

Original **Research** Article**Effects of Processing on the Levels of Pesticides in
some Commonly Consumed Meats from Sagamu,
South-western Nigeria****7 ABSTRACT**

8 Technological and kitchen processes can partially or fully remove or degrade pesticide residues to other
9 compounds often less toxic, which makes safer products for human consumption. This study was
10 conducted to determine the effects of processing on levels of pesticides in some commonly consumed
11 meat in Nigeria.

12 Cow, goat and pork muscles were purchased from three abattoirs in Sagamu, South-western Nigeria.
13 Each meat sample was separately packaged in a polyethylene bag and transported to the laboratory
14 immediately, where they were processed (boiled and fried) on the same day. Samples of raw, boiled and
15 fried meat were extracted and cleaned up before being quantitatively analyzed using gas chromatograph
16 with pulsed flame photometric detector.

17 The results showed that 35 pesticide residues were detectable in all the meat samples. However, only 10
18 of them were significantly affected by the processing methods. The levels of some organochlorine
19 pesticide (OCPs) residues and an organophosphorus pesticide (OPP) residue were relatively higher in all
20 the meat samples but were significantly ($P<0.05$) decreased by the processing methods; with frying being
21 better. The levels of carbamate, triazine, chlorophenoxy, dinitroanilin, chloroalkylthio, benzoylurea and
22 phenylurea were somewhat low in all the samples and were not significantly ($P>0.05$) affected by the
23 boiling and frying methods.

24 The mean levels of all the detected pesticide residues were far below the various internationally set
25 maximum residue limits for meat samples; making the meats analyzed safe for consumption.
26 Furthermore, processing methods greatly depleted pesticide residues, especially OCPs and OPP, in the
27 meats analyzed.

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

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30

31 1. INTRODUCTION

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

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

40 Globally, the use of pesticides is increasing due to the need to feed the world's ever-growing population,
41 while the amount of land available for food production is continually limited [1]. The increase in the use of
42 pesticides has simultaneously contributed to the hazards on human health and to environmental pollution.

43 Pesticides and their metabolites find their ways into the human body through the water cycle and
44 especially the food chain. Breeding animals can accumulate persistent organic pollutants from
45 contaminated feed and water, and/or from pesticide application in animal production areas (treatment of
46 cowsheds, pigsties, sheepfolds, warrens and/or treatment of animals themselves) [3]. While pesticide
47 compounds are mostly stored in the fat and muscle of animals, they can also reach other compartments
48 such as the brain, liver and lungs to cause unique damages [4].

49 Regular surveys on the levels of pesticides in meats have been reported in the developed world. Driss
50 and Bouguerra [5], Garcia-Regueiro *et al.* [6] and Krauthacker *et al.* [7] reported the levels of
51 organochlorine pesticides (OCPs) in some foodstuffs of animal origin from Tunisia, Spain and Yugoslavia
52 respectively. Suzuki *et al.* [8] surveyed pesticide residues in imported Australian meat, while Cantoni *et al.*
53 [9] also reported the OCPs in pork collected from Italy. Furthermore, in a surveillance of marketed foods
54 (including meat products, fish, egg, milk and dairy) in Barcelona, Spain from 2001-2006, Fontcuberta *et*
55 *al.* [10] discovered a gradual disappearance of regulated OCPs as a consequence of the growing
56 worldwide implementation of current regulatory agreement.

57 In addition, efforts have been made in some developing countries to evaluate pesticide residues in meats.
58 The contents of OCPs in camel, cattle and sheep carcasses slaughtered in Sharkia province of Egypt

59 were determined and reported to be well below the respective minimal permissible limits set by local or
60 international organizations [11]. Blankson-Arthur *et al.* [12] reported the levels of OCP residues in
61 grasscutter tissues from Ghana as being below the acceptable maximum residue limits (MRL) of
62 WHO/FAO Codex Alimentarius Commission.

63 However, limited reports are available in Nigeria on this same subject. The concentrations of OCP
64 residues in cow, pig and goat were stated to be higher than some values reported in similar animals at
65 some other parts of the world but below FAO's maximum residue limit (MRL) [13]. This makes it needful
66 to provide recent information on pesticide residue in meat and thereby protect meat consumers in Nigeria.
67 It has been observed that technological and kitchen processes can partially or fully remove or degrade
68 pesticide residues to other compounds often less toxic, which makes products safer for human
69 consumption [14,15]. A reduction rate of 44% has been detected for DDT after thermal processing of
70 lamb meat cuts [16]. A reduction rate of 60% in lindane contents has been reported for cooked beef meat
71 after heating at 115 °C for 2 hours [17]. Also, a high reduction rate of 65% in lindane contents has been
72 reported in rabbit meat after boiling for 1.5 hours [18]. However, there is dearth of information on the
73 extent of reduction of specific pesticide residue in cow, pork and goat meats after conventional
74 processing of boiling and frying. More so, limited information also exist on the most effective processing
75 method for the depletion of pesticide residues in meat as consumed in Nigeria. Therefore, this study was
76 designed to investigate the effect of kitchen processing (boiling and frying) on the levels of pesticide
77 residues in some commonly consumed meats (cow, pork and goat) in Nigeria.

78 **2. MATERIALS AND METHODS**

79 **2.1 Sampling**

80 Cow, goat and pork meat samples were purchased from three abattoirs in Sagamu, Ogun State, South-
81 western Nigeria. Sampling was done within February 2012. The meat samples were separately packaged
82 in a polyethylene bag and transported to the laboratory immediately. Each pulled raw meat sample of
83 about 5 Kg was sub-divided into three subsamples. A raw subsample was retained that way for analysis.
84 The remaining two subsamples were boiled (without additional condiment) and the broths discarded. One
85 of these boiled subsamples was then further fried. The samples - raw, boiled and fried for each of cow,

86 pork and goat meat - were then analyzed for various pesticide residues within 72 hours after processing.
87 All samples were stored at -18 °C before the analysis.

88 **2.2 Chemicals**

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

93 **2.3 Meat Processing**

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

100 **2.4 Pesticide Residue Extraction and Clean-up**

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

104 The sub-sample materials were pulverized using the laboratory milling machine Janke & Kunkel (IKA
105 Labortechnik, Breisgau, Germany). The pulverized samples were stored at -18 °C until analysis. 10.0 g of
106 the sample was weighed and extracted after the addition of the surrogate standard solution to the sample
107 and later transferred to the extracting bottle that was cocked with TEF-fluorocarbon.

108 Fifty milliliters of the phosphate buffer was added, followed by pH measurement with the addition of drops
109 of 9 M sulfuric acid or 10 M sodium hydroxide solution for pH adjustment to 7, if necessary. One gram of
110 the sodium chloride salt was added to the sample, sealed and shaken to dissolve the salt. Twenty
111 milliliters of the redistilled analytical grade methylene dichloride (dichloromethane) was measured and
112 added to the sample. The sample was extracted for about 30 minutes. The extract was filtered into the

113 Erlenmeyer flask. Then, the extraction was repeated two more times with fresh solvent and the filtrates
 114 were combined. The combined extract was dried by pouring through a drying column containing a 10 cm
 115 column of anhydrous sodium sulphate (previously rinsed with methylene dichloride), and the filtrate was
 116 concentrated in the concentrator flask with a stream of nitrogen. The wall of the concentrator flask was
 117 rinsed with extracting solvent so as to bring the final volume of the extract to 5 mL. The clean-up of the
 118 concentrated extract was carried out using florisil packed into column. The concentrated extract was
 119 eluted with hexane and later concentrated to the required final volume of 5 mL.

120 2.5 Determination of Pesticide Residue Concentrations

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

128 **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:	1.0mL/min
Inlet Temperature:	250 °C
Column Type:	HP 5MS
Parameters	Specification
<i>Column Dimensions:</i>	30 m x 0.25 mm x 0.25 µm
Oven Program:	Initial at 60 °C for 2 minutes First Ramp at 10 °C/min to 200 °C Second Ramp at 8 °C/min to 300 °C constant at 5 minutes
Detector:	PFPD
Detector Temperature:	300°C
Hydrogen Pressure:	22psi
Compressed Air:	28psi

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131 **2.6 Statistical Analysis**

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

137 **3. RESULTS**

138 **3.1 Effect of Processing on the Levels of Organochlorine and Organophosphorus** 139 **Pesticide Residues in Cow, Pork and Goat Muscle Samples from Sagamu, Ogun State**

140 The levels of organochlorine pesticides (OCP) and organophosphorus pesticides (OPP) in various meat
141 (muscle) samples as affected by processing methods are presented in Table 2. The table shows the
142 presence of four OPPs and twelve OCPs in the various samples. The levels of OCPs in the raw cow
143 muscle range from 0.76 ng/Kg of alachlor to 221.14 $\mu\text{g/Kg}$ of dichlorodiphenyl trichloroethane (DDT);
144 while the levels of OPPs in the same sample range from 0.73 ng/Kg of phosmet to 143.75 $\mu\text{g/Kg}$ of
145 chlorpyrifos. Comparing the concentration of the various OCPs and OPPs in the three muscle samples,
146 the levels of mollinate, dimethoate, chlorothalonil, alachlor, metachlor and phosmet are not significantly
147 different ($p>0.05$) from one another. All other OCPs and OPPs are significantly different ($p<0.05$) in
148 concentration in the three muscle samples.

149 The levels of mollinate, dimethoate, chlorothalonil, alachlor, metachlor and phosmet are somewhat low
150 in all the samples and are not significantly ($p>0.05$) affected by the processing (boiling and frying)
151 methods. All other OCPs and OPPs are higher in concentrations and were significantly decreased
152 ($p<0.05$) by the processing methods. The result of this study shows a significant reduction in the levels of
153 9 out of 12 OCP residues determined in the cow, pork and goat muscle samples. In all, the frying method
154 diminished the pesticide residues better (Table 2).

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156 **Table 2. Effect of processing on the levels (ng/Kg edible portion on dry weight basis) of organochlorine and organophosphorus**
 157 **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.	Chlorothalonil [*]	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)

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

159 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
 160 method

161 * - Organochlorine pesticide; # - Organophosphorus pesticides

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

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166 **Table 2. Effect of processing on the levels (µg/Kg edible portion on dry weight basis) of organochlorine and organophosphorus**
 167 **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)

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.Epoxyde	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)

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

170 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

171^{*} - Organochlorine pesticide; # - Organophosphorus pesticides

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

174 HCB = Hexachlorobenzene

175 DDT = Dichlorodiphenyltrichloroethane

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178 The result further indicated a reduction of 4.6% for endosulfan to 34.9% for DDT in the boiled muscle
179 samples relative to the raw. The frying yielded a reduction of 13.6% for endosulfan to 62.4% for lindane
180 and chlordane in the fried muscle samples compared with the raw samples. From another perspective,
181 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
182 goat muscle samples respectively, whereas frying reduced the residues by 13.6-62.4%, 22.3-62.4% and
183 21.6-60.6% relative to the raw cow, pork, and goat muscle samples respectively (Table 2).

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

189 **3.2 Effect of Processing on the Levels of Carbamate and Triazine Pesticides in Cow, Pork** 190 **and Goat Muscle Samples from Sagamu, Ogun State**

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

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201 **Table 3.** Effect of processing on the levels (ng/Kg edible portion on dry weight basis) of carbamate and triazine pesticides in commonly
 202 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 ^a (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.	Terbutylazine [#]	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)

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

204 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
 205 method

206 * - Carbamate pesticide, # - Triazine pesticides.

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

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213 **3.3 Effect of Processing on the Levels of Chlorophenoxy, Dinitroanilin and**
214 **Chloroalkylthio Pesticides in Cow, Pork and Goat Muscle Samples from Sagamu, Ogun**
215 **State**

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

223 Comparing the concentration of the various chlorophenoxy, ditroanilin and chloroalkylthio pesticide
224 residues in the three muscle samples, their levels are not significantly ($p>0.05$) different from one another.

225 The result also indicated no percentage reduction in all the chlorophenoxy, dinitroanilin and
226 chloroalkylthio pesticide residues (Table 4).

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228 **Table 4. Effect of processing on the levels (ng/Kg edible portion on dry weight basis) of chlorophenoxy, dinitroanilin and chloroalkylthio**
 229 **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 (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)

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

231 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
 232 method

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

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

235 2, 4, 6-TCP = 2, 4, 6-trichlorophenol

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

237 2, 4-D = 2, 4-dichlorophenoxy

238 DBCP = 1, 2-dibromo-3-chloropropane

239 2, 4-DB = 4-(2, 4-dichlorophenoxy) butyric acid

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241 **3.4 Effect of Processing on the Levels of Benzoylurea and Phenylurea in Cow, Pork and**
242 **Goat Muscle Samples from Sagamu, Ogun State**

243 The levels of benzoylurea and phenylurea pesticide residues in the various muscle samples as affected
244 by processing methods are presented in Table 5. The table shows one phenylurea and two benzoylurea
245 pesticides in the various samples. The levels of isoproturon, chlorotoluron and fenprothrin are very low in
246 all the samples and are not significantly ($p>0.05$) affected by processing methods. Comparing the
247 concentration of the benzoylurea and phenylurea pesticide residues in the three muscle samples, their
248 levels are not significantly different ($p>0.05$) from one another. The result indicated no percentage
249 reduction in all the benozoylurea and phenylurea pesticide residues after boiling and or frying.
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251 **Table 5. Effect of processing on the levels (ng/Kg edible portion on dry weight basis) of benzoylurea and phenylurea pesticides in**
 252 **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)

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

254 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
 255 method

256 * - Benzoylurea pesticide, # - Phenylurea pesticides

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

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265 **3.5 The Levels of Pesticide Residues in Cow, Pork and Goat Muscle Samples from**
266 **Sagamu, Ogun State Compared with Available International Maximum Residue Limits**
267 **(MRLs)**

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

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

	Pesticide	Concentration ($\mu\text{g}/\text{Kg}$)			MRLs ($\mu\text{g}/\text{Kg}$)			
		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

287 HCB = Hexachlorobenzene; DDT = Dichlorodiphenyltrichloroethane; NS – Not set

288 a – Australian Pesticides and Veterinary Medicines Authority (APVMA) [20]

289 b – FAO/WHO [21]

290 c – Commission Regulation [22]

291 d – The Japan Food Chemical Research Foundation [23]

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

	Pesticide	Concentration ($\mu\text{g}/\text{Kg}$)			MRLs ($\mu\text{g}/\text{Kg}$)			
		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

309 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

310 a – Australian Pesticides and Veterinary Medicines Authority (APVMA) [20]

311 b – FAO/WHO [21]

312 c – Commission Regulation [22]

313 d – The Japan Food Chemical Research Foundation [23]

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

	Pesticide	Concentration ($\mu\text{g}/\text{Kg}$)			MRLs ($\mu\text{g}/\text{Kg}$)			
		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.	Fenprothrin	0.00187	0.00190	0.00181	NS	10	NS	100

321 DBCP = 1,2-dibromo-3-chloropropane; 2,4-DB = 4-(2, 4-dichlorophenoxy) butyric acid; NS= Not set

322 a – Australian Pesticides and Veterinary Medicines Authority (APVMA) [20]

323 b – FAO/WHO [21]

324 c – Commission Regulation [22]

325 d – The Japan Food Chemical Research Foundation [23]

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327 4. DISCUSSION

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

336 The percentage reduction of lindane residues (37.6% in pork and 31.1% in goat) in fried samples
337 compared with raw samples is similar to reduction rates (17-35%) in lindane content of ovine meat after
338 grilling, roasting and cooking as reported by Conchello *et al.* [25]. However, these figures are lower than
339 55% reduction reported by Sallam and Mohammed Ali Morshedy [11] for camel, cattle and sheep boiled
340 for 1.5hrs, 60% reduction reported by Jan & Malnersic [17] in cooked beef meat after heating at 115°C for
341 2hrs and 65% reduction reported by Mirna and Coretti [18] in rabbit meat after boiling for 1.5hrs.
342 Nonetheless, these reports [11,17,18] are similar to the 62.4% reduction in lindane content noted in the
343 fried cow meat. Variation in these percentage reductions seem to mainly reflect the long heating time of
344 90-120 minutes applied in various studies compared with 20-30 minutes cooking done in this study. The
345 biological and physiological characteristics of the various meat samples might have also contributed.

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

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

355 The results on Table 3 show that the cow, pork and goat meats have detectable amount of carbamate
356 and triazine residues in them, though at infinitesimal quantities (0.23-3.14 ng/Kg). The carbamate
357 (aldicarb) and all the triazine residues being not significantly reduced by the cooking methods might be
358 due to the very limited amount of the residues available in the meat samples. As far as our search
359 covered, no data is available on the effect of processing on the levels of carbamate and triazine in meat.
360 Thus, useful comparison is no quite feasible. Though there were detectable amount of chlorophenoxy,
361 dinitroanilin, chloroalkylthio, benzoylurea, and phenylurea residues in the raw cow, pork and goat meats
362 (Tables 4 and 5), the processing methods (boiling and frying) did not significantly ($p>0.05$) affect the
363 levels of these residues in the various meats. The minute levels of residues might also be the main
364 contributing factor to this outcome along with their physico-chemical characteristics.

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

370 5. CONCLUSION

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

378 the levels of pesticide residues in them are completely below the MRLs set by the various international
379 organizations.

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