Assessment of Polychlorinated Biphenyls (PCBs) in some foods commonly consumed in Nigeria

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Introduction

Persistent organic pollutants (POPs) are toxic organic compounds, which are released into the environment by human activities [1] and include organic compounds such as polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and the very toxic polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) [2]. The Stockholm Convention has listed PCBs and some other organohalogenated compounds such as organochlorine pesticides (OCPs) and polybrominated diphenyl ether (PBDEs) as persistent organic pollutants (POPs) for strict regulation because of their persistence and toxicity to the environment [3]. PCBs are a group of synthetic organic chemicals that are produced by the direct chlorination of the biphenyl ring system and are thought to be among the most ubiquitous and resistant pollutants in the global ecosystem [4]. PCBs are widely used as paint ingredients, coolants and lubricants in transformers, capacitors, and other electrical equipment [4, 5]. There are 209 congeners of PCBs out of which the World Health Organization designated 12 to be very toxic to human health and the environment [6] and are known as dioxin-like PCBs.

The PCBs pollution status in Nigeria is as a result of increase in anthropogenic activities and lack of modern environmentally sound waste management technologies to dispose of the materials that contain them. PCBs are not produced in Nigeria and its contamination of the environment is through improper maintenance of waste sites where PCBs are present and unregulated dumping of PCB wastes, which include leaking of old transformer fluids, electrical transformers and other PCB-containing consumer products [8]. Other human activities that contribute to PCBs contamination include agriculture, discharge of industrial waste into water bodies and incineration [9]. These contaminants can be transported long distances via air and water, can sink in soil and sediment, persist in the environment, bioaccumulate through the food chain and finally deposit in higher animals including humans [10]. There is little information on the levels of POPs in foods consumed in Nigeria [9-13]. Therefore, this study assesses the levels of PCBs in some food commonly consumed in Nigeria using QuEChERS extraction kit and GC-ECD.

Materials and method

All chemicals and reagents used were of analytical grade and of high purity. HPLC grade acetone and n-hexane used for the extraction were obtained from Merck (Germany). The magnesium sulphate and sodium

chloride were purchased from BDH Laboratories (England). A mixture of 10 dioxin-like PCBs: 77, 105, 114, 118, 126, 156, 157, 167, 169, 189) and 20 non-dioxin-like PCBs: 8, 28, 44, 49, 52, 37, 60, 66, 70, 74, 82, 87, 99, 101, 128, 170, 138, 153, 179, 180 (PCBs Congener Mix, mainly for food and human tissue analysis) was from AccuStandard Inc. (New Haven, CT06513, USA). All glassware were washed thoroughly and rinsed with solvent prior to use. A total of 102 composite food samples of 7 different food categories were collected in 2 superstores and 3 local markets in Lagos and Ibadan. The samples collected include: meat (6 raw beef, 8 raw chicken, 4 canned beef, 4 canned chicken), fish (6 frozen fish, 8 seafood, 6 dried fish, 4 canned fish), dairy (2 raw cheese, 4 processed cheese, 4 evaporated milk), edible oil (10 vegetable oil, 6 palm oil), 6 eggs, fruits and vegetables (4 apples, 2 canned apple juice, 4 tomato, 2 canned tomato paste) and cereals (6 beans and 6 rice). Each composite sample was made up of 3 different samples collected at three different sampling points. The raw beef, chicken and cheese; frozen fish and eggs were boiled and homogenised in an electric blender prior to extraction. Canned beef, canned chicken, seafood, dried fish, canned fish, processed cheese, evaporated milk, vegetable oil, palm oil, apples, canned apple juice, tomato, canned tomato paste, beans and rice were homogenized without processing prior to extraction. The food samples were kept in an air tight glass containers and refrigerated until further analyses. 5 g of the homogenized food samples were placed in 50 mL centrifuge tubes, 20 mL of 1:1 acetone: hexane (v/v) was added, and then shaken for 1 min. 1 g of NaCl and 4 g of $MgSO_4$ were added and was shaken for 3 min. Samples were centrifuged for 5 minutes at 3400 rpm. 1 mL of the extracts were transferred into a Supel QuE PSA/C18/ENVI-Carb (AC) tubes (QueChERS kit), shaken for 1 min and centrifuged for another 3 minutes at 3400 rpm. Supernatants were separated into a 2 mL glass vials and analysed with Agilent model 6890A gas chromatograph equipped with a ^{63}Ni microelectron capture detector (μECD). An Agilent DB-XLB fused silica column (30 m x 250 mm x 0.25 um i.d) was used. The operating conditions was: injector temperature set at 250°C, detector temperature 300°C, oven temperature was programmed initially at 100°C (1 min hold), then increased to 200°C at 10°C/min (2 min hold) and finally increased to 300°C at 10°C/min (1 min hold) to give a total run time of 24 min. The carrier gas was nitrogen (99.99 % purity) and flow rate was 1 ml/min. One microliter of the extracts was injected. Calibration curve was obtained using PCBs working standards (500, 250, 125, 62.5, 31.25 and 15.63 ng/g). Recovery ranged between 76–115 %. The LODs ranged from 0.009 - 0.03 ng/g while LOQs ranged from 0.031 - 0.1 ng/g.

Results and Discussion

The concentrations of the dioxin-like PCBs in all the food samples ranged from 3.79 - 9.61, 5.06 -43.8, 1.13 - 2.86, 1.45-4.33, 0.55-1.41, 1.36-3.84 and 0.43-1.36 ng/g in the meat, fish, dairy, edible oil, vegetable and fruits, eggs and cereals, respectively. The mean concentrations in the food samples were 6.53±2.4, 11.9±14, 2.12±1.0, 2.60±1.9, 1.06±0.5, 2.61±1.6 and 0.95±0.4 in the meat, fish, dairy, edible oil, vegetable and fruits, eggs and cereals, respectively. The range of TEQ-WHO_{2005} of dioxin-like PCBs were 0.0009-0.103, 0.00018-0.26, 0.00005-0.0124, 0.00006-0.0422, 0.00005-0.0281, 0.00713-0.0154 and 0.00288-0.00861 pg/g, in the meat, fish, dairy, edible oil, vegetables and fruits, eggs and cereals, respectively (Table 1). When compared with what was reported in the literature, the mean TEQ-WHO_{2005} obtained in this study

was lower than what was reported in the studies conducted in Europe and North America [15] (Table 1). The concentrations of the non-dioxin like PCBs in all the food samples ranged from 10.1-18.3, 12.2-123, 5.01-7.63, 2.60-9.44, 1.65-3.05, 3.71-6.16 and 1.76-3.12 ng/g in the meat, fish, dairy, edible oil, vegetables and fruits, eggs and cereals, respectively (Table 2). The mean concentrations were within the threshold values defined for non-dioxin like PCBs by the European Union Reference Laboratory [16].

Table 1: Minimum, maximum and mean concentrations and SD of dioxin-like PCBs TEQ-WHO_{2005} in the food samples and other studied reported in the literature

Food categories	Minimum concentrations (ng/g)	Maximum concentrations (ng/g)	Mean ± SD (ng/g)	European Mean TEQ-WHO_{2005} (pg/g)	North America Mean TEQ-WHO_{2005} (pg/g)
Meat (n = 22)	0.001	0.10	0.04±0.02	0.7	0.3
Fish (n = 24)	0.0002	0.26	0.1±0.1	0.03	0.11 - 0.28
Dairy (n = 10)	0.0001	0.01	0.01±0.003	0.2 - 1.8	0.5
Edible oil (n = 16)	0.0001	0.04	0.03±0.02	-	-
Eggs (n = 6)	0.0001	0.03	0.01±0.003	0.2 - 0.6	0.029
Vegetables and fruits (n = 12)	0.01	0.02	0.01±0.001	-	-
Cereal (n = 12)	0.003	0.01	0.01±0.001	-	-

The levels of the non-dioxin-like PCBs were higher than those of the dioxin-like PCBs in all the food samples as shown in Figure 1. The results showed that PCBs are present in all the foods commonly consumed in Nigeria. Though, the concentrations were lower than what was reported in the literature and the European Union permissible limit of PCBs in foods. Accumulation over time may results in human health risks and environmental impacts. Thus, the need to monitor this ubiquitous, toxic, bio-accumulative and persistent chemical including dioxins and furans in foods and animal feeds is imperative and highly recommended.

Table 2: Minimum, maximum, mean concentrations and SD in (ng/g) of NDL PCBs in the food samples

Food categories	Minimum	Maximum	Mean ±SD	NDL PCB Threshold limit (ng/g)
Meat (n = 22)	10.1±5.9	18.3±5	13.2±3.5	10 – 25
Fish (n = 24)	12.2±4	123±150	31.7±47	10 - 100
Dairy (n = 10)	5.01±1.1	7.63±1.0	6.40±1.6	10 -20
Edible oil (n = 16)	2.60±0.6	9.44±5.9	4.52±3.5	5 - 8
Eggs (n = 6)	3.71±1.2	6.16±4.1	4.80±2.5	10 - 40
Vegetables and fruits (n = 12)	1.65±0.5	3.05±0.8	2.22±0.8	-
Cereal (n = 12)	1.76±0.6	3.12±0.6	2.34±0.7	-

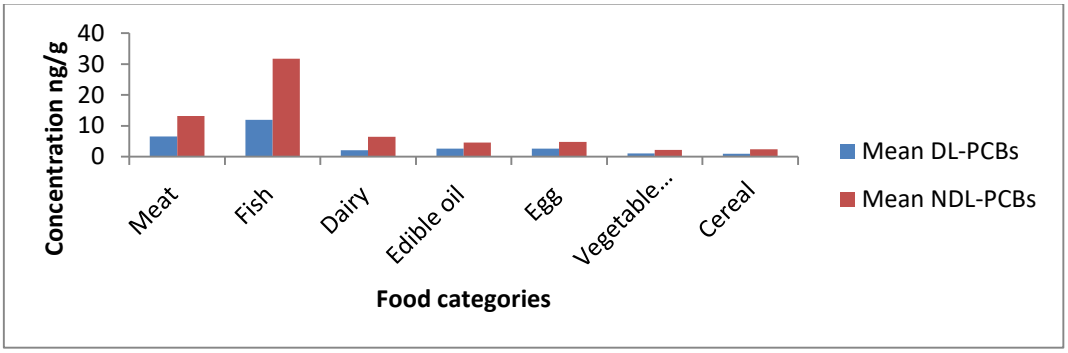

Figure 1: Variation in mean concentrations of dioxin-like and non-dioxinlike PCBs in foods commonly consumed in Lagos and Ibadan, Nigeria

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