Effects of Processing on the Levels of Pesticides in Some Commonly Consumed Meats from Sagamu, South-Western Nigeria

Olutayo S. Shokunbi[1*], David O. Oladejo[1], Elizabeth O. Ngozi[2] and Gogonte H. Amah[1]

[1]Department of Biochemistry, Benjamin S. Carson (Snr.) School of Medicine, Babcock University, Ilisan Remo, Ogun State, Nigeria.
[2]Department of Nutrition and Dietetics, Benjamin S. Carson (Snr.) School of Medicine, Babcock University, Ilisan Remo, Ogun State, Nigeria.

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ABSTRACT

Technological and kitchen processes can partially or fully remove or degrade pesticide residues to other compounds often less toxic, making the products safer for human consumption. This study was therefore conducted to determine the effects of processing on levels of pesticides in some commonly consumed meat in Nigeria.
Cow, goat and pork muscles were purchased from three abattoirs in Sagamu, South-western Nigeria. Each meat sample was separately packaged in a polyethylene bag and transported immediately to the laboratory, where they were processed (boiled and fried) on the same day.

**Corresponding author: E-mail: shokunbio@babcock.edu.ng;*

Samples of raw, boiled and fried meat were extracted and cleaned up before being quantitatively analyzed using gas chromatograph with pulsed flame photometric detector.
The results showed that 35 pesticide residues were detectable in all the meat samples. However, only 10 of them were significantly affected by the processing methods. The levels of some organochlorine pesticide (OCPs) residues and an organophosphorus pesticide (OPP) residue were relatively higher in all the meat samples but were significantly (P<0.05) decreased by the processing methods; with frying being better. The levels of carbamate, triazine, chlorophenoxy, dinitroanilin, chloroalkylthiol, benzoylurea and phenylurea were somewhat low in all the samples and were not significantly (P>0.05) affected by the boiling and frying methods.
The mean levels of all the detected pesticide residues were far below the various internationally set maximum residue limits for meat samples; making the meats analyzed safe for consumption. Furthermore, processing methods greatly depleted pesticide residues, especially OCPs and OPP, in the meats analyzed.

Keywords: Pesticide residues; cow; goat; pork; red meat; boiling; frying; maximum residue limit.

1. INTRODUCTION

Pesticides are substances intended for destroying, preventing, repelling, attracting, or controlling any pest and in some cases species of plants or animals that are not desirable at the period of production, storage, transport, distribution and processing of food, agricultural commodities, or animal feeds or those that are given to animals for the control of ectoparasites [1].

Generally, pesticides have been classified relative to target organism and chemical structure. Classes of pesticides according to target organism mainly include herbicides, insecticides, disinfectants, rodenticides and fungicides. In lieu of chemical structure, they have been classified into 6 major groups which are organochlorine (OC), organophosphorus (OP), carbamate, triazine, chlorophenoxy and pyrethroid [2].

Globally, the use of pesticides is increasing due to the need to feed the world's ever-growing population, while the amount of land available for food production is continually limited [1]. The increase in the use of pesticides has simultaneously contributed to the hazards on human health and to environmental pollution. Pesticides and their metabolites find their ways into the human body through the water cycle, and especially the food chain. Breeding animals can accumulate persistent organic pollutants from contaminated feed and water, and/or from pesticide application in animal production areas (treatment of cowsheds, pigsties, sheepfolds, warrens and/or treatment of animals themselves) [3]. While pesticide compounds are mostly stored in the fat and muscle tissues of animals, they can also be found in other organs of the body such as the brain, liver and lungs where they could cause unique damages [4].

Regular surveys on the levels of pesticides in meats have been reported in the developed world. Driss and Bouguerra [5], Garcia-Regueiro et al. [6] and Krauthacker et al. [7] reported the levels of organochlorine pesticides (OCPs) in some foodstuffs of animal origin from Tunisia, Spain and Yugoslavia respectively. Suzuki et al. [8] surveyed pesticide residues in imported Australian meat, while Cantoni et al. [9] also reported the OCPs in pork collected from Italy. Furthermore, in a surveillance of marketed foods (including meat products, fish, egg, milk and dairy) in Barcelona, Spain from 2001-2006, Fontcuberta et al. [10] discovered a gradual disappearance of regulated OCPs as a consequence of the growing worldwide implementation of current regulatory agreement.

In addition, efforts have been made in some developing countries to evaluate pesticide residues in meats. The contents of OCPs in camel, cattle and sheep carcasses slaughtered in Sharkia province of Egypt were determined and reported to be well below the respective minimal permissible limits set by local or international organizations [11]. Blankson-Arthur et al. [12] reported the levels of OCP residues in grasscutter tissues from Ghana as being below the acceptable maximum residue limits (MRL) of WHO/FAO Codex Alimentarius Commission.

However, limited reports are available in Nigeria on this same subject. The concentrations of OCP residues in cow, pig and goat were stated to be higher than some values reported in similar animals at some other parts of the world but below FAO's maximum residue limit (MRL) [13]. This makes it needful to provide recent

information on pesticide residue in meat and thereby protect meat consumers in Nigeria.

It has been observed that technological and kitchen processes can partially or fully remove or degrade pesticide residues to other compounds often less toxic, which makes products safer for human consumption [14,15]. A reduction rate of 44% has been detected for DDT after thermal processing of lamb meat cuts [16]. A reduction rate of 60% in lindane content has been reported for cooked beef after heating at 115 ^{o}C for 2 hours [17]. Also, a high reduction rate of 65% in lindane content has been reported in rabbit meat after boiling for 1.5 hours [18]. However, there is dearth of information on the extent of reduction of specific pesticide residue in cow, pork and goat meats after conventional processing of boiling and frying. More so, limited information also exist on the most effective processing method for the depletion of pesticide residues in meat as consumed in Nigeria. Therefore, this study was designed to investigate the effect of kitchen processing (boiling and frying) on the levels of pesticide residues in some commonly consumed meats (cow, pork and goat) in Nigeria.

2. MATERIALS AND METHODS

2.1 Sampling

Cow, goat and pork meat samples were purchased from three abattoirs in Sagamu, Ogun State, South-western Nigeria. Sampling was done within February 2012. The meat samples were separately packaged in a polyethylene bag and transported to the laboratory immediately. Each pulled raw meat sample of about 5 Kg was sub-divided into three subsamples. A raw subsample was maintained that way for analysis. The remaining two subsamples were boiled (without additional condiment) and the broths discarded. One of these boiled subsamples was then further fried. The samples - raw, boiled and fried for each of cow, pork and goat meat - were then analyzed for various pesticide residues within 72 hours after processing. All samples were stored at -18 ^{o}C before the analysis.

2.2 Chemicals

All reagents used were of analytical grade from Merck group, Darmstadt, Germany. They include, surrogate standard solution, TFE-fluorocarbon, sodium dihydrogen phosphate, disodium hydrogen phosphate, sulphuric acid, sodium hydroxide, sodium chloride, redistilled analytical grade methylene dichloride (dichloromethane), anhydrous sodium sulphate, nitrogen gas, florisil, and hexane.

2.3 Meat Processing

On delivery of the meat samples to the laboratory, they were thoroughly washed, cut into about 100 g pieces and washed again with tap water as available in the laboratory. Both processing methods – boiling and frying followed the conventional procedures used in preparing meat for table consumption in Nigeria. The boiling was done with water at 120 ^{o}C until the pieces were well cooked and tender. The deep frying was done in different oil portion, for each of the meat type at 120 ^{o}C. Frying was achieved within 15 minutes. All the processing methods were carried out without the addition of any ingredient or additive.

2.4 Pesticide Residue Extraction and Clean-up

The pesticide residue extraction and analysis was carried out by following the modified standard test methods of Manual of Analytical Methods for the Analysis of Pesticides Residues in Human Environmental Samples, EPA-600/8-80-038 [19]. The method is as described subsequently:

The sub-sample materials were pulverized using the laboratory milling machine Janke & Kunkel (IKA Labortechnik, Breisgau, Germany). The pulverized samples were stored at -18 ^{o}C until analysis. Ten gram of each sample was weighed and extracted after the addition of the surrogate standard solution to the sample and later transferred to the extracting bottle that was cocked with TEF-fluorocarbon.

Fifty milliliters of the phosphate buffer was added, followed by pH measurement with the addition of drops of 9 M sulfuric acid or 10 M sodium hydroxide solution for pH adjustment to 7, if necessary. One gram of the sodium chloride salt was added to the sample, sealed and shaken to dissolve the salt. Twenty milliliters of the redistilled analytical grade methylene dichloride (dichloromethane) was added to the sample. The sample was extracted for about 30 minutes. The extract was filtered into the Erlenmeyer flask. Then, the extraction was repeated two more times with fresh solvent and the filtrates were combined. The combined extract was dried by pouring through a drying

Table 1. Gas chromatography conditions for the pesticide analysis

Parameters	Specification
GC:	HP 5890/6890 Powered with HP ChemStationrev.A09.01[1206] Software
Injection temperature:	Split injection
Split ratio:	20:1
Carrier gas	Hydrogen
Flow rate:	1.0 mL/min
Inlet temperature:	250 ^{o}C
Column Type:	HP 5MS
Parameters	Specification
Column dimensions:	30 m x 0.25 mm x 0.25 µm
Oven program:	Initial at 60 ^{o}C for 2 minutes
	First Ramp at 10 ^{o}C/min to 200 ^{o}C
	Second Ramp at 8 ^{o}C/min to 300 ^{o}C constant at 5 minutes
Detector:	PFPD
Detector temperature:	300 ^{o}C
Hydrogen pressure:	22 psi
Compressed air:	28 psi

column containing a 10 cm column of anhydrous sodium sulphate (previously rinsed with methylene dichloride), and the filtrate was concentrated in the concentrator flask with a stream of nitrogen. The wall of the concentrator flask was rinsed with extracting solvent so as to bring the final volume of the extract to 5 mL. The clean-up of the concentrated extract was carried out using florisil packed into column. The concentrated extract was eluted with hexane and later concentrated to the required final volume of 5 mL.

2.5 Determination of Pesticide Residue Concentrations

The Agilent 6890 gas chromatography (GC) with Pulsed Flame Photometric Detector (PFPD) (Agilent Technologies Inc., Wilmington, Delaware) was used for the quantitative analysis. The conditions of the GC are as presented in Table 1. Fortified samples were used for the determination of percentage recoveries of all the pesticide residues under study. This revealed recoveries above 85% for all residues. The detection limit was 0.1 µg/kg for hexachlorobenzene (HCB), lindane, chloropyrifos, dichlorodiphenyltrichloroethane (DDT), aldrin, heptachlor, endrin, heptachlor epoxide, endosulfan and chlordane, whereas all other residues determined were detectable at 0.01 pg/Kg.

2.6 Statistical Analysis

All values were reported as means ± standard deviation (SD), and all analysis were carried out in triplicates. Data were subjected to one-way analysis of variance (ANOVA) to determine the differences in and the effects of processing on the multi-residual pesticide contents of the meat samples. Significant differences among the mean were determined by least significant difference (LSD). All data analyses were performed using the statistical package for social sciences (SPSS) version 22.

3. RESULTS

3.1 Effect of Processing on the Levels of Organochlorine and Organophosphorus Pesticide Residues in Cow, Pork and Goat Muscle Samples from Sagamu, Ogun State

The levels of organochlorine pesticides (OCP) and organophosphorus pesticides (OPP) in various meat (muscle) samples as affected by processing methods are presented in Table 2. The table shows the presence of four OPPs and twelve OCPs in the various samples. The levels of OCPs in the raw cow muscle ranged from 0.76 ng/Kg of alachlor to 221.14 µg/Kg of dichlorodiphenyl trichloroethane (DDT); while the levels of OPPs in the same sample ranged from 0.73 ng/Kg of phosmet to 143.75 µg/Kg of chlorpyrifos. Comparing the concentration of the various OCPs and OPPs in the three muscle samples, the levels of mollinate, dimethoate, chlorothaloniol, alachlor, metachlor and phosmet were not significantly different (p>0.05) from one another. All other OCPs and OPPs were significantly different (p<0.05) in concentration in the three muscle samples.

The levels of mollinate, dimethoate, chlorothaloniol, alachlor, metachlor and phosmet were somewhat low in all the samples and were not significantly (p>0.05) affected by the processing (boiling and frying) methods. All other OCPs and OPPs were higher in concentrations and were significantly decreased (p<0.05) by the processing methods. The result of this study showed a significant reduction in the levels of 9 out of 12 OCP residues determined in the cow, pork and goat muscle samples. In all, the frying method diminished the pesticide residues better (Table 2).

The result further indicated a reduction of 4.6% for endosulfan to 34.9% for DDT in the boiled muscle samples relative to the raw. The frying yielded a reduction of 13.6% for endosulfan to 62.4% for lindane and chlordane in the fried muscle samples compared with the raw samples. From another perspective, boiling reduced the residues by 4.6-21.6%, 6.4-18.9%, and 6.5-34.9% relative to the raw cow, pork, and goat muscle samples respectively, whereas frying reduced the residues by 13.6-62.4%, 22.3-62.4% and 21.6-60.6% relative to the raw cow, pork, and goat muscle samples respectively (Table 2).

All the meat (muscle) varieties showed detectable levels of four OPP residues (0.73-148.10µg/kg) of which chlorpyrifos was the most prevalent (Table 2). Only chlorpyrifos was significantly depleted by the cooking (boiling and frying) methods. Other residues seem to be too minute or with characteristics that made them not readily depleted by the cooking methods. Boiling reduced chlorpyrifos residue by 3.8 – 13.8% whereas frying reduced it by 29.3 – 37.4%.

3.2 Effect of Processing on the Levels of Carbamate and Triazine Pesticides in Cow, Pork and Goat Muscle Samples from Sagamu, Ogun State

The levels of carbamate and triazine pesticides in various muscle samples as affected by conventional processing methods are presented in Table 3. The table shows the presence of one carbamate and five triazine pesticides in the various samples. The levels of aldicarb, simazine, atrazine, carbofuran, terbuthylazine, and cyanazine were very low in all the samples and were not significantly (p>0.05) depleted by the processing methods. Comparing the concentration of the various carbamate and triazine pesticides in the three muscle samples, the levels of aldicarb, simazine, atrazine, carbofuran, terbuthylazine, and cyanazine were not significantly (p>0.05) different from one another. The result indicated no significant (p>0.05) percentage reduction in all of carbamate and triazine pesticide residues after treatment with conventional processing methods.

3.3 Effect of Processing on the Levels of Chlorophenoxy, Dinitroanilin and Chloroalkylthio Pesticides in Cow, Pork and Goat Muscle Samples from Sagamu, Ogun State

The levels of chlorophenoxy, ditroanilin and chloroalkylthio pesticides in various muscle samples as affected by processing methods are presented in Table 4. The table shows the presence of eight chlorophenoxy, one dinitroanilin and one chloroalkylthio in the various samples. The levels of 2,4,6-trichlorophenol (2,4,6-TCP), 4-(2-methyl-4-chlorophenoxy) acetic acid (MCPA), mecoprop, 2, 4-dichlorophenoxy (2,4-D), 1, 2-dibromo-3-chloropropane (DBCP), dichloroprop, fenoprop, 4-(2, 4-dichlorophenoxy) butyric acid (2,4-DB), pendimethalin and captan were very low in all the samples and were not significantly (p>0.05) affected by the processing methods.

Comparing the concentration of the various chlorophenoxy, ditroanilin and chloroakylthio pesticide residues in the three muscle samples, their levels were not significantly (p>0.05) different from one another. The result also indicated no percentage reduction in all the chlorophenoxy, dinitroanilin and chloroalkylthio pesticide residues (Table 4).

3.4 Effect of Processing on the Levels of Benzoylurea and Phenylurea in Cow, Pork and Goat Muscle Samples from Sagamu, Ogun State

The levels of benzoylurea and phenylurea pesticide residues in the various muscle samples as affected by processing methods are presented in Table 5. The table shows one phenylurea and two benzoylurea pesticides in the various samples. The levels of isoproturon, chlorotoluron and fenprothrin were very low in all the samples and were not significantly (p>0.05) affected by processing methods. Comparing the concentration of the benzoylurea and phenylurea pesticide residues in the three muscle samples, their levels were not significantly different (p>0.05) from one another. The result indicated no percentage reduction in all the benozoylurea and phenylurea pesticide residues after boiling and or frying.

Table 2. Effect of processing on the levels (ng/Kg edible portion on dry weight basis) of organochlorine and organophosphorus pesticides in commonly consumed meat (muscle) samples in Nigeria

S/N	Pesticide	Cow			Pork			Goat		
		Raw	Boiled	Fried	Raw	Boiled	Fried	Raw	Boiled	Fried
1.	Mollinate[#]	1.48±0.05[a]	1.48±0.07[a] (0.0)	1.48±0.05[a] (0.0)	1.50±0.04[a]	1.50±0.10[a] (0.0)	1.50±0.08[a] (0.0)	1.46±0.06[a]	1.46±0.03[a] (0.0)	1.46±0.09[a] (0.0)
2.	Dimethoate[#]	1.25±0.07[a]	1.25±0.03[a] (0.0)	1.25±0.05[a] (0.0)	1.30±0.05[a]	1.30±0.03[a] (0.0)	1.30±0.09[a] (0.0)	1.22±0.02[a]	1.22±0.03[a] (0.0)	1.22±0.02[a] (0.0)
3.	Chlorothaloniol[*]	2.71±0.04[a]	2.71±0.04[a] (0.0)	2.71±0.03[a] (0.0)	2.65±0.05[a]	2.65±0.04[a] (0.0)	2.65±0.04[a] (0.0)	2.61±0.07[a]	2.61±0.05[a] (0.0)	2.61±0.09[a] (0.0)
4.	Alachlor[*]	0.76±0.01[a]	0.76±0.02[a] (0.0)	0.76±0.02[a] (0.0)	0.79±0.02[a]	0.79±0.03[a] (0.0)	0.79±0.01[a] (0.0)	0.74±0.01[a]	0.74±0.02[a] (0.0)	0.74±0.01[a] (0.0)
5.	Metachlor[*]	0.98±0.04[a]	0.98±0.02[a] (0.0)	0.98±0.05[a] (0.0)	0.95±0.04[a]	0.95±0.02[a] (0.0)	0.95±0.04[a] (0.0)	0.96±0.04[a]	0.96±0.04[a] (0.0)	0.96±0.06[a] (0.0)
6.	Phosmet[#]	0.73±0.02[a]	0.73±0.04[a] (0.0)	0.73±0.04[a] (0.0)	0.75±0.06[a]	0.74±0.02[a] (1.4)	0.74±0.04[a] (1.4)	0.74±0.03[a]	0.73±0.04[a] (1.4)	0.73±0.06[a] (1.4)

Values represent mean ± standard deviation (SD), n=3

Values (of specific pesticide residue) with different alphabets for each animal are significantly different (at p<0.05) from one another as affected by processing method

[*] - Organochlorine pesticide; [#] - Organophosphorus pesticides

Values in ( ) represent percentage reduction in pesticide levels, relative to the raw samples

Table 2. Effect of processing on the levels (µg/Kg edible portion on dry weight basis) of organochlorine and organophosphorus pesticides in commonly consumed meat (muscle) samples in Nigeria (continued)

S/N	Pesticide	Cow			Pork			Goat		
		Raw	Boiled	Fried	Raw	Boiled	Fried	Raw	Boiled	Fried
7.	HCB[*]	4.51±0.10[a]	3.96±0.05[b] (12.2)	3.66±0.22[c] (18.8)	4.30±0.03[a]	3.91±0.01[b] (9.1)	3.33 ±0.02[c] (22.6)	2.80±0.17[a]	2.49±0.02[b] (11.1)	1.59±0.07[c] (43.2)
8.	Lindane[*]	3.99± 0.05[a]	3.63± 0.06[b] (9.0)	1.50± 0.01[c] (62.4)	1.70± 0.02[a]	1.49± 0.03[b] (12.4)	1.06± 0.01[c] (37.6)	1.48±0.03[a]	1.30±0.03[b] (12.2)	1.02±0.00[c] (31.1)
9.	Chlorpyrifos[#]	143.75±0.30[a]	138.34± 0.40[b] (3.8)	101.58±0.63[c] (29.3)	148.10±0.34[a]	133.34±0.44[b] (6.7)	102.35±0.04[c] (30.9)	115.10±0.10[a]	99.22±0.68[b] (13.8)	72.01±0.16[c] (37.4)
10.	DDT[*]	221.14±0.35[a]	197.17± 0.50[b] (10.8)	138.04±0.48[c] (37.6)	166.63±0.23[a]	150.94±0.36[b] (9.4)	112.30±0.06[c] (32.6)	98.21± 0.27[a]	63.95±0.35[b] (34.9)	56.54±0.50[c] (42.4)
11.	Aldrin[*]	2.28± 0.06[a]	1.88± 0.06[b] (17.5)	1.49±0.03[c] (34.6)	5.13±0.05[a]	4.71± 0.10[b] (8.2)	3.70±0.06[c] (27.9)	4.67±0.05[a]	3.73±0.04[b] (20.1)	2.30± 0.04[c] (50.7)

S/N	Pesticide	Cow			Pork			Goat		
		Raw	Boiled	Fried	Raw	Boiled	Fried	Raw	Boiled	Fried
12.	Heptachlor*	0.91± 0.01[a]	0.82± 0.01[b] (9.9)	0.64±0.05[c] (29.7)	1.80± 0.03[a]	1.62±0.03[b] (10.0)	1.12± 0.02[c] (37.8)	1.55±0.02[a]	1.45±0.03[b] (6.5)	1.22±0.01[c] (21.3)
13.	Endrin*	3.76± 0.02[a]	3.16± 0.12[b] (16.0)	2.55±0.12[c] (32.2)	2.35±0.04[a]	2.20±0.02[b] (6.4)	1.52±0.01[c] (35.3)	2.05±0.07[a]	1.79±0.04[b] (12.7)	1.15±0.03[c] (43.9)
14.	Hept.Epoxide*	2.54±1.89[a]	2.21±0.09[b] (13.0)	1.69±0.01[c] (33.5)	2.20±0.06[a]	2.0±0.04[b] (9.1)	1.71±0.03[c] (22.3)	2.19±0.03[a]	1.61±0.02[b] (26.5)	1.35±0.02[c] (38.4)
15.	Endosulfan*	17.26±0.09[a]	16.46±0.06[b] (4.6)	14.92±0.06[c] (13.6)	15.73± 0.10[a]	12.76±0.12[b] (18.9)	11.15±0.12[c] (29.1)	7.86±0.04[a]	5.06±0.08[b] (34.9)	4.18±0.11[c] (46.8)
16.	Chlordane*	7.90±0.40[a]	6.24±0.01[b] (21.0)	4.03±0.00[c] (49.0)	6.81±0.07[a]	5.95±0.10[b] (12.6)	2.56±0.00[c] (62.4)	5.86±0.07[a]	5.14±0.04[b] (11.9)	2.31± 0.03[c] (60.6)

Values represent mean ± standard deviation (SD), n=3.

Values (of specific pesticide residue) with different alphabets for each animal are significantly different (at p<0.05) from one another as affected by processing method

** - Organochlorine pesticide; # - Organophosphorus pesticides*

Values in ( ) represent percentage reduction in pesticide levels, relative to the raw samples

HCB = Hexachlorobenzene; DDT = Dichlorodiphenyltrichloroethane

Table 3. Effect of processing on the levels (ng/Kg edible portion on dry weight basis) of carbamate and triazine pesticides in commonly consumed meat (muscle) samples in Nigeria

S/N	Pesticide	Cow			Pork			Goat		
		Raw	Boiled	Fried	Raw	Boiled	Fried	Raw	Boiled	Fried
1.	Aldicarb*	0.23±0.01[a]	0.23±0.02[a] (0.0)	0.23±0.01[a] (0.0)	0.25±0.02[a]	0.25±0.02[a] (0.0)	0.25±0.03[a] (0.0)	0.27±0.01[a]	0.27±0.02[a] (0.0)	0.27±0.02[a] (0.0)
2.	Simazine#	2.44±0.06[a]	2.44±0.04[a] (0.0)	2.44±0.05[a] (0.0)	2.34±0.02[a]	2.34±0.02[a] (0.0)	2.34±0.04[a] (0.0)	2.40±0.03[a]	2.40±0.05[a] (0.0)	2.40±0.03[a] (0.0)
3.	Atrazine#	2.22±0.03[a]	2.22±0.05[a] (0.0)	2.22±0.02[a] (0.0)	2.28±0.05[a]	2.28±0.03[a] (0.0)	2.28±0.06[a] (0.0)	2.25±0.04[a]	2.25±0.04[a] (0.0)	2.25±0.03 (0.0)[a]
4.	Carbofuran#	1.11±0.04[a]	1.11±0.03[a] (0.0)	1.11±0.02[a] (0.0)	1.19±0.03[a]	1.19±0.05[a] (0.0)	1.19±0.05[a] (0.0)	1.14±0.03[a]	1.14±0.04[a] (0.0)	1.14±0.04[a] (0.0)
5.	Terbuthylazine#	1.01±0.03[a]	1.01±0.02[a] (0.0)	1.01±0.04[a] (0.0)	1.07±0.04[a]	1.07±0.05[a] (0.0)	1.07±0.03[a] (0.0)	1.00±0.04[a]	1.00±0.03[a] (0.0)	1.00±0.02[a] (0.0)
6.	Cyanazine#	3.06±0.02[a]	3.06±0.04[a] (0.0)	3.06±0.05[a] (0.0)	3.14±0.04[a]	3.14±0.03[a] (0.0)	3.14±0.05[a] (0.0)	3.02±0.03[a]	3.02±0.04[a] (0.0)	3.02±0.04[a] (0.0)

Values represent mean ± standard deviation (SD), n=3.

Values (of specific pesticide residue) with different alphabets for each animal are significantly different (at p<0.05) from one another as affected by processing method

** - Carbamate pesticide, # - Triazine pesticides.*

Values in ( ) represent percentage reduction in pesticide levels, relative to the raw samples

Table 4. Effect of processing on the levels (ng/Kg edible portion on dry weight basis) of chlorophenoxy, dinitroanilin and chloroalkylthio pesticides in commonly consumed meat (muscle) samples in Nigeria

S/N	Pesticide	Cow			Pork			Goat		
		Raw	Boiled	Fried	Raw	Boiled	Fried	Raw	Boiled	Fried
1.	2,4,6-TCP*	0.02±0.01[a]	0.02±0.00[a] (0.0)	0.02±0.00[a] (0.0)	0.03±0.00[a]	0.03±0.01[a] (0.0)	0.03±0.00[a] (0.0)	0.02±0.00[a]	0.02±0.01[a] (0.0)	0.02±0.00[a] (0.0)
2.	MCPA*	1.14±0.04[a]	1.14±0.02[a] (0.0)	1.14±0.02[a] (0.0)	1.10±0.02[a]	1.10±0.05[a] (0.0)	1.10±0.04[a] (0.0)	1.06±0.02[a]	1.06±0.04[a] (0.0)	1.06±0.03[a] (0.0)
3.	Mecoprop*	0.73±0.03[a]	0.73±0.02[a] (0.0)	0.73±0.02[a] (0.0)	0.78±0.03[a]	0.78±0.02[a] (0.0)	0.78±0.02[a] (0.0)	0.70±0.02[a]	0.70±0.01[a] (0.0)	0.70±0.03[a] (0.0)
4.	2,4-D*	2.05±0.04[a]	2.05±0.04[a] (0.0)	2.05±0.02[a] (0.0)	2.10±0.03[a]	2.10±0.04[a] (0.0)	2.10±0.04[a] (0.0)	2.01±0.03[a]	2.01±0.02[a] (0.0)	2.01±0.02[a] (0.0)
5.	DBCP*	2.43±0.04[a]	2.43±0.07[a] (0.0)	2.43±0.03[a] (0.0)	2.47±0.03[a]	2.47±0.05[a] (0.0)	2.47±0.05[a] (0.0)	2.40±0.03[a]	2.40±0.04[a] (0.0)	2.40±0.04[a] (0.0)
6.	Dichloroprop*	2.44±0.02[a]	2.44±0.04[a] (0.0)	2.44±0.03[a] (0.0)	2.47±0.04[a]	2.47±0.03[a] (0.0)	2.47±0.04[a] (0.0)	2.41±0.02[a]	2.41±0.03[a] (0.0)	2.41±0.04[a] (0.0)
7.	Fenoprop*	1.81±0.04[a]	1.81±0.02[a a] (0.0)	1.81±0.03[a] (0.0)	1.86±0.02[a]	1.86±0.03[a] (0.0)	1.86±0.03[a] (0.0)	1.78±0.04[a]	1.78±0.02[a] (0.0)	1.78±0.02[a] (0.0)
8.	2,4-DB*	2.35±0.02[a]	2.35±0.03[a] (0.0)	2.35±0.02[a] (0.0)	2.33±0.02[a]	2.33±0.01[a] (0.0)	2.33±0.02[a] (0.0)	2.30±0.03[a]	2.30±0.02[a] (0.0)	2.30±0.03[a] (0.0)
9.	Pendimethalin#	2.08±0.02[a]	2.08±0.04[a] (0.0)	2.08±0.03[a] (0.0)	2.05±0.02[a]	2.05±0.01[a] (0.0)	2.05±0.02[a] (0.0)	2.01±0.02[a]	2.01±0.03[a] (0.0)	2.01±0.03[a] (0.0)
10.	Captan^	1.22±0.02[a]	1.22±0.02[a] (0.0)	1.22±0.03[a] (0.0)	1.20±0.02[a]	1.20±0.01[a] (0.0)	1.20±0.02[a] (0.0)	1.12±0.01[a]	1.12±0.02[a] (0.0)	1.12±0.01[a] (0.0)

Values represent mean ± standard deviation (SD), n=3.

Values (of specific pesticide residue) with different alphabets for each animal are significantly different (at p<0.05) from one another as affected by processing method

**- Chlorophenoxy pesticide, # - Dinitroanilin pesticide and ^ - Chloroalkylthio*

Values in ( ) represent percentage reduction in pesticide levels, relative to the raw samples

2, 4, 6-TCP = 2, 4, 6-trichlorophenol

MCPA = 4-(2-methyl-4-chlorophenoxy) acetic acid

2, 4-D = 2, 4-dichlorophenoxy

DBCP = 1, 2-dibromo-3-chloropropane

2, 4-DB = 4-(2, 4-dichlorophenoxy) butyric acid

Table 5. Effect of processing on the levels (ng/Kg edible portion on dry weight basis) of benzoylurea and phenylurea pesticides in commonly consumed meat (muscle) samples in Nigeria

S/N	Pesticide	Cow			Pork			Goat		
		Raw	Boiled	Fried	Raw	Boiled	Fried	Raw	Boiled	Fried
1.	Isoproturon*	2.19±0.12 [a]	2.19±0.07 [a] (0.0)	2.19±0.09 [a] (0.0)	2.29±0.15 [a]	2.29±0.21 [a] (0.0)	2.29±0.17 [a] (0.0)	2.14±0.06 [a]	2.14±0.12 [a] (0.0)	2.14±0.20 [a] (0.0)
2.	Chlorotoluron*	1.68±0.09[a]	1.68±0.13[a] (0.0)	1.68±0.16[a] (0.0)	1.65±0.11[a]	1.65±0.07[a] (0.0)	1.65±0.13[a] (0.0)	1.60±0.08[a]	1.60±0.07[a] (0.0)	1.60±0.10[a] (0.0)
3.	Fenprothrin#	1.87±0.17[a]	1.87±0.11[a] (0.0)	1.87±0.09[a] (0.0)	1.90±0.12[a]	1.90±0.21[a] (0.0)	1.90±0.14[a] (0.0)	1.81±0.09 [a]	1.81±0.08 [a] (0.0)	1.81±0.13 [a] (0.0)

Values represent mean ± standard deviation (SD), n=3.

Values (of specific pesticide residue) with different alphabets for each animal are significantly different (at p<0.05) from one another as affected by processing method

** - Benzoylurea pesticide, # - Phenylurea pesticides*

Values in ( ) represent percentage reduction in pesticide levels, relative to the raw samples

3.5 The Levels of Pesticide Residues in Cow, Pork and Goat Muscle Samples from Sagamu, Ogun State Compared with Available International Maximum Residue Limits (MRLs)

The highest residue levels of pesticides in the various muscle samples were compared with international standards from some developed countries and organization as presented in Table 6. The highest levels of the pesticides in all samples analyzed (as found in raw samples) were relatively low and none was above the least maximum residue limit (MRL) set by the various international regulatory agents. Maximum residue limit for alachlor, endrin, cyanazine, 2,4,6-trichlorophenol (2,4,6-TCP), mecoprop, fenoprop, isoproturon, chlorotoluron and DBCP are not available.

Table 6. The levels of pesticide residues in cow, pork and goat muscle samples from Sagamu, Ogun state compared with available international Maximum Residue Limits (MRLs)

	Pesticide	Concentration (µg/Kg)			MRLs (µg/Kg)			
		Cow raw	Pork raw	Goat raw	Australia[a]	FAO/WHO[b]	EU[c]	Japan[d]
1.	Mollinate	0.00148	0.00150	0.00146	50	NS	NS	NS
2.	Dimethoate	0.00125	0.00130	0.00122	50	50	NS	50
3.	Chlorothalonil	0.00271	0.00265	0.00261	20	20	NS	20
4	Alachlor	0.000760	0.000790	0.000740	NS	NS	NS	20
5.	Metalachlor	0.000980	0.000950	0.000960	50	NS	NS	NS
6.	Phosmet	0.000730	0.000750	0.000740	50-1000	1000	100	200
7.	HCB	4.51	4.30	2.80	1000	NS	200	200
8.	Lindane	3.99	1.70	1.48	2000	10	20	20
9.	Chlorpyrifos	144	148	115	500	1000	NS	50-500
10.	DDT	221	167	98.2	5000	5000	1000	1000
11.	Aldrin	2.28	5.13	4.67	50	200	200	200
12.	Heptachlor	0.91	1.80	1.55	200	NS	NS	200
13.	Endrin	3.76	2.35	2.05	NS	NS	NS	50

HCB = Hexachlorobenzene; DDT = Dichlorodiphenyltrichloroethane; NS – Not set
a – Australian Pesticides and Veterinary Medicines Authority (APVMA) [20]; b – FAO/WHO [21];
c – Commission Regulation [22]; d – The Japan Food Chemical Research Foundation [23]

Table 6. The levels of pesticide residues in cow, pork and goat muscle samples from Sagamu, Ogun state compared with available international Maximum Residue Limits (MRLs) (continued)

	Pesticide	Concentration (µg/Kg)			MRLs (µg/Kg)			
		Cow raw	Pork raw	Goat raw	Australia[a]	FAO/WHO[b]	EU[c]	Japan[d]
14.	Hept.Epoxide	2.54	2.20	2.19	200	200	200	200
15.	Endosulfan	17.3	15.7	7.86	200	200	50	100
16.	Chlordane	7.90	6.81	5.86	200	50	50	80
17.	Aldicarb	0.000230	0.000250	0.000270	10	10	NS	NS
18.	Simazine	0.00244	0.00234	0.00240	50	NS	NS	20
19.	Atrazine	0.00222	0.00228	0.00225	10	NS	NS	20
20.	Carbofuran	0.00111	0.00119	0.00114	50	50	NS	50
21.	Terbuthylazine	0.00101	0.00107	0.00100	10	NS	NS	NS
22.	Cyanazine	0.00306	0.00314	0.00302	NS	NS	NS	NS
23.	2,4,6-TCP	0.0000200	0.0000300	0.0000100	NS	NS	NS	NS
24.	MCPA	0.00114	0.00110	0.00106	50	100	NS	80
25.	Mecoprop	0.000730	0.000780	0.000700	NS	NS	NS	50
26.	2,4-D	0.00205	0.00210	0.00201	200	NS	NS	200

2,4,6- TCP = 2, 4, 6-trichlorophenol; MCPA = 4-(2-methyl-4-chlorophenoxy) acetic acid; 2, 4-D = 2, 4-dichlorophenoxy; NS – Not set
a – Australian Pesticides and Veterinary Medicines Authority (APVMA) [20]; b – FAO/WHO [21]
c – Commission Regulation [22]; d – The Japan Food Chemical Research Foundation [23]

Table 6. The levels of Pesticide residues in cow, pork and goat muscle samples from Sagamu, Ogun state compared with available international Maximum Residue Limits (MRLs) (continued)

	Pesticide	Concentration (µg/Kg)			MRLs (µg/Kg)			
		Cow raw	Pork raw	Goat raw	Australia[a]	FAO/WHO[b]	EU[c]	Japan[d]
27.	DBCP	0.00243	0.00247	0.00240	NS	NS	NS	NS
28.	Dichlorprop	0.00244	0.00247	0.00241	20	NS	NS	NS
29.	Fenoprop	0.00181	0.00186	0.00176	NS	NS	NS	NS
30.	2,4-DB	0.00235	0.00233	0.000230	200	NS	NS	200
31.	Pendimethalin	0.00208	0.00205	0.00201	10	NS	NS	NS
32.	Captan	0.00122	0.00120	0.00112	50	NS	NS	50
33.	Isoproturon	0.00219	0.00229	0.00214	NS	NS	NS	NS
34.	Chlorotoluron	0.00168	0.00165	0.00160	NS	NS	NS	NS
35.	Fenpropathrin	0.00187	0.00190	0.00181	NS	10	NS	100

DBCP = 1,2-dibromo-3-chloropropane; 2,4-DB = 4-(2, 4-dichlorophenoxy) butyric acid; NS= Not set
a – Australian Pesticides and Veterinary Medicines Authority (APVMA) [20]; b – FAO/WHO [21]
c – Commission Regulation [22]; d – The Japan Food Chemical Research Foundation [23]

4. DISCUSSION

It has been proven that the technological and kitchen processes can partially or fully remove or degrade organochlorine pesticide residues to other compound often less toxic, which makes products safer for human consumption [14,15,24]. The result patterns showed that frying is a better method to minimize the OCP residues in the various meats (Table 2). This makes it necessary to reach a compromise around pesticide residues (toxicants), palatability and healthy nature of these foodstuffs for human consumption. The significant loss in OCP residues of the cow, pork and goat meats after boiling and frying might be due to the polarity of the compounds which made them leach with the fat into the broth as affected by the heat treatment applied.

The percentage reduction of lindane residues (37.6% in pork and 31.1% in goat) in fried samples compared with raw samples was similar to reduction rates (17-35%) in lindane content of ovine meat after grilling, roasting and cooking as reported by Conchello et al. [25]. However, these figures are lower than 55% reduction reported by Sallam and Mohammed Ali Morshedy [11] for camel, cattle and sheep boiled for 1.5hrs, 60% reduction reported by Jan and Malnersic [17] in cooked beef meat after heating at 115^{o}C for 2hrs and 65% reduction reported by Mirna and Coretti [18] in rabbit meat after boiling for 1.5hrs. Nonetheless, these reports [11,17,18] are similar to the 62.4% reduction in lindane content noted in the fried cow meat. Variation in these percentage reductions seem to mainly reflect the long heating time of 90-120 minutes applied in various studies compared with 20-30 minutes cooking done in this study. The biological and physiological characteristics of the various meat samples might have also contributed.

The meat samples analyzed in this study showed 33-42% reduction of DDT in the fried samples (Table 2). This is comparable with 40% and 44% reduction in DDT residue reported by Sallam and Mohammed Ali Morshedy [11] and Bayarri et al. [16], respectively in various heat treated meats. The varied lengths of time allowed for processing seem not to count here. The percentage reduction of aldrin (35-51%) and endrin (32-44%) residues are somewhat higher than 33.5% and 29.2% reported by Sallam and Mohammed Ali Morshedy [11], respectively for aldrin and endrin residues.

Similar to the trend with the OCPs, frying is quite more favorable to minimize the level of chlorpyrifos (an OPP residue) in the three kinds of meat. There is paucity of data on the effect of processing on the levels of OPP residues in meat samples so very little comparison can be done.

The carbamate (aldicarb) and all the triazine residues being not significantly reduced by the cooking methods (Table 3) might be due to the very limited amount of the residues available in the meat samples. As far as our search covered, no data is available on the effect of processing on the levels of carbamate and triazine in meat. Thus, useful comparison is not quite feasible. Though there were detectable amount of chlorophenoxy, dinitroanilin, chloroalkylthio, benzoylurea, and phenylurea residues in the raw cow, pork and goat meats (Tables 4 and 5), the processing methods (boiling and frying) did not significantly (p>0.05) affect the levels of these

residues in the various meats. The minute levels of these residues might also be the main contributing factor to this outcome along with their physico-chemical characteristics.

A comparison of the detected pesticide residues with international standards [20-23] of Maximum Residue Limits (MRLs) shows that they are totally below the MRLs (Table 6). This affirms the safety of these foodstuffs to their consumers in Sagamu, Ogun state and beyond. However, it is still very necessary to regularly monitor the levels of these residues in the meats to provide safety information to consumers and ensure that good agricultural practices are maintained by meat farmers.

5. CONCLUSION

This study indicates some levels of contamination of cow, pork and goat meats by the various pesticide residues determined. The organohlorine pesticides (OCP) and organophosphorus (OPP) residues were predominantly found in the samples analyzed. Processing methods – boiling and frying – significantly (p<0.05) reduced the levels of OCPs (lindane, HCB, DDT, aldrin, heptachlor, endrin, heptachlor epoxide, endosulfan, and chlordane) and OPP (chloropyrifos) in the cow, pork and goat meats. Though not universally promoted as healthy food processing method, frying was shown to be exceptionally advantageous in reducing these residues in meats. All the meat varieties are safe for consumption, since the levels of pesticide residues in them are completely below the MRLs set by the various international organizations.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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