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Sub-Chronic Effects of three Plant Part Extracts on the Liver, Kidney, and Blood of Wistar Rats Co-Administered Dichlorvos in Lafia, Nasarawa State, Nigeria

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ABSTRACT

Dichlorvos (2,2-dichlorovinyl dimethyl phosphate, DDVP) is a widely used organophosphate insecticide pesticide in Nigeria for agricultural and domestic pest control, but it poses documented cytotoxic, hepatotoxic, and nephrotoxic risks to nontarget organisms. The purpose of this exploratory research was to examine the behavioural, morphometric (body weight), biochemical, hematological and histological impact of aqueous extracts of *Zingiber officinale* (ginger rhizome), *Cocos nucifera* (coconut endosperm) and *Cyperus esculentus* (tiger nut tuber) in the liver, kidneys and peripheral blood of male Wistar rats co-exposed to dichlorvos during an eight-week trial. A total of 72 male Wistar rats were acclimatized for 3 weeks; 24 were used for preliminary toxicity screening and 48 were assigned to four experimental groups (n = 12 per group, housed in 3 replicates of 4 rats per cage). Group W served as vehicle control, while treatment groups were co-administered 10 mg/kg body weight of a single plant extract (Group X: ginger; Group Y: coconut; Group Z: tiger nut) followed by a sublethal dose of 5 mg/kg body weight of dichlorvos intraperitoneally every 14 days for eight weeks. Standard AOAC and spectrophotometric methods were used to determine the proximate, mineral, and phytochemical profiles of the extracts. The results show that all extracts contained appreciable amounts of carbohydrate, crude lipids, and proteins, as well as high levels of phosphorus and potassium. Anthraquinones were not detected in any of the samples. There was an incremental dose-dependent increase in mean body weight of the various groups, but all were significantly lower than that of the unexposed control group, which showed an increase of 11.18% ($P < 0.05$) increase in mean body weight. Serum activities of AST, ALT, and ALP varied significantly ($P < 0.05$) among the groups, with treated groups exhibiting lower transaminase activities than the unexposed control group, without significant difference ($P > 0.05$) in serum creatinine levels. Hematological parameters such as total white blood cell count, total red blood cell count, hemoglobin levels, and hematocrit levels did not vary significantly between the groups ($P > 0.05$). Histopathological lesions such as hepatocytic degeneration, sinusoidal congestion, and tubular necrosis of the kidneys were observed. The results suggest that the biweekly administration of aqueous extracts at a dose of 10 mg/kg may be inadequate to counteract the cellular damage caused by dichlorvos. Due to the flaw in the study design in not including a dichlorvos-only group and groups given extracts only without toxicant, the study cannot conclusively demonstrate protective effects, and future studies should consider daily oral administration, positive toxicant-only controls, and tissue levels of oxidative stress biomarkers.

Keywords: Dichlorvos; Organophosphate Poisoning; Plant Extract; *Zingiber Officinale*; *Cocos Nucifera; Cyperus Esculentus*; Liver; Kidney; Blood; Hepatotoxicity; Nephrotoxicity; Hematology

Abbreviations: ROS: Reactive Oxygen Species; AAS: Atomic Absorption Spectroscopy; NVRI: National Institute of Veterinary Research; SPSS: Statistical Package for Social Sciences; AST: Aspartate Aminotransferase; ALT: Alanine Aminotransferase

Introduction

Dichlorvos (IUPAC name: 2,2-dichloroethenyl dimethyl phosphate; Synonyms: 2,2-dichlorovinyl dimethyl phosphate, DDVP) is a broad-spectrum synthetic contact and oral organophosphate insecticide with pronounced fumigant and penetrant actions. It is classified as a Class 1B chemical ('highly hazardous') by the World Health Organization [1-3]. In Nigeria, dichlorvos is commercially distributed under the brand name 'Sniper' and is also marketed as an adulterant in unregulated artisanal formulations known as 'ota-piapia' [4,5]. The chemical is widely used as a household and agricultural insecticide in field crops and stored grains, as an antihelminthic agent in veterinary farming (dogs, horses, and swine), and in aquaculture to suppress crustacean ectoparasites [6-8]. On the basis of the known mechanism of the action of dichlorvos in insects, however, it is speculated that the enzyme inhibition is irreversible and prevents the loss of ACh at the cholinergic nerve terminal. This produces an abnormal accumulation of ACh within the synaptic cleft, driving persistent stimulation of neurotransmitter receptors, neuromuscular paralysis, and lethality [9,10]. In mammals and other non-target organisms, dichlorvos induces multi-organ toxicity mediated primarily through reactive oxygen species (ROS) overproduction, mitochondrial membrane collapse, membrane lipid peroxidation, and protein alkylation [7,11]. Routes of exposure include mainly inhalation, oral, by consuming contaminated food and water, and dermal contact.

Subacute and chronic exposure has been reported to be associated with conditions such as considerable organotoxicity, hepatotoxicity, neurotoxicity, nephrotoxicity, reproductive toxicity, and genotoxicity [12,13]. Furthermore, microenvironmental conditions such as temperature and nutritional status, as well as dose and exposure frequency, have been proposed as factors that could affect the extent of organ damage that occurs [14,15]. Small-scale farming areas are crucial for small farmers in developing countries like Nigeria to provide crop protection against losing harvested crop grains [5]. It has been observed that in Lafia Metropolis, and its neighbouring agricultural areas of Nasarawa State, dichlorvos is widely accessible and could be used as a grain protector otherwise known as deterred by an uninformed person [16]. These off-labelled uses could be associated with risks of household poisoning, environmental pollution, and occupational exposure [16]. Consequently, the search for nontoxic plant-derived dietary compounds that could potentially serve as counters against xenobiotic oxidative stress has become a major area of interest for phytodieticians. Edible plant parts such as ginger rhizome (*Zingiber officinale*), coconut endosperm (*Cocos nucifera*) and tiger nut tuber (*Cyperus esculentus*) are enriched with antioxidant phytochemicals, dietary fiber, essential micronutrients, and lipophilic vitamins [17-19]. Gingerols and shogaols from *Z. officinale* scavenge free radicals and down-regulate pro-inflammatory cytokines during toxic insult [17,20]. Similarly, *C. nucifera* endosperm and water exhibit documented hepatoprotective and free radical scavenging properties against xenobiotics [18,21], while flavonoids and phytosterols of *C. esculentus* protect biological membranes from lipid peroxidation [19,22].

However, there exist limited empirical data on whether coadministration of crude aqueous extracts of these commonly consumed plants can attenuate organ injury when coadministered with dichlorvos. The aim of this exploratory research was to determine the impacts of the aqueous extracts of ginger, coconut, and tiger nuts on behavior, body weight, selected serum biochemical indices, hematological parameters, and liver and kidney histology of Wistar rats coexposed to dichlorvos in Lafia, Nasarawa State, Nigeria.

Materials and Methods

Study Area

The study was carried out in Lafia, which is the headquarters of Nasarawa State in the north-central zone of Nigeria. Lafia has a total land area of about 2,827 square kilometers within the geographical coordinate of 8° 29'N and longitude 8° 31'E [23]. The total population of the metropolis according to the 2006 national population census was 329,922 people but it is estimated that there are over 500,000 people in the population currently [24]. Lafia experiences a tropical wet and dry (savanna) climate with an average annual maximum temperature of 36.48°C and an average minimum temperature of 24.46°C [25]. It can be observed that August to September had the most rain, while November to March had the dry season [26] (Figure 1).

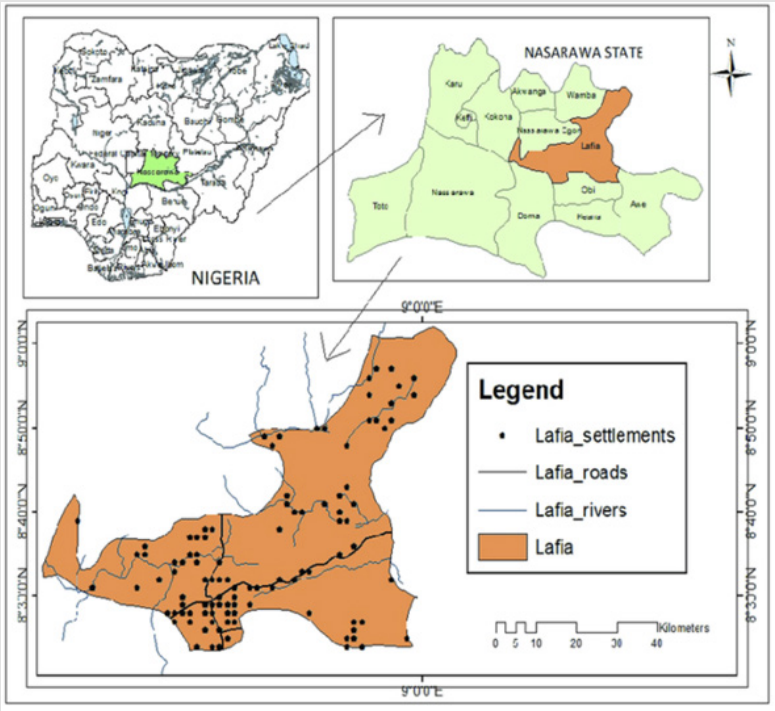


Figure 1: Map showing Nigeria, Lafia, Lafia Local Government Area of Nasarawa State [27].

Sourcing and Botanical Authentication of Experimental Plant Materials

The *Zingiber officinale* Roscoe rhizomes (ginger), *Cocos nucifera* L. (nypa) fruits, and *Cyperus esculentus* L. (tiger nut) tubers used in the study were purchased from the Lafia Modern Market, Lafia, Nasarawa State. However, the references seem to confirm that plant identification was confirmed at the Herbarium Department of the Department of Plant Science and Biotechnology, Federal University of Lafia, where voucher samples were probably kept.

Preparation of Aqueous Plant Extracts

Plant materials were sorted, thoroughly washed under running tap water followed by rinsed distilled water to eliminate debris, and dried in the shade at ambient temperature (25 to 28°C) for three weeks [28]. The plant tissues of the dried plant material were ground to coarse powders by an electric blender (Philips HR-2815), then by a 2.0 mm mesh sieve. The powdered material was kept in airtight polyethylene bottles at 4°C until extraction. Aqueous extraction was performed using the modified cold maceration technique described by Abubakar and Haque [29] and (Osuagwu, et al. [30]). About 50 g of each powdered sample were weighed and placed in sterile amber glass bottles containing 250 ml of sterile distilled water (1:5, w/v). The glass bottles were stirred intermittently using an orbital shaker for 72 hours at room temperature. The resultant suspension was filtered with sterile non-absorbent cotton wool and then with Whatman No. 1 filter paper. The extract was concentrated in a water bath at 45°C and dried in a desiccator. The percentage yield of the extract was calculated as described by (Kumar, et al. [31]).

$$Percentage\ Yield = \frac{Weight\ of\ Extract\ (g)}{Weight\ of\ Crude\ Powder(g)} X \frac{100}{1}$$

Phytochemical Screening, Proximate and Mineral Analysis

Crude aqueous extracts were qualitatively screened for secondary metabolites (flavonoids, tannins, saponins, alkaloids, cardiac glycosides, phenols, terpenoids, steroids, resins, phlobatannins, anthraquinones) following (Trease and Evans [32]) and (Sofowora [33]). The approximate parameters, such as moisture, ash, crude protein, crude fat, crude fiber, and total carbohydrate, were determined in triplicate as outlined in AOAC [34]. Calculating the amount of total carbohydrate was calculated by the difference as outlined by AOAC [34,35]:

% carbohydrate = 100 - (% moisture +% ash +% crude protein +% crude fat +% crude fibre)

Furthermore, mineral levels (calcium, magnesium, iron, zinc, copper and manganese) were also characterized by wet acid digestion (nitric and perchloric acid 2:1 v/v mixture) and subsequent atomic absorption spectroscopy (AAS, Buck Scientific 210 VGP). Sodium and potassium were quantified by flame photometry, and phosphorus was colorimetrically analyzed by the vanadomolybdate reaction [34].

Experimental Animals, Ethics, and Acute Toxicity Bioassay

Seventy-two (72) clinically healthy male Wistar rats (Rattus norvegicus; 7–10 weeks; 110–165 g) were obtained from the National Institute of Veterinary Research (NVRI), Vom, Plateau State, Nigeria. The animals were kept under standard laboratory conditions (24±2°C, 50–65% humidity, 12 h light/dark cycle) with a commercial rodent diet (ECWA feeds) and ad libitum water. Ethical approval was issued by the Ethics Committee of the Department of Zoology of the Federal University of Lafia (Protocol ID: FUL/FS/ZLY/2021/007). Preliminary toxicity to determine the median lethal dose (LD_{50}) was evaluated using 24 rats following Lorke [36]. For dichlorvos, LD_{50} was determined as the geometric mean of the highest nonlethal dose (20 mg/kg) and lowest lethal dose (40 mg / kg), resulting in 28.28 mg/kg body weight (ip). For aqueous extracts, there were no mortalities up to 5000 mg / kg (LD_{50}> 5,000 mg/kg (LD_{50} > 5,000 mg/kg).

Subchronic Treatment Regimen

Forty-eight (48) male Wistar rats were randomly assigned to four experimental groups (n = 12 per group, maintained in 3 replicate cages of 4 rats each):

1) Group W (Vehicle Control): Received sterile vehicle (distilled water, 10 ml / kg, ip) every 14 days for 8 weeks.
2) Group X (Ginger + DDVP): Received Z. officinale extract (10 mg / kg, ip) followed 3 minutes later by dichlorvos (5 mg / kg, ip) every 14 days for 8 weeks.
3) Group Y (coconut + DDVP): Received C. nucifera extract (10 mg / kg, ip) followed 3 minutes later by dichlorvos (5 mg / kg, ip) every 14 days for 8 weeks.
4) Group Z (Tiger Nut + DDVP): Received C. esculentus extract (10 mg / kg, ip) followed 3 minutes later by dichlorvos (5 mg / kg, ip) every 14 days for 8 weeks.

Biochemical, Haematological, and Histological Analyses

At the conclusion of the 8-week trial, blood was collected under isoflurane anesthesia by cardiac puncture. Whole blood in K2-EDTA was analyzed for hemodynamic parameters (WBC, RBC, HGB, HCT, MCV, MCH, MCHC) using an automated analyzer (CELL-DYN 3700). Serum was harvested for kinetic determination of AST, ALT, ALP, and creatinine using commercial Randox kits. The excised liver and kidney tissues were fixed in 10% neutral buffered formalin, dehydrated using graded alcohols, cleared in xylene and infiltrated with molten paraffin wax at 55°C [37]. The sections were cut at 5–6 µm thickness using a rotary microtome and stained with hematoxylin and eosin (H&E). Photomicrographs were captured using a digital microscope camera without scale bars and relative magnifications were specified by the total optical magnification of the objective lens system (x10, x40, x100).

Statistical Analysis

Data obtained was analysed using the statistical package for social sciences (SPSS), version 22. One way analysis of variance (ANOVA) was used for comparison of the means. Differences between means were considered to be significant at $P < 0.05$. Where significant differences were detected, Tukey's post-hoc test was used to identify differences between groups.

Results

Proximate, Mineral Composition and Phytochemical Screening

The approximate composition of the plant powders (Table 1) revealed that the crude protein was highest in ginger (17.46±0.94%), while coconut contained the highest crude fat (26.01±0.80%) and crude fibre (26.79±0.76%). Mineral analysis (Table 2) shows that potassium and phosphorus were the predominant macro elements, with coconut exhibiting significantly ($P < 0.0001$) higher potassium (519.40±1.77 mg/100 g) than tiger nut (481.23±1.53 mg/100 g) and ginger (476.36±5.03 mg/100 g). Qualitative screening (Table 3) showed abundant flavonoids, glycosides, total phenols, and terpenoids in all three plants, with anthraquinones absent in all samples.

Table 1: Proximate Composition of *Zingiber officinale*, *Cocos nucifera,* and *Cyperus esculentus*.

Component	*Z. officinale* Concentration (%)	*C. nucifera* Concentration (%)	*C. esculentus* Concentration (%)	F-Statistic	P-value
Moisture	10.63 ± 0.97^{b}	2.53 ± 0.11^{a}	10.29 ± 0.94^{b}	102.86	< 0.0001
Dry matter	89.37 ± 1.81^{a}	97.47 ± 0.56^{b}	89.71 ± 3.24^{a}	13.41	< 0.0061
Crude Fat	9.87 ± 0.11^{a}	26.01 ± 0.80^{c}	23.37 ± 1.29^{b}	291.24	< 0.0001
Crude protein	17.46 ± 0.94^{c}	10.04 ± 0.74^{b}	6.16 ± 0.34^{a}	191.82	< 0.0001
Crude fiber	5.86 ± 0.36^{a}	26.79 ± 0.76^{c}	14.72 ± 1.46^{b}	349.93	< 0.0001
Ash	5.69 ± 0.29^{b}	1.96 ± 0.08^{a}	2.41 ± 0.44^{a}	131.33	< 0.0001
Carbohydrates	50.49 ± 2.67^{b}	32.67 ± 2.49^{a}	43.05 ± 4.47^{b}	21.64	< 0.0018

Note: $P < 0.05$; Values are Mean ± Standard deviation n = 3

Components with different superscripts in a row are statistically significant ($P < 0.05$).

Table 2: Mineral Composition of *Zingiber officinale*, *Cocos nucifera*, and *Cyperus esculentus*.

Components	*Z. officinale* (mg/100g)	*C. nucifera* (mg/100g)	*C. esculentus* (mg/100g)	F-Statistic	P-value
Magnesium	4.04 ± 0.45^{a}	38.71 ± 0.75^{b}	129.04 ± 1.86^{c}	11,829.06	0.0001
Calcium	32.60 ± 1.12^{a}	21.40 ± 0.43^{b}	2.08 ± 0.11^{c}	1,970.75	0.0001
Manganese	1.20 ± 0.58^{a}	1.09 ± 0.13^{a}	0.93 ± 0.22^{a}	0.55	0.5948
Copper	0.43 ± 0.16^{a}	0.68 ± 0.07^{b}	0.87 ± 0.14^{b}	11.66	0.0032
Zinc	0.68 ± 0.05^{a}	1.60 ± 0.19^{b}	1.70 ± 0.13^{b}	68.35	0.0001
Iron	1.62 ± 0.06^{a}	2.04 ± 0.14^{ab}	2.83 ± 0.15^{b}	107.58	0.0001
Potassium	476.36 ± 5.03^{a}	519.40 ± 1.77^{c}	481.23 ± 1.53^{b}	216.61	0.0001
Sodium	2.93 ± 0.08^{a}	34.70 ± 1.05^{b}	3.78 ± 0.14^{a}	3,484.45	0.0001
Phosphorus	95.40 ± 1.10^{a}	122.25 ± 1.06^{b}	248.05 ± 7.91^{c}	1,227.97	0.0001

Note: Values are Mean ± Standard deviation n = 3

Minerals with different superscripts in a row are statistically significant ($P < 0.05$).

Table 3: Phytochemical Composition of *Zingiber officinale*, *Cocos nucifera*, and *Cyperus esculentus*.

Components	*Z. officinale*	*C. nucifera*	*C. esculentus*
Saponins	+	-	++
Flavonoids	++	++	++
Tannins	+	+	+
Glycosides	++	++	++
Resins	+	+	+
Phenols	++	++	++
Steroids	+	+	+
Terpenoids	++	++	++
Alkaloids	++	++	++
Anthraquinones	-	-	-
Phlobatannins	+	-	+

Note: Key: -: Not detected, +: Moderate, ++: High

Behavioural and Mean Weight Changes

Changes in the behavior of the rats in the treatment group showed transient signs of cholinergic stimulation (tremors, piloerection, altered daytime rest patterns). As summarized in (Table 4), all groups exhibited mean body weight gains over 8 weeks; however, the percentage gain was highest in the control group (+11.18%) and significantly suppressed in the coconut cotreatment group (+6.81%, $P < 0.05$).

Table 4: Mean Body Weight Changes in Wistar Rats during the 8-Week Study.

Group	Initial weight (g)	Final weight (g)	Weight diff (g)	% Gain/ Loss
W (Control)	153.62	170.81	17.19	$+11.18^{b}$
X (Ginger + Dichlorvos)	127.38	139.97	12.59	$+9.88^{ab}$
Y (Coconut + Dichlorvos)	156.47	167.14	10.67	$+6.81^{a}$
Z (Tiger nut + Dichlorvos)	147.61	160.63	13.02	$+8.82^{ab}$

Note: n = 4, F-Statistic = 4.79, P-value < 0.05

The percentage of gain / loss columns that have different superscript letters are statistically significant ($P < 0.05$).

Effect on the Serum Biochemical Parameters

The serum biochemical evaluation (Table 5) showed statistically significant differences between the groups for AST ($F = 51.00$, $P < 0.0001$), ALT ($F = 38.52$, $P < 0.0001$), and ALP ($F = 9.36$, $P = 0.0018$). The transaminases were highest in the untreated control rats (AST: 174 U/L; ALT: 119 U/L), whereas all treated groups exhibited lower transaminase activities (AST: 157–164 U/L; ALT: 105–114 U/L). Serum creatinine did not show significant differences between groups ($P = 0.9739$).

Table 5: Serum Biochemical Parameters in Wistar Rats After 8 Weeks.

Parameter	AST (U/L)	ALT (U/L)	ALP (U/L)	Creatinine (mg/dL)
Group				
W (Control + Dichlorvos)	174 ± 1.59^{c}	119 ± 1.09^{c}	325 ± 2.57^{b}	1.62 ± 0.82^{a}
X (Ginger + Dichlorvos)	157 ± 2.94^{a}	105 ± 0.97^{a}	316 ± 3.83^{a}	1.44 ± 0.76^{a}
Y (Coconut + Dichlorvos)	164 ± 2.08^{b}	114 ± 2.34^{bc}	311 ± 6.18^{a}	1.41 ± 0.89^{a}
Z (Tiger nut + Dichlorvos)	159 ± 1.61^{a}	109 ± 2.78^{ab}	321 ± 1.91^{ab}	1.38 ± 0.74^{a}
F-Statistic	51.00	38.52	9.36	0.07
P-value	< 0.0001	< 0.0001	< 0.0018	0.9739

Note: Values are given as Mean ± SD (n=4).

Values within a column that share different superscripts tend to be significantly different (P < 0.05).

Effect on the Haematological Parameters

Haematological data (Table 6) showed that no statistically significant effects were observed between the groups (P > 0.05). In addition, all the main erythrocyte parameters and leukocyte counts were evidently within the typical reference ranges.

Table 6: Haematological parameters in Wistar Rats After 8 Weeks.

Parameter	WBC (10^3/μL)	RBC (10^6/μL)	HB (g/dL)	HCT (%)	MCV (fL)	MCH (pg)	MCHC (g/dL)
Group							
W (Control)	16 ± 1.34	12 ± 1.73	18 ± 0.31	55 ± 0.69	45.83	15.00	32.73
X (Ginger)	15 ± 1.91	11 ± 1.96	16 ± 0.76	52 ± 2.67	47.27	14.54	30.77
Y (Coconut)	16 ± 1.02	11 ± 1.14	17 ± 1.72	54 ± 1.81	49.09	15.45	31.48
Z (Tiger nut)	15 ± 2.03	12 ± 1.53	16 ± 2.41	54 ± 0.88	45.00	13.33	29.63
F-Statistic	0.44	0.40	1.48	2.11	-	-	-
P-value	0.7258	0.7570	0.2703	0.1523	-	-	-

Note: Data are shown as the means ± SD of 4 measurements.

No Significance (P > 0.05).

Effect on the Histology of the Liver and Kidney

Histopathologically, the cytostructure was observed to remain in the liver (Plate 1) and kidney (Plate 2) of the control group while all treatment groups had liver sections showing some degree of necrosis of isolated hepatocytes, sinusoidal dilatation and portal vein dilation (Plates 3-5). Kidney sections from all treatment groups showed varying degrees of global tubular necrosis and loss of luminal brush borders, vascular congestion with interstitial infiltrates (Plates 6-8).

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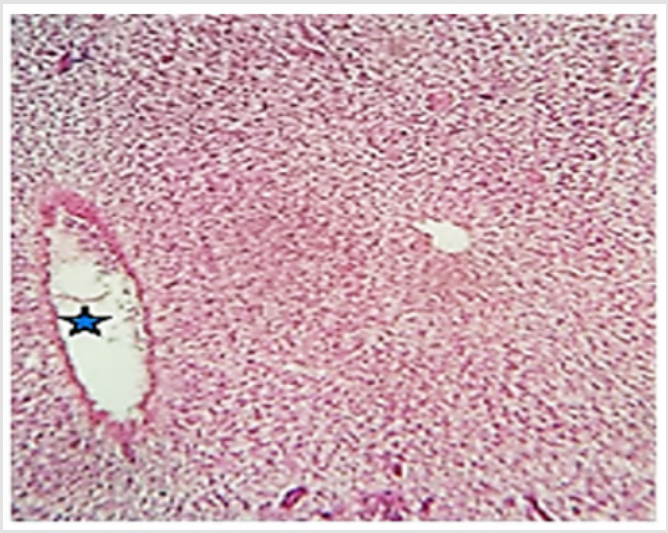


Plate 1: Liver section of untreated rats (Group W: No Plant extract +no Dichlorvous). No Alteration was observed, as hepatocytes and sinusoids are not distorted. The central vein is indicated by the blue star.
Magnification x40. H & E staining.

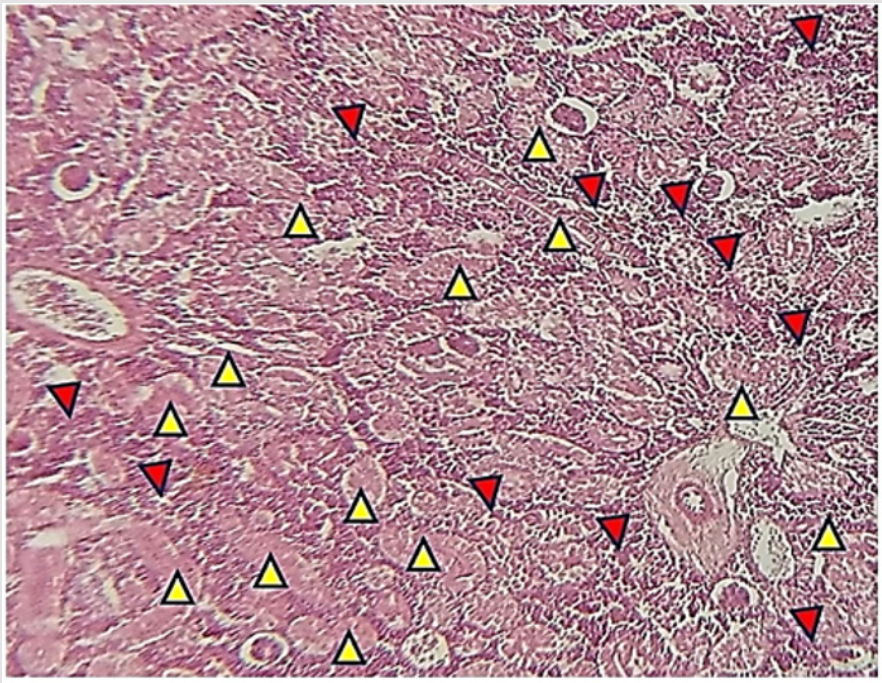


Plate 2: Kidney section of untreated rats (Group W: No Plant extract +no Dichlorvous). No alteration of cells is observed. Renal tubules (yellow arrow heads) and the blood vessels with interstitial spaces) are normal
Magnification x100. H & E staining.

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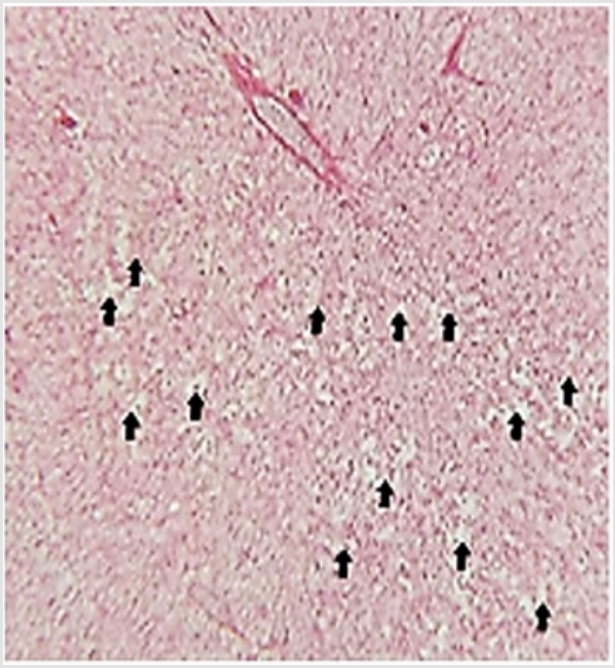


Plate 3: Liver section of treated rat (Group X: Ginger + Dichlorvous). Minor necrosis of the hepatocytes (black arrows). The central vein is observed to have deposits (white arrow).
Magnification x 10.H & E stain.

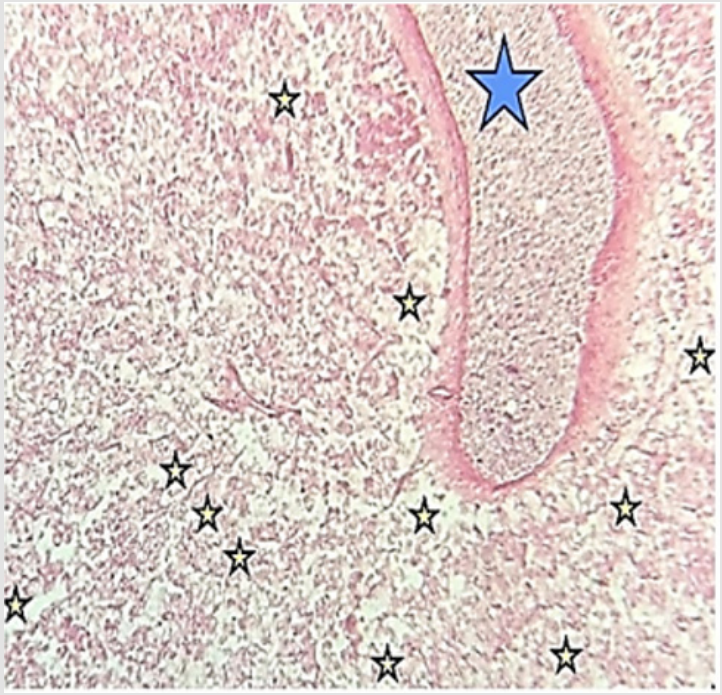


Plate 4: Liver section of the treated rat (Group Y: Coconut + Dichlorvos). Necrosis of hepatocytes (yellow starts). The central vein is indicated by the blue star and is filled with deposits. Note the dilation of sinusoids due to inflammation.
Magnification x 100.H & E stain.

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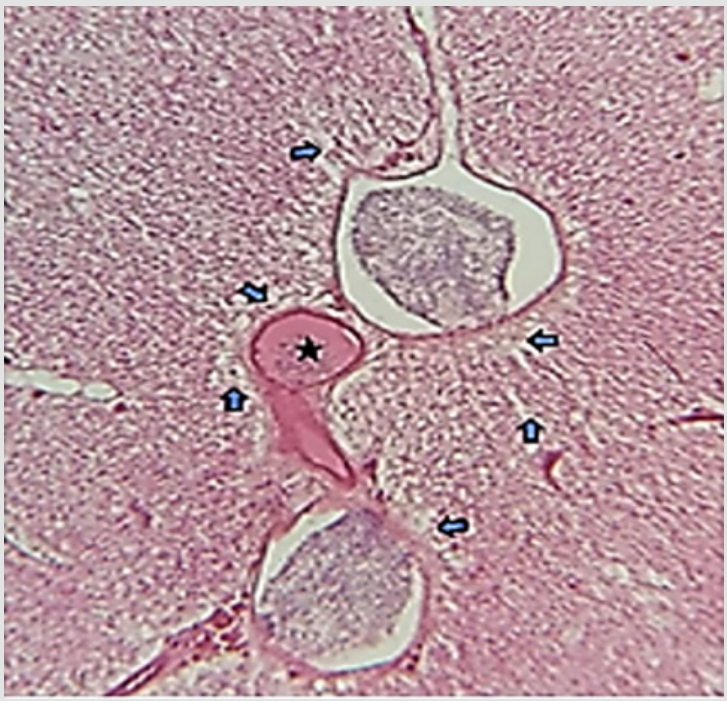


Plate 5: Liver section of the treated rat (Group Z: Tiger nuts +Dichlorvos). Necrosis of the hepatocytes (blue arrows). Observed congestion of the portal vein (black star). Deposits present in the portal vein. Similar observations are observed in Group X and Y.
Magnification x100. H & E stain.

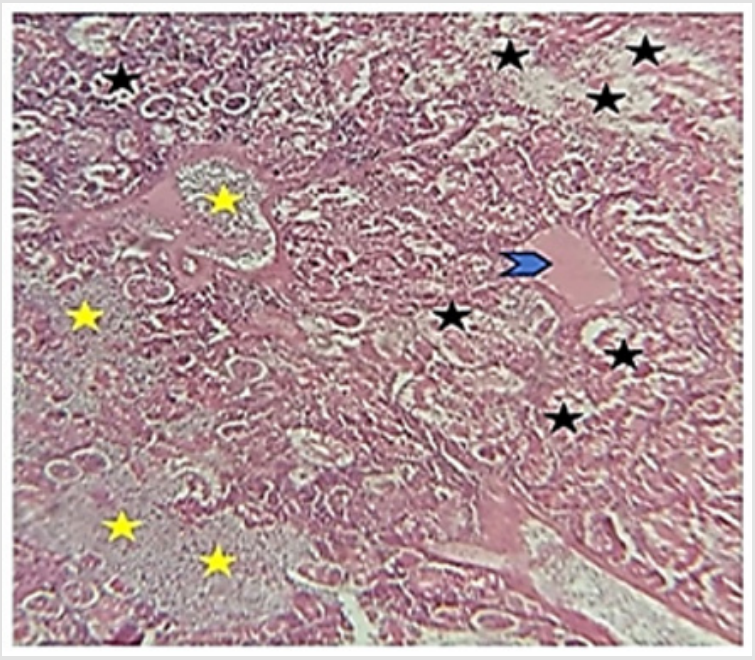


Plate 6: Kidney section of the treated rat (Group X: Ginger + Dichlorvos). Necrosis observed (black stars). There is congestion of the renal blood vessel (blue arrow). Hemopoitic cells are indicated by yellow stars.
Magnification x100. H & E stain.

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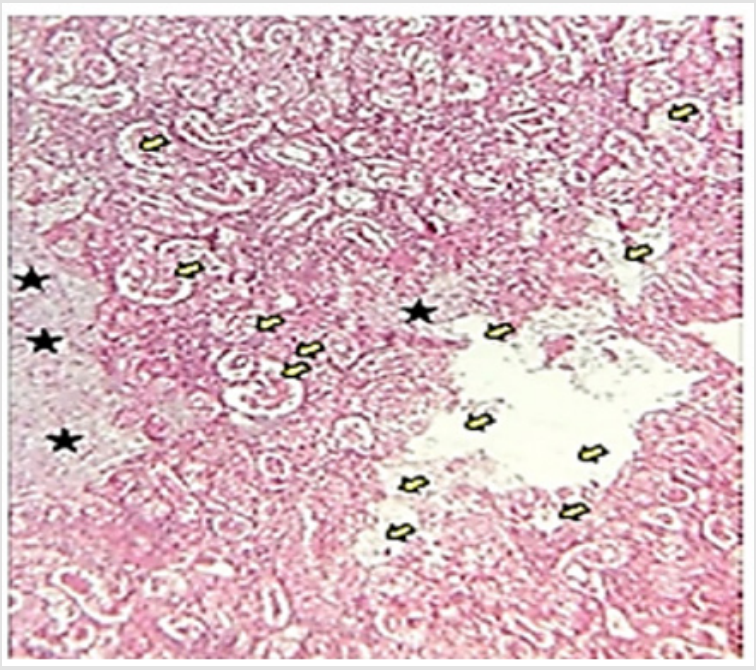


Plate 7: Kidney section of the treated rat (Group Y: coconut +Dichlorvos). Necrosis of the cells in the renal tubules (yellow arrows). Distortions in the blood vessels with interstitial spaces are indicated by the black stars.
Magnification x100. H & E stain.

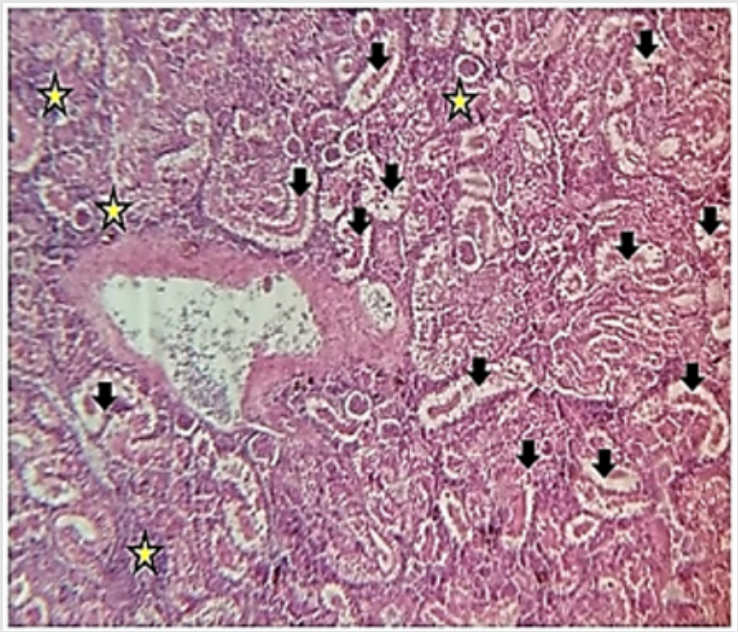


Plate 8: Kidney section of the treated rat (Group Z: Tiger nuts + Dichlorvos). Necrosis of cells in the renal tubules (black arrows). Alteration in blood vessels with interstitial spaces (yellow stars).
Magnification x100. H & E stain.

Discussion

This study provides exploratory toxicological data on the physiological and histomorphological responses of male Wistar rats co-exposed to the organophosphate insecticide dichlorvos and crude aqueous extracts of *Zingiber officinale*, *Cocos nucifera*, and *Cyperus esculentus*. Given the extensive use of dichlorvos for post-harvest protection of cowpeas in sub-Saharan Africa and household pest control, the evaluation of potential dietary protectants seems to be of the most relevance to public health [3,5,16]. Taking into account the proximate and mineral compositions of the three plant components, as well as the literature [38-40], this suggests that they are high-quality sources of food ingredients and micronutrients. Coconut endosperm is particularly a rich source of crude fat (26.01%) and fiber (26.79%), in agreement with (Divya, et al. [21]). Ginger, on the other hand, was identified by its high levels of protein (17.46%) and carbohydrate storage compounds (50.49%) [41,42]. The total carbohydrate content of the tiger nut (43.05%) was lower than those found by Orhevba [43] and (Sánchez Zapata, et al. [44]), possibly resulting from ecotypic and soil edaphic differences, as well as postharvest dehydration [19] Interestingly, the 3 plants were high potassium, phosphorus and phytochemical reservoirs such as bioactive polyphenols, flavonoids and terpenoids [20,31,45,46].

In the eight-week experiment, temporary signs of cholinergic toxicity such as tremors, piloerection, and disrupted circadian activity were observed after every other injection. This is a key symptom of an acetylcholinesterase inhibitor that causes elevated levels of acetylcholine within neuromuscular synapses [9,10]. All groups showed a positive weight gain, but the coconut co-treated group had a reduced percentage weight gain (6.81%) compared to the control (11.18%). Reduced weight gain is known to be a biomarker of chronic organophosphate-induced metabolic stress and mitochondrial uncoupling [2,13].

One of the main results of the study, which was not anticipated, was that the tests showed serum transaminases levels, particularly aspartate aminotransferase (AST) and alanine aminotransferase (ALT), and ALP were significantly lower than controls in all experimental groups. In classic toxicologic pathology, cellular necrosis ruptures hepatocyte membranes, releasing intracellular transaminases into the bloodstream and triggering marked serum enzyme elevations [11,37]. Although several studies report that botanical antioxidants can normalize xenobiotic-induced transaminase spikes [19,39,47], lower transaminase activities in treatment groups, however, were observed with histological evidence of hepatocyte alteration.

This apparent divergence between serum biochemistry and tissue histology can be explained by several pharmacodynamic factors. First, direct interactions between organophosphates and plant secondary metabolites can suppress enzyme synthesis or inhibit circulating transaminase catalytic activity [10,14]. Second, because treatments were administered biweekly and blood collection occurred 14 days after the final injection, transient post-necrotic transaminase spikes likely resolved back to baseline before sacrifice. Third, severe centrilobular cell collapse can exhaust viable hepatocyte mass, paradoxically reducing the active pool of synthesizing enzymes [11]. Similar biochemical-pathological divergences have been documented in chronic organophosphate models [14]. Serum creatinine remained unchanged between groups, indicating that while tubular structural damage was histologically evident, the glomerular filtration capacity was maintained during the 8-week trial.

Haematological parameters (WBC, RBC, HGB, HCT) did not show statistically significant variations between groups. This indicates that an intermittent low-dose regimen of dichlorvos (5 mg/kg every 14 days) was not sufficient to induce overt myelosuppression or severe intravascular hemolysis, in contrast to daily oral or continuous inhalation models where marked anemia and leukocytosis are common [48,49]. Histological examination indicated that although serum creatinine and blood levels of the collected data remained unchanged; rats exposed to dichlorvos with or without various plant extracts showed more evident liver and kidney damage, including degenerated hepatocytes with loss of the structure of the liver plate, congested sinusoids with hemorrhage, degenerate epithelial cells in renal tubules with nuclear loss, and hypersegmentation of the nuclei of the degenerate cells. This result suggests that the 2-week dose regime of 10 mg/kg of aqueous extract(s) may not be adequate to provide adequate protection to the target organ (s) against dichlorvos challenge [17,22].

Conclusion

This study established the proximate, mineral and phytochemical profiles of the aqueous extracts of *Zingiber officinale*, *Cocos nucifera*, and *Cyperus esculentus* sourced in Lafia, Nigeria. In an 8-week coexposure trial with dichlorvos, animals exhibited positive mean weight gains and stable hemodynamic parameters. However, histological examination revealed liver and renal tissue injury in all treatment groups, showing that the biweekly administration of 10 mg/kg crude aqueous extracts did not confer protection against tissue injury, but definitive protective claims cannot be made without toxicant-only and extract-alone reference groups. To further clarify these mechanisms, future research should quantify tissue-level biomarkers of oxidative stress—such as malondialdehyde, catalase, superoxide dismutase, and reduced glutathione—alongside acetylcholinesterase activity. Furthermore, given the observed tissue injury, stricter public health regulatory enforcement on dichlorvos usage within Nigeria is urgently required to mitigate environmental exposure and protect public health.

Declarations

Conflict of Interest

This study does not conflict with the financial and personal interests of the authors.

Ethical Approval

Ethical approval was granted by the Ethical Committee of the Department of Zoology, Federal University of Lafia under protocol ID FUL/FS/ZLY/2021/007.

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Nil.

Authors Contributions

HOA, AO, and ETA designed and planned the experiments. HOA, MOI, AO, YAA, and JIM performed experiments on the bench and *in vivo*. KSD, LEK, HA and SY performed biochemical and histological assays. HOA, AO, ETA and AO wrote the manuscript. All authors read and approved the final manuscript.

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