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RESEARCH ARTICLE

QUALITY ASSESSMENT OF CRUDE PALM OIL FROM SMALLHOLDERS IN ALEPEDEPARTMENT, SOUTHEAST COTE D IVOIRE

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Abstract

Chemical quality of crude palm oil (CPO) processed by smallholders and small-scale, artisanal producersin Alépé, Southeast department of Côte d'Ivoire is investigated. A total of 90 palm oil samples were collected in6 localities from five producerswomen each. Parameters measured included: moisture content (MC), impurity content (IC), free fatty acid (FFA), iodine value (IV), saponification value (SV), peroxide value (PV), para-anisidine value (p-AV), total oxidation (Totox), deterioration of bleachability index (DOBI) and total carotenoids (TC). Results revealed that all samples produced in Alépédepartment exhibited higher levels in MC(0.29-0.35%), IC (0.54-0.67%), FFA (10.70-17.27 %) and lower level DOBI (0.83-1.61) in comparison torecommended standards. IV, SV and PV levels recorded were within the stipulated standards except for MontézoPV (17.65 ± 1.38 mEq/kg) level above the above the acceptable limit. Whilep-AV, Totox and TC ranged from 2.61-15.86, 11.38-41.39 and 318 to 616 mg/kg levels, respectively.The high values of FFA and moisture recorded wereabove recommended limits due the chosen processing methods.

Introduction:-

Palm oil is the world's largest source ofedible oil, accounting for 75.45 million tons or 36% of global edible oil and fat production[1] . Palmoil is a product extracted from fleshy mesocarp of the palm fruit (Elaeisguineensis). It contains 50% saturated fatty acids, 40% unsaturated fatty acids and 10% polyunsaturated fatty acids[2]. It is also a rich source of phytonutrients such as tocotrienols, tocopherols, carotenoids, phytosterols, squalene, and coenzyme Q10, all of them exhibit nutritional properties and contribute to increasing oxidative stability [3].In Côte d'Ivoire, similar to Nigeria [4] and Cameroon [5], palm oil meets 80-90% of total edible oil needs and the oil is extracted by different methods.Oil production is an important support of home agriculture[6]. Palm fruit oil processing in Côte d'Ivoire is ensured by two main sectors: industrial and informal (smallholders).Farms of industrial sector, which

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provides about 80% of total palm oil, are nearthe oil-producing companies.Bunches areharvested when fruits are at optimum ripeness which is handled, bruised carefully, and directlyprocessed and sterilized with pressurized steam. The palm oil obtained does not degrade easily and has better grade. Small farm sector, provides 20% of total palm oil, but bunches are treated several days after harvesting[7]. Small producers predominantly women use artisanal processing methods throughoutsquizing and others small scale equipment namely mortar and pestle[8]. This practice may reduce the quality of extracted palm oil. However, this sector largely supplies rural and urban markets consumers, in a product considered specific (which does not provide local agribusiness) and still appreciated by consumers[9].Therefore, the need of assessing the quality of palm oil from this sector is of great importance as most people utilize the palm oil direct without any further purification.There is also limited information available about the quality of palm oil produce by small-scale extraction units in Côte d'Ivoire.The aim of this research was to assess thechemical quality of crude palm oil produced by smallholders and small-scale, artisanal producers of Alépé department in the Southeast of Côte d'Ivoire.

Materials And Methods:-

Palm oil samples collection

A non-probability sampling method known as a "snowball" was used to collect crude palm oil (CPO) samples in six localities of Alépédepartment (Mé region) (latitude 5°30' North and longitude 3°40 'West) in the Southeast of Côte d'Ivoire, 60 km from Abidjan[10]. These localities wereAlépé, Grand Alépé, Montézo, Ahoutoué, LaméandAghein. In each locality, meetings were organized with the smallholders to present the study. Then, three samples were collected in 100 mL tinted bottle from eachwomanproducer in triplicate. Crude palm oil samples were then taken to the laboratory and kept at 30°C for analysis. A total of 90 samples were collected from February to March 2020.

Chemical analysis

Moisture (MC)and impurities content (IC), free fatty acid (FFA), iodine value (IV) and deterioration of bleachability index (DOBI) were carried out using a MPA BRUKER OPTICS GBMHNearInfrared Spectrometer (NIRS) equipped with OPUSLAB software, 2015[11]. Thereby, 1 mL of oil placed in a 8 mm cuvette was preheated on a hot plate at 50 °C for 15 min before analyzing. Saponification value (SV) was performed by titrimetric method according to Association of Official Analytical Chemists protocol [12].

Oxidative indexes and total carotenoids content analysis

French standards NF T 60-220[13] and NF EN ISO 6885[14] were used to determine the peroxide (PV) and para-anisidine(p-AV) values by titration respectively. Equation of total oxidation value (TOTOX) = 2PV + p-AV was used to calculate Totox value [15]. Total carotenoids content (TC) was determined using MPOB test methods p2.6 [16].

All chemicals and solvents used were of analytical grade purchased from Merck, Germany. The results are the mean values obtained from each test repeated three times.

Statistical Analysis

Data were statistically performed using SPSS software (version 20.0). It consists in analysis of variance. Means derived from parameters were compared with the Tukey High Significant Difference test at 5% significance level.Correlations between parameters were also assessed according to Pearson index.

Results And Discussion:-

Chemical properties of palm oil

Table 1 summarizes the chemical properties of oil sampled in the selected localities. Regarding the moisturecontent of palm oil samples,results show any significant differences ($p>0.05$) with thesix localities and all palm oil samples have slightly higher values (from 0.29 to 0.35%)than the recommended value of 0.25% for moisture in oils and fats [17]. The impuritycontentof palm oilvary significantly($p<0.05$) from 0.54% to 0.67%. The localities of Grand Alépé, Ahoutoué and Aghein recorded the highest percentage with values of 0.66% and 0.67% respectively, whereasMontézo and Alépérecorded the least percentage of impurity (0.54% and 0.56%). However, impurities content from all localities have greater values than the reference which is 0.05% [17].The free fatty acid percentage (FFA) obtained ranges significantly ($p<0.05$) from 10.70 ± 1.05 to 17.27 ± 1.50%. These values were all above specification, with Aghein locality recording the highest amounts, which is about three times the recommended value. Concerning iodine value, results showed that palm oil samples from the different localities fall within the

recommended standardswith values between 50.90 ± 1.21 and 58.08 ± 4.63 g I_2/100 g. The highest valuewas recorded byAghein locality.In terms of saponification values, palm oil sampled from Aghein locality recorded the highest (217 ± 14.73 mg KOH/g) value, which was significantly ($p<0.05$) different from all other localities.

Table 1:- Chemical characteristics of palm oils sampled from Alépé department.

	Moisture content (%)	Impurities content (%)	Free fatty acid (%)	Iodine value (g I_2/100 g)	Saponification value (mg KOH/g)
Alépé	0.31 ± 0.04^{a}	0.56 ± 0.05^{a}	11.56 ± 3.02^{ab}	53.46 ± 1.46^{abc}	195.60 ± 14.40^{a}
Grand Alépé	0.29 ± 0.05^{a}	0.66 ± 0.04^{b}	14.50 ± 3.66^{abc}	51.58 ± 2.24^{ab}	193.72 ± 4.31^{a}
Montézo	0.31 ± 0.02^{a}	0.54 ± 0.03^{a}	10.70 ± 1.05^{a}	53.08 ± 0.09^{abc}	192.61 ± 3.68^{a}
Ahoutoué	0.29 ± 0.05^{a}	0.67 ± 0.06^{b}	14.90 ± 1.21^{bc}	50.90 ± 1.21^{a}	195 ± 10.75^{a}
Lamé	0.36 ± 0.06^{a}	0.61 ± 0.05^{ab}	14.04 ± 4.18^{abc}	54.31 ± 0.51^{bc}	188 ± 2.21^{a}
Aghein	0.35 ± 0.01^{a}	0.67 ± 0.07^{b}	17.27 ± 1.50^{c}	58.08 ± 4.63^{c}	217 ± 14.73^{b}
C.V%	17.30	12.05	24.62	5.03	6.71
Recommended standards	0.25	0.05	5	50.0-55.0	190-209

Values followed by the same letters in the same column are not significantly different at $p \leq 0.05$.

Lipid oxidation, DOBI and total carotenoidscontent

Table 2portrays the results of the range of oxidation properties assessed by the determination of peroxide (PV), para-anisidine (p-AV), total oxidative (totox) value, deterioration of bleachability index(DOBI)and total carotenoids content (TC) of palm oil sampled as well.Results showed an important variability for each of five parameters assessed, with coefficients variationof71, 51, 43,35and 34% for PV, p-AV, Totox, DOBI and total carotenoids content, respectively. This variability was observed on samples collected from the small women producers.PV of palm oil samples from Montézo (17.65 ± 1.38mEq/kg) were significantly ($p<0.05$) higher than all other localities which revealed values below the 15mEq/kg maximal limit for cold pressed and virgin oils[17]. The p-AVin the CPO were different among the various localities ($P<0.05$) between 2.61 ± 0.30 and 11.20 ± 1.57, except Aghein locality which recorded highest value of 15.86 ± 1.18.Concerningtotox value, results showed that palm oil sampled from Montézo localityshowed the highest value (41.39 ± 2.70) followed by Grand Alépé (30.16 ± 1.66). The other localities have values between 11.38 ± 3.22 and 21.34 ± 1.21. About DOBI, values obtained were between 0.83 ± 0.03 and 1.61 ± 0.15. From results, all samples presented low values below the recommended limit.Accepted value DOBI for CPO is between 3and 3.2[18].Carotenoidsvalues of palm oil samples were between318 ± 87.71 and 616 ± 59.36 mg/kg and were found to be lower than therecommended standard except for values from localities of Ahoutoué and Alépé.

Table 2:- Oxidative indexes, DOBI and Carotenoids content of palm oils samples from Alépé department.

Localities	Peroxide value (mEq/kg)	Para-anisidine value	Totox value	DOBI	Carotenoids (mg/kg)
Alépé	8.58 ± 0.32^{c}	2.61 ± 0.30^{a}	19.57 ± 0.86^{bc}	1.50 ± 0.29^{c}	567 ± 12.66^{c}
Grand Alépé	9.34 ± 1.26^{c}	11.20 ± 1.57^{c}	30.16 ± 1.66^{d}	1.05 ± 0.37^{ab}	401 ± 14.46^{ab}
Montézo	17.65 ± 1.38^{d}	6.40 ± 0.98^{b}	41.39 ± 2.70^{e}	0.85 ± 0.07^{a}	327 ± 28.53^{a}
Ahoutoué	1.86 ± 1.42^{a}	7.40 ± 0.73^{b}	11.38 ± 3.22^{a}	1.61 ± 0.15^{c}	616 ± 59.36^{c}
Lamé	5.38 ± 1.15^{b}	6.58 ± 1.10^{b}	17.56 ± 1.88^{b}	1.30 ± 0.43^{bc}	496 ± 65.15^{bc}
Aghein	2.80 ± 0.83^{a}	15.86 ± 1.18^{d}	21.34 ± 1.21^{c}	0.83 ± 0.03^{a}	318 ± 87.71^{a}
C.V%	71.21	51.31	42.84	35.40	34.35
Recommended standards	15			3.0 - 3.24	500 - 1000

Values followed by the same letters in the same column are not significantly different at $p \leq 0.05$.

Correlations between palm oil parameters

Pearson indexes (r) indicate positive and negative significant correlations between the 10 parameters assessed for palm oil sampled. Thus, FFA, MC, IC, PV, p-AV and Totoxwere closely correlated, r varying from 0.50 to 0.96. Also, DOBI and TC changed tightly (r = 0.89). The SV was directly correlated with the p-AV (r = 0.53). Positive significant correlations were observed between Totox and PV (r = 0.92) and between PV and DOBI (r = 0.55). On

the other hand, FFA and DOBI were reversely correlated (r = -0.92). Inverse correlation was also between IC and TCwith r value about -0.84 (Table 3).

Table 3:- Statistically significant Pearson's correlations between chemical parametersof palm oils samples.

Parameter	FFA	IV	MC	DOBI	IC	SV	PV	p-AV	Totox	TC
FFA	1									
IV	0.1	1								
MC	0.56**	0.46*	1							
DOBI	-0.82**	0.14	-0.23	1						
IC	0.70**	-0.22	0.01	-0.84**	1					
SV	0.27*	0.28*	0.23	-0.13	-0.06	1				
PV	0.51**	-0.09	-0.16	0.55**	-0.53**	-0.26	1			
p-AV	0.53**	0.20	0.22	-0.51**	0.47*	0.53**	-0.36*	1		
Totox	0.61**	-0.01	-0.08	0.37*	-0.37*	-0.05	0.92**	0.04	1	
TC	-0.82**	0.14	-0.23	0,89**	-0.84**	-0.13	0.55**	-0.51**	0.37	1

** P< 0.01, * P< 0.05 are indicated statistically significant. FFA, free fatty acid, IV, iodine value, MC, moisture content, DOBI, deterioration of bleachability index, IC, impurity content, SV, saponification value, peroxide value, PV, para-anisidine, p-AV, total oxidation, Totox, TC, total carotenoids content.

Discussion:-

This study covering the department of Alépé, one of the main palm oil areas inCôte d'Ivoire, helped highlight the quality of traditional oil palm producebysmallholders who arepredominantly women.The data of palm oil sampled from smallholders in the six localities of Alépédepartment revealed that the moisturecontent was slightly higher than the recommended value.It may be explained by inadequate processing of CPO to evaporate moisture, which is characteristic of smallholder producers. Moisture content of small-scale processing of palm oil makes oil unstable and prone to microbial attack[19].Similar trends were observed by [20] who reported moisture value between 0.26% and 0.86% from different local oil palm processing factories in Imo state, Nigeria. The relatively high impurity value observed inthis study may be influenced by the methods of oil palm extraction and the poor hygienic processing conditionof the smallholder [21]. High impurity levels have been determined in crude palm oil produced by smallholder processors in rivers state, Nigeria with values between 5.40 and 12.52 [8].[21]reported Impurity levels of locally processed palm oil in the order of 0.11%, 0.05 – 0.31% and 0.01% for traditionallyprocessed, semi-mechanically and industrially processed respectively.The free fatty acid is the most important criterion for determining the quality of edible oil, for consumption as well as for export and the oil price is dictated by FFA content [22]. The FFA content must not exceed 5% as oleic acid or palmitic acid according to [17] and [23], respectively. Anyway the free fatty acid of palm oil sampled is high and this could be attributed to how palm oil is generally extracted by smallholder producers[24]. The length of time between harvesting of fruits and production coupled with the use of inappropriate equipment and inadequate processing time compromise the quality of CPO[25]. During this process, the fruits are more likely to get contaminated with microorganisms which may promote deterioration of oil and therefore enhance activities of endogenous lipase[26].Results of this study agree with those of [2]. These authors determined values between 6.77 and 13.49% on crude palm oilmarketed in Bahia, Brazil. Regarding the fluidity of palm oil sampled, iodine value in the present study was much higher than results obtained in a study on palm oil samples from seven regions in Ghana which recorded values between 43.50and 46.92g I_2/100 g[22].The saponification value is an indication of molecular weights of triglycerides of the oils. SV of this study was quite close to artisanal crude palm oilcollected in the districts of Lagunes, Sassandra-Marahoué, Bas-Sassandra and Montagnes of Côte d'Ivoire [10]. The SV isalso similar the maximum values recorded for palm oil samples in the China, Nigeria and Ghana studies[22], [27], [28]with value ranging between 195.76 - 207.22 mg KOH/g.These values indicate that the palm oils sampled are suitable for soapmaking.

The peroxide value, p-anisidine value and totox value are the most commonly used tests for oxidative status of oil.Apart from Montézo locality, none of the samples exceeded the upper limit of PV rate (15.0 mEq/kg oil) established by the Codex Alimentarius. [21] reported alsoa lower PV (2.07mEq/kg oil) for traditionallyoil palm processing methods in Cameroon when compareto that obtained in the present study.Secondary oxidation products, determined through p-AV recorded during the study (2.61 ± 0.30 - 15.86 ± 1.18) was quite higher than those

reported in palmoil obtained after direct extraction of palm fruits (0.52 to 48.44 ± 0.20)[29].Totox value provides a measure of both primary and secondary oxidation products. Valuesrecorded in this study were lower than those of vegetable oils reported in the literature and indicates high primary and secondary oxidative stability[30].Oxidation of fatty acids generates a sequence of breakdown products, starting with primary oxidation products (peroxide value, dienes, free fatty acids) then secondary products (carbonyls, aldehydes, trienes and alcohols) and then tertiary products that impart off-flavours and limit shelf-life and storage stability of oil and fats[31]. PV, p-AVand Totox were positively correlated to FFA content,as indicated by significant Pearson correlation coefficients of 0.51,0.53 and 0.61, respectively. This result showed the pro-oxidative effect of FFA produced during palm fruit postharvest treatments on oxidation levels in crude palm oils produced in artisanal,small-scaleworkshops[29].

Deterioration of bleachabilityindex is basically the ratio of the carotene content to the content of secondary oxidation products. DOBI value higher than 3.3, indicates an excellent CPO grade, whereas values from 3-3.2 indicate good CPO [18].It also indicates how easy it is to refine crude palm oil. DOBI values found in this studytranslate into the lower carotenoid rate.Indeed, compared to the standard, carotenoids values were significantly lower. These results were within results of [32] and [33], who demonstrated that traditional extraction oils retained more β-carotene than mechanically processed oils. During processing techniques employed by the smallholders in Alépédepartment, palm fruits are exposed to sunlight and long sterilized after harvest, resulting in prolonged heating of the crude oil and greater fluctuations in impurity levels. Under these conditions, carotenoid oxidation may be more pronounced [2].

Conclusion:-

Finally it emerges from the analysis that the levels of moisture content, impurity level, FFA, DOBI and carotenoids content in the samples produced were not within international quality standards. However, process improvements must be made by these smallholders to increase quality of palm oil to makes it fit for consumption, export and other downstream applications such as fractionation and bleaching production.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could haveappeared to influence the work reported in this paper.

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