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Detection of Polychlorinated Biphenyls in the Atlantic Mackerel (*Scomber scrombus*) Sourced from Cold Storage in Benin City, Nigeria

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Abstract

This study aimed to determine the PCB levels in the Atlantic Mackerel (*Scomber scrombus*) sourced from cold storage points in Benin City, Nigeria by GC analysis and its suitability for human consumption. The PCB concentrations (mg/kg) in *S. scombrus* ranged from 0.0183 for PCB 114 to 0.5542 for PCB 126 with a recorded total of 0.991 while the mean concentrations (mg/kg) of PCBs in *S. scombrus* by cold storage point ranged from 0.0111 for PCB 114 to 0.684 for PCB 126 both at the New Benin points, with no observed significant difference (P>0.05) in the mean concentrations of PCBs 126, 156 and 180 in fish between these points. The mean concentration (mg/kg) of PCBs in *S. scombrus* by month peaked in June with a value of 0.615 for PCB 126. However, there was no observed significant difference (P>0.05) in the mean concentrations of PCBs 114, 118, 138, 153, 156, and 180 in fish specimens between months. Essentially, data from the study revealed that the experimental fish species are suitable to eat by the consuming public as there was no glaring indication of immediate health hazards.

INTRODUCTION

Polychlorinated biphenyls (PCBs) are synthetic and hazardous organic pollutants that chemically consist of the biphenyl molecule that has been chlorinated several folds over (Wangboje and Okotie, 2021). These compounds were once heavily used in industrial applications before their outright proscription over four decades ago in an attempt to arrest their deleterious nature on both aquatic and terrestrial ecosystems. They remain significant in fish biology and ecotoxicology owing to their carcinogenic and endocrine-disrupting capabilities in man. They are also known to trigger reproductive problems, reduce the body's immune response to disease, and impair kidney and metabolic functions (Cui *et al.,* 2017; Lemaitre *et al.,* 2021).

The marine environment is a repository for these pollutants thereby placing marine species including fish at risk. According to Dryden and Duncan (2021), persistent organic pollutants (POPs) such as PCBs that are harmful to natural aquatic resources are invariably harmful to humans. The consumption of oily marine species such as the Atlantic Mackerel (*Scomber scrombus* Linnaeus, 1758) has increased worldwide owing to the health benefits to be derived from polyunsaturated fatty acids (PUFAs)

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which this fish species contains (Stojić *et al.,* 2020).

However, fish is a veritable source of PCBs in the diet of man along with a host of other POPs and must therefore be closely scrutinized for harmful substances. Recent scientific researches on imported marine fish species in Nigeria have confirmed the presence of PCBs in fish. For example, Wangboje *et al.* (2020) revealed the presence of PCBs in *S. scombrus* sourced from markets in Benin City while Wangboje and Okotie (2021) reported the presence of PCBs in *Clupea harengus* (Atlantic Herring) also sourced from markets in Benin City. In the aforementioned cases, samples of experimental fish were sourced directly from fishmongers at selected market stands.

According to the Food and Agriculture Organization of the United Nations (FAO, 2020), *S. scombrus* is widely distributed in the North Atlantic Ocean including the Baltic Sea, Eastern Atlantic including the Mediterranean, and the Black Sea as well as the Western Atlantic. It is a mesodermal and epipelagic species most abundant in cold and temperate regions. This fish species is imported into Nigeria chiefly from Norway as observed by Wangboje *et al.* (2017).

Available literature has revealed the paucity of ecotoxicological information regarding the PCB content in fish from cold rooms which are also important sources of fish for the consuming public. Cold rooms are essentially refrigerated enclosures in which freezing temperatures are generated and maintained to preserve highly perishable food like fish for longer periods.

This research was particularly geared towards filling an existing gap in knowledge by purposely examining *S. scombrus* sourced from cold rooms in Benin City for PCB content to ascertain its suitability for human consumption.

METHODOLOGY

Place and Time

The research was conducted between February and July 2020 in Benin City, Edo State, Nigeria. Details of the study area have been published by Wangboje *et al.* (2017). Cold rooms from four strategically located points within the City were selected after a comprehensive pre-survey viz; Ikpoba-Okah, Ekiosa, New Benin, and Oluku points. The GPS coordinates of Ikpoba-Okah are 6.1649^0 N, 5.6879^0 E while Ekiosa lies within 6.3231^0 N, 5.6363^0 E. New Benin lies within 6.3448^0 N, 5.6340^0 E while Oluku lies within 6^0 $27^'$ 0 N, 5^0 36 ^{0}E. (Fig. 1).

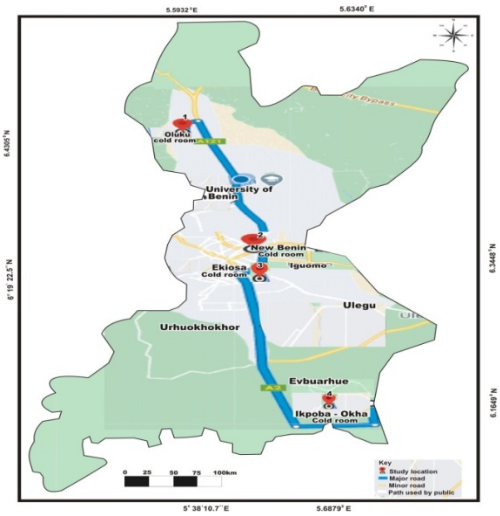

Figure 1. Map of the study area.

Research Materials

The tools and materials used in this research were Food and Agriculture Organization of the United Nations (FAO) species identification sheet, Atlantic Mackerel (*Scomber scombrus*) fish species, Polythene bags, Selotape®, Thermolineo® icebox, Electronic scale (Mettler® PM4800 Delta Range), Stainless steel lancet, Assorted glassware, Sigma® glassware cleaning detergent, Anhydrous sodium sulfate, Dichloromethane, n-hexane, Silica gel, Acetone, Standard mixture of PCB Congeners, Fisher® Rotary evaporator, and Perkin® model 5890 gas chromatograph.

Research Design

The research was a factorial experiment within a randomized complete design involving four cold room points, six months, and one source, replicated twice.

Work Procedure

Collection of Fish Samples

Replicate fish samples were purchased once a month (mid-month) from the aforesaid four cold room points between February and July 2020 giving a combined total of 48 frozen fish samples. The fishes were placed in labeled newly purchased polythene bags, sealed with selotape®, and transported to the laboratory in a Thermolineo® icebox within 24 hours.

Laboratory Procedures

The identities of the fish species were confirmed by using the electronic version of the Food and Agriculture Organization of the United Nations species identification sheet (FAO, 2020). Total length (cm) measurements were taken using a measuring board while weight (g) of fish samples were measured using an electronic scale (Mettler® PM4800 Delta Range). The mean total length was 28.15 ± 2.66 cm while the mean weight was 211.94 ± 1.63 g. All reagents and chemicals used were of analytical grade (BDH, Poole, England, and Sigma, USA). All glassware was soaked in glassware detergent and then rinsed alternately with running tap water and distilled water. Ten (10) g of muscle tissue was excised from the flanks with a stainless steel lancet and ground with anhydrous sodium sulfate until a completely dry homogenate was obtained.

The extraction of PCB in fish tissue was performed according to standard procedures (USEPA, 1996). The extract was concentrated to 2 ml with a rotary evaporator (rotovap) at 40°C. The concentrated extract was thereafter used for clean-up and gravimetric lipid determination. Clean-up of extracts was done in line with the method by Kampire *et al.* (2015) while a Perkin® model 5890 gas chromatographs equipped with Ni 63 electron capture detector (ECD) was used for quantification of PCBs. The quality control was performed by regular analyses of procedural blanks and blind duplicate samples along with the random injection of standards and solvent blanks.

Estimation of Daily Intake (EDI) of PCBs by Man

The EDI was calculated based on the method by Wangboje and Okpobo (2019):

EDI = 40g/person/day * (CPCB)mg/kg/ 1000g/kg = X mg/person/day

Where:

40g/person/day = Estimated average fish consumption in Niger Delta, Nigeria.

(CPCB) = Concentration of PCB in fish.

Toxicity/Hazard Quotient (TQ) for PCBs

The Toxicity/Hazard Quotient (TQ) for chemical compounds is a comparison of the measured concentration of site-related chemical compounds in ecological matrices with specific health-based criteria (Newsted *et al.*, 2002):

$$TQ = \frac{\text{Concentration of PCB in fish sample}}{\text{Health based criteria}}$$

Toxic Equivalency (TEQ) for PCBs

According to the Commission Regulation (2008), the toxic equivalency (TEQ) for PCBs is expressed as follows;

$TEQ = \sum Ti * TEF$

Where:

TEQ = Toxic equivalency
Ti = PCB concentration in organism
TEF = Toxic equivalency factor

Data Analysis

GENSTAT® computer software (Version 12.1 for Windows) was used for statistical analysis. Data were subjected to Analysis of variance (ANOVA) to determine significant differences between mean values of PCBs while significance means ($P<0.05$) were separated with Duncan multiple range tests(DMRT). Microsoft® Excel (for Windows 2010) was used for all graphical presentations.

RESULTS AND DISCUSSION

The PCB profile in *S. scrombus* consisted of both mono-ortho (PCBs 114, 156) and non-ortho (PCBs 126, 169) Congeners with a total of eight (8) PCB Congeners detected in this research. It was observed that PCB 126 and PCB 114 had the highest and lowest mean concentrations in fish (Table 1) suggesting that there could have been a higher influx and retention of the former in the fish in its ambient water medium from where it was harvested. The opposite scenario may be posited for PCB 114 in which case the degree of depuration for this Congener could have been higher. It was observed that PCB 126 dominated the rank profile accounting for over half (55.92%) of the residual PCBs with a very strong temporal total (Figs. 6 and 7 respectively). It is pertinent to note that there are 209 PCB Congeners in existence but not all of them would appear in environmental compartments simultaneously (Wong *et al.*, 2007).

Fishes are bio accumulators of hydrophobic POPs such as PCBs thus it will come as no surprise to find levels of these xenobiotics in their superstructure (Ismayil and Joseph, 2021). Furthermore, PCBs have been observed to accumulate predominantly in the adipose or fatty tissue of fish as a result of their lipophilic nature thereby making their presence marked in such tissues (Singh *et al.,* 2021). It was observed that there was no significant difference ($P>0.05$) in the mean concentrations of PCBs 126, 156, and 180 in fish between the cold room points (Table 2) suggesting a negligible variation in the mean concentrations of the aforesaid PCB Congeners. Similarly, it was observed that there was no significant difference ($P>0.05$) in the mean concentrations of PCBs 114, 118, 138,153, 156, and 180 in fish between the months (Table 3).

Table 1. Summary statistics for the mean concentrations (mg/kg) of PCBs in *Scomber scombrus*.

PCB Congener	Mean	Minimum	Maximum
PCB 114	0.0183	0.00	0.04
PCB 118	0.0342	0.01	0.08
PCB 126	0.5542	0.24	0.82
PCB 138	0.0293	0.00	0.09
PCB 153	0.2442	0.00	0.06
PCB 156	0.0192	0.00	0.30
PCB 169	0.0621	0.00	0.40
PCB 180	0.0308	0.01	0.05
	ΣPCB_8=0.9910		

Table 2. Mean concentrations (mg/kg) of PCBs in *Scomber scombrus* by cold room point.

PCB Congener	Ekiosa	Ikpoba-Okha	New Benin	Oluku
PCB 114	0.0233±0.0122[a]	0.0211±0.0154[a]	0.0111±0.0176[b]	0.0176±0.0156[a]
PCB 118	0.0483±0.0214[a]	0.015±0.005[b]	0.035±0.0105[a]	0.0383±0.0183[a]
PCB 126	0.561±0.05	0.472±0.090	0.684±0.122	0.482±0.12
PCB 138	0.031±0.03[a]	0.0272±0.02[b]	0.0356±0.0198[a]	0.0239±0.015[b]
PCB 153	0.0262±0.023[a]	0.018±0.015[b]	0.0275±0.021[a]	0.0275±0.017[a]
PCB 156	0.0213±0.018	0.034±0.075	0.0087±0.0083	0.0127±0.0306
PCB 169	0.0329±0.03[b]	0.108±0.148[a]	0.068±0.05[a]	0.0441±0.03[b]
PCB 180	0.02±0.017	0.02±0.00	0.04±0.00	0.0433±0.011

Note: Means with different superscripts are significantly different (P<0.05). Horizontal comparison only.

Table 3. Mean concentrations (mg/kg) of PCBs in *Scomber scombrus* by month.

PCB	Feb	March	April	May	June	July
PCB 114	0±0.00	0.0208±0.01	0.0133±0.011	0.0208±0.017	0±0.00	0 ±0.00
PCB 118	0.0308±0.016	0.0375±0.02	0±0.00	0 ±0.00	0 ±0.00	0 ±0.00
PCB 126	0.468±0.130[b]	0.55±0.084[a]	0.483±0.14[b]	0.583±0.132[a]	0.615±0.108[a]	0.614±0.136[a]
PCB 138	0.0225±0.014	0.0133±0.01	0.023±0.010	0.02±0.007	0.0708±0.016	0.0258±0.015
PCB 153	0.0325±0.009	0.0275±0.01	0±0.00	0.0458±0.009	0.015±0.0145	0.0066±0.007
PCB 156	0.0342±0.035	0 ±0.00	0.0358±0.083	0.0158±0.012	0.0042±0.0079	0.00583±0.006
PCB 169	0.134±0.04[a]	0.036±0.02[b]	0.137±0.154[a]	0.0283±0.01[b]	0.0408±0.013[b]	0.025±0.017[b]
PCB 180	0.0308±0.014	0 ±0.00	0 ±0.00	0 ±0.00	0 ±0.00	0 ±0.00

Note: Means with different superscripts are significantly different (P<0.05). Horizontal comparison only.

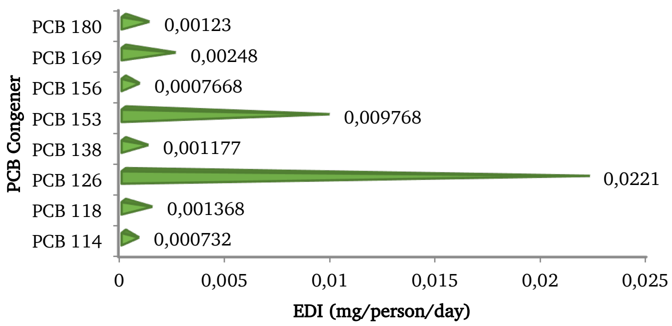

Figure 2. Estimated daily intake (EDI) values for PCBs.

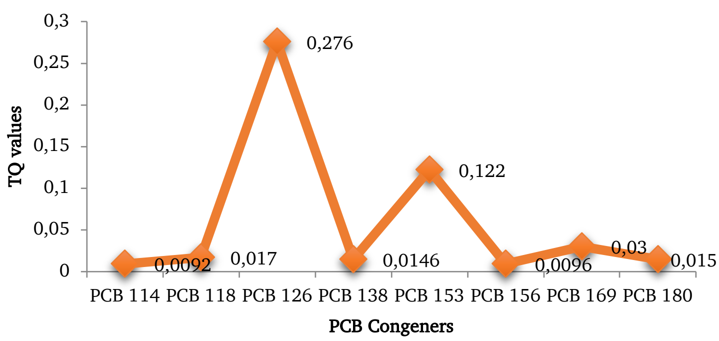

Figure 3. Toxic quotient (TQ) values for PCBs in *Scomber scrombus*.

This observation is a clear reflection of a relatively stable PCB profile in fish between months and is suggestive of the fishes probably coming from the same or

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similar supplier. The estimated daily intake (EDI) values for PCBs were dominated by PCB 126 and least represented by PCB 114 (Fig. 2). This trend was influenced by the respective mean concentrations of the aforementioned PCBs in the experimental fish. The toxic quotient (TQ) values for non-oncological risk (Fig. 3) were all below unity indicating that the mean concentrations of PCBs in *S. scrombus* do not present an immediate risk to potential consumers.

However, PCB 126 is the Congener that has the potential for risk in the future as it accounted for a whopping 98.85% of the toxic equivalency (Fig. 4). The toxic equivalent factors (TEF) which are used in computing the TEQ, are specific for each Congener and together they can be used to assess the potential risk to man (Li *et al.,* 2021). The TEQ value recorded in this research would have been higher but for the fact that TEF values for PCBs 138,153 and 180 are yet to be published. The total PCB content (TPCB) in fish per cold room revealed that the highest and lowest figures were obtained for New Benin and Oluku points respectively (Fig. 5).

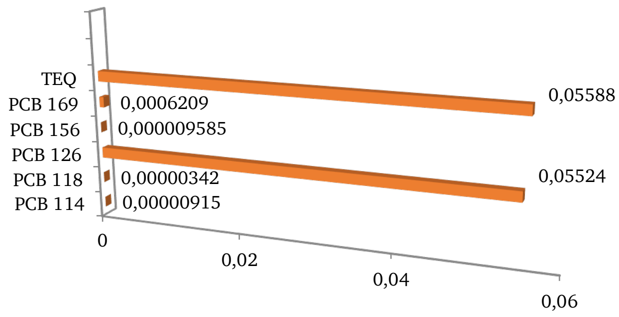

Figure 4. Toxic equivalency (TEQ) value for PCBs in *Scomber scrombus*.

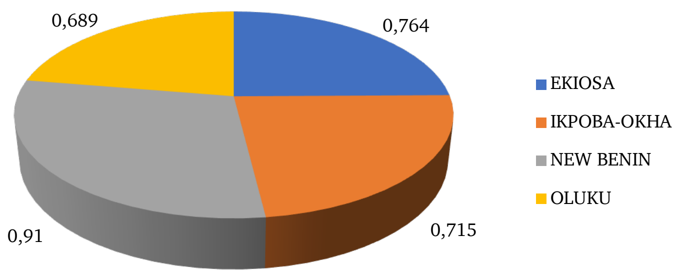

Figure 5. Total PCB content (mg/kg) in *Scomber scrombus* by cold room point.

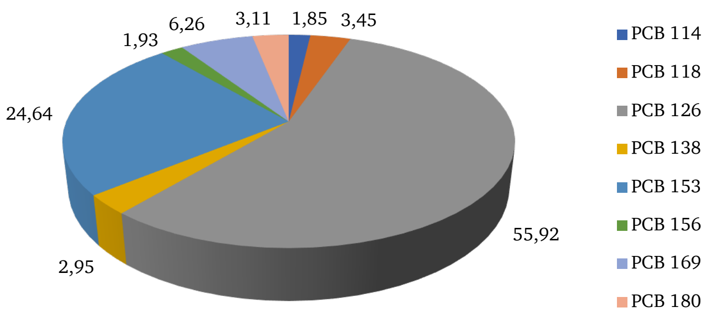

Figure 6. Percentage quota (%) of PCB Congeners in *Scomber scrombus*.

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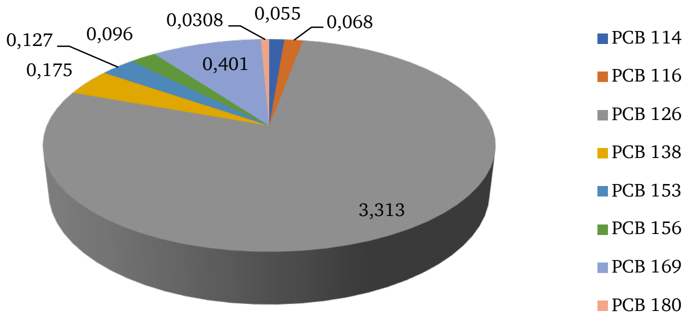

Figure 7. Temporal total (mg/kg) for available PCB Congeners.

This observation could serve as an Advisory to the consuming public in the sense that it would be advised to patronize the cold room at Oluku because of the lower PCB burden in *S. scrombus* found there. To further buttress the suitability of *S. scrombus* for human consumption, the mean concentrations of PCBs in *S. scombrus,* as well as the TPCB, did not exceed the threshold of 2.0 mg/kg established for fish by the Food and Agriculture Organization of the United Nations (1983) and Agency for Toxic Substances and Disease Registry (2016).

The PCB profile in *S. scrombus* in this research compared well to some selected studies (Table 4) which dwelt on marine fish species sourced directly from main markets. It is pertinent to note that a higher number of Congeners were detected in fish in this research, further driving home the significance of this work compared to the other cited studies.

Table 4. Comparison of PCB profile in *Scomber scrombus* to selected studies.

Fish species	Location	Detected PCB Congeners	Direct source of samples	Advisory	Verdict	Potential risk	Reference
Atlantic Mackerel *(Scomber scrombus)*	Benin City	114, 118, 126, 138, 153, 156, 169, 180 (Total=8)	Cold rooms	Oluku point	Safe to eat	PCB 126	This study
Atlantic Mackerel *(Scomber scrombus)*	Benin City	114, 126, 138, 153, 156, 169 (Total=6)	Market	Ekioba/Ekiosa markets	Safe to eat	PCB 126	Wangboje *et al.* (2020)
Atlantic Mackerel *(Scomber scrombus)*	Asaba	126, 138, 153, 169 (Total=4)	Market	Cable market	Safe to eat	PCB 126	Wangboje and Obotha-Adigo (2020)
Atlantic Herring (*Clupea harengus*)	Benin City	114, 118, 126, 138, 153, 156 (Total=6)	Market	Santana market	Safe to eat	PCB 126	Wangboje and Okotie (2021)
Atlantic Salmon (*Salmo salar*)	Slovenia	28, 52, 101, 138, 153, 180 (Total=6)	Market	None	Safe to eat	PCB 138	Heath *et al.* (2019)

CONCLUSION

Data generated on PCBs in this research has clearly shown that *S. scrombus* sourced from selected cold storage points in Benin City, Nigeria are suitable for human consumption. However, constant monitoring must be executed by relevant compliance and regulatory authorities to ensure that safety thresholds are not surpassed at any point in time.

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