an appreciable content of oil. this is the case for example of the pulp of Safou, Kumu and Nkamba nut oil.

The two least are studied recently (Dzondo et al. 2015a, Dzondo et al 2015b). Some physicochemical characteristics were the same like fluidity and color. But their oxidation must be different because the content of palmitic acid of Kumu oil.

Kumu "Bombax aquaticum" is a plant of the family of Bombacaceae. It grew up in Congo, Cameroun, Gabon, Nigeria, and Madagascar (Pieraerts, 1917). The Common name of Kumu in DR Congo or Pindi dia bibamba (white peanut) by analogy to groundnut) in the south west of Congo-Brazzaville. In Nigeria, in the wild plant an edible floral part is used as vegetable (Nwagba et al. 2013). The thermal oxidation was investigated. The level of byproducts from oil oxidation was very low. The oil was very stable when heated may be due to the high saturated fraction (Dzondo et al. 2015b).

The Nkamba nut (Ricinodendron africanum var Nkamba) is named kingoma-ngoma in the south west of DR Congo and belongs to the family of the Euphorbiaceae.

The thermal oxidation of oil was also investigated. The instability was due to the high unsaturated fatty acid fraction contained in this oil (Dzondo et al 2015a).

The Manga ground nut belongs to family of Fabacae, one of more cultivated in Africa. The current use of Manga peanut is much reduced for the extraction of oil.

In Republic of Congo, these seeds are however well used by the populations not to extract and directly use its oils, but indirectly through recipes integrating these sources of oils i.e groundnut paste.

The aim of this work was to compare oxidation status of the two oils from Kumu "Bombax aquaticum" and the Nkamba nut (Ricinodendron africanum var Nkamba) using peanut oil (Manga) as template.

II. Materials and Methods

Raw material, and oil extraction.

The Kumu "white peanut" and Nkamba nuts harvested from Nkamba (south west of democratic republic of Congo); the *Manga* groundnut from Makoua (centrum of republic of Congo) were crushed in a coffee grinder (Moulinex model SeB PREP'LINE 850). 30 g of powder were placed into a cellulose paper cone and extracted using n-Hexane (60°C)

in a 2 L soxlhet extractor for 5 h. The solvent was removed using rotary evaporator model N-1 (Eyela, Tokyo Rikakikal Co., Ltd., Japan). Residual solvent was removed by drying in an oven at 60°C for 1h; flushing with 99.9% nitrogen.

Average Composition

The samples of Manga,Kumu and Nkamba nuts were analyzed for crude proteins, crude fat, moisture and crude fiber using the Pearson procedures (Pearson, 1976). The crude protein content (N x 6.25) of the samples was estimated by the macro-Kjeldahl method; the crude fat was determined by extracting a known weight of powdered sample with petroleum ether, using a Soxhlet apparatus. The moisture content and the level of ashes were determined also by current methods (Pomeraz and Meloan; 1994). Total carbohydrates were calculated by difference. Energy was calculated according to the following equation:

$$Energy\,(Kcal) = 4X\,(g\ protein) + 4X\,(g\ carbohydrate) + 9X\,(g\ fat) \quad \text{Eq. (1)}$$

Color aspects

The colors of the natural and defatted seeds were measured using a CIE (1986) colorimeter (datacolor International, microflash 200d). This system uses three values to describe the precise location of a color inside a three-dimensional visible color space. The measurements were displayed in *L*, *a* and *b* values [(*L* = 0 (black) to 100 (white), a = *-a* (green) to *+a* (red), and *b= -b* (blue) to *+b* (yellow)]. The colorimeter was calibrated with the standards white and black before color measurements.

The color of the oil was measured using the Lovibond (Lovibond PFX195, VWR International France). Each sample was taken in a cube and placed in the space provided in the tintometer. A sample of 5mL was analyzed at 45°C (Atanu et al. 2008) and the Gardner was automatically read on the apparatus. The total color change (ΔE) was calculated using Eq. (2), where the subscript '0' indicates the initial color of the seeds before defatted as a reference. Color was measured three times in triplicate.

$$\Delta E = \left[\left(L^t - L_0\right)^2 + \left(a^t - a_0\right)^2 + \left(b^t - b_0\right)^2\right]^{1/2} \quad \text{Eq. (2)}$$

III. Fatty acid determination

Fatty acid methyl esters (FAMEs) from seeds were prepared according to the Ackman method (1998). The transmethylation was performed using 1,5 mL of BF_3 in methanol (8%, w/v) and 1,5 mL of hexane at 100 °C. After the extraction of FAMEs with hexane, they were washed with distilled water and analyzed with a split mode by gas chromatography (CG-2010 Plus, Shimadzu, Kyoto, Japan) equipped with a flame ionization detector and a capillary column (60 m, 0.25 mm i.d. × 0.20 µm film thicknesses). Oven temperature was set at 200 °C; detector and injector temperatures were at 250 °C. Helium was the carrier gas at a flow rate of 0.79 $mL \cdot min^{-1}$. A temperature program of column was initially set at 120 °C for 2 min, then rose to 180 °C for 2 min at a rate of 2 °C/min and kept at 220 °C for 25 min. FAMEs (PUFA1 from marine source and PUFA2 from vegetable source; Supelco, Sigma-Aldrich, Bellefonte, PA, USA) were used as standards to identify fatty acids. The percentage of FAMEs was calculated from the total area of all peaks. The results were presented as triplicate analyses.

The usual indices of oils

The usual indices determinate in oils were acid value (AOAC, standard method 969.1), iodine value (AOAC, standard method 993.20), and peroxide value (AOAC, standard method 920.160). p-Aniside value was measured according to AOAC standard Cd 18-90. The value of absorptivity at 232 and 270 nm (K232 and K270) was determined by spectrophotometry according to recommendations in AOCS Official Methods.

Thermal behavior

Thermal analyses were performed with a Perkin-Elmer Differential Scanning Calorimeter, DSC-7, equipped with a thermal analysis data station (Perkin-Elmer Corp, Norwalk, CT, USA). Nitrogen was the purge gas and flowed at 20 ml/min. The calorimeter was calibrated according to standard procedures established in the manufacturer user book using indium and distilled water. Samples of 15 mg were weighed into aluminum pans and cooled and/or heated at 2.5 °C/min from -60°C to +60°C. The heat-of-fusion enthalpies ΔH (J/g) were calculated for each peak by the Pyris software (Perkin-Elmer Corp, Norwalk, CT, USA). DSC measurements were carried out in triplicate. The peak enthalpy value (assumed that peak enthalpy =| value from computer- generated data|) was expressed as Joules per gram of oil samples and calculated from the area below the crystallization peak according to Tan et Man (1999).

Lots

For each sample (oil from 3 vegetables), 2 lots were examined. The fresh one FO, and the 4 years old lots OO kept at room temperature.

Determination of β carotens and polyphenols

The β carotens and the polyphenols content were determined by spectrophotometry according to recommendations in AOCS Official Methods, by measuring DO at 430 nm and 794 nm (respectively for β carotens and polyphenols).

Statistics

Each analysis was done in triplicate. The MINITAB 14 software was used to analyze data for determining ANOVA, standard deviation and Ducan's multiple range test for significance at 5%.

IV. Results

Proximate composition of raw materials

The biochemical composition of the seeds is represented in table 1. Results showthatNkamba nut presents the largest oil content (65.97%) follow-up from Manga (47.43%) and then the Kumu (36.97%). It appears that the latter is very rich in total sugars, with a relatively high percentage of 54.74%, whereas Nkamba nuts and peanuts seeds represent only 6.20% and 17.56% respectively. We also note the presence of a certain quantity of fibers where Nkamba nuts and Kumu are almost the same proportion (2.61%); while the peanut is two times higher (5.67%). We can also note that latest reveals a fairly good amount of protein (32.64%) compared to the nuts of Nkamba (21.34%) and Kumu (5.58%). However, the three samples have almost same proportion in terms of moisture.The more energetically seeds wereNkamba nut due to its oil content level.

Colors aspects

Table 2presents the obtained values for color measurements of oils samples. It well known that color is an important indicator of product composition, purity and degree of deterioration (Kabri et al., 2011).The three 3 oils compared are yellow shiny. For the parameter L(lightness) the oils went on clear along the storage. The statistical analysis for lightness showed significant differences for Nkamba and Kumu oils, except Manga. Redness parameter a increased with the time as storage, excepting for the Nkamba nut oil where the initial a value 0.27 gradually decreased to -2.35.For the bparameter an increasing behavior was found for Nkamba and Manga oils (see table 2). Also, Kumu oil exhibited a decreasing behavior. The totalcolor of oils determined using Eq.(2), see the values range of 16.79 – 18.51 depending on treatment and storage time of oils.

The storage at room temperature is a real problem, as it's the only usual conditions of Congolese people. When the oils were stored for a long time at room temperature, the color changes indicate the levels of oils's deterioration. According to the 3 parameters, the Manga oil was the most stable after 4 years of room temperature storage.We confirm the previous work as oxidation lead to color changes (DzondoGadet et al. 2015a).

Variations of indices values

The storage at room temperature lead to fatty acids deterioration, well evaluated by indices changes (Table 3).

Acid value

This indice (Av) was used to assess hydrolytic rancidity of oils. The changes in the Av of Nkamba, Kumu and Manga oils are given in the table 3. The initial values of fresh oils FO under investigation were seen to range from 2.97 for Nkamba oil to 8.18 for Kumu oil. These low value reflect the quality of these oils. The highest changes (OO) in acid value at the end of storage was shown principally for Nkamba oil. Av increased from 2.97 at the beginning of the storage experiments to 42.09 at the end of storage of 4 years; whereas the lowest change was observed for Manga oil. The Av of Manga oil increased from 4.56 to 20.43 during 4 years of storage. The higher oxidative stability of Manga oil, compared to Nkamba and Kumu oils is due to the high amount of oleic acid (53.18%) and low polyunsaturated fatty acid content of triacylglycerol. However, Manga oil contains high level of β carotens and polyphenols compounds. These compound have antioxidative effects and possess surely antihydrolytic effects during storage period.

FThe Peroxide value (Pv) and p-Aniside (p-AV) O: fresh oil; OO: oxidised oil

Peroxide value (Pv) measures the hydroperoxides concentration, primary products of lipids oxidation. Howeverhydroperoxides which are generally referred to as peroxides are unstable and which decompose spontaneously and rapidly in secondary products, namely aldehydes, far more stable than hydroperoxides.

The results for Pv and p-Aniside (p-AV) levels are detailed in table 3. All fresh oils (FO) samples presented Pv within the legal limits; below 20 mEq O_2/kg. Peroxide values for fresh oils ranging from 2.01 to 6.86 mEq O_2/kg were very low which indicates the high quality of the oils used in this work. Also, our numbers are in agreement to the *codex alimentarius*(Codex, 1999) who fixed the acceptability at 10 mEq O_2/kg.

After 4 years of storage, the peroxide value of the three oils (OO) were progressively increased. But the Pv in Manga oil was always lower (5.51 mEq O_2/kg) than in Nkamba who had significantly ($p<0.001$) the highest value of peroxide (19.77 mEq O_2/kg). This difference can be explained considering the different fatty acid composition of the two oils. Mangaoil exhibits lower content of polyunsaturated fatty acids (29.32 %) than Nkamba oil (88.7 %) and is less susceptible to free radical chain reaction leading to the formation of hydroperoxides. It well known that unsaturated fatty acids easily react with oxygen to form peroxides (Ali-Rehab et El-Anany. 2012, Marina et al. 2009)

The p-Aniside values before storage were below 5 indicating the almost absence of secondary oxidation products in all samples of the study. In the all oils of this work, p-Aniside values increased with the time of storage (Table 3) independently of the initial peroxide values and variations, with final values ranging from 16.22 for Kumu, via 17.11 for Manga and 27.92 for Nkambaoils.

Totox value is a parameter related to the all compound generated by PUFA degradation. The accepted value was of 25. In our experiments, we are over this number. The high level of palmitic acidof Kumuoil could, may be, lowers value. Unfortunately, the presence of 8.87% of DHA lead to smooth this oil and the Totox value neighboring Nkamba nut oil seems tightly conform.

Evaluation of hydroperoxides level:

The formation of hydro-peroxides is closed with conjugation of double bonds in polyunsaturated fatty acids, measured by absorptivity in the UV spectrum at 232 and 270 nm respectively for primary and secondary product of oxidation (Besbes et al. 2005),

The level of byproducts from oil oxidation was very low in fresh oils FO (Table 3). It well known that the proximal products peaked at λ = 232 nm and the distal products peaked at λ = 270 nm. For fresh oils FO, we have found in proximal products the value of 0.057 for Nkamba nut oil; 0.857 for Kumu peanut oil and 0.038 for Manga oil.For the 4 years old oils OO, the distal products were abounded with storage. The amount in Nkamba nut oil was for 1683 times, in Kumu oil for 62.6 times and in Manga oil for 196.7 times (Table 3). The early and the distal products in all fresh oils are as trace. But along the storage it seems that we have an accumulation of secondary byproducts showing the oxidation status of different oils.

β Carotens and polyphenols content

By measuring DO at 430nm and 794nm we have determined respectively the βcarotens and the polyphenols contents of both, fresh and old oils.Along the storage the Nkamba nut oil leave its protection capacity by losing both βcarotensfor 99.2% and the polyphenols for 98.9%. For Kumu oil, the decrease of β carotens was for 76.8% and of polyphenols was 92%. For Manga oil the decrease of β carotens was for 63.1% and of polyphenols was 81.98% (Table 4). So the loss ofcarotenswas ranging from 63.1 to 99.2% and the loss of polyphenol was ranging from 81.98% to 98.9%.

Vitamin A is an essential nutrient and is physiologically important in the immune system, vision, skin, cell growth, differentiation, and reproduction.High doses of vitamin A inhibited adipogenesis in 3T3-L1 and NIH3T3 (Kim et al. 2019).We have concluded thatβCarotens and polyphenols could become some indicators for oil's deterioration.

Fatty acids evolution:

According to Tarmizi et al. (2013), fatty acid composition is widely used for the establishment of oil authenticity. Additionally, Fatty acid composition measurement is one factor that helps to predict the oxidative stability of oil.

The composition of the major fatty acids in the fresh and the old oils is shown in

When we compared the fresh and the old oils, it appeared that there was a deterioration meaning by the bond saturation (Table 5).

For the Nkamba nut oil there is a little amount of oleic acid from 22.08 to23.51% and of linoleic acid.We relieve the accumulation of trans fatty acids (Table 5). The level of elaïdic acid varies from 0.0064% in fresh oil (FO) to 8.1-12.4% in old oils (OO). In the same time, the level of linolenic acid decrease strongly from 30.62 to 1.07%. Mohanarangan (2012) workingon fish oils, have shown the slight increase of saturated fatty acid from 6.11 to 6.28% when a little increased of temperature (from 55 to 70°C). In the same work, the increase of oleic acid was shown for 1% and the loss of PUFA was up to 2%.

The oxidization ofManga oil is characterized by absence of trans fatty acids after 4 years. It is may be due to the high oleic fraction containing only one bond as MUFA. We could relieve the slight amount of palmitic and stearic fatty acids (<1%). The strong effect was on linoleic acid shifting for 30% in 4 years and Behenic acid became in trace state.

The high content (54%) in palmitic fatty acid in Kumu oil conferred a strong resistance to oxidation. The amount of saturated fatty acids was under 1%. The level of trans fatty acids was very stable. The amount of oleic acid was for 22.9% when the linoleic acid decreased for 32.5%. The previsibledecrease was of DHA which went from 8.87 % to trace state (Table 5). The Kumu oil was rich in palmitic acid leading to its high stability. But the presence of PUFA carried out a strong fragility to oil.

Acharya and Talahalli 2019, on dyslipidemia induced changes in rats, have shown a synergetic effects of EPA + DHA leading to lows oxidation like phenomenon. Adkins et al. 2019, working on autoimmune encephalomyelitis in mice have shown that isolated phospholipids were less efficient that TAG to protect against oxidation. But, clearly we have confirmed (Dzondo et al. 2015) that oil deterioration is closed to *trans* fatty acids accumulation and progressive saturation of double bonds.

Thermal behavior:

It's well known that the melting points were the results of many fractions of oil as SFA, MUFA and PUFA. So when the oil is rich in double bonds, the peak is very low. But the progressive saturation of oxidized bonds led to carry out the saturated fraction and then the number grew up neighboring zero. Indeed, it's well known that the lipid oxidation led to decal the curve at the right (Gill et al., 2010). These results confirm the physical status changes in oils.

The fresh Nkamba nut oil shows one melting point at -27.1°C which went at 15.1 °C in old oil confirming the strong oxidization (Table 6).

The Kumu fresh oil presents 3 peaks at -4.3°C, at +4.70°C and +19.1°C corresponding to all fractions of fatty acids present in oil. After 4 years, the negative value disappeared confirming the trace state of DHA. The number went on the right as the oil became semi-solid at room temperature.

The fresh Manga peanut oil present one peak at -12.90°C. When the oil is stored at room temperature for 4 years, the peak decaled normally to the right. But the oleic nature of oil limited oxidization.

The Manga peanut oil is the more oxidation resistant along the time.

V. Conclusion

The storage of 3 oils at room temperature carried out the high differences in oxidization status. The most unsaturated oil (Nkamba nut oil) was the more deteriorated. TheKumu oil was at 54% of palmitic acid leading to stability. Unfortunately,the relative oxidability of Kumu oil was dueto the fraction of DHA contained. The indices of oils as Totox value were over norm after 4 years. The alteration of color and the accumulation of aldehydes and ketones in old oils shown the deterioration state of them. The level of vitamins and polyphenols was decreased with storage.

The nutritional value of these oils were completely exhibited by oxidization along the storage. The oxidation status varies according to the content of oil.The oxidative status was ordered as Manga oil <Kumu oil <Nkamba oil.

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Table 1: Proximate composition of raw material

Parameters	Kumu	Nkamba	Manga
Moisture%	5.89 ± 0.12	6.61±0.93	7.58±0.86
Lipids %	36.97 ± 0.03	65.97±3.00**	47.43±1.60
Crude Proteins% (N_T x 6,25)	5.68 ± 0.20	21.34±2.75	32.64±0.26*
Ashes %	2.61 ± 0.34	2.60±0.70	5.67±0.98*
Total carbohydrates %	54.74 ± 0.05*	6.20±0.70	17.56±1.33
Energy (kcal)	574.41± 3.75	703.89± 5.11**	627.67± 4.65

Values are means ± standard deviation of triplicate determinations.
*p<0.05 ;** p<0.001 ; *** p<0.0001

Table 2: Color Hunter parameters L (lightness), a (redness) and b (yellowness) of different oils

	Parameters of color			ΔE
Oils types	L	a	b	
Kumu FO	57.85±4.03	5.73±3.95	76.55±5.14	16.79
OO	84.76±7.74**	11.23±2.31**	62.17±5.11*	
Nkamba FO	31.22±4.98	0.27±0.00	11.97±3.76	17.00
OO	91.73±8.91***	-2.35±0.55*	18.85±6.06*	
Manga FO	79.65±5.26	-2.97±0.47	33.13±5.89	18.51
OO	81.61±7.81*	5.06±1.21*	44.71±5.09*	

FO fresh oils and OO oxidized oils. *p<0.05; ** p<0.001 ; *** p<0.0001

Table 3: Values Of hydrolytic rancidity (AV), of oxidative rancidity indexes (p-anisidine and PV : peroxide values) and Totox value for Nkamba, Kumu and Manga after different storage

	Nkamba		Kumu		Manga	
	FO	OO	FO	OO	FO	OO
Av	2.97±0.13	42.09±8.76***	8.18±2.15	28.17±4.52**	4.56±1.65	20.43±6.07**
Pv	2.01±0.10	19.77±4.112***	6.86±1.09	7.58±1.44*	2.48±0.78	5.51±1.22*
PA v	1.31±0.09	27.92±7.33***	3.95±0.98	16.22±2.77**	2.58±0.66	17.11±3.29**
TOTOX v	5.33±0.71	87.46±9.42***	17.67±3.73	72.56±8.63**	7.54±1.87	28.13±5.88***
CD (ƛ= 232 nm)	0.057±0.00	0.02±0.00***	0.857±0.01**	1.12±0.01***	0.038±0.00	0.011±0.00
CT (ƛ = 270nm)	0.007±0.00	17.78±5.17***	0.063±0.001*	3.95±0.89***	0.015±0.00***	2.95±0.24***

Av : mg NaOH/g ; Pv :méq 02/kg ; Totox v= 2Pv + PAv ; FO : fresh oil ; CD : conjugated dienes ; CT : conjugated trienes ; OO : oxidized oil. Values are means ± standard deviation of triplicate determinations. *p<0.05 ; ** p<0.001 ; *** p<0.0001

Table 4. β Carotens and polyphenols content during storage.

Sample content	Nkamba		Kumu		Manga	
	FO	OO	FO	OO	FO	OO
β Carotens	94.9±8.32	0.8±0.0***	98.76±9.17	22.89±3.56**	59.33±6.67	21.9±4.21**
Polyphenols	96.1±7.98	1.1±0.0***	98.88±7.89	7.90±2.33**	63.97±5.46	11.53±2.19**

Values are means ± standard deviation of triplicate determinations. FO : fresh oil ; OO : oxidized oil. *p<0.05 : ** p<0.001 ; *** p<0.0001

Table 5. Fatty acids evolution

Fatty acids	Nkamba nut oil		Manga oil		Kumu oil	
	FO	OO	FO	OO	fresh	Old
C14 :0	0.079	12.23±1.11**				
C16:0	7.701±0.41	16.70±1.94**	12.43±1.52	13.22±0.77*	54.89±0.19	55.03±0.32**
C18 :0	2.814±0.13	8.8±1.23*	1.52±0.66	2.11±0.87*	3.19±0.21	3.98±0.11*
C22 :0	0.0294		1.21±0.45	0.009±0.350***		
Total SFA	*10 :623*	*37.73*	*15.16*	*15.34*	*58.08*	*59.01*
C16 :1	0.035	8.0±2.42*				
C18 :1n9t	0.006	12.4±1.73**			0.73.±0.21	0.99±0.17*
C18 :1n9c	22.082±0.22	8.2±1.67*	53.18±2.94	54.09±0.65	7.54±0.78	9.78±0.83**
C22 :1n9c	0.0056					
Total MUFA	*22.129*	*28.6*	*53.18±2.94*	*54.09±0.65*	*8.27*	*10.77*
C18 :2n6c	36.816±1.29	22.17±0.27*	29.32±3.02	20.76±1.81 *	6.09±0.99	4.11±0.45**
C18 :3n6	0.217				2.17±0.66	1.06±0.59**
C18 :3n3	31.63±2.78	1.07±0.89***				
C18 :3n4	0.434					
C20 :2n6	0006				0.89±0.31	0.005±0.14***
C20 :6n6	0.038					
C20 :3n3C22 :2 n6	0.006					0.007±0.85
Total PUFA	*69.140.0381*	*23.24*	*29.32±3.02*	*20.76±1.81*	*18.02*	*5.182*
∑AGPl n-6	37.1	22.17	29.32	20.76	9.15	5.18
∑AGPl n-3	31.7	1.07				
Others		10.34	2.34	9.8	15.63	19.3

Values are means ± standard deviation of triplicate determinations. *p<0.05 ; ** p<0.001 ; *** p<0.0001
FO : fresh oil ; OO : oxidized oil.

Table 6. Thermal Behavior changes in all oils studied

	Nkamba		Kumu		Manga
Peak [°C] FO	-27.1	-4.30	+4.70	+19.1	-12.90
Peak [°C] OO	-15.1		+13.5	+25.7	-9.78

T° set at -30°C for 10 min, rising to + 30°C at 5°C/min, FO: fresh oil ; OO : oxidized oil.

Dzondo-Gadet M. " Comparative study of oxidation of three vegetable oilsin Congo: Nkamba nut oil (RicinodendronafricanumvarNkamba),Kumu oil (Bombaxacquaticum) and Manga peanut oil (Arachis hypogea)." IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT) 13.12 (2019): 42-47.