



ORIGINAL RESEARCH ARTICLE

## Quantification of the Pesticide Residue in Ready-To-Eat Lettuce Produced in Adamawa State, Nigeria for Healthy Nutrition

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### ABSTRACT

Ready-to-eat lettuce has become popular among residents of Adamawa State nowadays due to its convenience and changing lifestyle. This product may be loaded with both chemical and biological contaminants, either during production or processing, thereby exposing consumers to health risks. There is a need to evaluate the wholesomeness of ready-to-eat lettuce marketed in the state. To achieve this, three Agricultural zones were purposively selected out of the four zones of Adamawa State. One major horticultural market was also purposively selected from each of the three selected zones, and ten samples of ready-to-eat lettuce were sampled from each market. The pesticide analysis was conducted using an HPLC method at the Nutrition Laboratory of Adamawa State University, Mubi. Data collected was subjected to Analysis of Variance (ANOVA) using IBM SPSS Statistics version 23, and means were separated using Least Significant Difference (LSD) at a 5% level of significance. The results showed that there were significant ( $P \leq 0.05$ ) differences in the levels of some of the pesticides. The highest concentration of Bifenthrin ( $0.0021 \text{mgkg}^{-1}$ ), Hexaconazole ( $0.0018 \text{mgkg}^{-1}$ ), Metalaxyl ( $0.0024 \text{mgkg}^{-1}$ ), Parathion ( $0.0014 \text{mgkg}^{-1}$ ), Pyridaben ( $0.0039 \text{mgkg}^{-1}$ ) and Hexachlorobenzene ( $0.0020 \text{mgkg}^{-1}$ ) were recorded in Mubi. Numan chronicled the highest values of Azoxystrobin ( $0.0067 \text{mgkg}^{-1}$ ), Cadusafus ( $0.0047 \text{mgkg}^{-1}$ ), Chlorfenapyr ( $0.0057 \text{mgkg}^{-1}$ ), Isoprothiolane ( $0.0073 \text{mgkg}^{-1}$ ) and Malathion ( $0.0075 \text{mgkg}^{-1}$ ). However, Yola recorded the highest values of Diazinon ( $0.0073 \text{mgkg}^{-1}$ ) and Dichlorvos ( $0.0078 \text{mgkg}^{-1}$ ). The concentration levels of pesticide in Ready-to-eat lettuce produced in the State were below the FAO/WHO Maximum Residues Levels (MRLs) for all the pesticide under study. However, banned pesticide such as Hexachlorobenzene, Dichlorvos and Parathion were found in the fresh-cut lettuce produces in the State at very low concentrations. Thus the Ready-to-eat lettuce marketed in the State is safe for consumption.

### Introduction

Vegetables are the edible part of plants which are either biological fruits or any economic

part that is consumed by man as a source of food and nutrition. Vegetables, just like fruits are also rich in vitamins, minerals, and phytochemicals that act as antioxidants and dietary fiber required for proper body functioning (Kabir *et al.*, 2020).

Ready-to-eat fruits and vegetables products was defined by the International Fresh-cut Produce Association (IFPA) as “any physical change done on fresh fruit and vegetables such as cleaning, peeling, cutting, trimming making the product 100% edible which are packaged and refrigerated and offered to consumers which are high in nutrition and flavor, while still maintaining its freshness is considered to be fresh-cut or minimally treated fruits and vegetables” (Yousuf *et al.*, 2018a; Musa *et al.*, 2023). Fresh-cut vegetables have a very high content of vitamins, dietary fiber, and minerals which play a key role in human nutrition (Yousuf *et al.*, 2018b). They also help in maintaining health and minimizing the probability of cardiovascular disorders, stroke, cancer, and chronic disorders, since they contain many phytochemicals for example phenolic compounds, antioxidants, and carotenoids (Yusouf *et al.*, 2020).

According to FAO/WHO (2016), “pesticide” is referred to as an active ingredient in any form, irrespective of to whether or to, what extent, it has been designed for application. The term is usually concomitant with materials intended to kill or control pests (insecticide, fungicide, herbicide, etc.) but, for the present purposes, it also include materials used to change the behaviour or physiology of pests (e.g. insect repellents and synergists) or of crops during production or storage (herbicide safeners, germination inhibitors).

Consumers usually prefer ready-to-eat vegetables because of their suitability,

nutrition, freshness, safety, and ease of eating. It also saves time for preparation and less pollution due to waste generation. Garden egg (*Solanum melongena*), carrots (*Daucus carota*), cabbage (*Brassica oleracea*) and lettuce (*Lactuca sativa*) are the most popular fresh-cut vegetables in Nigeria Edeghor *et al.*, 2019; Ugwu and Edeh, 2019; Kabir *et al.*, 2020; Nnenna and Gift, 2020; Uzor and Dick, 2022).

Despite the huge benefits obtained from the production and consumption of fresh-cut vegetables, the quality and safety of these products remain a major challenge for the industry (Yousuf *et al.*, 2020). Quality and safety of fresh vegetables are difficult to maintain because of the highly perishable nature of the products as they contain a large percentage of water by weight (80%-90%) and cannot be subjected to both thermal and chemical preservation methods (Yousuf *et al.*, 2018b; Yousuf *et al.*, 2020). Another serious concern is the natural protective cover provided by both the skin and cuticle on the surface of fresh vegetables are often removed during postharvest processing which increase the rate of deterioration of fresh-cut fruits and vegetables (Yousuf *et al.*, 2020) by providing avenues for contamination.

Ready-to-eat vegetables are bedeviled by many problems globally and Nigeria in particular, with the most pressing been the quality and safety arising from microbial, nutritional, and chemical contaminants like heavy metals, pesticide and other physical contaminants which could affect human health adversely ( Yousuf *et al.*, 2020; Kabir *et al.* 2020; Garba *et al.*, 2023; Musa *et al.*, 2023). The recent studies conducted in other parts of Nigeria on quality and safety of ready-to-eat vegetables showed an increase in incidence of foodborne diseases linked to fresh-cut vegetables (Kabir *et al.* 2020; Oyedele *et al.*, 2020; Garba *et al.*, 2021; Uzor and Dick, 2022; Garba *et al.*, 2023; Musa *et al.*, 2023).

Nevertheless, there is dearth of information on the quality and safety of ready-to-eat vegetables processed and marketed in the Adamawa State. There is need to explore and document the pesticide content of Ready-to-eat lettuce marketed in the State. In view of this hazard caused by contaminants present in ready-to-eat vegetables coupled with the increasing demands for such products, necessitate the present study to evaluate the concentration levels of pesticide in ready-to-eat lettuce salads vended in the State to determine their quality and safety status. This will facilitate in setting up procedures for hygienic and healthy handling, processing and marketing of these products in line with the world's best practices. This will also help in creating a products that can be exported and generate more revenue for both the State and the Country at large. Additionally, it will improve the living standard of both the farmers and processors of fruits and vegetables in the State. The aim of this work is to quantify the concentration of commonly used agricultural pesticide in ready-to-eat lettuce salads vended in the streets of Adamawa State.

### **Materials and Methods**

The study was carried out at the Nutrition Laboratory of Adamawa State University Mubi, which is located between latitudes 10° 06' and 10° 29'N of the Equator and between longitudes 13° 07' and 13° 30'E of the Greenwich Meridian. The study covered three Agricultural zones which were purposively selected out of the four zones of the State and one major horticultural market was also purposively selected based on market size from each of the selected zones. Ten samples of fresh-cut lettuce salads which are the most commonly traded fresh-cut vegetables in the State were collected. Pesticide contaminants such as Aldrin, Azoxystrobin, Bifenthrin, Cadusafus, Chlordane, Chlorfenapyr,

Chlorothalonil, Chlorovos, Diazinon, Dichlorovos, Dieldrin, Endrin, Hexaconazole, Hexachlorobenzene, Isoprothiolane, Kresoxim-methyl, Malathion, Metalaxyl, Parathion, Pencycuron, Pyridaben and Tebuconazole were determined on the collected samples using HPLC method.

### ***Measurement of Pesticide Residue in samples by High-Performance Liquid Chromatography (HPLC)***

#### ***Sample Extraction Procedure***

The samples were blended in 200mL deionized water and extracted with 100 mL of n-hexane by shaking several times in a separating funnel. The extraction procedure was repeated thrice. The organic layers were collected and passed through anhydrous sodium sulphate to remove water content. The collected fraction was reduced to 1 mL on a rotary evaporator. Two mL of acetonitrile was then added, and samples were filtered through a syringe filter of 0.22 µm before analysis.

#### ***Procedure and Chromatographic Conditions***

The detection and determination of the residues were carried out by injecting 12 µL of the 1.0 cm<sup>3</sup> purified extract into the injection port of a 130 MPa Shimadzu RP-HPLC system purchased from Shimadzu Corporation (Japan). The system was coupled with a degasser, solvent mixing unit, column oven, and system controller (CBM-20 A). The chromatographic separation was carried out using a C<sub>18</sub> column with dimensions of 250 × 4.6 mm and a pore size of 5 µm. The mobile phase consisted of acetonitrile (A) and HPLC water (B). The mobile phase was filtered using a 0.22 µm membrane and degassed for 30 min by sonication. The gradient elution started with 45% A and 55% B, continued with 30% B at 5.00 min., 20% B at 7.50 min., then 25% B at 9.00 min., followed by 35% B at 14.01 min. and stopped at 18.01 min. The flow rate was maintained at 1.00 mL/min, 12 µL injection volume, 38 °C column temperature, and the maximum pres-

sure limit of 15,000 psi. Identification of POPs and PAHs residues was accomplished using reference standards and relative retention time techniques, while the residues were determined by comparing the peak heights of the samples with the corresponding peak heights of the reference standards of known concentrations using the system controller (Colberg *et al.*, 2015). The concentrations of the residues were calculated directly from the chromatograph.

#### **Quality Assurance**

Cleaning procedures, recovery of spiked standards, and monitoring of detector response were carried out. Blank runs were made for background correction. The correlation coefficients of calibration curves of the pesticides were higher than 0.998. The stock solution of the pesticide standards was purchased from Restek Corporation, USA, and contained 1000 ppm in n-hexane. It was serially diluted to obtain desired concentrations of 10, 20 and 40ng/mL.

#### **Recovery study**

The recovery of pesticide residues was carried out in replicate and was determined by spiking the previously analysed samples with the pesticide standard at concentrations similar to those expected in the samples.

#### **Data Analysis**

Data collected were subjected to Analysis of Variance (ANOVA) using IBM SPSS Statistics version 23, and means were separated using the Least Significant Difference (LSD) at a 5% level of significance.

### **Results and Discussion**

#### **Concentration of Pesticide (mgKg<sup>-1</sup>) in Ready-to-eat Lettuce Salads Vended in Adamawa State**

##### **Bifenthrin**

The concentration of Bifenthrin pesticides in ready-to-eat lettuce in the study area showed a

significant ( $P \leq 0.05$ ) difference among the three zones studied (Table 1). The highest concentration was observed in Mubi (0.0021 mgkg<sup>-1</sup>), although Numan and Yola recorded the lowest concentrations (0.000 mgkg<sup>-1</sup> each). In the same vein, Horska *et al.* (2020) recorded 0.01 - 0.03mgkg<sup>-1</sup> of pesticide concentration in lettuce and Machezano *et al.* (2019) also recorded a value of range of 0.01 - 1.0mgkg<sup>-1</sup> concentration levels for fruits and vegetables in Botswana. Likewise, Kumah *et al.* (2023) reported concentration levels of pesticides in cabbage, lettuce and tomatoes ranging from 0.013mgkg<sup>-1</sup> - 1.23mgkg<sup>-1</sup> in Ghana. Okediran *et al.* (2019) recorded concentration levels that ranged from 0.025 - 0.529mgkg<sup>-1</sup> in Lagos on cabbage, lettuce, fluted pumpkin, bitter leaf and African spinach, which are all above the values obtained in this study. However, the value of 0.00000 - 0.000098mgkg<sup>-1</sup> reported by Maigari *et al.* (2021) in Gombe on cabbage, lettuce, calyces and tiger nut was far lower than the concentration levels of Adamawa State. The variation in values may be attributed to both pre- and post-harvest factors. Even though the level of concentration of pesticides in Adamawa State is below the Maximum Residue Limit (MRL) of FAO/WHO (2021) and CODEX ALIMENTARIUS (2025) recommendations, thereby make the ready-to-eat lettuce salads marketed in the State to be safe for consumption in terms of pesticide residue.

##### **Metalaxyl**

There was a significant ( $P \leq 0.05$ ) difference in the concentration levels of Metalaxyl pesticide content of the ready-to-eat lettuce from the three towns as presented in Table 1. Mubi recorded the highest value of 0.0024mgkg<sup>-1</sup>, while Numan and Yola had the least value of 0.0000 and 0.000mgkg<sup>-1</sup> each. Other researchers reported a value range of 0.01 - 1.0mgkg<sup>-1</sup> (Machezano *et al.*, 2019), 0.013mgkg<sup>-1</sup> - 1.23mgkg<sup>-1</sup> (Okediran *et al.*, 2019), and 0.01 - 1.0mgkg<sup>-1</sup> (Kumah *et al.*,

(2023) which are below the values recorded in this study. Though, Maigari *et al.* (2021) reported a lower value of 0.00000 -

0.000098mgkg<sup>-1</sup>. The inconsistencies can be attributable to difference in environment and agronomic practices. Nonetheless, the level of

**Table 1:** Pesticide concentration (mgkg<sup>-1</sup>) in Ready-to-eat lettuce marketed in Adamawa State

Pesticides	Location			LSD	P of F	FAO/WHO MRLs (mgkg <sup>-1</sup> )
	Mubi (mgkg <sup>-1</sup> )	Numan (mgkg <sup>-1</sup> )	Yola (mgkg <sup>-1</sup> )			
Chlorothalonil	0.0054	0.0045	0.0022	0.0017	0.168	0.01
Bifenthrin	0.0021	0.0000	0.0000	0.0009	0.032	3.0
Tebuconazole	0.0062	0.0065	0.0053	0.0010	0.478	0.03
Isoprothiolane	0.0051	0.0073	0.0068	0.0008	0.034	0.1
Kresoxim-methyl	0.0056	0.0070	0.0056	0.0008	0.161	0.03
Metalaxyl	0.0024	0.0000	0.0000	0.0010	0.032	0.5
Pyridaben	0.0039	0.0032	0.0008	0.0011	0.029	0.05
Chlorfenapyr	0.0040	0.0057	0.0044	0.0006	0.030	0.028
Azoxystrobin	0.0045	0.0067	0.0046	0.0008	0.021	4.0
Pencycuron	0.0029	0.0046	0.0018	0.0014	0.148	0.01
Diazinon	0.0041	0.0071	0.0073	0.0009	0.002	0.01
Hexaconazole	0.0018	0.0000	0.0000	0.0007	0.032	0.01
Cadusafus	0.0038	0.0045	0.0006	0.0013	0.010	0.01
Aldrin	ND	ND	ND	ND	ND	0.0
Dieldrin	ND	ND	ND	ND	ND	0.0
Chlordane	ND	ND	ND	ND	ND	0.0
Endrin	ND	ND	ND	ND	ND	0.0
Hexachlorobenzene	0.0020	0.0000	0.0000	0.0008	0.032	0.0
Chlorvos	ND	ND	ND	ND	ND	0.0
Malathion	0.0041	0.0075	0.0066	0.0009	0.003	0.01
Dichlorvos	0.0054	0.0063	0.0078	0.0008	0.024	0.0
Parathion	0.0014	0.0000	0.0000	0.0006	0.032	0.0

MRLs = Maximum Residue Levels; ND = Not Detected

Concentration of pesticide in this work is lower than the MRL declared by FAO/WHO (2021) and CODEX ALIMENTARIUS (2025) references.

### Hexaconazole

The concentration of Hexaconazole pesticide in Ready-to-eat lettuce in the study area showed a significant ( $P \leq 0.05$ ) difference as presented in Table 1. The highest concentration was observed in Mubi (0.0018mgkg<sup>-1</sup>) whereas; Numan and Yola recorded the lowest concentration (0.000mgkg<sup>-1</sup> each). Other researchers reported earlier, different values such as those obtained in Botswana by Machekano *et al* (2019) who reported a of 0.01-1.0mgkg<sup>-1</sup>; Okediran *et al* (2019) who had 0.01-1.0mgkg<sup>-1</sup> in Lagos State and Kumah *et al.*, (2023) in Ghana reported a value of 0.013 -1.23mgkg<sup>-1</sup>. However, all these figures were higher than the values discovered

in this research. Nevertheless, Maigari *et al.* (2021) found a lower concentration than values recorded in this work where they obtained a level of 0.00000 - 0.000098mgkg<sup>-1</sup> in Gombe State. The divergence may be caused by discrepancy in cultural practices and environmental influences. Nevertheless, the level of concentration of pesticides in this work is lower than the MRL declared by FAO/WHO (2021) and CODEX ALIMENTARIUS (2025) in their recommendations.

### Pyridaben

In the case of Pyridaben pesticide, a significant ( $P \leq 0.05$ ) difference in concentration levels in

Ready-to-eat lettuce occurred among the three sampled areas as shown in Table 1. Samples collected from both Mubi and Numan had the highest amount of pyridaben pesticide with a value of 0.0039 - 0.0032mgkg<sup>-1</sup> respectively that statistically comparable. Yola however, recorded the least levels of 0.0008mgkg<sup>-1</sup>. The outcome of this work differ with that of Machekano *et al* (2019) who recorded a value of range of 0.01 - 1.0mgkg<sup>-1</sup> concentration levels for fruits and vegetables in Botswana. In the same way, Kumah *et al*, (2023) also reported concentration levels of pesticide in cabbage, lettuce and tomatoes ranging from 0.013mg<sup>-1</sup>kg - 1.23mg<sup>-1</sup>kg in Ghana and equally Okediran *et al* (2019) recorded a concentration levels that ranged from 0.025 to 0.529mg<sup>-1</sup>kg in Lagos on cabbage, lettuce, fluted pumpkin, bitter leaf and African spinach which are all above the values obtained in this study. Yet, the value of 0.00000 - 0.000098mg<sup>-1</sup>kg reported by Maigari *et al.* (2021) on cabbage, lettuce, calyces and tiger nut in Gombe was far lower than the concentration levels of Adamawa State. The dissimilarity may arise from variation in agronomic practices. Despite that, the level of concentration of pesticides in Adamawa State is below the Maximum Residue Limit (MRL) of FAO/WHO (2021) and CODEX ALIMENTARIUS (2025) approvals thereby making the ready-to- eat lettuce salads marketed in the State to by acceptable with regard to pesticide loads.

#### Hexachlorobenzene

In terms of Hexachlorobenzene pesticide, a significant ( $P \leq 0.01$ ) dissimilarity in concentration levels were observed among the three sampled areas as revealed in Table 1. Samples collected from Mubi had the highest quantity of Hexachlorobenzene with a value of 0.0020mg<sup>-1</sup>Kg whilst both Numan and Yola reported the least levels of 0.0000 and 0.0000mg<sup>-1</sup>Kg each. 0.0036mg<sup>-1</sup>.

The result obtained from this experiment disagrees with other authors like Machekano *et al* (2019) recorded a value of range of 0.01 - 1.0mg<sup>-1</sup>kg concentration levels for fruits and vegetables in Botswana; Kumah *et al*, (2023) who reported a concentration levels of 0.013mg<sup>-1</sup>kg - 1.23mg<sup>-1</sup>kg in Ghana on cabbage, lettuce and tomatoes and lastly, Okediran *et al* (2019) who recorded 0.025 - 0.529mg<sup>-1</sup>kg in Lagos on cabbage, lettuce, fluted pumpkin, bitter leaf and African spinach which are all above the values obtained in this study. However, the value of 0.00000 - 0.000098mg<sup>-1</sup>kg obtained by Maigari *et al.* (2021) on cabbage, lettuce, calyces and tiger nut in Gombe was far lower than the concentration levels of Adamawa State which could be due varietal, environmental and human activities. Even though, the level of concentration of pesticide in Adamawa State is below the Maximum Residue Limit (MRL) of FAO/WHO (2021) and CODEX ALIMENTARIUS (2025) references thereby make the ready-to- eat lettuce salads marketed in the State to by tolerable for consumption in respect of pesticide content.

#### Isoprothiolane

The concentration level of Isoprothiolane pesticide in Ready-to-eat lettuce from the three study areas showed a significant ( $P \leq 0.05$ ) difference amongst them (Table 1). The highest concentration was detected in Numan (0.0073mgkg<sup>-1</sup>) and followed by Yola (0.0068mgkg<sup>-1</sup>) even though both are statistically equal. On the other hand, least concentration was recorded in Mubi (0.0051mgkg<sup>-1</sup>).

The findings reported in this research was incongruent with other scholars for instance Machekano *et al* (2019) recorded a value of range of 0.01 - 1.0mgkg<sup>-1</sup> concentration levels for fruits and vegetables in Botswana. Similarly, Kumah *et al*, (2023) reported concentration levels of pesticide in cabbage,

lettuce and tomatoes which ranged from 0.013mgkg<sup>-1</sup> to 1.23mgkg<sup>-1</sup> in Ghana and correspondingly Okediran *et al* (2019) also recorded concentration levels that ranged from 0.025 to 0.529mgkg<sup>-1</sup> in Lagos on cabbage, lettuce, fluted pumpkin, bitter leaf and African spinach which are all above the values obtained in this study. However, the value obtained by Maigari *et al.* (2021) of 0.00000 - 0.000098mgkg<sup>-1</sup> on cabbage, lettuce, calyces and tiger nut in Gombe was far lower than the concentration levels of Adamawa State. This could be due varietal, and human activities. Even though, the level of concentration of pesticide in Adamawa State is below the Maximum Residue Limit (MRL) recommended by FAO/WHO (2021) and CODEX ALIMENTARIUS (2025) thereby making the Ready-to-eat lettuce salads marketed in the State suitable for consumption in respect of pesticide content.

#### ***Chlorfenapyr***

There was highly a significant ( $P \leq 0.05$ ) difference in the concentration levels of Chlorfenapyr pesticide in lettuce salads produced in the three towns under study as presented in Table 1. Numan recorded the highest value of 0.0057mgkg<sup>-1</sup> while both Mubi and Yola had the least value of 0.0040 and 0.03044mgkg<sup>-1</sup> accordingly that are statistically alike.

The discoveries stated in this investigation was contrasting with other researchers for example Machekano *et al* (2019) who recorded a higher value of range of 0.01 - 1.0mgkg<sup>-1</sup> concentration levels for fruits and vegetables in Botswana. Similarly, Kumah *et al.*, (2023) reported concentration levels of pesticide in cabbage, lettuce and tomatoes ranging from 0.013mgkg<sup>-1</sup> to 1.23mgkg<sup>-1</sup> in Ghana and correspondingly Okediran *et al* (2019) noted a concentration levels that ranged from 0.025 to 0.529mgkg<sup>-1</sup> in Lagos on cabbage, lettuce, fluted pumpkin, bitter leaf and African

spinach which are all above the values obtained in this study. However, the value gotten by Maigari *et al.* (2021) of 0.00000 - 0.000098mgkg<sup>-1</sup> on cabbage, lettuce, calyces and tiger nut in Gombe was far below than the concentration levels of Adamawa State. The disparity could be due, environmental and agronomic factors. So be it, the level of concentration of pesticide in Adamawa State is below the Maximum Residue Limit (MRL) of FAO/WHO (2021) and CODEX ALIMENTARIUS (2025) recommendations thereby make the Ready-to-eat lettuce salads marketed in the State to be acceptable for consumption in respect of pesticide content.

#### ***Cadusafus***

The concentration of Cadusafus pesticide in ready-to-eat lettuce from Mubi, Numan and Yola showed a highly significant ( $P \leq 0.01$ ) difference (Table 1). The highest concentration was observed in Numan (0.0045mg<sup>-1</sup>Kg) followed by Mubi with a concentration level of 0.0038mgkg<sup>-1</sup> that statistically the same while Yola had the least concentration of 0.0006mgkg<sup>-1</sup>. The results recorded in this inquiry was distinct from other scholars as Machekano *et al* (2019) documented a value of range of 0.01 - 1.0mgkg<sup>-1</sup> concentration levels for fruits and vegetables in Botswana. Similarly, Kumah *et al.*, (2023) described concentration levels of pesticide in cabbage, lettuce and tomatoes ranging from 0.013 to 1.23mgkg<sup>-1</sup> in Ghana and similarly Okediran *et al* (2019) recorded a concentration levels that ranged from 0.025 to 0.529mgkg<sup>-1</sup> in Lagos on cabbage, lettuce, fluted pumpkin, bitter leaf and African spinach which are all above the values obtained in this study. However, the value obtained by Maigari *et al.* (2021) of 0.00000 - 0.000098mgkg<sup>-1</sup> on cabbage, lettuce, calyces and tiger nut in Gombe was far lower than the concentration levels of Adamawa State. The variation could be due environmental and human activities. Even though, the level of concentration of pesticide

in Adamawa State is below the MRL of FAO/WHO (2021) and CODEX ALIMENTARIUS (2025) sanctions thereby making the ready-to-eat lettuce salads marketed in the State to be acceptable for consumption in respect of pesticide content.

#### Diazinon

The concentration of Diazinon pesticide in Ready-to-eat lettuce in Adamawa State was found to be highly significantly ( $P \leq 0.01$ ) different (Table 1). The highest concentration was recorded in Yola ( $0.0073\text{mgkg}^{-1}$ ) followed by Numan with a concentration level of  $0.0071\text{mgkg}^{-1}$  that are statistically identical while Mubi had the least concentration of  $0.0041\text{mgkg}^{-1}$ .

The outcomes reported in this research was different from other researchers for instance Machekano *et al* (2019) obtained a value of range of  $0.01 - 1.0\text{mgkg}^{-1}$  concentration levels for fruits and vegetables in Botswana. Similarly, Kumah *et al*, (2023) reported concentration levels of pesticide in cabbage, lettuce and tomatoes ranging from  $0.013$  to  $1.23\text{mgkg}^{-1}$  in Ghana and similarly Okediran *et al* (2019) recorded a concentration levels that ranged from  $0.025$  to  $0.529\text{mgkg}^{-1}$  in Lagos on cabbage, lettuce, fluted pumpkin, bitter leaf and African spinach which are all above the values obtained in this study. However, the value obtained by Maigari *et al.* (2021) of  $0.00000 - 0.000098\text{mgkg}^{-1}$  on cabbage, lettuce, calyces and tiger nut in Gombe was lesser than the concentration levels of Adamawa State. The dissimilarity could be due varietal, environmental and cultural practices. Even though, the level of concentration of pesticide in Adamawa State is below the MRL of FAO/WHO (2021) and CODEX ALIMENTARIUS (2025) recommendations thereby making the ready-to-eat lettuce salads marketed in the State to be fit for human consumption in respect of pesticide content.

#### Malathion

In the case of Malathion pesticide, a highly significant ( $P \leq 0.01$ ) difference in concentration levels in Ready-to-eat lettuce occurred among the three sampled areas as shown in Table 1. Samples collected from both Numan and Yola had the highest concentration of Malathion pesticide with a value of  $0.0075$  and  $0.0066\text{mgkg}^{-1}$  respectively that are statistically akin. Mubi however, recorded the least levels of  $0.0041\text{mgkg}^{-1}$ . Other researchers reported different values such as those obtained in Botswana by Machekano *et al* (2019) of  $0.01-1.0\text{mg}^{-1}\text{kg}$ , Okediran *et al* (2019) in Lagos State of  $0.01-1.0\text{mgkg}^{-1}$  and Kumah *et al*, (2023) in Ghana reported a value of  $0.013\text{mgkg}^{-1} - 1.23\text{mgkg}^{-1}$  were all lower than the values discovered in this research. Nevertheless, Maigari *et al.* (2021) however, found a lower concentration level ( $0.00000 - 0.000098\text{mgkg}^{-1}$ ) in Gombe State. The divergence may be caused by inconsistency in agronomic practices and environmental factors. Nevertheless, the level of concentration of pesticide in this work is lower than the MRL declared by FAO/WHO (2021) and CODEX ALIMENTARIUS (2025) recommendations.

#### Dichlorvos

There was a significant ( $P \leq 0.05$ ) difference in the concentration levels of Dichlorvos pesticide content of the Ready-to-eat lettuce from the three towns as presented in Table 1. Yola and Numan recorded the highest value of  $0.0078$  and  $0.0063\text{mgkg}^{-1}$  respectively which are statistically similar. Equally, Mubi had the least value of  $0.0054\text{mg}^{-1}\text{kg}$ .

The findings reported in this research were incongruent with other scholars like Machekano *et al* (2019) who recorded a value of range of  $0.01 - 1.0\text{mgkg}^{-1}$  concentration level for fruits and vegetables in Botswana. Similarly, Kumah *et al*, (2023) also reported a concentration levels of from  $0.013\text{mgkg}^{-1}$  to

1.23mgkg<sup>-1</sup> pesticide on cabbage, lettuce and tomatoes in Ghana and similarly Okediran *et al* (2019) and Ahmadi *et al.*, (2024) both reported a higher concentrations of 0.0036mgkg<sup>-1</sup> and 0.025 to 0.529mgkg<sup>-1</sup> respectively on cabbage, lettuce, fluted pumpkin, bitter leaf and African spinach which are all above the values obtained in this study. However, the value obtained by Maigari *et al.* (2021) of 0.00000 - 0.000098mgkg<sup>-1</sup> on cabbage, lettuce, calyces and tiger nut in Gombe was far lower than the concentration levels of Adamawa State. This inconsistency could be due varietal, environmental and human activities. Even though, the level of concentration of pesticide in Adamawa State is below the Maximum Residue Limit (MRL) of FAO/WHO (2021) and CODEX ALIMENTARIUS (2025) endorsements thereby making the ready-to-eat lettuce salads marketed in the State to be suitable for consumption in respect of pesticide content

#### Parathion

In the case of Parathion pesticide a significant ( $P \leq 0.05$ ) difference in concentration levels in Ready-to-eat lettuce was observed among the three sampled areas as shown in Table 1. Samples gathered from both Mubi had the highest level of parathion pesticide with a value of 0.0014mgkg<sup>-1</sup>. However, Numan and Yola had the least value of 0.0000mgkg<sup>-1</sup> each.

The result reported in this research was incongruent from other scholars such as Machekano *et al* (2019) who recorded a value range of 0.01 - 1.0mgkg<sup>-1</sup> concentration levels for fruits and vegetables in Botswana. Similarly, Kumah *et al.*, (2023) reported a concentration level of pesticide in cabbage, lettuce and tomatoes ranging from 0.013mgkg<sup>-1</sup> to 1.23mgkg<sup>-1</sup> in Ghana and similarly Okediran *et al* (2019) and Ahmadi *et al.*, (2024) who all reported a higher concentration of 0.0036mgkg<sup>-1</sup>. in Lagos on cabbage, lettuce, fluted pumpkin, bitter leaf and African

spinach which are all above the values obtained in this study. However, the value obtained by Maigari *et al.* (2021) of 0.00000 - 0.000098mgkg<sup>-1</sup> on cabbage, lettuce, calyces and tiger nut in Gombe was below than the concentration levels of Adamawa State. This difference could be due varietal, environmental and agronomic practices. Even though, the level of concentration of pesticide obtained in Adamawa State is below the MRL of FAO/WHO (2021) and CODEX ALIMENTARIUS (2025) endorsements thereby making the ready-to-eat lettuce salads marketed in the State to be allowable for consumption in respect of pesticide content

#### Azoxystrobin

The concentration level of Azoxystrobin pesticide in ready-to-eat lettuce from the three study areas showed a significant ( $P \leq 0.05$ ) difference (Table 1). The highest concentration was reported in Numan (0.0067mgkg<sup>-1</sup>). Though, least concentration was recorded in Yola (0.0046mgkg<sup>-1</sup>) and Mubi (0.0045mgkg<sup>-1</sup>) even though both are statistically identical.

The discoveries of other workers like Machekano *et al* (2019) recorded a value of range of 0.01 - 1.0mgkg<sup>-1</sup> concentration levels for fruits and vegetables in Botswana. Similarly, Kumah *et al.*, (2023) also reported concentration level of pesticide in cabbage, lettuce and tomatoes ranging from 0.013mgkg<sup>-1</sup> to 1.23mgkg<sup>-1</sup> in Ghana and likewise Okediran *et al* (2019) recorded a concentration levels that ranged from 0.025 to 0.529mgkg<sup>-1</sup> in Lagos on cabbage, lettuce, fluted pumpkin, bitter leaf and African spinach which are all above the values obtained in this study. However, the value of 0.00000 - 0.000098mgkg<sup>-1</sup> reported in Gombe by Maigari *et al.* (2021) on cabbage, lettuce, calyces and tiger nut was far lower than the concentration levels of Adamawa State. The variation in values may be attributed to both pre and postharvest factors. Though, the level of concentration of

pesticide in Adamawa State is below the Maximum Residue Limit (MRL) recommended by FAO/WHO (2021) and CODEX ALIMENTARIUS (2025) which made the ready-to-eat lettuce salads marketed in the State to be within the safe limits terms of pesticide residue.

#### **Banned Pesticides**

Banned pesticide such as Dieldrin, Hexachlorobenzene, Dichlorovos and Parathion were detected in the Ready-to-eat lettuce produced and marketed in Mubi, Numan and Yola towns during the study in very low concentrations. This may be due lack of awareness on the part of the farmers and agrochemical marketers or non-availability of authorized pesticide in the State.

#### **Conclusion**

In conclusion, this study proof that the Ready-to Eat lettuce salads processed and vended in Adamawa State have very minimal level of pesticide residues of all pesticide assessed in this work and is below the FAO/WHO Minimum Residue Limitation (MRL) recommendations. However, some few banned pesticide are discovered in the Ready-to Eat lettuce salads though at a very minute quantity. According to this research, the Ready-to Eat lettuce salads marketed in Adamawa State can be considered as safe for consumption in terms of pesticide residues.

The present pesticide level should be maintained by proper regulation of pesticide usage by farmers and the prohibition of banned pesticide should be vigorously enforced. Lastly, People should continue patronizing the Ready-to-eat lettuce since it contain safe pesticide concentration levels.

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