Original Research Article

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

ABSTRACT

Background: Kola nut represents a significant economic interestfor this country as well as many African households and public authorities. Despite its obvious importance, the sector of the kola nut is facing a delicate sanitary quality of the marketed product. The majority of the production (90%) of kola is consumed daily fresh by people and could cause a serious health problem for consumers if the toxicity due to organochlorine pesticide residues were proven.
Aims: This study aimed to detrmined the organochlorine pesticide residues levels in kola nuts and estimate the risks of kola nuts consumption on population health in Côte d'Ivoire.
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 ; 2917-2018 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 ± 0.96 µg/kg to 92.93 ± 51.85 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 $5.4.10^{-5} \pm 3.55.10^{-5}$ µg/kg/day to $7.96.10^{-4} \pm 4.44.10^{-4}$ 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 is no risk to the consumer's health.
Conclusion: The risk of adverse effects from consuming kola nuts contaminated with residues of organochlorine pesticide is very unlikely.

Comment [f1]: I suggest rewriting the text referring to the research objective (written in the body of the abstract), since the main objective of the work was to determine the levels of pesticides in cola nuts produced in Côte d'Ivoire, in order to estimate the risk for the health of the consumer, which is different from decreasing the levels of organochlorine pesticide residues in cola nuts

***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 pest. Nowadays, more than 1100 pesticides are used in various combinations and at different stages of cultivation and during postharvest 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 kolanut 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 the crops 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 crops carriage and processing. Indeed, the kola nuts distribution channel is generally from farmers to the big storage, processing and export centres, with temporary stay from rural collectors and small urban stores [12]. During their processing, carriage and sale, organochlorine pesticide could be laid on the kola nuts stock. Among organochlorines such as Dichloro Diphenyl Trichloroethane (DDT) and Hexachlorocyclohexane (HCH), though prohibited, are still used by some Ivorian farmers [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 showed the presence of organochlorine pesticides during kola nuts 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 maximal values admitted by the *Codex Alimentarius*.
The majority of the production (90%) of kola nuts is consumed daily fresh by people [10] and could cause a serious health problem for consumers if the toxicity due to organochlorine pesticide were proven. The presence of organochlorine pesticide 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 sector.
The aim of this study was to determine pesticide levels in kola nuts produced in Côte d'Ivoire in order to estimate the health risk for consumer.

2. MATERIAL AND METHODS

2.1 Investigation Site

The study was conducted in the main areas of kola nuts 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.).

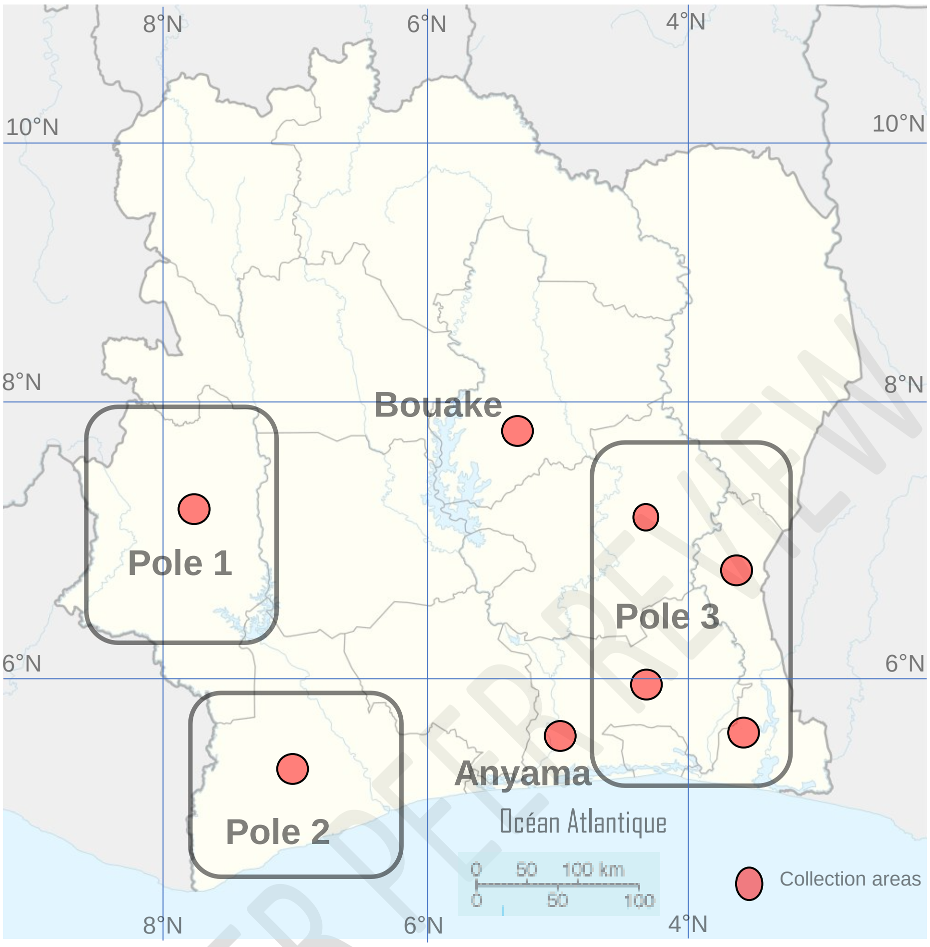

Fig.1. Map showing kolanut samples collection sites

2.2 Plant Material and Sampling

The biological material of this study consists 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 nuts harvesting (2016-2017 ; 2917-2018 and 2018-2019), in accordance with the Regulation No 333/2007 of the European Commission [18]. So, 81 Samples were collected by storage Centers (Anyama and Bouake cities) and by production pole namely 27 samples per type of actors. In total, 810 fresh kola nuts samples, weighing 2 kg each, were used for this study. Kola nuts was authenticated by N'Guessan botanist in the National Floristic Center (CNF) in Abidjan, Côte d'Ivoire, Training and Research Unit of Biosciences, Felix HOUPHOUËT-BOIGNY University where a voucher specimen was documented.

2.3 Extraction of Organochlorine Pesticides Residues according to 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 [19]. 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 ($MgSO4$). An aliquot of 1 µL of the final extract is injected into the analytical system.

2.4 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.

2.5 Estimation of the Risk of Exposure to Pesticides Residues from Kolanuts 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 model of Codex Alimentarius about risk assessment [20]. This procedure follows four main steps including the hazard identification, the hazard characterization, the exposure assessment and risk characterization [21].
Assessment risk organochlorine pesticides to the calculation of the Exposure Daily Dose (EDD) from the average amount of 0.6 g per day of kola nuts consumed by an Ivorian adult [22,10, 15]. The exposure scenarios where the individual is the most exposed have been used (maximalist assumption). EDD of organochlorine pesticides linked to the consumption of kola nuts were determined:

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

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) [23].

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

$$HQ = EDD/TRV$$

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) [24].

If HQ <1, the occurrence of a toxic effect is very unlikely.

If HQ ≥ 1, the appearance of a toxic effect cannot be excluded.

2.5 Statistical Analysis

Data has been captured with Excel Spreadsheet and were 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 have been 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 difference between different organochlorine pesticides levels determined in the kola nuts whatever the origins ($p<0.05$).

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

The concentration of dichlorodiphenylethane ranged from 11.11 ± 7.88 µg/kg to 17.59 ± 8.13 µg/kg, 12.22 ± 6.84 µg/kg to 66.48 ± 35.29 µg/kg, 12.96 ± 15.70 µg/kg to 95.74 ± 46.11 µg/kg and 13.89 ± 11.14 µg/kg to 94.54 ± 42.72 µg/kg for farmers, rural hawkers, communal storage sites and wholesale stores, respectively. The cumulative mean concentrations of farmers (73.89 ± 27.37 µg/kg) was less than rural hawkers (171.67 ± 88.57 µg/kg), communal storage sites (235 ± 112.38 µg/kg) and wholesale stores (239.81 ±118.03 µg/kg).

The concentration of cyclodienes range from 7.59 ± 4.88 µg/kg to 15.56 ± 7.64 µg/kg, 5.19 ± 0.96 µg/kg to 86.85 ± 39.10 µg/kg, 8.70 ± 7.15 µg/kg to 107.78 ± 33.84 µg/kg and 23.06 ± 11.87 µg/kg to 125.09 ± 54.33 µg/kg for farmers, rural hawkers, communal storage sites and wholesale stores, respectively. The total cyclodienes levels were 49.26 ± 3.82 µg/kg for farmers, 395.21 ± 172.66 µg/kg for rural hawkers, 469.66 ± 262.46 µg/kg for communal storage sites and 465.08± 201.22 µg/kg for wholesale stores.

The contents of HCHs had the respective range of not detected (ND) to 22.22 ± 10.86 µg/kg, 65.74 ± 26.88 µg/kg to 101.85 ± 38.66 µg/kg, 92.41 ± 54.41 µg/kg to 136.11 ± 27.01 µg/kg and 71.76 ± 43.62 µg/kg to 112.13 ± 46.35 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 ± 10.86 µg/kg, 329.07± 129.26 µg/kg, 387.03 ± 173.85 µg/kg and 438.7 ± 161.76 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 mean contents of the organochlorine pesticides residues in kola nuts samples collected ranging from 6.30 ± 4.14 µg/kg to 92.93 ± 51.85 µg/kg for Aldrin and Lindane, respectively. The total concentration of DDT, Cyclodienes and HCH were 192.04 ± 29.58 µg/kg, 374.88 ± 31.90 µg/kg and 315.82 ± 13.12 µg/kg, respectively.

Based on the Regulation Food and Agricultural Organisation/World Health Organisation (FAO/WHO) [25] setting maximum levels for 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 values.

The levels of benzene hexachloride (HCHs) in kola nuts samples were higher than the maximum limits set by FAO/WHO [25]. We noted that the percentage of analyzed samples above Maximum Residues Levels (MRLs) vary from 80 to 98.52 %.

Among the Cyclodienes detected in kola nuts, the means levels of Aldrin, Dieldrin, α-Endosulfan, β-Endosulfan and Endosulfan sulfate in kola nuts samples are below the maximum residue's levels. Heptachlor, Cis heptachlor epoxyde and Trans heptachlor epoxyde mean concentrations were higher than the maximum limits. Thus, 79.26 to 80 % of the determined concentrations are above the FAO Maximum Residues 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}

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

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 ± 11.93^{b}	32.22 ± 25.51^{b}	18.33 ± 14.14^{a}	67.22 ± 21.38^{ab}	<LD	72.22 ± 41.99^{c}	67.22 ± 20.33^{b}	103.89 ± 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**: 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 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	Ɣ-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}

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

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*

Means with the same letters exponentiating in the same column are not different at 5% according to Duncan test. ***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]
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	**-**	**-**	-	-

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

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 ($\mu g.kg^{-1}$)	Average ($\mu g.kg^{-1}$)	Maximum ($\mu g.kg^{-1}$)	EU-FML* ($\mu g.kg^{-1}$)	(%) ≥ 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
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 daily consume kola nuts. 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) [24]. In fact, mean EDD range from $5.4.10^{-5} \pm 3.55.10^{-5}$ µg/kg/d to $7.96.10^{-4} \pm 4.44.10^{-4}$ µg/kg/d for Aldrin and Lindane, respectively. Therefore, the average risks of oral exposure to Organochlorine Pesticides Residues from the consumption of the kolanut are all less than 1. Also, total HQ values for DDT, cyclodienes and HCH were less than 1 (Σ HQ = 0.13 < 1).

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

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

4. DISCUSSION

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

Many of the OCPs species evaluated are breakdown products of the parent pesticide. For example, breakdown products of DDT include DDD and DDE [26]. From their mean values, it was obvious that the most predominant dichlorodiphenylethane in kolanuts was DDT(pp'), while the least occurring was DDD (op'). The mean level of DDT(pp') detected in kola nuts samples (71.67 ± 46.67 µg/kg) was higher than the 50 ± 12 µg/kg mean value reported by Sosan [27] in kola nuts 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 some of the other factors that could account for the differences of pesticides found in kola nuts [26].

The results from this study have shown that cyclodienes subgroup being the most frequently detected. Obviously, heptachlor was the most predominant cyclodienes 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, level of aldrin in the kola nuts was lower than those of its metabolite, dieldrin. This might imply that there had been in vivo metabolism of the original aldrin into dieldrin [26].

All the HCH isomers were detected in the nuts with lindane as the most abundant organochlorine pesticides compounds in the kolanuts. According to Nuapia *et al*. [28] lindane is a reasonably stable compound and is considered as one of the less persistent organochlorine pesticides. The mean level of lindane detected in kola nuts samples (92.93 ± 51.85 µg/kg) was higher than the 31.0 ± 36.3 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 samples kola nuts from farmers. Indeed, the use of pesticides in kola plantations constitute a contamination source of kola nuts from farmers in lindane. According to Kouadio *et al*. [10], the majority of producers use phytosanitary products essentially consisting of Callifan super 40 EC, Rund up 360 SL, Thiosulfan 60 EC, Thiametoxam, Durexa, etc. for the maintenance of the plots.

Data obtained indicated that the content of organochlorine pesticides residues in the kola nuts among planters is low than the levels recorded from other actors (collectors, stores and storage centers). Indeed, the increase in organochlorine pesticides concentrations during the distribution circuit, from planters to big storage centers, would be due to the post-harvest treatment. The conservation of fresh kola nuts for long time and against pests requires several soaking in chemical pesticide often composed of prohibited pesticides such as DDT (dichlorodiphenyltrichloroethane) [11, 9, 10].

It can be seen that most of the OCPs detected had their levels below the recommended FAO/WHO values [25]. The average contents of Dichlorodiphenylethanes had values lower than the accepted maximum limits. A few of the cyclodienes had their value within the given FAO/ WHO-MRL range, whereas majority of the cyclodienes fell below the range. All the chlorinated benzenes had values that were higher than the recommended FAO/WHO values. It was noted from this 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) [24]. 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 human and would be safe for people 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*. [27] showed that the kola nuts 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 [29,30], liver cancer [31], diabetes [32], reproductive and developmental defects [33, 34] and act as endocrine disruption [35] with acute immunotoxicity [36] and neurotoxicity [37]. Thus, there is high need to give urgent attention to kola actors on the use of chemicals for protection against storage insects. 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.

5. CONCLUSION

This study revealed the presence of Organochlorine Pesticides Residues at varying levels in kola nuts. The 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, always remains below the different toxicological reference values. Total HQ values for DDT, cyclodienes and HCH were less than 1. Consequently, the occurrence of a toxic effect 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 conservation of kola nuts. Thus, the implementation of efficient technical during production and conservation will be able to guarantee better sanitary quality for kola nuts.

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 DISCLAIMER:

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