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Organochlorine Pesticide Residue Levels in Kola Nuts (*Cola nitida* Schott & Endl.) and Estimation of Risk Exposition in Côte d'Ivoire

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Authors' contributions

This work was carried out in collaboration among all authors. Author DMV designed the study, wrote the protocol, fitted the data and wrote the first draft of the manuscript. Author KKR checked the first draft of the manuscript and achieved the submitted manuscript. Authors KKR, NYB and CA performed the statistical analysis, managed the literature and assisted the experiments implementation. Author BGH expertized the results interpretations. All authors read and approved the final manuscript.

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ABSTRACT

Background: The kola nut represents a significant economic interest for Côte d'Ivoire as well as many households and public authorities. Despite its obvious importance, the kola nut sector is facing a delicate sanitary quality of the marketed product. About 90% of produced kolanut is consumed daily fresh by people and poses a serious organochlorine pesticide toxicity health problem for consumers.

Aims: This study aimed to determine the organochlorine pesticide residue levels in kola nuts and assess the risks of kola nuts consumption on population health in Côte d'Ivoire.

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Study Design: Samples were collected from Farmers, rural Collectors, urban Stores in Districts (Mountains, Comoe, Lagoons, Down-Sassandra) and big storage Centers of Anyama and Bouake for three separate periods of kola nuts harvesting (2016-2017 ; 2017-2018 and 2018-2019).
Methodology: Concentrations of 24 organochlorine pesticide (OCPs) residues were measured using a gas chromatograph equipped with an electron capture detector.
Results: The OCPs concentrations ranging from 5.19 to 92.93 µg/kg for Aldrin and Lindane. The results indicate that Methoxychlor, DDE (op'), Endrin ketone, Hexachlorobenzene, Chlorfenapyr, Chlorthal dimethyl and Quitozene concentrations are below the quantification limit (LOQ).
Based on the concentrations and the daily consumption of kola nuts estimated at 0.6 g/person in Côte d'Ivoire, the intakes values estimated of OCPs vary from $5.4.10^{-5}$ to $7.96.10^{-4}$ µg/kg/day for Aldrin and Lindane, respectively. The Exposure Daily Doses (EDD) are all lower than the toxicological reference values. Thus, the occurrence of a toxic effect from OCPs after kola nuts consumption is very unlikely since the hazard quotient HQ sum is less than 1 ($\sum HQ = 0.13 < 1$). Consumption of kola nuts from Côte d'Ivoire does not pose a health risk to consumers.
Conclusion: Kola nuts would not represent a health risk for humans and would be safe for comsumption.

Keywords: Cola nitida; organochlorine pesticide; health risk; consumption; Côte d'Ivoire.

1. INTRODUCTION

Pesticides are substances used to kill, repel, or control certain forms of plant or animal life that are considered to be pests. Nowadays, over 1100 chemicals are used in various combinations and at different stages of cultivation and during post-harvest storage to protect crops against a range of pests [1,2]. Pesticides belong to different chemical classes but the major ones are organophosphates, carbamates, pyrethroids and organochlorines [3].

Organochlorine pesticides (OCPs) are an important group of persistent organic pollutants, their chemical stability allows them to remain active in the environment for decades [4]. Such lipophilic compounds are persistent in the environment and are readily conveyed over long distances or bioaccumulated through the food chain. Being persistent in the environment, their accumulations in the food chain, their sub-acute and chronic toxicity are detrimental to human and animal health [5]. Moreover, they tend to accumulate in living organisms and are known to be responsible for carcinogenic, mutagenic and teratogenic effects. They also have toxic effects on the nervous, immune, reproductive, renal, hepatic and hematopoietic systems [6].

This proven toxicity is a real public health problem for many governments and a hindrance to the export of some agricultural products that are widely prized by Western industries such as kola nuts. Indeed, Kola nuts have an increasing interest for industries, mainly because of their richness in bioactive and functional compounds such as polyphenols, caffeine and theobromine [7,8]. They constitute an important raw material in the formulation of pharmaceutical, food, cosmetic and textile products [9,10].

Despite its obvious economic importance, the sector of kola nut is concerned with several troubles regarding the final quality of the marketed product. According to Deigna [9], one of the major constraints for the kola stakeholders is the post-harvest preservation of the raw crops. Indeed, kola nuts are generally consumed fresh [7,8,10]. Yet, the fresh crops state easily allows proliferation of microbes, ants and other parasites. In order to control this crop's post-harvest enemies and to keep the fruits fresh, the farmers and traders generally soak the raw kola nuts in organic pesticides solutions [11,9].

The use of pesticides in the kola sector is observed during the crop's carriage and processing. Indeed, the kola nut distribution channel is generally from farmers to the big storage, processing and export centres, with temporary stay at rural collectors and small urban stores [12]. During their processing, carriage and sale, kola nut is exposed to variable quantities of pesticides. Also, kola nut farmers use various types of pesticides banned such as Dichloro Diphenyl Trichloroethane (DDT) and Hexachlorocyclohexane (HCH) [6,11]. However, current bibliographic data available in Côte d'Ivoire concerning organochlorine pesticides are mostly about products such as coffee, cocoa, cotton, fish, milk, milk products and kola nuts [13,14,15]. Concerning kola nuts, A few data shows the presence of organochlorine pesticides during kola nut post-harvest processing. Furthermore, the works of Biego et al. [11], Aikpokpodion et al. [16] and Deigna [17] showed the presence of organochlorine pesticides in kola nuts at concentrations over the *Codex Alimentarius* maximum permissible limits [18].

About 90% of kola nut is consumed daily and fresh [10]. This potentially poses a serious organochlorine pesticide toxicity health risk for consumers. The presence of organochlorine pesticides could also slow down the export of this raw material to new markets, which would constitute a significant shortfall for all actors in the kola nut sector.

Therefore, the aim of this study was to determine pesticide levels in kola nuts produced in Côte d'Ivoire in order to assess the health risks for the consumers.

2. MATERIALS AND METHODS

2.1 Investigation Site

The study was conducted in the main areas of kola nut production, big storage and distribution centers in Côte d'Ivoire. The investigated regions are located between 2°30' and 8°30' of West longitude and between 4°30' and 10°30' of North latitude. Thus, the mountain district (pole 1), the Districts of Comoe and Lagoons (pole 2) and the District of Bas-Sassandra (pole 3) were selected as production areas while the cities of Anyama and Bouake represent the storage and distribution centers (Fig. 1.).

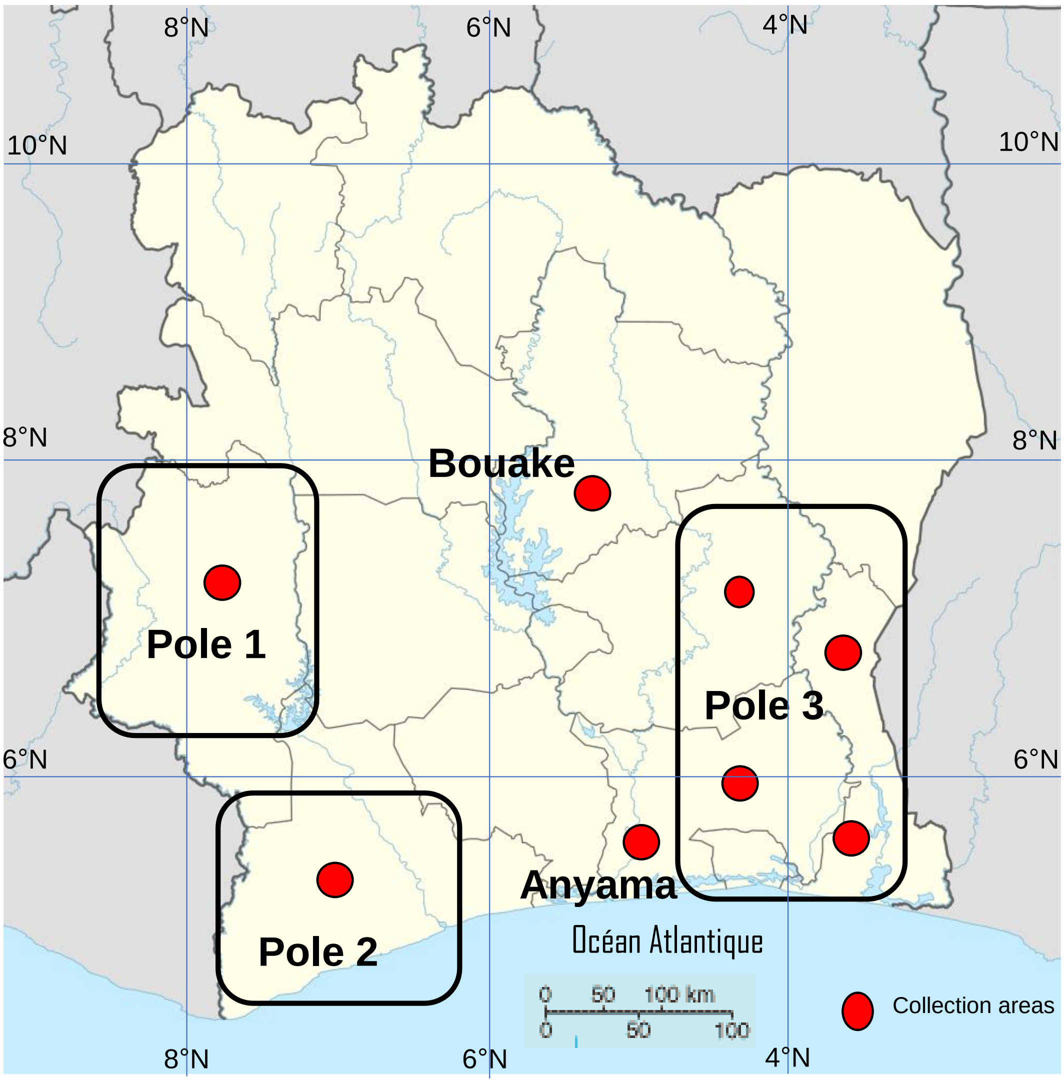

Fig. 1. Map showing kolanut samples collection sites

2.2 Plant Materials and Sampling

The biological materials of the current study consisted of fresh *Cola nitida* Vent. (Schott & Endl) nuts collected from farmers, rural collectors, urban stores and big storage centers for three separate periods of kola nut harvesting (2016-2017 ; 2017-2018 and 2018-2019), in accordance with Regulation No 333/2007 of the European Commission [19]. So, 81 Samples were collected by storage centers (Anyama and Bouake) and by production pole namely 27samples per type of actors (farmers, collectors and stores). In total, 405 fresh kola nuts samples, weighing 2 kg each, were used for this study. Kola nuts was authenticated by botanist N'Guessan. Voucher specimen of kola nut was documented in the National Floristic Center (CNF) in Abidjan, Côte d'Ivoire, Felix HOUPHOUËT-BOIGNY University.

2.3 Reagent and Solvents

Analytical grade reagents and solvents were used. They were High Performance Liquid Chromatography (HPLC) grade: Hexane and dichloromethane from Sigma Aldrich; deionized water from SDS and a mixed standard solution of 24 organochlorine pesticides (EPA 608 Supelco) concentrated at 20 µg/L. These standard organochlorine pesticides were , Hexachlorobenzene Chlorfenapyr, Chlorthal dimethyl, Quitozene, Aldrin, Endrin, Dieldrin, Heptachlor, α-Endosulfan, β- Endosulfan, Endosulfan sulfate, Endrin ketone, Cis heptachlor epoxyde, Trans heptachlor epoxyde, Hexachlorocyclohexane (α-HCH, β-HCH, δ-HCH and γ-HCH), The Dichloro Diphenyl Trichloroethane (DDT) family: dichlorodiphenyltrichloroethane and its metabolites (p,p'-DDT, o,p'-DDT, p,p'DDE, o,p'-DDE, p,p'-DDD) and Methoxychlor.

2.4 Extraction of Organochlorine Pesticide Residues according to the QuEChERS Procedure

An initial monophasic extraction of 10 or 15 g of sample by acetonitrile, at a rate of 1 mL of actetonitrile per 1 g of sample was carried out. The addition of salts (NaCl, 1 g) and buffers (1.5 g of sodium citrate or sodium acetate) promotes liquid-liquid separation [20]. After centrifugation, the acetonitrile phase containing the pesticide is recovered. The matrix can be further purified and the excess water removed during a solid phase extraction step and in dispersive mode with anhydrous magnesium sulfate ($MgSO_4$). An aliquot of 1 µL of the final extract is injected into the analytical system.

2.5 Estimation of the Risk of Exposure to Pesticide Residues from Kola nut Consumption

The risks considered in this study derived solely from the consumer exposure through ingestion of kola nuts contaminated with organochlorine pesticides. The assessment methodology was conducted according to the risk assessment model of the *Codex Alimentarius* [21]. This procedure follows four main steps including the hazard identification, hazard characterization, exposure assessment and risk characterization [22].

Health risk indices of the organochlorine pesticide residues detected were computed using the data obtained and food consumption assumptions since the consumption data play a major role in assessing the dietary risk of residues in food. So, 0.6 g per day of kola nuts is consumed by an Ivorian adult [23,10,15] The health risk estimates for the pesticide residues in kola nut was computed using two basic standard indices: the Exposure Daily Dose (EDD) and the Hazard Quotient (HQ). The exposure scenarios where the individual is the most exposed were used (maximalist assumption). EDD of organochlorine pesticides linked to the consumption of kola nuts were determined as follows:

$$EDD = C \times Q \times F/P$$

Where : EDD is the exposure daily dose (µg/kg/d) ; C the Concentration of organochlorine pesticides in kolanut (µg/kg) ; Q the Daily consumption kola nut (kg/d) ; F the Frequency of exposure (F = 1) and P the body weight of an Ivorian adult.

* The average body weight of an adult is conventionally equal to 70 kg according to the American Environmental Protection Agency (US EPA) [24].

The risk characterization for threshold effects was expressed by the hazard quotient (HQ). It was calculated for the oral route of exposure.

$$HQ = EDD/TRV$$

Where : HQ is the hazard quotient ; EDD the exposure daily dose (µg/kg/d) ; TRV the Toxicity

Reference Value fixed by the French Agency for Food, Environmental and Occupational Health and Safety (ANSES) [25].

If HQ <1, the occurrence of a toxic effect is very unlikely.
If HQ ≥ 1, the appearance of a toxic effect cannot be excluded.

2.6 Statistical Analysis

Data was captured with Excel Spreadsheet and statistically treated using Statistical Program for Social Sciences (SPSS 20.0, SPSS for windows, USA) at 5% significance. The statistical test consisted in a one-way analysis of variance (ANOVA) with the origin of kola nuts. The statistical differences were highlighted by the test of Duncan test at the 5% level of significance.

3. RESULTS

3.1 Organochlorine Pesticides Residues Contents Extracted from Kola nuts Collected

The concentrations of dichlorodiphenylethane, cyclodienes, benzene hexachloride, and other organochlorine pesticides (Chlorfenapyr, Chlorthal dimethyl, Quitozene and, Hexachlorobenzene) in kola nuts samples are presented in Tables 1, 2, 3 and 4. The results indicate that Methoxychlor, DDE (op'), Endrin ketone, Hexachlorobenzene, Chlorfenapyr, Chlorthal dimethyl and Quitozene concentrations are below the limit of quantification (LOQ) for all samples analyzed. The concentrations of Dieldrin, Heptachlor, Cis heptachlor epoxyde, Trans heptachlor epoxyde, a-Hexachlorocyclohexane, b-Hexachlorocyclohexane and d-Hexachlorocyclohexane from the farmers are below the limit of quantification (LOQ). Statistical analysis revealed significant differences between different organochlorine pesticide levels determined in the kola nuts regardless of origins ($p<0.05$).

Table 5 presents the average values of organochlorine pesticide contents in kola nuts collected from actors.

The concentration of dichlorodiphenylethane ranged from 11.11 to 17.59 µg/kg, 12.22 to 66.48 µg/kg, 12.96 to 95.74 µg/kg and 13.89 to 94.54 µg/kg for farmers, rural hawkers, communal storage sites and wholesale stores, respectively. The cumulative mean concentrations of farmers (73.89 µg/kg) was less than rural hawkers (171.67 µg/kg), communal storage sites (235 µg/kg) and wholesale stores (239.81 µg/kg).

The concentration of cyclodienes range from 7.59 to 15.56 µg/kg, 5.19 to 86.85 µg/kg, 8.70 to 107.78 µg/kg and 23.06 to 125.09 µg/kg for farmers, rural hawkers, communal storage sites and wholesale stores, respectively. The total cyclodienes levels were 49.26 µg/kg for farmers, 395.21 µg/kg for rural hawkers, 469.66 µg/kg for communal storage sites and 465.08 µg/kg for wholesale stores.

The contents of HCHs had the respective range of not detected (ND) to 22.22 µg/kg, 65.74 to 101.85 µg/kg, 92.41 to 136.11 µg/kg and 71.76 to 112.13 µg/kg for farmers, rural hawkers, communal storage sites and wholesale stores, respectively. Also, the cumulative levels estimated in these actors varied from 22.22 µg/kg, 329.07 µg/kg, 387.03 µg/kg and 438.7 µg/kg for farmers, rural hawkers, wholesale stores and communal storage sites, respectively.

The mean concentration of organochlorine pesticides residues in kola nuts samples are presented in Table 6.

Results showed the total concentration of DDT, Cyclodienes and HCH were 192.04 µg/kg, 374.88 µg/kg and 315.82 µg/kg, respectively.

Based on the FAO/WHO [26] regulations for levels of dichlorodiphenylethane and other organochlorine pesticides (Chlorfenapyr, Chlorthal dimethyl, Quitozene and, Hexachlorobenzene) in foodstuffs for human consumption, the samples analyzed revealed lower levels than the maximum permissible values.

The levels of benzene hexachloride (HCHs) in kola nut samples were higher than the FAO/WHO [26] maximum permissible limits. The analyzed samples that were above the Maximum Residue Levels (MRLs) varied from 80 to 98.52 %.

Among the Cyclodienes detected in kola nuts, the mean levels of Aldrin, Dieldrin, α-Endosulfan, β- Endosulfan and Endosulfan sulfate were below the maximum residue levels. Heptachlor, Cis heptachlor epoxyde and Trans heptachlor epoxyde mean concentrations were higher than the maximum permissible limits. Thus, 79.26 to 80 % of the determined concentrations were above the FAO Maximum Residue Levels (MRLs).

Table 1. Concentrations of dichlorodiphenylethane in kola nuts samples according to the collected area

Origin of the kola samples	Methoxychlor	DDD (op')	DDD (pp')	DDE (op')	DDE (pp')	DDT (op')	DDT(pp')
F1	<LD	9.44 ± 5.27[a]	9.44 ± 5.83[cd]	<LD	15.56 ± 3.91[b]	16.67 ± 7.07[d]	16.11 ± 6.01[c]
F2	<LD	13.89 ± 7.41[a]	18. 89 ± 7.41[b]	<LD	14.44 ± 9.50[b]	14.44 ± 9.82[d]	17.22 ± 6.67[c]
F3	<LD	11.67 ± 6.12[a]	<LD	<LD	21.67 ± 8.66[ab]	21.67 ± 6.12[de]	15.56 ± 8.46[c]
C1	<LD	13.33 ± 12.50[a]	15.00 ± 9.01[bc]	<LD	14.44 ± 7.26[b]	48.89 ± 22.83[cd]	61.67 ± 48.35[b]
C2	<LD	20.00 ± 13.46[a]	10.56 ± 5.27[bcd]	<LD	13.33 ± 8.29[b]	43.89 ± 17.10[cd]	72.78 ± 25.26[ab]
C3	<LD	14.44 ± 8.08[a]	11.11 ± 5.46[bcd]	<LD	18.89 ± 5.46[ab]	91.67 ± 47.37[b]	65.00 ± 31.62[ab]
S1	<LD	20.00 ± 26.10[a]	12.78 ± 5.07[bcd]	<LD	20.56 ± 7.63[ab]	59.44 ± 38.60[cb]	73.89 ± 47.55[ab]
S2	<LD	9.44 ± 3.91[a]	10.56 ± 5.27[bcd]	<LD	18.89 ± 5.46[ab]	95.00 ± 39.29[b]	92.22 ± 36.84[ab]
S3	<LD	9.44 ± 4.64[a]	28.89 ± 9.61[a]	<LD	27.78 ± 10.63[a]	132.78 ± 29.17[a]	93.33 ± 40.00[ab]
Center 1	<LD	11.48 ± 8.06[a]	18.89 ± 12.81[b]	<LD	27.41 ± 13.04[a]	97.96 ± 50.52[ab]	93.70 ± 41.24[ab]
Center 2	<LD	16.30 ± 13.27[a]	16.85 ± 9.82[bc]	<LD	26.48 ± 15.49[a]	75.19 ± 44.71[cb]	95.37 ± 44.91[a]

Means with the same letters exponentiating in the same column are not different at 5% according to Duncan test.
Concentrations in µg/kg. LD : Limits of detection = 5 µg/kg; F1, C1, S1: Farmers, Collectors, Stores of Bas-Sassandra; F2, C2, S2: Farmers, Collectors, Stores of districts of Comoe and lagoons; F3, C3, S3: Planters, Collectors, Stores of district of mountain district; Center: big storage and distribution centers (1: Anyama ; 2: Bouake)

Table 2. Concentrations of cyclodienes in kola nuts samples according to the collected area

Origin of the kola samples	Aldrin	Dieldrin	α-Endosulfan	β-Endofulfan	Endosulfan sulfate	Endrin ketone	Heptachlor	Cis heptachlor epoxyde	Trans heptachlor epoxyde
F1	<LD	<LD	13.33 ± 5.59[b]	13.33 ± 8.29[a]	12.78 ± 5.65[d]	<LD	<LD	<LD	<LD
F2	8.33 ± 5.59 [bc]	<LD	<LD	16.67 ± 7.50[a]	12.22 ± 5.07[d]	<LD	<LD	<LD	<LD
F3	9.44 ± 5.83[b]	<LD	21.67 ± 11.46[b]	16.67 ± 7.50[a]	13.33 ± 8.66[d]	<LD	<LD	<LD	<LD
C1	<LD	23.89 ± 11.67[b]	19.44 ± 10.14[b]	18.89 ± 10.83[a]	35.56 ± 20.53[cd]	<LD	93.33 ± 43.23[bc]	90.56 ± 28.88[ab]	95.56 ± 35.22[ab]
C2	5.56 ± 1.67 [c]	42.22 ± 16.79[a]	17.22 ± 7.12[b]	16.67 ± 9.68[a]	83.89 ± 37.81[a]	<LD	65.00 ± 32.79[c]	68.33 ± 35.35[b]	84.44 ± 35.22[ab]
C3	<LD	24.44 ± 9.50[b]	18.89 ± 11.12[b]	15.56 ± 10.14[a]	76.11 ± 28.81[a]	<LD	101.67 ± 26.57[abc]	101.67 ± 47.30[a]	76.67 ± 16.20[b]
S1	<LD	26.11 ±	32.22 ± 25.51[b]	18.33 ±	67.22 ± 21.38[ab]	<LD	72.22 ±	67.22 ± 20.33[b]	103.89 ±

Origin of the kola samples	Aldrin	Dieldrin	α-Endosulfan	β-Endofulfan	Endosulfan sulfate	Endrin ketone	Heptachlor	Cis heptachlor epoxyde	Trans heptachlor epoxyde
		11.93[b]		14.14[a]			41.99[c]		17.10[ab]
S2	<LD	43.89 ± 5.46[a]	73.89 ± 122.77[a]	24.44 ± 17.70[a]	44.44 ± 6.35[bc]	<LD	124.78 ± 2.36[ab]	105.00 ± 29.37[a]	102.78 ± 31.93[ab]
S3	16.11 ± 5.58 [a]	35.00 ± 9.35[a]	20.00± 7.91[b]	23.33 ± 10.31 [a]	82.78 ± 45.35[a]	<LD	115.56 ± 50.96[ab]	83.33 ± 33.35[ab]	116.67 ± 47.70[a]
Center 1	<LD	25.56 ± 11.87[b]	25.56± 10.95[b]	23.15 ± 18.04[a]	48.70 ± 28.61[bc]	<LD	134.81 ± 66.32[a]	91.11 ± 20.72[ab]	102.22 ± 39.72[ab]
Center 2	<LD	24.26 ± 11.24[b]	20.56 ± 12.43[b]	25.74 ± 20.93[a]	90.56 ± 43.20[a]	<LD	115.37 ± 37.70[ab]	97.19 ± 36.68[a]	105.37 ± 45.82[ab]

Means with the same letters exponentiating in the same column are not different at 5% according to Duncan test.
Concentrations in µg/kg. .LD : Limits of detection = 5 µg/kg; F1, C1, S1: Farmers, Collectors, Stores of Bas-Sassandra; F2, C2, S2: Farmers, Collectors, Stores of districts of Comoe and lagoons; F3, C3, S3: Planters, Collectors, Stores of district of mountain district; Center: big storage and distribution centers (1: Anyama ; 2: Bouake)

Table 3. Concentrations of benzene hexachloride in kola nuts samples according to the collected area

Origin of the kola samples	α-HCH	β-HCH	δ-HCH	Ƴ-HCH
F1	<LD	<LD	<LD	13.89 ± 7.82^{e}
F2	<LD	<LD	<LD	27.22 ± 12.28^{e}
F3	<LD	<LD	<LD	25.56 ± 7.26^{e}
C1	56.11 ± 12.69^{c}	99.44 ± 46.40^{bc}	55 ± 15.41^{d}	81.67 ± 33.17^{d}
C2	61.67 ± 15.61^{c}	92.78 ± 44.73^{bc}	77.22 ± 40.93^{bcd}	92.78 ± 44.66^{cd}
C3	100.00 ± 31.22^{ab}	113.33 ± 21.36^{ab}	65.00± 12.50^{cd}	92.22 ± 28.63^{cd}
S1	85.00 ± 31.72^{bc}	76.67 ± 54.60^{c}	49.44 ± 40.35^{d}	126.11 ± 34.53^{abc}
S2	120.56 ± 24.68^{a}	136.67 ± 30.10^{a}	124.44 ± 199.11^{a}	132.78 ± 16.60^{ab}
S3	121.67 ± 31.52^{a}	90.00 ± 33.07^{bc}	103.33 ± 65.29^{ab}	149.44 ± 24.04^{a}
Center 1	113.52 ± 34.92^{ab}	89.07 ± 29.09^{bc}	88.70 ± 31.61^{bc}	116.11 ± 48.56^{abc}
Center 2	110.74 ± 54.89^{ab}	99.80 ± 49.75^{bc}	54.81 ± 47.79^{d}	101.30 ± 40.56^{bcd}

Means with the same letters exponentiating in the same column are not different at 5% according to Duncan test. Concentrations in µg/kg. LD : Limits of detection = 5 µg/kg

F1, C1, S1: Farmers, Collectors, Stores of Bas-Sassandra; F2, C2, S2: Farmers, Collectors, Stores of districts of Comoe and lagoons; F3, C3, S3: Planters, Collectors, Stores of district of mountain district; Center: big storage and distribution centers (1: Anyama ; 2: Bouake)

Table 4. Concentrations of other pesticides in kola nuts samples according to the collected area

Origin of the kola samples	Hexachlorobenzene	Chlorfenapyr	Chlorthal dimethyl	Quitozene
F1	<LD	<LD	<LD	<LD
F2	<LD	<LD	<LD	<LD
F3	<LD	<LD	<LD	<LD
C1	<LD	<LD	<LD	<LD
C2	<LD	<LD	<LD	<LD
C3	<LD	<LD	<LD	<LD
S1	<LD	<LD	<LD	<LD
S2	<LD	<LD	<LD	<LD
S3	<LD	<LD	<LD	<LD
Center 1	<LD	<LD	<LD	<LD
Center 2	<LD	<LD	<LD	<LD

Concentrations in µg/kg. LD : Limits of detection = 5 µg/kg

LD : Limits of detection; F1, C1, S1: Farmers, Collectors, Stores of Bas-Sassandra; F2, C2, S2: Planters, Collectors, Stores of districts of Comoe and lagoons; F3, C3, S3: Planters, Collectors, Stores of district of mountain district; Center: big storage and distribution centers (1: Anyama ; 2: Bouake)

Table 5. Concentrations of Organochlorine Pesticides in kola nuts according to the actors

Organochlorine Pesticides	Farmers	Collectors	Stores	Centers
Methoxychlor	<LD	<LD	<LD	<LD
DDD (op')	11.67 ± 6.35^{a}	15.93 ± 11.52^{a}	12.96 ± 15.70^{a}	13.89 ± 11.14^{a}
DDD (pp')	11.11 ± 7.88^{b}	12.22 ± 6.84^{b}	17.41 ± 10.68^{a}	17.87 ± 11.35^{a}
DDE (op')	<LD	<LD	<LD	<LD
DDE (pp')	17.22 ± 8.13^{b}	15.56 ± 7.25^{b}	22.41 ± 8.81^{a}	26.94 ± 14.19^{a}
DDT (op')	17.59 ± 8.13^{c}	61.48 ± 37.67^{b}	95.74 ± 46.11^{a}	86.57 ± 48.63^{a}
DDT(pp')	16.30 ± 6.88^{c}	66.48 ± 35.29^{b}	86.48 ± 41.08^{a}	94.54 ± 42.72^{a}
ΣDDTs	**73.89 ± 27.37**	**171.67 ± 88.57**	**235 ± 112.38**	**239.81 ±118.03**
Aldrin	7.59 ± 4.88^{a}	5.19 ± 0.96^{b}	8.70 ± 7.15^{a}	<LD
Dieldrin	<LD	30.19 ± 15.22^{a}	35.00 ± 11.60^{a}	24.91 ± 11.47^{b}

Organochlorine Pesticides	Farmers	Collectors	Stores	Centers
α-Endosulfan	13.33 ± 9.90^{b}	18.52 ± 9.28^{b}	42.04 ± 73.55^{a}	23.06 ± 11.87^{b}
Endofulfan beta	15.56 ± 7.64^{b}	17.04 ± 9.93^{ab}	22.04 ± 32.00^{ab}	24.44 ± 19.39^{a}
Endosulfan sulfate	12.78 ± 6.40^{b}	65.19 ± 35.93^{a}	64.81 ± 32.30^{a}	69.63 ± 41.99^{a}
Endrin ketone	<LD	<LD	<LD	<LD
Heptachlor	<LD	86.67 ± 37.13^{b}	104.10 ± 45.66^{b}	125.09 ± 54.33^{a}
Cis heptachlor epoxyde	<LD	86.85 ± 39.10^{a}	85.19 ± 31.36^{a}	94.15 ± 29.67^{a}
Trans heptachlor epoxyde	<LD	85.56 ± 30.11^{b}	107.78 ± 33.84^{a}	103.80 ± 42.50^{a}
ΣCyclodienes	**49.26 ± 3.82**	**395.21 ± 172.66**	**469.66 ± 262.46**	**465.08± 201.22**
α-HCH	<LD	72.59 ± 28.63^{b}	109.07 ± 33.22^{a}	112.13 ± 46.35^{a}
β-HCH	<LD	101.85 ± 38.66^{a}	101.11 ± 47.12^{a}	94.44 ± 38.94^{a}
δ-HCH	<LD	65.74 ± 26.88^{b}	92.41 ± 54.41^{a}	71.76 ± 43.62^{b}
Ƴ-HCH	22.22 ± 10.86^{d}	88.89 ± 35.09^{c}	136.11 ± 27.01^{a}	108.70 ± 44.94^{b}
ΣHCH	**22.22 ± 10.86**	**329.07± 129.26**	**438.7 ± 161.76**	**387.03 ± 173.85**
Hexachlorobenzene	<LD	<LD	<LD	<LD
Chlorfenapyr	<LD	<LD	<LD	<LD
Chlorthal dimethyl	<LD	<LD	<LD	<LD
Quitozene	<LD	<LD	<LD	<LD
∑ Other pesticides	**-**	**-**	-	-

Means with the same letters exponentiating in the same line are not different at 5% according to Duncan test. Concentrations in µg/kg. LD : Limits of detection = 5 µg/kg

Table 6. Mean concentrations of Organochlorine Pesticides in kola nuts samples

Organochlorine Pesticides	Minimun (µg.kg^{-1})	Average (µg.kg^{-1})	Maximum (µg.kg^{-1})	EU-FML* (µg.kg^{-1})	(%) ≥ FML
Methoxychlor	-	<LD	-	100	0
DDD (op')	<LD	13.67 ± 11.51	85	500	0
DDD (pp')	<LD	15.30 ± 10.16	45	500	0
DDE (op')	-	<LD	-	500	0
DDE (pp')	<LD	21.81 ± 11.85	50	500	0
DDT (op')	<LD	69.59 ± 49.48	185	500	0
DDT(pp')	<LD	71.67 ± 46.67	180	500	0
ΣDDTs		**192.04 ± 29.58**			
Aldrin	<LD	6.30 ± 4.14	35	50	0
Dieldrin	<LD	24.00 ± 15.11	75	50	2.96
α-Endosulfan	<LD	24.00 ± 35.16	400	100	0
β-Endofulfan	<LD	20.70 ± 15.09	85	100	0
Endosulfan sulfate	<LD	56.41 ± 40.52	180	100	16,30
Endrin ketone	-	<LD	-	10	0
Heptachlor	<LD	89.21 ± 61.92	280	20	79.26
Cis heptachlor epoxyde	<LD	73.07 ± 44.90	189	20	80
Trans heptachlor epoxyde	<LD	81.19 ± 51.33	180	20	80
ΣCyclodienes		**374.88 ± 31.90**			
α-HCH	<LD	82.19 ± 54.31	185	10	80
β-HCH	<LD	79.37 ± 52.19	175	10	80
δ-HCH	<LD	61.33 ± 48.47	180	10	76.30

Organochlorine Pesticides	Minimun (µg.kg^{-1})	Average (µg.kg^{-1})	Maximum (µg.kg^{-1})	EU-FML* (µg.kg^{-1})	(%) ≥ FML
ϒ-HCH	<LD	92.93 ± 51.85	190	10	98.52
ΣHCH		**315.82 ± 13.12**			
Hexachlorobenzene	-	<LD	-	10	0
Chlorfenapyr	-	<LD	-	50	0
Chlorthal dimethyl	-	<LD	-	50	0
Quitozene	-	<LD	-	100	0
∑ Other pesticides		-			

LD : Limits of detection = 5 µg/kg

3.2 Human Health Risk Assessment

The regularly exposed populations are those adults who consume kola nuts on a daily basis. Table 7 presents the data of the model of quantitative evaluation of the risks related to the consumption of kola nuts. The estimated daily intake and health risk index (HI) were calculated for each chemical contaminant. The Exposure Daily Doses (EDD) are all lower than the Toxicity Reference Value (TRV) fixed by the French Agency for Food, Environmental and Occupational Health and Safety (ANSES) [25]. In fact, mean EDD values ranged from $5.4.10^{-5}$ to $7.96.10^{-4}$ µg/kg/d for Aldrin and Lindane, respectively. Therefore, the average risks of oral exposure to Organochlorine Pesticides Residues from the consumption of the kola nut are all less than 1. Also, total HQ values for DDT, cyclodienes and HCH were less than 1 (Σ HQ = 0.13 < 1).

4. DISCUSSION

Quantitative analysis of the different samples revealed the presence of these organochlorine pesticide residues (OCPs) in the kola nuts with variable levels according to the collected area and the type of pesticide. Thus, all the sub-groups of organochlorine pesticides, DDT, cyclodienes and HCH were present in the samples collected from farmers, rural hawkers, communal storage sites and wholesale stores. These results show that kola nut actors use various types of pesticides to ward off pests from kola nuts and to overcome the insect pest problems during storage [9,11].

Many of the OCP species evaluated are breakdown products of the parent pesticide. For example, breakdown products of DDT include DDD and DDE [27]. From their mean values, it was obvious that the most predominant dichlorodiphenylethane in kola nuts was DDT (pp'), while the least occurring was DDD (op'). The mean level of DDT (pp') detected in kola nut samples (71.67 µg/kg) was higher than the 50 µg/kg mean value reported by Sosan [28] in kola nut samples from selected markets in Osun State, Southwestern Nigeria. Factors responsible for the observed difference might include difference in the systemic abilities to store the pesticides in kola nuts. Amount of pesticides applied and mode of contamination are other factors that could account for the differences in pesticides found in kola nuts [27].

The results from the present study reveal that the cyclodiene subgroup is the most frequently detected. Heptachlor was the most predominant cyclodiene detected in the kola nuts, while the least occurring was aldrin. The predominance of Heptachlor could probably be as a result of biochemical transformations of parent OCPs to this metabolite. Also, the level of aldrin in the kola nuts was lower than those of its metabolite, dieldrin. This might imply that there migth have been in vivo metabolism of the original aldrin into dieldrin [27].

All the HCH isomers were detected in the nuts with lindane as the most abundant organochlorine pesticide compound in the kola nuts. According to Nuapia et al. [29] lindane is a reasonably stable compound and is one of the less persistent organochlorine pesticides. The mean level of lindane detected in kola nuts samples (92.93 µg/kg) was higher than the 31.0 µg/kg mean value reported by Biego et al. [11] in similar samples obtained from a big storage centers of Anyama in Côte d'Ivoire. Lindane residues were detected in kola nut samples from farmers. Indeed, the use of pesticides in kola plantations constitute a contamination source from farms. According to Kouadio et al. [10], most producers use phytosanitary products essentially consisting of Callifan super 40 EC, Round up 360 SL, Thiosulfan 60 EC, Thiametoxam and Durexa among others. for the maintenance of the plots.

Table 7. Quantitative evaluation of the exposure of Organochlorine Pesticide Residues

Measured parameters		Mean concentrations of OCPs (µg/kg)	EDD (µg/kg/d)	TRV (µg/kg/d)	HQ = R
Dichlorodiphenylethane	**Methoxychlor**	<LD	<$4.28.10^{-5}$ ± 0.00	5	<$8.57.10^{-6}$
	DDD (op')	13.67 ± 11.51	$1.17.10^{-4}$± $9.86.10^{-5}$	10	$1.17.10^{-5}$
	DDD (pp')	15.30 ± 10.16	$1.31.10^{-4}$ ± $8.71.10^{-5}$	10	$1.31.10^{-5}$
	DDE (op')	<LD	<$4.28.10^{-5}$ ± 0.00	10	<$4.28.10^{-6}$
	DDE (pp')	21.81 ± 11.85	$1.87.10^{-4}$ ± $1.01.10^{-4}$	10	$1.87.10^{-5}$
	DDT (op')	69.59 ± 49.48	$5.96.10^{-4}$ ± $4.24.10^{-4}$	10	$5.96.10^{-5}$
	DDT(pp')	71.67 ± 46.67	$6.14.10^{-4}$ ±$4.00.10^{-4}$	10	$6.14.10^{-5}$
Cyclodienes	**Aldrin**	6.30 ± 4.14	$5.4.10^{-5}$ ± $3.55.10^{-5}$	0.1	$5.4.10^{-4}$
	Dieldrin	24.00 ± 15.11	$2.06.10^{-4}$ ± $1.29.10^{-4}$	10	$2.06.10^{-5}$
	α-Endosulfan	24.00 ± 35.16	$2.06.10^{-4}$ ± $3.01.10^{-4}$	6	$3.43.10^{-5}$
	β-Endofulfan	20.70 ± 15.09	$1.77.10^{-4}$ ± $1.29.10^{-4}$	6	$2.96.10^{-5}$
	Endosulfan sulfate	56.41 ± 40.52	$4.83.10^{-4}$ ± $3.47.10^{-4}$	6	$8.06.10^{-5}$
	Endrin ketone	<LD	<$4.28.10^{-5}$ ± 0.00	0.2	<$2.14.10^{-4}$
	Heptachlor	89.21 ± 61.92	$7.65.10^{-4}$ ± $5.31.10^{-4}$	0.1	$7.65.10^{-3}$
	Cis heptachlor epoxyde	73.07 ± 44.90	$6.26.10^{-4}$ ± $3.85.10^{-4}$	0.1	$6.26.10^{-3}$
	Trans heptachlor epoxyde	81.19 ± 51.33	$6.96.10^{-4}$ ± $4.40.10^{-4}$	0.1	$6.96.10^{-3}$
Benzene hexachloride	α-HCH	82.19 ± 54.31	$7.04.10^{-4}$ ± $4.65.10^{-4}$	0.06	$1.17.10^{-2}$
	β-HCH	79.37 ± 52.19	$6.80.10^{-4}$ ± $4.47.10^{-4}$	0.06	$1.13.10^{-2}$
	δ-HCH	61.33 ± 48.47	$5.26.10^{-4}$ ± $4.15.10^{-4}$	0.06	$8.76.10^{-3}$
	ϒ-HCH	92.93 ± 51.85	$7.96.10^{-4}$ ± $4.44.10^{-4}$	0.01	$7.96.10^{-2}$
Other pesticides	**Hexachlorobenzene**	<LD	<$4.28.10^{-5}$ ± 0.00	0.07	<$6.12.10^{-4}$
	Chlorfenapyr	<LD	<$4.28.10^{-5}$ ± 0.00	0.1	<$4.28.10^{-4}$
	Chlorthal dimethyl	<LD	<$4.28.10^{-5}$ ± 0.00	20	<$2.14.10^{-6}$
	Quitozene	<LD	<$4.28.10^{-5}$ ± 0.00	70	<$6.12.10^{-7}$
Σ HQ		**0.13**			

LD : Limits of detection = 5 µg/kg

EDD : Exposure Daily Dose ; TRV : Toxicity Reference Value ; HQ : Hazard Quotient ; R : Risk ; d : da

Data obtained indicated that the content of organochlorine pesticide residues in the kola nuts among planters is lower than the levels recorded from other actors (collectors, stores and storage centers). Indeed, the increase in organochlorine pesticides concentrations during the distribution channel, from planters to big storage centers, would be due to post-harvest treatment. The preservation of fresh kola nuts for long time and against pests requires several soaking cycles in chemical pesticides often composed of prohibited pesticides such as DDT (dichlorodiphenyltrichloroethane) [11,9,10]. The occurrence of organochlorine pesticide residues in the samples may be attributed to the illegal use of the pesticides by farmers in the study area or due to their historic use, since organochlorine pesticides are prohibited from agricultural use in Côte d'Ivoire.

It can be seen that most of the OCPs detected had their levels below the recommended FAO/WHO values [26]. The average contents of Dichlorodiphenylethanes had values lower than the permissible maximum limits. A few of the cyclodienes had their value within the given FAO/ WHO-MRL range, whereas a majority of the cyclodienes fell below that range. All the chlorinated benzenes had values that were higher than the recommended FAO/WHO values [26]. It was noted from the present study that the kola nuts investigated contained chlorinated benzenes and cyclodienes at a much higher level than dichlorodiphenylethanes.

The exposure daily doses (EDD) obtained are all lower the Toxicity Reference Value (TRV) fixed by French Agency for Food, Environmental and Occupational Health and Safety (ANSES) [25]. Thus, Hazard Quotient (HQ) calculated from EDD and TRV are less than 1. Indeed, the risk estimates revealed that total HQ values for DDT, cyclodienes and HCH were less than 1 (Σ HQ < 1).This situation indicates that kola nuts would not represent a health risk for humans and would be safe for comsumption. On the other hand, the regular consumption of a quantity of kola nuts leading to an EDD higher than the TRV would represent a danger for the consumer's health. However, the findings from study of Sosan *et al*. [28] showed that the kola nuts from their study were highly contaminated with the investigated pesticides with unacceptable exposure risk. Contaminated kola nuts in Organochlorine Pesticides Residues represent a health risk for prostate cancer [30,31], liver cancer [32], diabetes [33], reproductive and developmental defects [34, 35] and act as endocrine disruption [36] with acute immunotoxicity [37] and neurotoxicity [38]. Thus, there is high need to give urgent attention to kola nut actors on the use of chemicals for protection against insects at storage. Indeed, kola nut is largely consumed fresh, it is therefore important to intensify efforts to reduce the presence of these Organochlorine Pesticides Residues by raising awareness among actors on good practices for the production and conservation of kola nuts. These good practices pass by the restriction of the use of pesticides in the production and storage of kola nuts. So, it is therefore recommended that, alternative insecticides which are safe, biodegradable and environmental friendly should be sought for the purpose of kola nut preservation.

5. CONCLUSION

This study revealed the presence of Organochlorine Pesticide Residues at varying levels in kola nuts. Most of the OCPs detected had their levels below the recommended FAO/WHO values. These chemical contaminants in kola nuts come from the use of chemical pesticides for storage of the kola nuts. Also, the use of chemical pesticides in kola plantations constitute a contamination source of kola nuts in Organochlorine Pesticides Residues. Estimated daily doses in Organochlorine Pesticides Residues from kola nuts, remains below the different toxicological reference values. Total HQ values for DDT, cyclodienes and HCH were less than 1. Consequently, toxicity is very unlikely for the consumer. Kola nuts from Côte d'Ivoire would be safe for consumption. However, this satisfaction must not forget the bad practices of the actors in production and preservation of kola nuts. Thus, the implementation of efficient technical during production and preservation will be able to guarantee better sanitary quality for kola nuts. Kola nut protection with human health and environment safety needs to be assessed on alternative uses of pest control methods that do not only rely on conventional and synthetic pesticides.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Akinneye Joseph O, Adedolapo A, Adesina Femi P. Quantification of Organophosphate and Carbamate residue on stored grains in Ondo State, Nigeria. J Biol Med. 2018;2(1):001-006.

   Avaialble:http://dx.doi.org/10.17352/aur.000003
2. Kolani L, Mawussi G, Devault D, Sanda K. Organochlorine Pesticide Residues in Agricultural Soils from Région Des Plateaux in Togo. Rev. Inter. Cont. Amb. 2017;33:33-42.
3. Ogah C, Coker H. Quanti fi cation of Organophosphate and Carbamate Pesticide Residues in Maize. J. Appl. Pharm. Sci.. 2012;2:093-097.

   Available:https://tinyurl.com/yb2ew62g
4. Eunyoung P, Jiho L, Junghak L, Jonghwa L, Hye Suk L, Yongho S, Jeong-Han K. Method for the simultaneous analysis of 300 pesticide residues in hair by LC-MS/MS and GC- MS/MS, and its application to biomonitoring of agricultural workers. J. hom. 2021;1-12.
5. Leong K, Tan L, Mustafa A. Contamination levels of selected organochlorine and organophosphate pesticides in the Selangor River, Malaysia between 2002 and 2003. Chem. 2007;66:1153-1159.

   Available: https://tinyurl.com/y7fxupgm
6. Biego H, Yao D, Ezoua P, Kouadio L. Assessment of organochlorine peticides residues in fish sold in Abidjan markets and fishing sites. Afr J. Food Agric. Nut Develop. 2010 ;10(3):2305-2323.
7. Nyamien Y, Coulibaly A, Belleville M, Petit E, Adima A, Biego G. Simultaneous determination of caffeine, catechin, epicatechin, chlorogenic and caffeic acid in *Cola nitida* dried nuts from Côte d'Ivoire using HPLC. Asian J. Biotech. Bioresour. Technol. 2017;1(2):1 -7.
8. Kouadio R, Biego H, Nyamien Y, Ake Y, Coulibaly A. Evaluation of effective and safe extraction method for analysis of ploycyclic aromatic hydrocarbons in kolanuts from Côte d'Ivoire. *Asian Food Sci. J.* 2020;14(1):1-10.
9. Deigna-Mockey V, Kouadio K, Konan N, Biego G. Diagnosis in Production and Post-harvest Processing of Nuts of *Cola nitida* (Malvaceae) in Côte d'Ivoire. J. Agri. Eco.Res. Inter. 2016;9(2):1-11.
10. Kouadio R., Deigna-Mockey V., Ake A., Nyamien Y., Coulibaly A., Sidibe D., Biego H. Levels of Heavy Metals and Their Risk Assessment in Kolanuts (*Cola nitida* Schott & Amp; Endl.) Collected from Cote d'Ivoire, West Africa. Euro. J. Nutri. & Food Saf. 2020;12(7):58-68.
11. Biego H, Yao K, Ezoua P, Chatigre K, Kouadio P. Contamination levels of organochlorine pesticides in *Cola nitida* nuts. Int. J. Biol. Chem. Sci. 2009;3(6):1238-1245.
12. Kouadio R, Biego H, Nyamien Y, Konan Y, Konan C, Coulibaly A, Sidibe D. Validation of efficiency method for heavy metals determination in kola nuts (*Cola nitida* Schott & Endl.) from Côte d'Ivoire. Asian J. Adv. Res. Rep. 2019;6(3):1-9.
13. Mroueh M. Contribution to the study of food contamination by pesticides in Côte d'Ivoire: Dosage of organochlorine insecticides in cereals. Pharmacy Thesis. UFR of Pharmaceutical and Biological Sciences, University of Cocody. Côte d'Ivoire, Abidjan; French ; 1992.
14. Fleischer G, Andoli V, Coulibaly M, Randolph T. Socio-economic analysis of the pesticide industry in Côte d'Ivoire. Faculty of Horticulture. Institute of Economic Sciences. University of Hanover. Belgium, Hanovre. French ; 1998.
15. Kouadio K, Biego G, Nyamien Y, Ake A, Konan Y, Coulibaly A. Sidibe D. Polycyclic Aromatic Hydrocarbons Kolanuts (*Cola nitida* Schott & Amp; Endl) Daily Intake Exposure Risk from Côte d'Ivoire, West Africa. J. Appl. Lif. Sci. Inter. 2020;23(10):1-12.
16. Aikpokpodion P, Oduwole O, Adebiyi S. Appraisal of Pesticide Residues in Kola Nuts Obtained from Selected Markets in Southwestern, Nigeria. J. Sci. Res. Rep. 2013;2(2):582-597.

17. Deigna-Mockey V, Biego H, Nyamien Y, Konan Y, Coulibaly A, Ake A, Sidibe D. Organochlorine Residues Levels in Some Selected Kolanuts (Cola nitida Schott & Endl.) in Côte d'Ivoire. Asian J. Adv. Agri. Res. 2020;13(4):24-35.
18. Codex alimentarius. Residues in food. Joint FAO/WHO Food standard program. Rome. 2005 ; 61-81
19. Regulation (EC) No. 333/2007 of 28 March 2007 laying down the sampling methods of samples and methods of analysis for the official control of the levels of lead, cadmium, mercury, inorganic tin, 3-MCPD and benzo (a) pyrene in foodstuffs. Official Journal of the European Union. 2007;10.French.
20. Anastassiades M, Lehotay J, Stajnbaher D, Schenck F. Fast and easy multiresidue method employing acetonitrile extraction/partitioning and "dispersive solid-phase extraction" for the determination of pesticide residues in produce, Journal of AOAC. 2003.
21. FAO. Food and Agriculture Organization of the United Nations. Food quality and safety system - Training manual on food hygiene and the risk analysis system – critical points for their control (HACCP). 2007; 220. French.
22. Gay G, Denys S, Doornaert B, Coftier A, Hazebrouck B, Lever N, Kimmel M, Quiot F. Methodology for quantitative assessment of health risks relating to chemical substances, Convention 03 75 C 0093 and 06 75 C 0071, ADEME / SYPREA / FP2E / INERIS. 2007;45. French.
23. Nyamien Y, Adje F, Niamke F, Chatigre O, Adima A, Biego G. Caffeine and phenolic compounds in *Cola nitida* (vent) Schodt and Endl and *Garcinia kola* Heckel grown in Côte d'Ivoire. Brit. J. Appl. Sci. Techn. 2014 ;4(35): 4846-4859.
24. ASTEE. Guide for health risk assessment in the context of the impact study of a UIOM. Sci. Techn. Assoc. for Wat. Environ. 2003 ;60. French.
25. Anses. Rapport d'appui scientifique et technique. Premières interprétations des résultats de la Campagne Nationale Exploratoire des Pesticides (CNEP) dans l'air ambiant (Autosaisine n° 2020-SA-0030) : Anses. 2020;141.
26. FAO/WHO. *Codex Alimentarius* Commission, Pesticide Residues in Food and Feed. Codex Pesticide Residues in Food Online Database ; 2012.
27. Oyekunle A, Akindolani O, Sosan M, Adekunle A. Organochlorine pesticide residues in dried cocoa beans obtained fromcocoa stores at Ondo and Ile-Ife, Southwestern Nigeria. J. Toxi. Rep. 2017;4:151-159.
28. Sosan M, Oyekunle J. Organochlorine Pesticide Residue Levels and Potential Human Health Risks in Kolanuts from Selected Markets in Osun State, Southwestern Nigeria. Asian J. Chem. Sci. 2017;2(4):11.
29. Nuapia Y., Chimuka L., Cukrowska E. Assessment of organochlorine pesticide residues in raw food samples from open markets in two African cities. Journal Homepage, Chem. 2016;164: 480-487.
30. Alavanja M, Samanic C, Dosemici M, Lubin J, Tarone R, Lynch C, Knott C, Thomas K, Hoppin J, Barker J, Coble J, Sandler D, Blair A. Use of agricultural pesticides and prostate cancer risk in the Agricultural Health Study cohort, Am. J. Epidemiol. 2003 ;157(9): 800–814.
31. Settimi A, Mashina A, Andrion A, Axelson O. Prostate cancer and exposure to pesticides in agricultural setting, Int. J. Cancer. 2003;104 458–461.
32. Figa-Talamanca I, Mearelli I, Valente P, Bascherini S. Cancer mortality in a cohort of rural licensed pesticide users in the province of Rome, Int. J. Epidemiol. 1993;22:579–583.
33. Beard J, Sladden T, Morgan G, Berry G, Brooks L, McMicheal A. Health impacts of pesticide exposure in a cohort of outdoor workers, Environ. Health Perspect. 2003;111:724–730.
34. Toft G., Hagmar L., Giwercman A., Bonde J. Epidemiological evidence on reproductive effects of persistent organochlorines in humans, Reprod. Toxicol. 2004;19:5–26.
35. Yucra S., Rubio J., Casco M., Gonzales C., Steenland K., Gonzales G. Semen quality and reproductive sex hormones levels in Peruvian Pesticide sprayers,Int. J. Occup. Res. 2006;63(2): 295–300.

36. Barlow S. Agricultural Chemicals and Endocrine mediated chronic toxicity or carcinogenicity, Scand. J. Work Environ. Health. 2005;31:119–122.
37. Galloway T, Handy R. Immuno-toxicology of organo- phosphorus pesticides. Ecotoxiol. 2003 ;12(1–4): 343–363.
38. Kamel F., Hoppin J. Association of Pesticide exposure with neurologic dysfunction and disease, Environ. Health Perspect. 2004;112(9):950–958.

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