LIPID, HEAVY METAL AND PESTICIDE CONTENTS OF FREE RANGE CATTLE SLAUGHTERED AT OBINZE ABATTOIR, IMO STATE, NIGERIA.

BY

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CERTIFICATION

This is to certify that this work, "**Lipid, heavy metal and pesticide contents of free range cattle slaughtered at Obinze Abattoir, Imo State, Nigeria,**" was carried out by Amini, Ifukikaloawaji George with Reg no: **20194194058** in partial fulfilment of the requirements for the award of the Degree of Master of Science (M.Sc.) degree in Biochemistry.

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DEDICATION

This work is dedicated to God Almighty, my family and friends.

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ABSTRACT

This study aimed at determining the lipid, heavy metal and pesticide contents in commonly consumed cattle meat parts obtained from Obinze Abattoir, Imo State, Nigeria. Cholesterol, fatty acid profile, heavy metals and pesticide concentrations were determined in cattle meat to evaluate the nutrient compositions and safety of regular consumption of these products. Nutrient composition was determined using standard methods. Pesticide and heavy metal levels were measured by gas chromatography (GC) and atomic absorption spectrometry (AAS), respectively. Forty-five samples comprising 15 each of torso, skin, stomach, lean meat and intestine were collected and analysed. The result of the cholesterol estimation showed that there were significant differences ($p< 0.05$) in cholesterol content between torso, stomach, skin and lean meat. Cholesterol content was found to be highest in the torso meat (115.2±6.48 mg/kg), followed by lean meat (94.7±2.27 mg/kg) and skin (79.3 ± 6.30 mg/kg) and lowest in the intestine (74.9 ± 2.33 mg/kg) and stomach (67.76 ± 5.69 mg/kg). The concentration of polyunsaturated fatty acid (PUFA) was higher than saturated fatty acids (SFA) in all meat parts which indicates that these meat parts have less risk hazard to human health. Oleic acid was the only monounsaturated fatty acid recorded in this study with highest concentration in torso (21.59± 6.13 mg/kg). Results of the heavy metal analysis obtained shows mean concentrations ranging from Mn (0.178±0.020 – 0.348±0.025 mg/kg), As (0.004±0.002 – 0.037±0.001 mg/kg), Cu (0.042±0.029 – 0.385±0.009 mg/kg), Fe (0.333±0.113 – 1.510±0.042 mg/kg), Zn (0.173±0.007 – 0.406±0.086 mg/kg), Ni (0.035±0.016 – 0.154±0.028 mg/kg), Cr (0.314±0.067 – 0.734±0.234 mg/kg), Pb (0.021±0.002 – 0.089±0.009 mg/kg), Co (0.021±0.004 – 0.049±0.010 mg/kg), and Cd (0.019±0.003 – 0.092±0.002 mg/kg). These were below the World Health Organization/Food and Agricultural Organization maximum permissible limits for heavy metals except for Fe, Cr and As. Pesticides analysis showed that 16 pesticides were detected across sample: DDT and its metabolites (p′p′-DDE and p′p′-DDD), chlordanes (gamma-chlordane and trans-nonachlor), heptachlor, lindane, endosulfan, hexachlorobenzene (HCB), biphenyl, dichlorobiphenyl and 4-4 bipyridinium dichloride, chlorpyrifos, dichlorvos and emamectin. No statistical differences at $p<0.05$ were observed for most pesticides detected. Heptachlor was the most abundant pesticide with the highest concentration recorded in the skin (2.16 ± 1.88 mg/kg), followed by torso (1.58 ± 1.38 mg/kg). Comparing with residue limits set by FAO/WHO and European Union, residual concentrations of heptachlor, lindane, HCB, biphenyl and chlorpyrifos recorded levels exceeding the maximum residue limits. This study revealed that there may be some benefits to human health not only in terms of essential fatty acids such as linoleic and linolenic acids, but also polyunsaturated fatty acids such as arachidonic, eicosapentaenoic and docosahexanoic acids. However, it also highlighted the potential risk associated with the presence of heavy metal and pesticides above tolerable limits, which significantly diminished the nutritional advantages consumers may otherwise derive from the consumption of these meats.

Keywords: Cattle meat, cholesterol, fatty acid profile, heavy metals, pesticide residues.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

The human diet is largely composed of protein, fat, and vitamins (Akan, Abdurahman, Sodipo & Chiroma, 2010; Kurnaz & Filazi 2011; Shaheen et al., 2016). In Nigeria, cattle meat is the most consumed source of animal protein, with 90,000 cattle slaughtered daily (Anuforo, Ogbulie, Elumezie & Nwachukwu, 2020). Different parts of cattle (muscle, liver, kidney, tongue, skin) are used as delicacies in many diets in Nigeria, as it is widely available and can be prepared in various ways (Tongo & Ezemonye, 2015).

Toxic substances in beef tissues can be caused by a variety of sources, including animal drugs, pesticides, feed, and other agricultural or industrial chemicals. Pesticides are used to protect crops from insects, pests, and diseases, and have a positive effect on agricultural production (Maitera et al., 2018). However, these compounds are toxic and can accumulate in soil, exposing grazing animals to pesticides through direct contact, inhalation of contaminated air, or ingestion of contaminated soil and fodder. In Nigeria, cattle graze freely and are exposed to high levels of contaminants in the environment.

Studies have revealed increasing cases of soil contamination by heavy metals due to applications of pesticides, fertilisers, industrial processes, and exhaust gases from automobiles (Hoha, Costăchescu, Leahu & Păsărin, 2014; Ekundayo & Fatoba, 2020). Metals such as copper, cobalt, iron, zinc, and magnesium, are found in both abiotic and biotic components of the ecosystem and have essential functions in human metabolism, but their deficiency and excessiveness can lead to chronic metabolic disturbances (Katnoria, Arora, Bhardwaj & Nagpal, 2011; Wang et al., 2012).

Heavy metals, such as lead, cadmium, mercury, chromium, nickel, and arsenic, can cause profound biochemical and neurological changes in the body, even at low concentrations.

Due to their lipophilic nature, some of these compounds are found adhering to or dissolved in fatty tissues. Eating contaminated food is the most common way for humans to be exposed to heavy metals, which is a cause for concern due to their toxicity, bioaccumulation potentials, and bio-magnification along food chains (Liu et al., 2013; Zwolak, Sarzyńska, Szpyrka & Stawarzyk, 2019). Reports of contamination in meat samples by heavy metals have raised serious questions about food safety and human health (Khalafalla, Abdel-Atty, Abd-El-Wahab, Ali, & Abo-Elsoud, 2015), making it necessary to regularly evaluate food and meat sources to ensure their safety. Therefore, the aim of this study is to determine lipid profile, minerals and pesticide concentration in common cattle parts consumed in Nigeria.

1.2 Statement of the problem

The free-range system of rearing cattle in Nigeria has led to uptake and bio-accumulation of toxic substances from grazing floors and water bodies in tissues of these animals. Most consumers of meat and meat products are unaware or underinformed of the presence of these toxicants in meat and their associated health risks.

1.3 Justification for the study

1. Pesticides and heavy metals can bio-accumulate in the tissues and organs of animals.
2. Consumption of pesticides and heavy metal residues in animals slaughtered for daily consumption pose great health challenges such as nephrotoxicity, neurotoxicity, gastrointestinal disorders etc.

3. This study will reveal the level of these toxic substances and also further establish the need to educate consumers of meat on the adverse health issues these substances could predispose them to.

1.4 Aim and objectives of the study

The aim of this study is to determine the lipid content, heavy metals and pesticide residues of cattle slaughtered at Obinze abattoir, Imo State, Nigeria.

The objectives of the study include;

i. To determine cholesterol concentration in the selected meat parts.
ii. To determine lipid content in the selected meat parts.
iii. To determine the concentration of heavy metals in the selected meat parts.
iv. To determine the residue concentration of pesticides in the selected meat parts.

CHAPTER TWO

LITERATURE REVIEW

2.1 Meat as a source of nutrients

One of the healthiest and most nutrient-dense natural foods that humans eat to meet their daily nutritional needs is meat. It is crucial for maintaining a balanced diet, which is required for the best possible development and growth of humans. Meat is defined by European legislation as edible parts from domestic animals, including goats, cows, sheep, and pigs, as well as poultry farmed animals, and wild animals (European Commission, 2004). Good-quality proteins, different fats (omega-3 polyunsaturated fatty acids), zinc, iron, selenium, potassium, magnesium, sodium, vitamin A, B-complex vitamins, folic acid etc are all abundant in them. While minerals are present in lesser amounts, meat is also a major source of important amino acids. Meat contains fat and fatty acids, which are beneficial and high in calories and micronutrients that support a healthy body weight and provide needed nourishment (Vannice & Rasmussen, 2014). Organ meat, such as liver, is an especially rich source of Vitamin A, Vitamin B_1, nicotinic acid as well as cholesterol (Pareira & Vicente, 2013). The most valuable component in beef is meat protein. It is the building block that makes up muscle tissue. Amino acids are simple organic compounds that combine to form proteins, which are complex molecules. Twenty amino acids are required for human growth and metabolism, eight of these amino acids are considered essential, meaning that our diets must contain them because they cannot be synthesized by our body (Geletu, Usmael, Mummed, & Ibrahim, 2021).

Table 2.1 Nutrient composition of meat

Class of Food	Composition	Reference
Protein	Amino acids; leucine, isoleucine, lysine, methionine, cystine, threonine, tryptophan, valine, phenylalanine, arginine and histidine Peptides; taurine, creatine, hydroxyproline, carnosine, and anserine.	Olaoye, (2011), Wu, (2020), Geletu, Usmael, Mummed, & Ibrahim, (2021),
Lipids	Triglycerides, cholesterol. Fatty acids; saturated fatty acids e.g myristic, lauric, palmitic and stearic acids. Unsaturated fatty acids e.g palmitoleic, oleic, linoleic, linolenic, arachidonic docosahexanioc,	Cabrera & Saadoun, (2014), Dinh, To & Schilling, (2021).
Micronutrients/Minerals	zinc, iron, selenium, potassium, magnesium, sodium, copper, cobalt etc	Soetan, Olaiya & Oyewole, (2010), Cabrera & Saadoun, (2014).
Vitamins	Water soluble vitamins; biotin, folic acid, pyridoxine, choline, thiamin, riboflavin, nicotinic acid, inositol, cyanocobalamin, and vitamins B_6, B_{12} and Vit. C Fat soluble vitamins; vitamin A, D & K	Bourre, (2011), Wyness et al. (2011), Hassan, Sandanger & Brustad, (2012).

2.2 Meat as source of toxic substances

Toxicants found in meat tissues can originate from a range of sources, such as animal drugs, pesticides, feed, and other industrial or agricultural chemical substances (Khalafalla, Ali, Schwagele & Abd-El-Wahab, 2011). Toxicants in the diet are one of the most significant aspects of environmental pollution for humans. Several authors have reported cases of pesticide and heavy metal contamination in meat products (Anuforo, Ogbulie, Elumezie & Nwachukwu, 2020; Ndahi, Maitera, Kubmarawa & Joseph, 2020). Human health is negatively impacted by these harmful substances.

2.3 Pesticides

Any chemical or mixture of chemicals intended to reduce, remove, repel, or prevent pests from harming plants and animals is referred to as a pesticide (Ndahi, Maitera, Kubmarawa & Joseph, 2020). Pesticides are very hazardous compounds that persist in the environment and are mostly employed to eradicate insects, weeds, and fungi (Maitera et al., 2018). Intentional or inadvertent use of pesticides in our surroundings has contributed to their persistence and have negatively impacted ecosystems and non-target organisms.

Herbicides, insecticides, fungicides, fumigants, and rodenticides are among the many target groups for pesticide use (Sharma, Thapa, Manandhar, Shrestha & Pradhan, 2012). Due to their toxicity and persistence in the environment, each type of pesticide or pesticide class has a unique set of environmental concerns (Lamberth, Jeanmart, Luksch & Plant, 2013). Sadly, a significant portion of these chemicals end up in unintended places such as non-target species, the air, water, and soil, which can lead to soil contamination and water pollution (Lovanh, Ruiz-Aguilar, Rothrock jr & Cook, 2012; Miller & Spoolmal, 2012). Furthermore, pesticides can harm a variety of organisms since they are unable to distinguish between species that are targeted and those that are not (Bolognesi & Merlo, 2011).

The utilisation of pesticides in agriculture is particularly prominent, with agriculture being the main consumer of pesticides to control various pests chemically. Traditionally, Nigerian farmers heavily relied on pesticides to control a variety of weeds, insect pests, and diseases, resulting in a high importation of these products (Desalu, Busari & Adeoti, 2014). Pesticides are also used in public health to control vector-borne diseases such as malaria and dengue, as well as to suppress or avoid the proliferation of insects, pests, bacteria, fungi, and algae in various materials (Gilden, Huffling & Sattler, 2010).

Nonetheless, accidental pesticide exposure can pose a serious risk to people and other living things (Sarwar, 2015). Pesticide exposure can occur when a person uses pesticides at work or home, eats or drinks items that have been contaminated with pesticide residue, or breathes in or comes into touch with pesticide-contaminated air (Pimentel, Culliney & Bashore, 2013). Early on, even low exposure levels can have detrimental consequences on one's health at early stages (Damalas & Eleftherohorinos, 2011). The most common causes of both acute and chronic pesticide poisoning include chemical accidents in industry, occupational exposure in agriculture, and consumption of contaminated food. Many health problems, including thyroid dysfunction, low sperm counts in men, birth defects, increased testicular cancer, immune system and reproductive disorders, dermatitis, cancers, immunotoxicity, neurobehavioral and developmental disorders, and endocrine disruptors, have been related to pesticide exposure (Ikpeme, Okonko & Udensi, 2016; Gill & Garg, 2014; Okoffo, Mensah & Fosu-Mensah 2016). There have also been reports of headaches, body pains, coughing, stomach aches, skin and eye irritation, respiratory issues, dizziness, impaired eyesight, and nausea (Okoffo et al., 2016; Jallow, Awadh, Albabo, Devi & Thomas, 2017).

The phrase "pesticide residue" refers to the pesticides that, after being applied to food crops, may end up on or in food (Wolde & Abirdew, 2019). International organizations like the Codex Alimentarius Commission, the National Agency for Food and Drug Administration (NAFDAC), and the World Health Organisation (WHO) regulate the levels of these residues in food (Damalas & Eleftherohorinos, 2011). The main ways that people are exposed to these residues are by consumption of treated food or by being close to places that have been treated with pesticides, like residences' lawns or farms (Damalas & Eleftherohorinos, 2011). These persistent compounds have been found in a variety of goods, including meat, poultry, fish, vegetable oils, nuts, fruits, and vegetables (Grewal, 2017).

2.3.1 Classification of pesticides

Insecticides, fungicides, herbicides, garden chemicals, household disinfectants, and rodenticides are all included in the broad category of pesticides, which are used to eradicate and deter pests (El Nemr, Mohamed, El-Sikaily, Khaled & Ragab, 2012; El Nemr, Moneer, El-Sikaily & Khaled, 2012; El Nemr, Moneer, Khaled & El-Sikaily, 2012). It's critical to categorize and research these pesticides according to their distinct groupings as their chemical and physical properties vary. The three most popular methods for classifying pesticides are their chemical makeup, mode of entry, and how they affect the organisms they kill (Yadav et al., 2015). The most widely accepted method for classifying insecticides is based on their chemical composition and active ingredients (Hassaan & El Nemr, 2020).

2.3.1.1 Organochlorines

These were the first synthetic organic pesticides used in agriculture and public health; they include five or more chlorine atoms (Bajwa et al., 2016). Although they work very well against a variety of insects, they have been connected to harmful consequences for the environment and human health (Nuapia, Chimuka & Cukrowska, 2016; Rani, Shanker & Jassal, 2017). Organochlorines are difficult to degrade in the environment because they are hydrophobic, persistent, and resistant to degradation (Muzyed, Kucuksezgin & Tuzmen, 2017; Wang et al., 2017). Moreover, they can adhere to human and animal fatty tissues due to their lipophilic nature, which causes long-term buildup in soil, water, sediments, and plants (Taiwo, 2019). These pesticides are present in human bodily tissues for extended periods, including breast milk, adipose tissue, and blood (Padhi & Pati, 2016). Organochlorines act as neurotoxins, causing convulsions and paralysis of the insect, leading to its death (Thomas et al., 2017). Long-term exposure to organochlorines can lead to endocrine disruption, neurotoxicity, cancer, and other adverse health effects (Bonnineau et al., 2016). Structurally, organochlorines fall into five classes (Blus, 2003): (1) DDT and its analogs including DDT and dichlorodiphenyldichloroethylene (DDE); Dichlorodiphenyldichloroethane (DDD) (2) hexachlorocyclohexane (HCH), such as lindane; (3) cyclodienes including aldrin, dieldrin, endrin, heptachlor, chlordane, and endosulfan; (4) toxaphene; and (5) mirex and chlordecone as seen in figure 2.1. The field half-life time of some organochlorines such as DDT, DDE and DDD) is 15 years, while for aldrin and toxaphene is 365 and 9 days respectively (Sparling, 2016). The acute toxicity of most organochlorine pesticides (OCPs) generally occurs at concentrations that are higher than those considered environmentally realistic so death under natural conditions may be slow and often is seen as a general wasting away or chronic illness. The lipophilic and persistent nature of most OCPs can lead to long-term storage in adipose tissue, followed by a release into the circulatory system during harsh environmental conditions. This can cause delays from the time of first exposure to the onset of effects. DDT can remain in the human body for 50 years or more (Mrema et al., 2013)

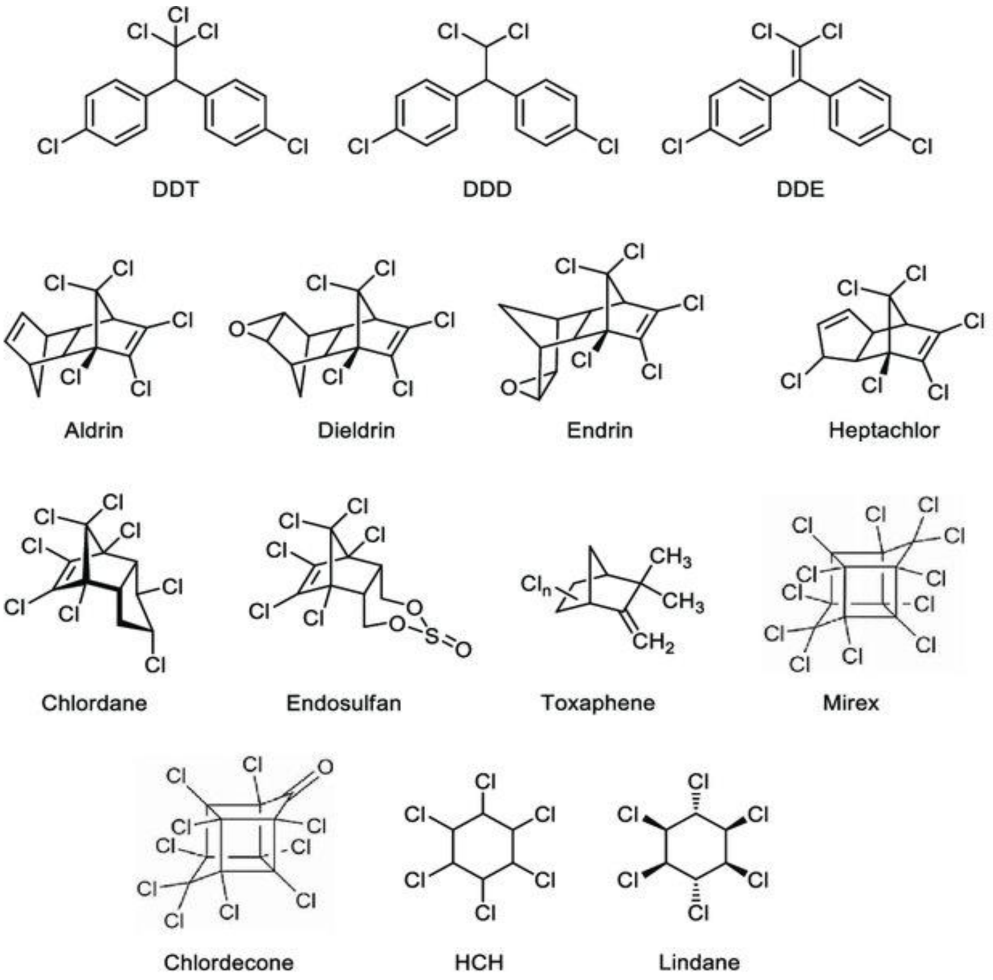


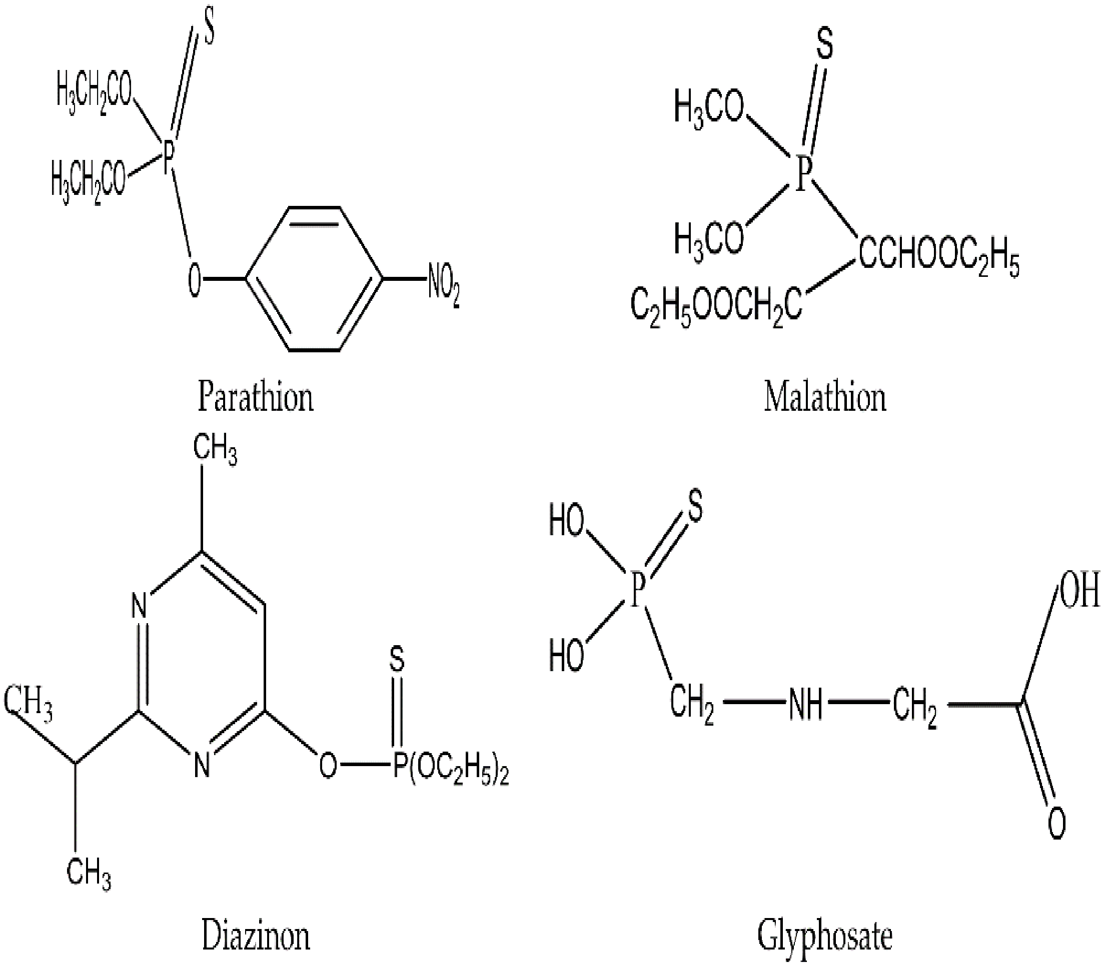
Figure 2.1: Structure of common organochlorines (Hassan & El Nemr, 2020)

2.3.1.2 Organophosphates

Although organophosphates were initially developed in the early 1800s, it wasn't until 1932, that their effects on insects, which are comparable to those on humans were identified (Ko, Shin, Kim, Kim & Son, 2014). These substances are a broad category of chemicals that are utilized in both industrial and household contexts, including anthelmintics, nerve gases, and insecticides (García-Reyes, Gilbert-López, & Molina-Díaz, 2010). Acetylcholinesterase (AChE), an enzyme that hydrolyzes acetylcholine in nerve synapses, is inhibited by organophosphates. Acetylcholine (ACh) accumulates as a result, and ACh receptors are overstimulated (Yatendra, Joshi, Singh, Joshi & Kumar, 2014). Acute poisoning can cause respiratory failure due to inhibition of central (medullary) respiratory drive, excessive bronchial secretions, and bronchospasms coupled with depolarizing blockade at neuromuscular junctions (diaphragm and inter-costals) (Yatendra et al., 2014; Eze, Ndu & Edelu, 2018).

Cholinesterase activity is inhibited by organophosphates (Seebunrueng, Santaladchaiyakit & Srijaranai 2014). Muscle twitching and weakening result from the body's nerves continuously signaling the muscles when the enzyme is unable to carry out its intended activity. Convulsions and possibly death may result from severe poisoning (Ren & Xia, 2016). According to Pirsaheb et al. (2013), these substances are irreversible cholinesterase inhibitors, meaning that it will take several days, weeks, or even months for the level of enzyme activity to return to normal. Mild poisoning can cause fatigue, headache, and dizziness (Zhao, Zhao, Han, Jiang & Zhou, 2007), while moderate poisoning can lead to difficulty in walking, weakness and chest discomfort.

In Nigeria, organophosphate pesticides are extensively utilized, especially against mosquitoes and other home pests including bed bugs and cockroaches. The locally produced “Otapiapia variant” is the most widely used source of organophosphate insecticide/pesticide in Nigeria (Eze et al., 2018). This substance, which is sold on the streets, contain 5–10% w/v dichlorvos, also known as 2, 2-dichlorovinyl dimethyl phosphate (DDVP). Another popular DDVP variation is called "Sniper," which is more sophisticated and costs more in retailers around the country. Organophosphate poisoning can be suicidal, unintentional, or homicidal, and it can happen by ingestion, inhalation, or penetration through the intact skin (Razweidani & Rautenbach, 2017; Eze et al., 2018). Among the commonly used organophosphorus pesticides include glyphosate, diazinon, parathion, and malathion, as shown in figure 2.2.



Parathion Malathion

Diazinon Glyphosate

Figure 2.2: Structure of common organophosphates (Mdeni et al., 2022)

2.3.1.3 Carbamates

Carbamates are inorganic compounds derived from carbamic acid (NH_2COOH) (fig.2.3), and were first marketed as insecticides in 1951 (Nantia et al., 2017). They function by blocking cholinesterase and influencing nerve impulse transmission, much like organophosphates (Zhou et al., 2018). Although carbamates are often used in homes, gardens, and agriculture, their environmental half-lives are brief due to a hydrolysis reaction that converts them into simple, non-toxic chemicals (Rahman et al., 2017). After cutaneous exposure, inhalation, or ingestion, they might result in acute cholinergic poisoning, which can produce symptoms including headaches, vomiting, cramping in the abdomen, uncontrollably urinating or defecating, and even a condition of unconsciousness (Nantia et al., 2017).

2.3.1.4 Pyrethroids

Conversely, pyrethroids are artificial insecticides that are made from chrysanthemum flowers; they are sometimes referred to as pyrethrin (Farajzadeh et al., 2014). Because of their strong insecticidal action, rapid environmental degradation, and relative low toxicity to mammals, they are extensively utilized in horticulture, public health, veterinary medicine, forestry, and agriculture (Hu et al., 2016). Their action on the central nervous system alters the dynamics of the sodium ion channels in the nerve cell membrane, leading to neuronal hyper-excitation, which kills insects through touch or ingestion (Ccanccapa-Cartagena et al., 2017; Yu et al., 2018). Most pyrethroid insecticides (Fig. 2.4) share several characteristics such as low toxicity to birds and mammals; high toxicity to arthropods since it requires very low doses to kill insects; highly toxic to fish if applied directly to water; and fast-acting especially against chewing insects (Hassan & El Nemr, 2020).

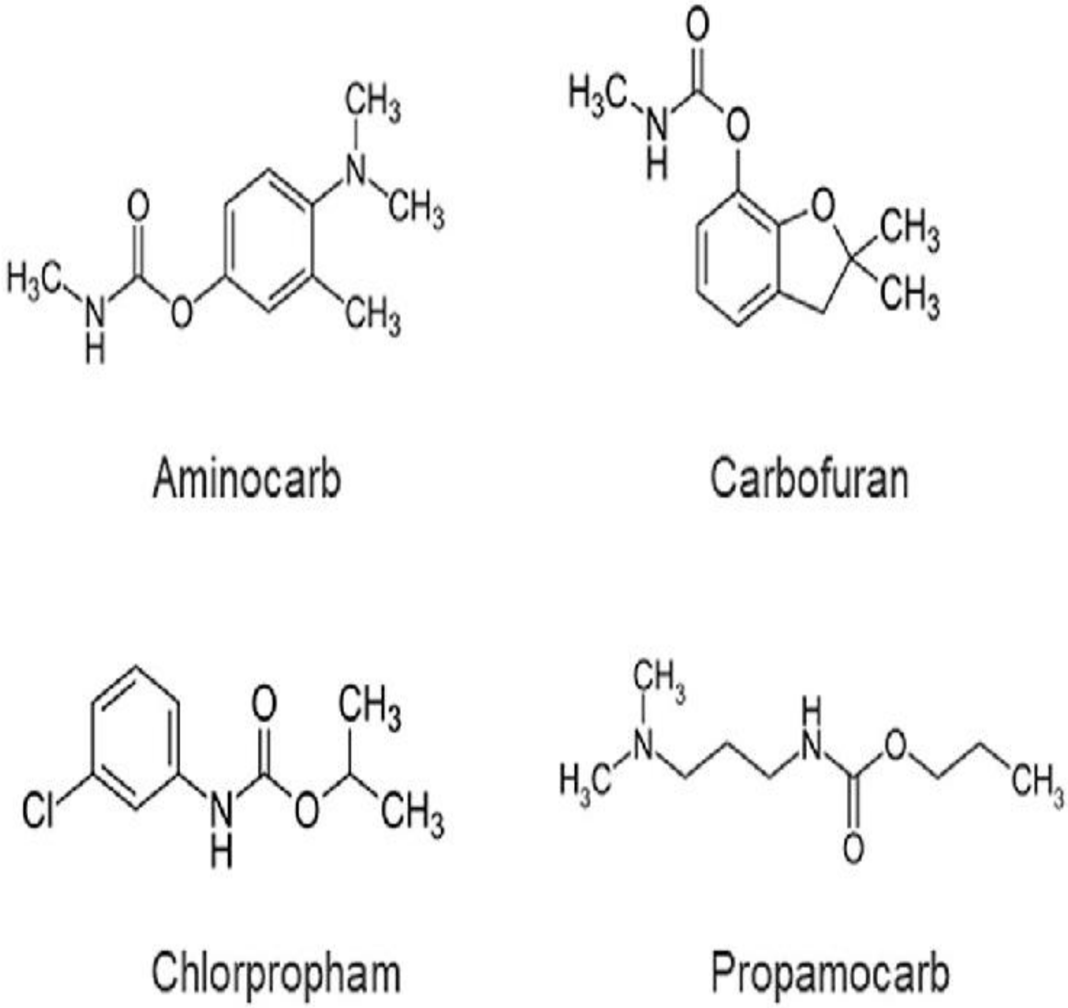
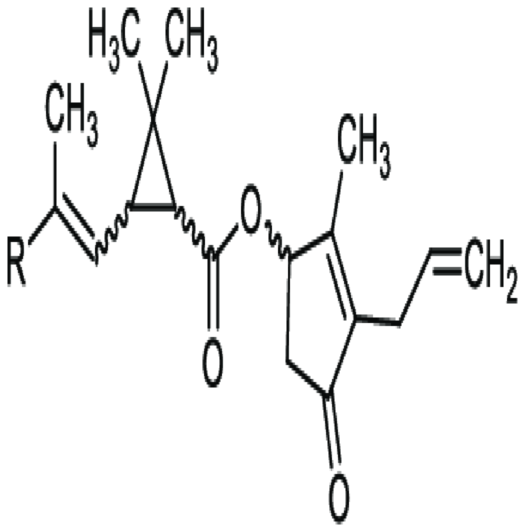


Figure 2.3: Structure of some common carbamates (Guéniche et al., 2020)



Pyrethroid

Figure 2.4: General structure of pyrethroids (Hassan & El Nemr, 2020)

2.4 Heavy metals

The term "heavy metals" is used to refer to a group of metals and metalloids that have been linked to contamination and potential toxicity to the environment and to various species of organisms (Briffa, Sinagra & Blundell, 2020). The United States Environmental Protection Agency (USEPA) (2024), defines heavy metals as a group of naturally occurring metallic elements of high molecular weight and density when compared to water. These metals are naturally occurring in the earth's crust and have a specific gravity of greater than 5 g/cm^3 or at least five times that of water (Duffus, 2002). Recently, the definition has been expanded to include naturally occurring elements with atomic numbers greater than 20 (Hazrat & Ezzat, 2018; Hazrat, Ezzat & Ikram, 2019). There are essential and non-essential components in heavy metals. Iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), cobalt (Co), nickel (Ni), molybdenum (Mo), and selenium (Se) are among the elements that are considered essential. They are necessary for basic metabolic processes in living things, which makes them essential. On the other hand, certain metals may have harmful physiological consequences if they are present in organisms in excess. Lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), tin (Sn), aluminium (Al), silver (Ag), gold (Au), antimony (Sb), bismuth (Bi), palladium (Pd), platinum (Pt), vanadium (V), strontium (Sr), tellurium (Te), titanium (Ti), uranium (U), and chromium (Cr), especially the hexavalent form (Cr VI), are examples of non-essential heavy metals that have no known advantages for living systems and can be toxic at low concentrations (Tchounwou, Yedjou, Patlolla & Sutton, 2012). These metals have the potential to contaminate drinking water sources or enter the food chain through bioaccumulation in plants and animal species. The latter is particularly dangerous in developing countries like Nigeria, where a large number of rural communities depend on exposed, unprotected surface water sources for domestic, recreational, and drinking needs.

The bulk of heavy metals are naturally occurring in the environment, but the amounts brought about by human activity are primarily responsible for the health risks they pose to the general people and the ecosystem. The production, use, and disposal of electronic devices, the mining, smelting, and burning of trash and biomass, industrial effluents, and other human-initiated activities all contribute to the release of heavy metals into the environment. In Nigeria, there have been recent cases of heavy metal poisoning and potential significant pollution, making it necessary to monitor them continuously. For example, in 2010, the Centre for Disease Control and Prevention (CDC, 2016) stated that the greatest known incidence of lead poisoning in history occurred in the Zamfara communities in Northern Nigeria, killing 163 people, including 111 children. This resulted from the high quantities of lead present in gold ores mined illegally and without authorization, which contaminated drinking water supplies and land. Children with high blood lead concentrations had symptoms including headaches, vomiting, stomach pains, seizures, and even death (Orisakwe, Oladipo, Ajaezi & Udowelle, 2017). This has prompted a great deal of individual research to determine the presence of heavy metals in different samples.

In general, the hazards associated with heavy metals outweigh their advantages; for instance, antimony and chromium can increase carcinogenicity (Sun, Brocato & Costa, 2015; Sundar & Chakravarty, 2010), and lead poisoning can induce intellectual anomalies in children (Hou et al., 2013). Mina-mata illness can be caused by mercury toxicity, whereas itai-itai sickness is caused by cadmium poisoning. Additionally, specific human organs, including the kidneys, brain, liver, skin, and heart, are susceptible to the harmful effects of heavy metals (Mitra et al., 2022).

2.4.1 Sources of heavy metal pollution

Two primary pathways lead to the relaese of heavy metals into the environment: natural resources and human activity (anthropogenic activities). Volcanic eruptions, weathering, and surface erosion are examples of natural sources (Burakov et al., 2018; Singh et al., 2021). Additional ways that environmental contamination can happen, including metal corrosion, atmospheric deposition, soil erosion, leaching of heavy metals from various sources like landfills, waste dumps, excretion, livestock and chicken manure, sediment re-suspension, and metal evaporation from water resources to soil and groundwater (Arruti, Fernandez-Olmo & Irabien, 2010). Environmental pollution is caused by industrial sources such as paper processing plants, plastics, textiles, microelectronics, wood preservation, coal burning in power plants, petroleum combustion, metal processing in refineries, high-tension lines, and nuclear power plants (Hazrat et al., 2019). A secondary cause of heavy metal contamination in agricultural areas has been the use of heavy metals in pesticides, insecticides, fertilizers, and other products (Gautam, Gautam, Banerjee, Chattopadhyaya & Pandey, 2016).

2.4.2 Heavy metal toxicity

Due to their toxicity, heavy metals are known to be persistent in the environment and to contaminate food systems, which can result in several health problems. Their non-degradable character is the primary cause of their build-up in a variety of organisms (El-Sharif, Tolani, Ofosu, Mohamed & Wanekaya, 2013; Abbas et al., 2016; He et al., 2020). In addition, heavy metals are easily absorbed by a variety of species due to their solubility in aqueous environments. When these metals find their way into the food chain, however, they build up significantly and have detrimental effects in living things (Akpor, Ohiobor & Olaolu, 2014; Harvey, Handley & Taylor, 2015; Bharteria & Singh, 2019).

Depending on the dose and duration of exposure, heavy metals can be toxic to living things even though certain heavy metals (essential heavy metals), are necessary for biological systems. Even in low quantities, non-essential heavy metals like Cd, Pb, and Hg, as well as metalloids like As, can be hazardous. The body requires trace amounts of essential heavy metals, but over specific threshold concentrations or limits, they can become poisonous. The window of toxicity and essentiality for particular elements is constrained. It has been found that heavy metals are teratogenic, mutagenic, and carcinogenic. They can produce reactive oxygen species (ROS), which can lead to oxidative stress. In organisms, oxidative stress can result in the emergence of a number of illnesses and abnormalities. In addition, heavy metals can be metabolic toxins. According to Hossain et al. (2012), toxic heavy metal species have the ability to attach to proteins and alter the target molecule's biological activity. Certain heavy metals can also participate in catalytic reactions, such as Fenton-type reactions, resulting in the production of ROS (Kim, Kim, & Seo, 2015).

2.4.3 Sources and toxicity of selected heavy metals

2.4.3.1 Chromium

Utilized in industrial processes, chromium is a naturally occurring heavy metal that can be found in seawater and in the earth's crust (Tchounwou et al., 2012). It exists in a variety of oxidation states, the most prevalent stable forms being trivalent and hexavalent (Shekhawat, Chartterjee & Joshi, 2015). Cr (VI) is linked to a variety of illnesses and pathologies, but Cr (III) is necessary in trace amounts for normal lipid and protein metabolism as well as a cofactor for insulin action

(Achmad, Budiawan & Ibrahim, 2017; Vincent, 2017; Vincent, 2019). Non-occupational human populations are mostly exposed to chromium through the consumption of food and water containing chromium or through skin contact with chromium-containing goods. Furthermore, a large amount of chromiun is released into the air, ground water, and soil by the metallurgical, refractory, and chemical sectors (Nickens, Patierno & Ceryak, 2010). This can harm marine life, humans, and animals. (Fang et al., 2014). Through bioaccumulation in the human body, chromium can lead to a range of diseases such as neurological, gastrointestinal, lung, larynx, kidney, testicular, bone, and thyroid malignancies, as well as dermal and renal problems (Fang et al., 2014). Hexavalent chromium is categorized as a group I occupational carcinogen in the 2018 International Agency for Research on Cancer (IARC) Report (Loomis, Guha, Hall & Straif, 2018). According to a recent meta-analysis, persons who are exposed to Cr (VI) may have higher rates of death and certain malignancies, such as lung, throat, bladder, kidney, testicular, bone, and thyroid cancer (Deng et al., 2019). An additional study conducted in India in 2012 found that people exposed to groundwater contaminated with Cr (VI) had a higher frequency of GI and dermatological problems (Sharma et al., 2012). It is believed that chromium toxicity and carcinogenicity are caused by DNA damage, genomic instability, and ROS formation; Cr (VI) and Cr (III) can both produce ROS (Pavesi & Moreira, 2020). Chromium carcinogenicity is thought to be caused by DNA damage due to disruption of transcription regulation.

2.4.3.2 Cadmium

Cadmium is a non-essential element that is naturally present in all soils (Smolders & Mertens, 2013) and is the seventh most toxic trace element (Jaishankar et al., 2014). It is naturally occurring in soil, minerals, carbonate, hydroxide, and sulphide salts (Balali-Mood, Naseri, Tahergorabi, Khazdair & Sadeghi, 2021). All soils and phosphate fertilizers include trace amounts of cadmium, which is harmful to almost all of the animal body's systems (Akan et al., 2010). Sources of cadmium contamination could also include small-scale workshops, garages, and municipal sources (batteries, fertilizers, oil from garage wastewater, etc.) (Wuana & Okieimen, 2011). Moreover, smoking can expose oneself to cadmium and raise blood and urine cadmium concentrations. Water contaminated with cadmium has the potential to cause short- or long-term problems by interfering with the body's required mechanisms (Jiang et al., 2015; Richter, Faroon & Pappas, 2017; Cao et al., 2018). The International Agency for Research on Cancer (IARC), Cd is classified as carcinogenic to humans (Group 1) (Kim et al., 2020).

Cadmium is bio-persistent once absorbed by an organism and stays in the body for a considerable amount of time before being eliminated. Humans who are exposed for an extended period may experience renal dysfunction; excessive exposure has been connected to lung cancer and obstructive lung disease (Tuzen, Sahiner, & Hazer, 2016). In both humans and animals, cadmium can also result in bone abnormalities e.g., osteoporosis (Zhang et al., 2011). It interacts with DNA repair pathways, produces reactive oxygen species (ROS), and induces apoptosis in addition to affecting cell proliferation, differentiation. Cadmium can mimic the function and behaviour of essential metals, such as zinc, by binding to albumin in plasma, which can lead to dysregulation of calcium, zinc, and iron homeostasis (Schaefer, Dennis & Fitzpatrick, 2020). One possible link between Cd-induced liver damage is the disruption of calcium (Ca) homeostasis.

Cadmium plays a key role in cardiovascular diseases caused by smoking, such as peripheral artery disease and coronary heart disease. It may also give rise to the occurrence of kidney, lung, pancreas, breast, prostate, and GI cancers (Djordjevic et al., 2019; Lin et al., 2018; Li et al., 2019). A proposed mechanism involves the formation of ROS, elevation of TNF-α level, overexpression of Nrf2, and eventually, aberrant gene expression, dysregulation of cell proliferation, and resistance to apoptosis (Wang et al., 2018). One prominent theory for the toxicity and cancer progression associated with cadmium exposure is the interaction of reactive nitrogen species (RNS) and ROS with cellular macromolecules, including proteins, lipids, and DNA (Aggarwal et al., 2019).

2.4.3.3 Iron

Iron is the 26th element in the periodic table and the second most common metal in the crust of the earth. It can be detected in surface water due to human activities like mining (Jaishankar et al., 2014). For many different proteins and enzymes, iron is a cofactor. Since iron is required for the synthesis of hemoglobin and other hemoglobin-containing enzymes, it is a vital trace element for all life forms (Food and Agricultural Organisation [FAO], 2011). It is a component of hemoglobin and myoglobin and participates in delivering oxygen to the muscles and blood (Aggett, 2012). Iron exists in two states, divalent ferrous (Fe^{2+}) and trivalent ferric (Fe^{3+}), with most dietary iron being in the ferric form. Therefore, it needs to be reduced before it can be absorbed. In addition, development, growth, and proper cellular function all depend on iron, as does the synthesis of hormones and connective tissue (Attar, 2020). Anemia, which is characterized by weakness, vertigo, shortness of breath, difficulty concentrating, heart palpitations, fatigue, and paleness in the hands and eyelids from low oxygenated hemoglobin levels, can result from an iron deficiency. On the other hand, an overload of iron can contribute to multiple degenerative diseases, including cancer, heart attack, liver fibrosis and oxidative stress (Bresgen & Eckl, 2015; Attar, 2020). In animals, high levels of Fe can cause depression, coma, convulsion, respiratory failure and cardiac arrest. In humans, excessive Fe intake may result in siderosis (deposition of Fe in tissue) in the liver, pancreas, adrenals, thyroid, pituitary and heart (FAO, 2011).

2.4.3.4 Lead

One dangerous environmental pollutant that can have devastating effects on the body's organs is lead. The stomach and respiratory systems are the primary routes of absorption (Balali-Mood et al., 2021). By blocking two important heme biosynthesis pathway enzymes, ferrochelatase and δ-aminolevulinic acid dehydratase (ALAD), lead poisoning can cause anemia as seen in figure 2.5. This disruption of the heme biosynthesis process can cause anaemia (Godwill et al., 2015; Balali-Mood et al., 2021; Ohiagu et al., 2022). Elevated Pb levels in humans can be hazardous to the kidneys, gastrointestinal tract, joints, reproductive system, synthesis of hemoglobin, and brain system, both acutely and over time (Pandey & Madhuri, 2014). Due to oxidative, inflammatory, and immune-modulatory pathways, lead exposure can also result in neurological, pulmonary, urinary, and cardiovascular diseases (Balali-Mood et al., 2021). Furthermore, Pb can cause inflammatory reactions in several organs and upset the equilibrium of the antioxidant-oxidant system.

Oxidative stress can arise from Pb exposure in humans due to a reduction in the levels of antioxidant enzymes such as glutathione reductase (GR), catalase (CAT), superoxide dismutase (SOD), glutathione peroxidase (GPx), and glutathione oxidized (GSSG) and thiol antioxidant molecules (Balali-Mood et al., 2021). Because Pb has a strong binding affinity for the reactive sulfhydryl (-SH) group of GSH, it can lower the amount of GSH in tissue (Balali-Mood et al., 2021). Human exposure to Pb also affects the antioxidant roles of metalloproteins including GPx, CAT, and SOD in the detoxification of free radicals. Oxidative damage to organs may result from this.

Lead can modify intracellular second messenger systems, which can interfere with the functions of the central nervous system (CNS) (Brown & Margolis, 2012). In addition to causing DNA damage, Pb may also change the DNA repair system and cellular cancer-regulating genes by generating reactive oxygen species (ROS). The ROS generated play a major in the alteration of structure and sequence of human chromosomal sequence (Ohiagu et al., 2022). By replacing zinc in some regulatory proteins, Pb can also impede the transcription process (Engwa et al., 2019).

Acute Pb poisoning can result in hallucinations, headaches, stomachaches, lethargy, appetite loss, impaired kidney function, dizziness, and arthritis (Martin & Griswold, 2009). Chronic lead poisoning can cause mental distortion, learning disabilities, autism, allergies, birth defects, renal failure, neurological impairments, muscle weakness, coma, and even death (Attar, 2020; Ohiagu et al., 2022).

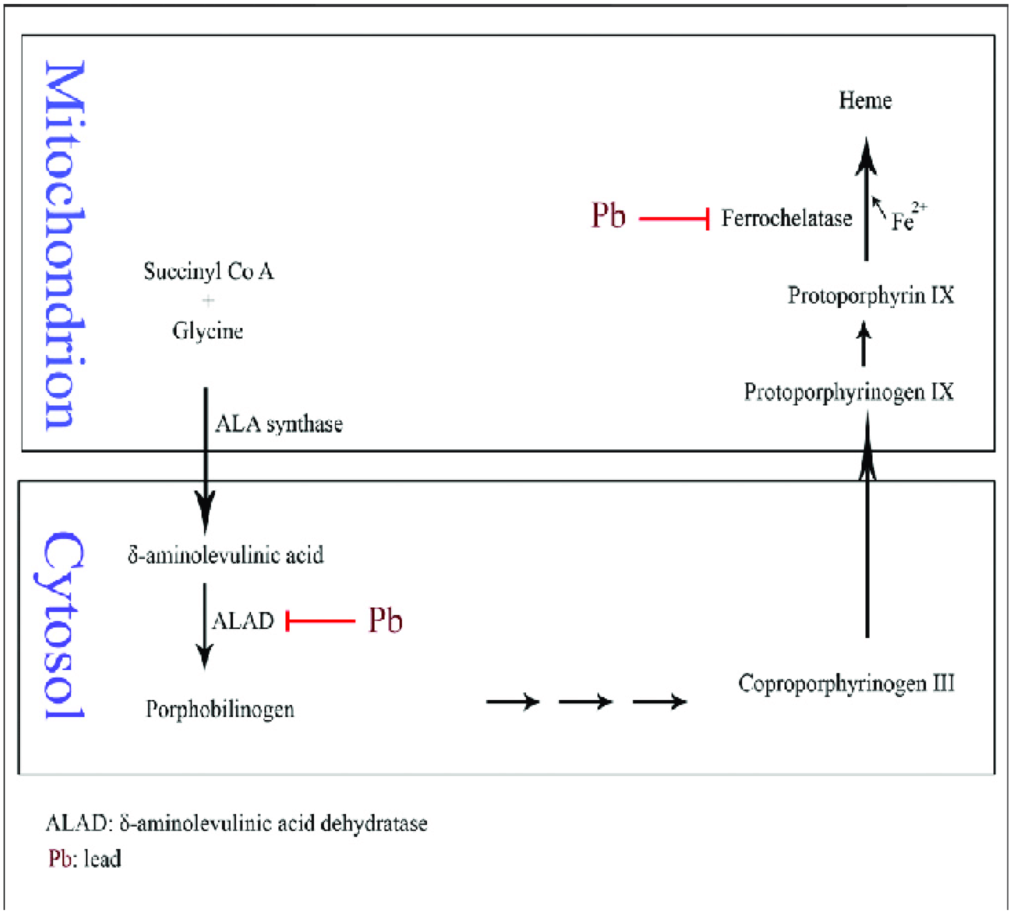


Figure 2.5: Scheme of Pb-induced anemia via the inhibition of δ-aminolevulinic acid dehydratase and ferrochelatase enzymes in heme biosynthesis (Balali-Mood et al., 2021).

2.4.3.5 Arsenic

Arsenic is a ubiquitous priority pollutant that can be found in the atmosphere, soils, rocks, natural waterways, and living things (Sun et al., 2014). Arsenic exposure can come from both man-made and natural sources. Anthropogenic causes include the smelting process, the application of gallium arsenide in the microelectronics sector, and the presence of arsenic in everyday goods including paints, insecticides, herbicides, and wood preservatives (Mandal, 2017). Furthermore, one frequent contaminant that can spread widely as a result of burning fossil fuels is arsenic (Balazs, Morello-Frosch, Hubbard & Ray, 2012).

The toxicity of an arsenic-containing compound is dependent on its valence state (zero-valent, trivalent, or pentavalent), its form (inorganic or organic), and factors that modify its absorption and elimination (Tyler & Allan, 2014). Trivalent arsenic is more harmful than pentavalent and zero-valent arsenic, and inorganic arsenic is often more lethal than organic arsenic (Tangahu et al., 2011). Heart problems including atherosclerosis, ischemic heart disease, ventricular arrhythmias, and hypertension are linked to human exposure to inorganic arsenic. After being ingested, arsenic builds up in soft tissue organs such as the liver, spleen, kidneys, and lungs; however, keratin-rich tissues like skin, hair, and nails are the main arsenic long-term storage sites (Sikdar & Kundu, 2018).

Many dysfunctions of important enzymes are associated with both acute and chronic arsenic poisoning. Like other heavy metals, arsenic can cause the malfunctioning of sulfhydryl group-containing enzymes by inhibiting them. Acute arsenic poisoning is known for being extremely fatal, because it destroys the integrity of blood vessels and gastrointestinal tissue in addition to harming the heart and brain (Ventura-Lima, Bogo, & Monserrat, 2011). Low amounts of arsenic exposure over time can induce blood vessel damage, diabetes, skin hyperpigmentation, and peripheral nerve damage, all of which can lead to gangrenous conditions affecting the limbs (Alissa & Ferns, 2011; Tyler & Allan, 2014). Long-term exposure to arsenic raises the risk of a number of cancers, including skin cancer, liver (angiosarcoma) cancer, lung, bladder, and maybe kidney and colon cancer (Kim et al., 2015). Moreover, arsenic binds to the lipoic acid moiety of pyruvate dehydrogenase to block it. This may prevent oxidative phosphorylation and stop the Krebs cycle, which would reduce ATP synthesis and cause harm to cells (Shen et al., 2013).

2.4.3.6 Nickel

Nickel is the 28th element on the periodic table and can exist in a range of oxidation states, from -1 to +4. According to Munoz and Costa (2012), the +2 oxidation state (Ni^{2+}) is the most prevalent form of nickel and is found in both the environment and biological systems. Nickel is a naturally occurring element that can be found in soil, meteorites, volcanic eruptions, and the earth's crust as sulphides and oxides (Ohiagu et al., 2022). Furthermore, the sea contains significant concentrations of nickel (Genchi et al., 2020). Human activities that emit nickel into the atmosphere include burning coal, fuel oil, diesel, and garbage; they also include smoking, using stainless steel and kitchen utensils, and making some types of jewelry (Genchi et al., 2020; Ohiagu et al., 2022). Nickel can also be found in several vegetables, chocolate, cocoa, and nuts (Carocci et al., 2016; Lavinia et al., 2018). Numerous health issues, including lung fibrosis, kidney and cardiovascular disorders, and respiratory tract cancer, can result from exposure to places with high levels of nickel (Zhao, Shi, Castranova & Ding, 2009; Zambelli & Ciurli, 2013). According to the International Agency for Research on Cancer (IARC, 2012), nickel and alloys are categorized as Group 2B (possibly carcinogenic to humans) and soluble and insoluble Ni compounds as Group 1 (agents that cause cancer in people).

Nickel also has the ability to inhibit certain enzymes that do not require metal cations for catalysis. This happens when nickel binds to particular amino acids, like cysteine, histidine, glutamate, and lysine, at the enzyme's active site, blocking the enzyme's ability to function (Ohiagu et al., 2022). As an alternative, nickel can attach to the enzyme's secondary sites and change how active it is. Additionally, nickel has been shown to cause cell death (Ohiagu et al., 2022).

2.4.3.7 Copper

Nature contains both elemental and compound forms of copper. According to Gaetke, Chow-Johnson & Chow (2014), it can exist as cupric ion (Cu^{2+}) or cuprous ion (Cu^{+}) depending on whether it is reduced or oxidized. Both man-made and natural processes, including the manufacture of iron and steel, municipal incinerators, and Cu smelters, as well as natural sources including volcanoes, forest fires, and wind-blown dust, release copper into the atmosphere (Pohl et al., 2011). Contaminated drinking water, vitamin and mineral supplements, birth control tablets, Cu cookware, Cu intrauterine devices, and Cu water pipes are some examples of environmental sources of copper (Pohl et al., 2011). Copper is necessary for the proper functioning of connective tissue components, including tendons, ligaments, skin, hair, nails, arteries, and veins, as well as for the metabolism of calcium in bones (Kopach et al., 2021).

Copper is also an essential component of several enzymes, such as lactase, tyrosinase, ascorbic acid oxidase, catalase, peroxidase, cytochrome oxidase, and monoamine oxidase (SOD). Superoxides in animal tissues can be converted to oxygen and hydrogen peroxide with the aid of copper, which is present in SOD (Angelova et al., 2011). Copper is a vital micronutrient that the neurological and hematopoietic systems require. It is essential for bone growth and formation, the development of myelin sheaths in the nervous systems, the incorporation of iron into hemoglobin, the absorption of iron from the gastrointestinal tract, and the transfer of iron from tissues to plasma (Al-fartusie & Mohsan, 2017).

In biological systems, copper ions can initiate the generation of reactive oxygen species (ROS) and be reduced to Cu^+ in the presence of biological reductants such as ascorbic acid or GSH. The Cu^+ then promotes the decomposition of hydrogen peroxide (H_2O_2) into hydroxyl radical (OH•) through the Fenton reaction. The OH• that is produced can react negatively with various biomolecules. Copper has also been linked to initiating breaks in DNA strands as well as DNA base oxidation from ROS generation (Ohiagu et al., 2022). Copper buildup in the liver and other body organs is linked to neurological and hepatic disorders, including hepatitis, as well as motor deficits and cognitive or mental impairments. Wilson's illness may be brought about by the presence of copper in the hepatocytes (Gaetke et al., 2014; Ohiagu et al., 2022). Copper can also cause human apoptosis through routes that are both p53 dependent and independent (Rana, 2008). Hepatotoxic and neurotoxic anomalies have been linked to apoptotic disease, which is brought on by Cu toxicity (Rana, 2008; Ohiagu et al., 2022). Cu^{2+} has been reported to induce apoptosis of the liver cells via the activation of acidic sphingomyelinase and the release of ceramide (an apoptotic signal (Lang, Ullrich, & Gulbins, 2011).

2.4.3.8 Zinc

Zinc is a trace element that occurs naturally in its divalent state (Terrin et al., 2015). Industrial sources and human activities that produce zinc include zinc and brass metal works, wood pulp production, newsprint paper manufacture, steel works with galvanizing lines, and brass platting (Mohan et al., 2020). It is important in the metabolism of proteins, carbohydrates, lipids, and energy and is a necessary component of numerous enzymes. Zinc is also essential for many bodily systems to work properly. It is involved in insulin activity, development and division of cells, testicular and ovarian metabolism, and liver function (Osredkar & Sustar, 2011; Burjonrappa and Miller, 2012).

Zinc deficiency can cause impaired cognitive function, memory loss, immune system dysfunction, problems with spatial learning, neuronal atrophy, and other disorders. In more severe situations, zinc deficiency can result in weight loss, delayed wound healing, taste anomalies, mental lassitude, hair loss, impotence, delayed sexual development, and hypogonadism in males (Al-fartusie & Mohsan, 2017). It can also impact energy metabolism, acidosis, blocking protein production, alcohol intoxication, and transmutation reaction inhibited superoxide radical-mediated cell death (Grissinger, 2011; Greenberg & Vearrier, 2015).

Excessive intake of Zn can lead to noticeable abdominal pain, nausea, vomiting and eventual anemia (Attar, 2020), shaking, fever and fatigue (Bartzatt, 2017). High zinc levels can also inhibit the body's ability to absorb copper and iron, which can result in deficiencies in the cell (Kasozi et al., 2021). This can also cause gastrointestinal disorders and a disruption in the body's lipid metabolism. It has even been suggested that improper regulation of zinc homeostasis may play a role in the onset and progression of Alzheimer’s disease (Lee, 2018; Attar, 2020).

2.4.3.9 Manganese

The majority of mammals need manganese in order to function normally. It is an ingredient in many different products and is used as an oxidant for cleaning, bleaching, and disinfecting (as potassium permanganate) (WHO, 2011). Manganese is a cofactor that binds to and controls enzymes in the body, including pyruvate carboxylase, arginase, and superoxide dismutase. It is necessary for healthy bone formation, reproduction, and central nervous system operation.

Manganese aids in the formation of bones, connective tissue, blood-clotting factors, and sex hormones (Al-fartusie & Mohsan, 2017). Additionally, it affects blood sugar regulation, calcium absorption, and the metabolism of fat and carbohydrates (Henn et al., 2010; Silva et al., 2013). It is also a part of the SOD antioxidant complex, which aids in the defense against free radicals (Treiber et al., 2012; Al-fartusie & Mohsan, 2017).

Male and female reproductive failure can result from deficiencies in manganese (Saraf & Samant, 2013). Additionally, several disorders like osteoporosis that are linked to skin lesions and bone malformations have been linked to it (Onyedikachi, Belonwu, & Wegwu, 2019). According to Sriram et al. (2010), an excessive buildup of manganese in the mitochondria can upset equilibrium and result in mitochondrial dysfunction. Moreover, overexposure to Mn in the brain can be neurotoxic, and has been implicated in several neurodegenerative disorders such as Alzheimer's disease (Yawei et al., 2014; Du et al., 2017; Paglia et al., 2016; Martins et al., 2019).

2.4.3.10 Cobalt

In the form of vitamin B_{12}, cobalt is an essential nutrient (Leyssens et al., 2017). It is required to manage anemia linked to the malabsorption of vitamin B_{12} in humans during ulceration (Malek & Sacher, 2014). Deficits in the neurological, endocrine, hematological, and cardiovascular systems can result from co-toxicity (Catalani et al., 2012; Apostoli et al., 2013). Excess cobalt in the human body can lead to hypothyroidism, overproduction of erythrocytes, occupational asthma, lung fibrosis, and disruption of thyroid gland iodine metabolism (Maier & Glazer, 2011; Attar, 2020). Additionally, cobalt normalizes blood pressure, and vascular reactivity, and activates adiponectin. These actions reduce the risk of cardiovascular disease by reducing diabetes mellitus, weight gain, hypertension, vascular thrombosis, and myocardial hypertrophy. (Attar, 2020). Furthermore, long-term cobalt chloride therapy or excessive cobalt exposure can result in allergic rhinitis, lung conditions, and possibly even a higher risk of lung cancer. According to Catalani et al. (2012) and Skalny et al. (2019), excessive cobalt consumption can have negative health effects on the liver, gastrointestinal tract, sensory organs, hearing loss, sensorimotor polyneuropathy, bilateral optic atrophy, retinopathy, and thyroid dysfunction. Cobalt may have goiterogenic effects by inhibiting one or more of the enzymatic processes involved in the production of thyroid hormone at various levels (Attar, 2020).

All heavy metals are toxic at certain concentrations, and may pose some serious health problems to both human and animals. Frequent consumption of meat containing elevated concentrations of heavy metals can result in accumulation of ingested metals in the human body, potentially causing toxic effects and health risks (Ali, Almashhadany & Khalid, 2020). To address the potential health hazards associated with heavy metal exposure, various regulatory bodies such as the World Health Organisation (WHO) and the European Food and Safety Authority, alongside many others, have established specific limits/range on the allowable levels of heavy metals in food products (Ali et al., 2020). To determine whether the levels of heavy metals in raw meat are within the acceptable range advised for human consumption by the Food and Agricultural Organisation (FAO), the World Health Organisation (WHO), and the USDA, a survey of heavy metal levels in raw meat is required.

Table 2.2: FAO/WHO recommended maximum permissible levels of heavy metals in meat

Metals	Maximum permissible levels (MPLs) in mg/kg
Iron (Fe)	0.01
Copper (Cu)	0.5
Zinc (Zn)	1.0
Nickel (Ni)	1.0
Cobalt (Co)	0.5
Manganese (Mn)	NS
Cadmium (Cd)	0.5
Chromium (Cr)	0.05
Lead (Pb)	0.1
Arsenic (As)	0.01

Source: Kasozi et al. (2021) (NS: not specified yet)

CHAPTER THREE

MATERIALS AND METHODS

3.1 MATERIALS

3.1.1 Chemicals/reagents

All chemicals used for the study were of analytical grade and were products of Sigma Aldrich, USA, Burgoyne, India, Qualikems, India and JHD, India.They include; Benzene, cholesterol, chloroform, acid mixture (650ml conc. HNO_3; 80ml perchloric acid; 20ml conc. H_2SO_4), Liebermann-Burchard reagent (7ml conc. sulfuric acid and 5ml glacial acetic acid), methanol, n-hexane, sodium chloride, sodium sulphate.

3.1.2 Glasswares and equipments

The following glasswares and equipments were utilized in this study; Testubes (Pyrex, England), digestion flask (Pyrex, England), centrifuge (Pyrex, England), standard volumetric flask (Pyrex, England), water bath (Gallenkamp, England), porcelain mortar and pestle and rotatory vacuum evaporator. Buck M910 scientific gas chromatograph fitted with FID detector (Bulk M910, USA), atomic absorption spectrophotometer Agilent FS240AA, USA), Buck M910 scientific gas chromatograph equipped with electron capture detector (Bulk M910, USA), SP65 UV/Vis spectrophotometer.

3.1.3 Collection of meat samples

Samples used in the study were collected on different days from abattoir in Obinze, Imo State, Nigeria. Total of 45 samples (15 samples each) were collected in three batches at weekly intervals for three weeks. Three samples of torso (cow hump), stomach, intestine, skin and lean meat of cow meat were obtained at early hours of the morning.

3.2 METHODS

3.2.1 Study location

The study area, Obinze, is a town in Owerri West Local Government Area (LGA) in Imo State. It shares boundaries with Ngor-Okpola LGA in the south, Owerri Municipal Council in the east, Mbaitolu LGA in the south and Ohaji/Egbema LGA in the west. Its geographical coordinates are latitude 5°25′0” North and longitude 6°58′0″ East. Obinze is a university town with population of Owerri West Local Government estimated to be 99,265 (National Population Census, 2006). This abattoir is patronized daily by this population and people within the environs for purchase of meat and meat products.

3.2.2 Preparation of samples

The meat samples were packaged in 250 ml sample bottles that contained 50ml normal saline. The sample bottles were placed in a cooler containing ice packs and transported to the laboratory for analysis. Each collected sample was carefully washed with distilled water, weighed and oven dried at 105 °C to constant weight. After which 10 g of each sample was homogenized using porcelain mortar and pestle into fine powder for further analysis.

3.2.3 Determination of cholesterol

Cholesterol content was estimated using Liebermann-Burchard reagent by the method of Attarde et al. (2010). Standard cholesterol solution used was 2mg/ml as stock solution. Liebermann-Burchard reagent was prepared with 7ml conc. sulfuric acid and 5ml glacial acetic acid and was covered with black paper and kept in ice bucket in a dark place.

Principle

In this reaction, the acetic anhydride reacts with cholesterol in the samples to give a green colour, whose absorbance can be determined by a UV/Vis spectrophotometer.

Procedure

Six standard volumetric flasks were marked as s1, s2, s3, s4, s5 and s6. Standard cholesterol solution was added as 0.4, 0.6, 0.8, 1.0 and 1.2 ml into five of the volumetric flasks whereas, flask six was kept blank. Two millilitres (2ml) Liebermann-Burchard reagent was added to all six flasks and diluted with chloroform to final volume of ten millilitres (10 ml). The flasks were covered with black carbon paper and kept in dark for 15 minutes. Then, the spectrophotometer was set to zero with the blank at 640nm. The absorbance of all the standards were determined on SP65 UV/Vis spectrophotometer and standard graph was plotted.

The absorbance of 1ml of sample extract was determined using SP65 UV/Vis spectrophotometer after adding 1 ml oil sample, 2 ml Liebermann-Burchard reagent and 7 ml chloroform. Afterwards, cholesterol concentration of each sample was determined using a standard curve prepared by plotting the absorbance against mg/L cholesterol.

3.2.4 Determination of fatty acid profile

Fat extraction

Fat extraction was carried using Soxhlet method as described by Association of Analytical Chemistry (AOAC, 1990).

Principle

Oil and fat from solid material are extracted by repeated washing (percolation) with an organic solvent, usually hexane or petroleum ether, under reflux in a special glassware (Soxhlet extractor).

Procedure

Five grammes (5g) of the homogenized sample was mixed with 60g of anhydrous sodium sulphate in mortar to absorb the moisture. The homogenate was placed into an extraction thimble and placed into a soxhlet extractor and extraction carried out with 300ml of n-hexane for 24 hours. Crude extract obtained was evaporated using a rotary vacuum evaporator at 40 ºC to dryness.

Fatty acid identification

Fatty acid analysis was analysed by Gas Chromatograph-Buck M910 scientific gas chromatograph fitted with FID detector. SP™-2560 fused capillary column (100 m × 0.25 mm × 0.20 µm) was employed. Helium was used as a carrier gas at a flow rate of 0.8 mL/min. Both the injector and the detector temperature were set at 250 ºC. The oven temperature was programmed as follows: 60 °C held for 1 min, ramped at 15 °C/min to 165 ºC held for 1 min and finally ramped at 2 °C/min to 225 ºC held for 20 min.

After analysis, the trans fatty acids were identified by retention time comparison to standard containing C4:0 – C24:0 saturated fatty acids (SFAs), C15:1 – C20:1 monounsaturated fatty acids

(MUFAs), and C18 – C22 polyunsaturated fatty acids (PUFAs). This same standard was used for the calculation of response factors, which were in turn used to calculate the levels of each fatty acid identified in the sample.

3.2.5 Determination of heavy metals

Heavy metals were determined using FS240AA atomic absorption spectrophotometer according to the method of American Public Health Association (APHA, 1995).

Principle

This assay is based on the sample being aspirated into the flame and atomized when the AAS's light beam is directed through the flame into the monochromator, and onto the detector that measures the amount of light absorbed by the atomized element in the flame. Since metals have their own characteristic absorption wavelength, a source lamp composed of that element is used, making the method relatively free from spectral or radiational interferences. The amount of energy of the characteristic wavelength absorbed in the flame is proportional to the concentration of the element in the sample.

Wet digestion

A portion of the dried sample weighing 2 g was transferred into a digestion flask and 20 ml of the acid mixture (650 ml conc. HNO_3; 80 ml perchloric acid; 20 ml conc. H_2SO_4) was added. The mixture was heated in a digesting flask until a clear digest was obtained. The digest was diluted with deionized water to the 50 ml mark.

Preparation of reference solutions

A series of standard metal solutions in the optimum concentration range was prepared, the reference solutions were prepared daily by diluting the single stock element solutions with deionized water containing 1.5 ml concentrated nitric acid/litre. A calibration blank was prepared using all the reagents except for the metal stock solutions. Calibration curve for each metal was prepared by plotting the absorbance of standards versus their concentrations.

3.2.6 Determination of polychlorinated biphenyls (PCB)

Extraction of PCB from samples

A portion of the ground sample weighing 10 g was transferred into a 500 mL beaker. Sodium sulphate weighing 6g was added. The setup was extracted using 300 ml n-hexane and the filtrate concentrated. One millilitre (1 ml) of the filtrate was dissolved in 50 ml of chloroform and transferred to a 100 ml volumetric flask and diluted to the mark. Most of the chloroform was then evaporated at room temperature and 1 ml of the reagent (20 vol% benzene and 55 vol% methanol) was added to the flask. The volumetric flask was sealed and incubated in a water bath at 40°C for 10 min. After heating, the organic sample was extracted with hexane and water, so that the final mixture of the reagent, hexane and water, was in proportion of 1:1:1 (i.e., 1ml each of hexane and water was added to the reaction mixture). Furthermore, the mixture was vigorously shaken by hand for 2 min (any stable emulsion formed, was broken by centrifugation) and half of the top hexane phase was transferred to a small test tube for injection.

Gas chromatographic conditions for PCB determination

The final extracts were analysed by Gas Chromatograph-Buck M910 scientific gas chromatography equipped with electron capture detector that allowed the detection of substances even at trace level concentrations (in the lower µg/g and µg/kg range) from the matrix to which other detectors do not respond. The GC conditions used for the analysis were capillary column HP 88 capillary column (100m x 0.25µm film thickness,).

The injector and detector temperature were set at 250 ºC and 290ºC, respectively. The oven temperature was programmed as follows: 110 ºC held for 10 min, ramp at 10 ºC/ min to 200 ºC, held for 5min, and finally ramp at 10 ºC/ min to 320 ºC. Helium was used as carrier gas at a flow rate of 1.0 mL/ min and detector make-up gas of 29 mL min^{-1}. The injection volume of the GC was 8.0 µL. The total run time for a sample was 48 min.

Quantification of PCB residues

The residue concentrations of PCB were quantitatively determined by the external standard method using peak area. Measurement was carried out within the linear range of the detector. The peak areas whose retention times coincided with the standards were extrapolated on their corresponding calibration curves to obtain the concentration

3.2.7 Statistical analysis

Experimental results were expressed as mean ± standard deviation of triplicate determinations. IBM SPSS Statistics version 20 was used to analyze the data collected. The data were subjected to one-way analysis of variance (ANOVA) at $p < 0.05$. Graphs were prepared using GraphPad Prism 8.4.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 Cholesterol concentration in the different meat parts of cattle

Figure 4.1 shows the mean values (±SD) of cholesterol concentration in the different meat parts studied. The result showed significant difference in cholesterol content between torso, stomach, skin and lean meat but no significant difference ($p>0.05$) in cholesterol content in the intestine when compared with stomach and skin meat. Cholesterol content was found to be highest in the torso meat (115.2±6.48 mg/kg), followed by lean meat (94.7±2.27 mg/kg) and skin (79.3 ± 6.30 mg/kg) and least in the intestine (74.9 ± 2.33 mg/kg) and stomach (67.76 ± 5.69 mg/kg).

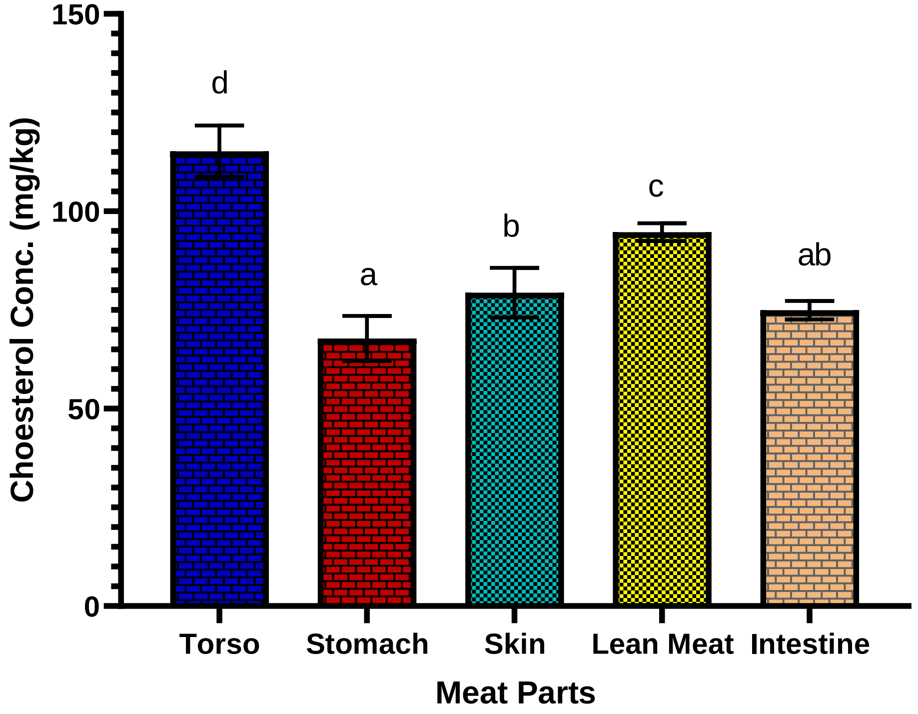


Figure 4.1: Cholesterol concentration in the different meat parts. Bars represent mean cholesterol concentrations ± standard deviation of triplicate determinations. Bars with different alphabets differ significantly ($p<0.05$).

4.1.2 Fatty acid profile in the different meat parts of cattle

Figures 4.2-4.14 shows the fatty acid profile of the different meat parts in this study. The saturated fatty acids (SFAs) detected are lauric acid (C12), myristic acid (C14), palmitic acid (C16) and stearic acid (C18). Higher levels of palmitic and stearic acids than lauric and myristic acids were observed. Also, there was no significant difference in lauric acid content ($p>0.05$) in torso, stomach, skin and intestine. Lauric acid content was higher in lean meat (5.65±1.38 mg/kg) than in torso, stomach, skin and intestine. Myristic acid content was also higher in lean meat (10.98±2.96 mg/kg) than in stomach and intestine, but was not detected in torso and skin meat. Oleic acid (C18:10) was the only monounsaturated fatty acid (MUFA) detected. Oleic acid content in the meat parts was higher in torso and skin meat than others. No significant difference ($p>0.05$) was observed between torso and skin parts and between stomach and intestine parts.

The predominant polyunsaturated fatty acids recorded are linoleic acid (C18:2n – 6) (6.67±3.36 mg/kg in intestine to 18.36±11.34 mg/kg in stomach meat) and α-linolenic acid (C18:3n – 3) (5.10±1.46 mg/kg in intestine to 13.98±3.95 mg/kg in skin meat). Other long-chain fatty acids include eicosadienoic acid (C20:2n – 6), dihomo – γ – linolenic acid (C20:3n – 6), arachidonic acid (C20:4n – 6), eicosapentaenoic acid (C20:5n – 3), docosahexaenoic acid (C22:6n – 3) and very long chain fatty acid tetracosapentaenoic acid (C24:5n – 3). Significant difference ($p<0.05$) among meat parts were observed for C18:3n – 3, C20:3n – 6, C20:5n – 3, and C24:5n – 3.

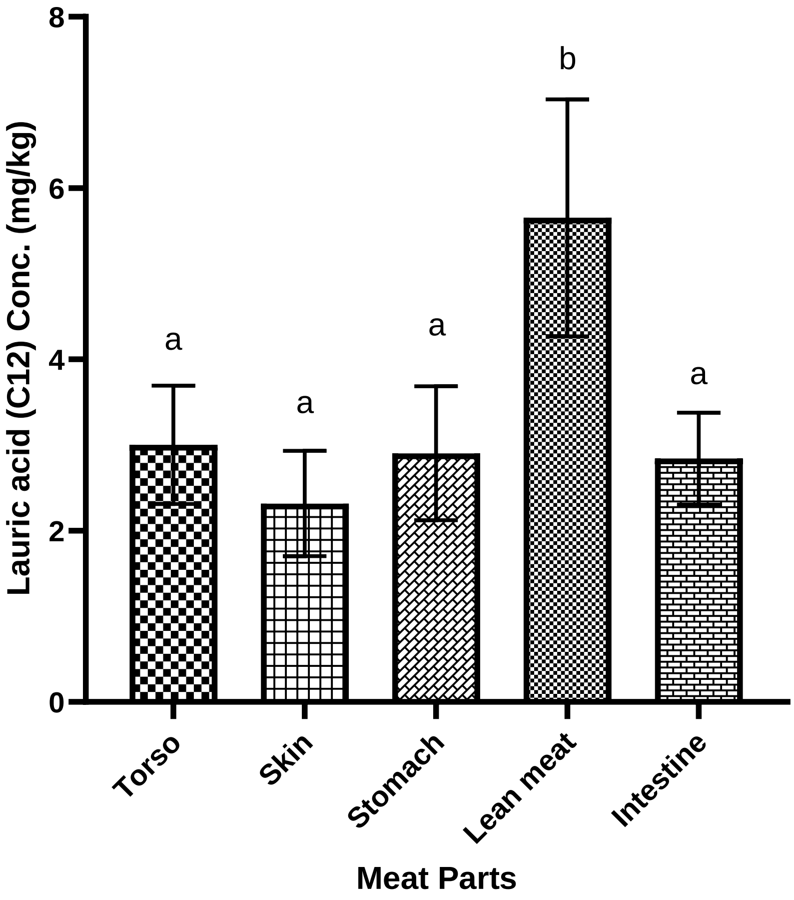


Figure 4.2: Lauric acid concentration and distribution in meat parts. Bars represent mean lauric acid concentration ± standard deviation of triplicate determinations. Bars with different alphabets differ significantly ($p<0.05$).

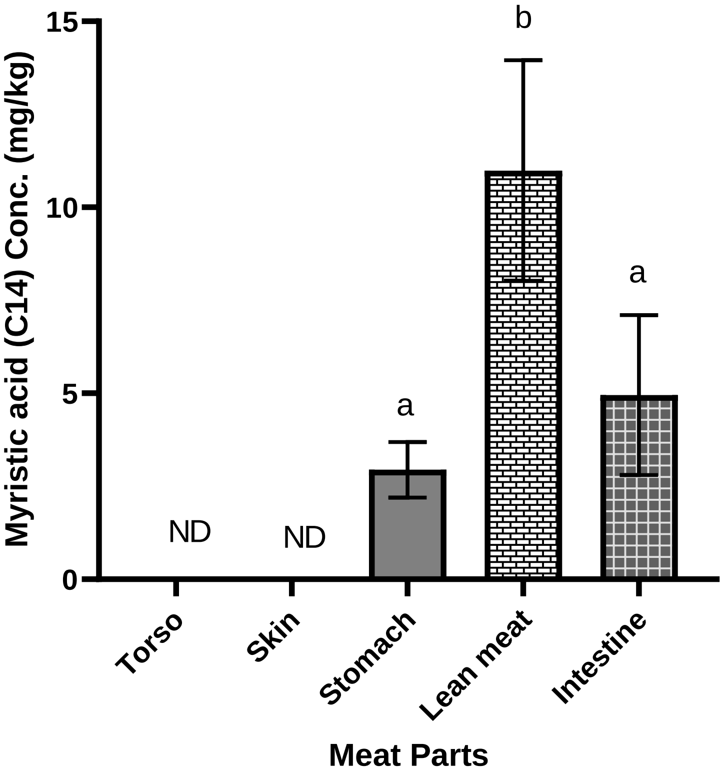


Figure 4.3: Myristic acid concentration and distribution in meat parts. Bars represent mean myristic acid concentration ± standard deviation of triplicate determinations. Bars with different alphabets differ significantly ($p<0.05$). ND: Not Detected

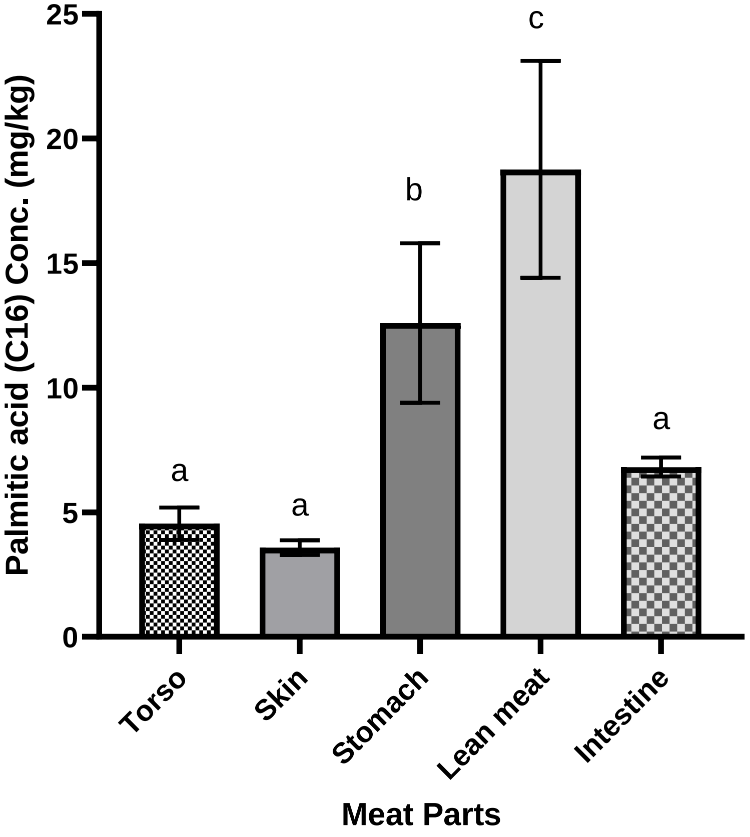


Figure 4.4: Palmitic acid concentration and distribution in meat parts. Bars represent mean palmitic acid concentration ± standard deviation of triplicate determinations. Bars with different alphabets differ significantly ($p<0.05$).

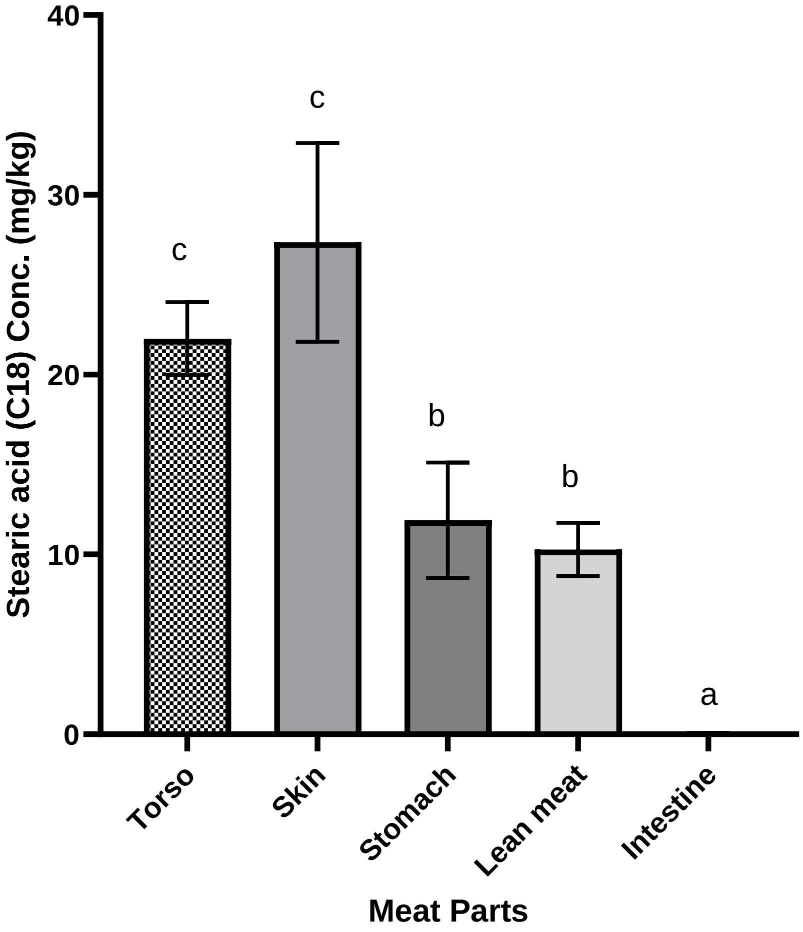


Figure 4.5: Stearic acid concentration and distribution in meat parts. Bars represent mean stearic acid concentration ± standard deviation of triplicate determinations. Bars with different alphabets differ significantly ($p<0.05$).

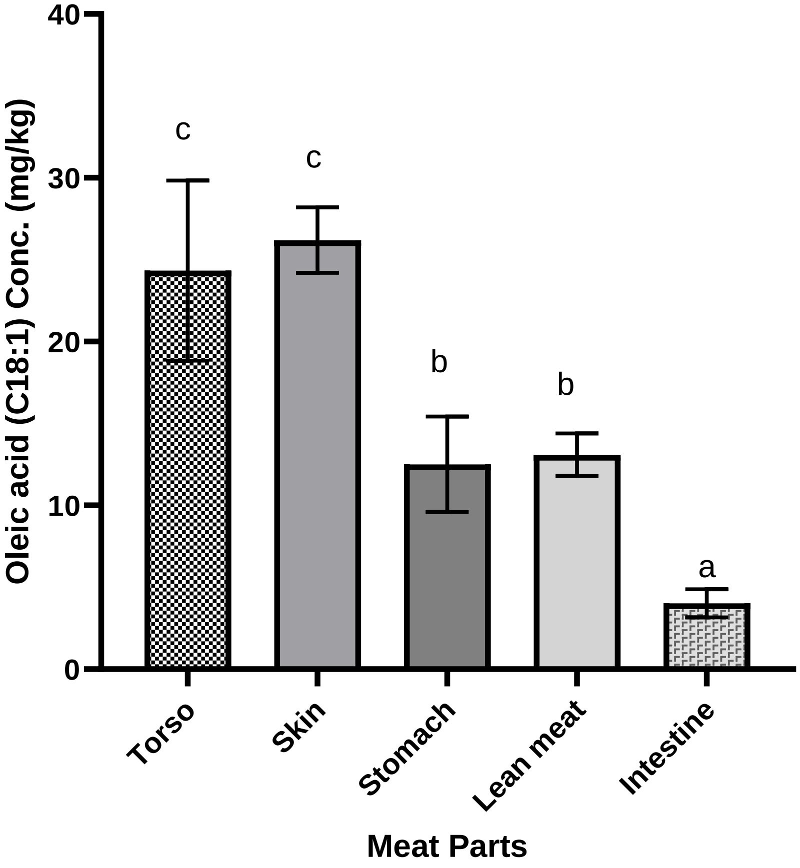


Figure 4.6: Oleic acid concentration and distribution in meat parts. Bars represent mean oleic acid concentration ± standard deviation of triplicate determinations. Bars with different alphabets differ significantly ($p<0.05$).

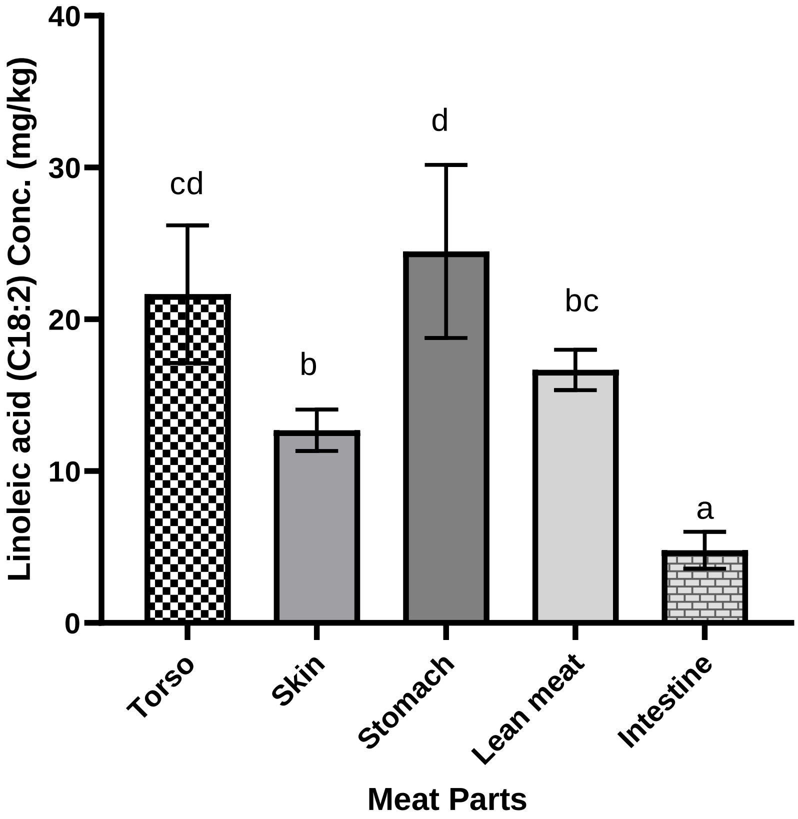


Figure 4.7: Linoleic acid concentration and distribution in meat parts. Bars represent mean lionoleic acid concentration ± standard deviation of triplicate determinations. Bars with different alphabets differ significantly (p>0.05).

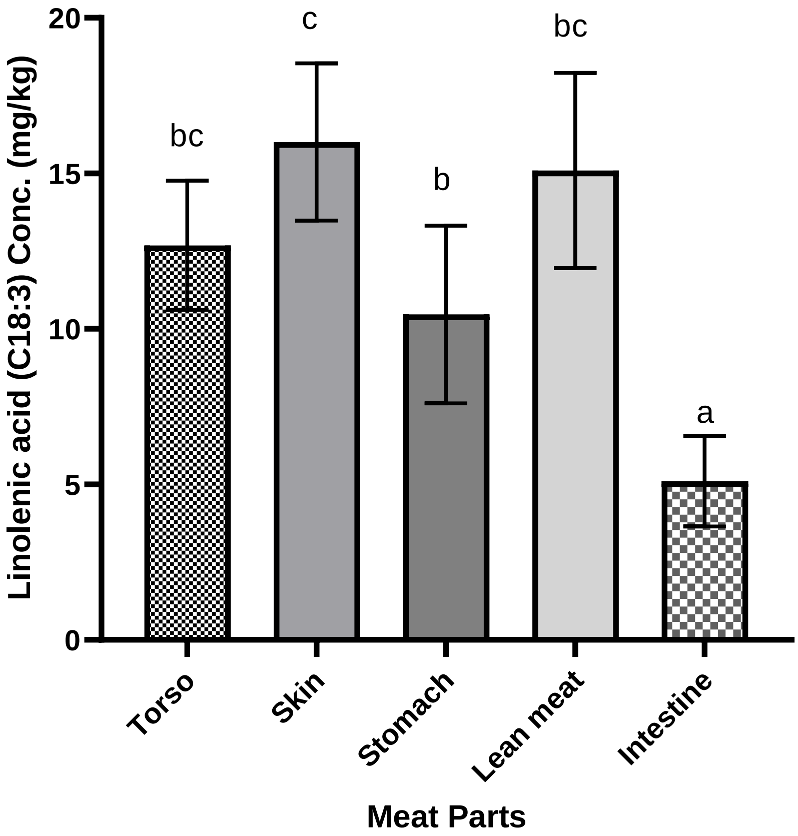


Figure 4.8: Linolenic acid concentration and distribution in meat parts. Bars represent mean linolenic acid concentration ± standard deviation of triplicate determinations. Bars with different alphabets differ significantly (p<0.05).

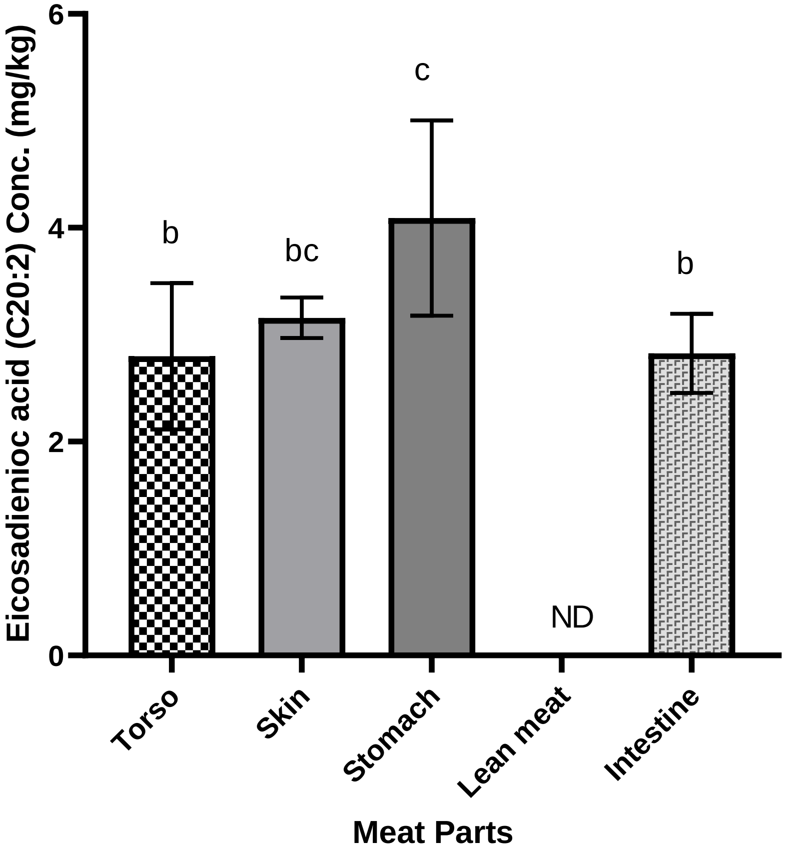


Figure 4.9: Eicosadienoic acid concentration and distribution in meat parts. Bars represent mean eicosadienoic acid concentration ± standard deviation of triplicate determinations. Bars with different alphabets differ significantly (p>0.05). ND: Not Detected

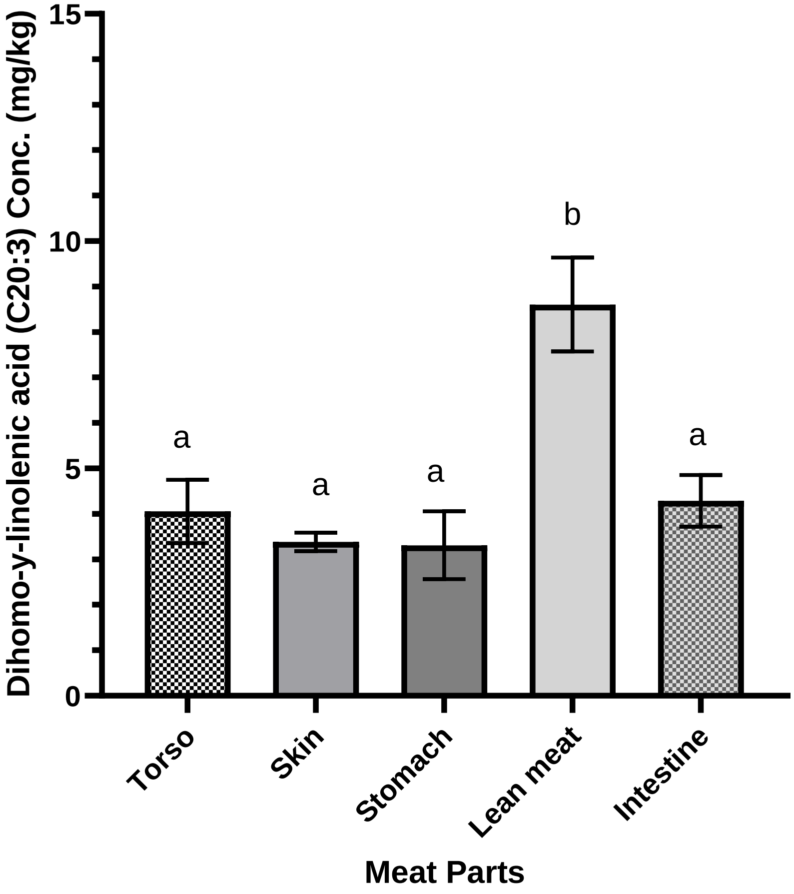


Figure 4.10: Dihomo-γ-linolenic acid concentration and distribution in meat parts. Bars represent mean dihomo-γ-linolenic acid concentration ± standard deviation of triplicate determinations. Bars with different alphabets differ significantly ($p<0.05$).

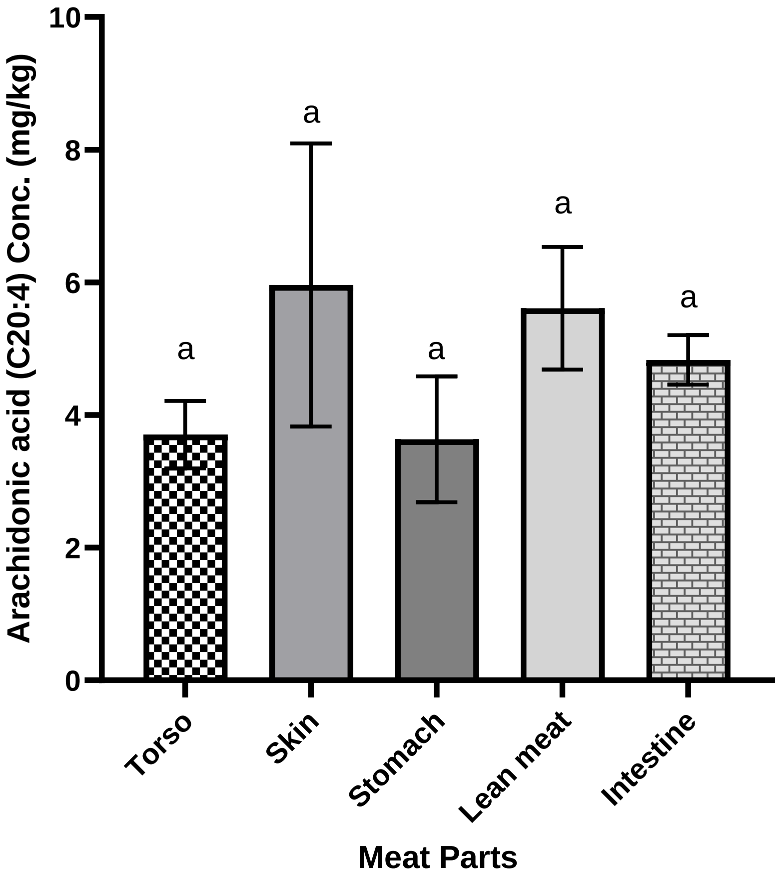


Figure 4.11: Arachidonic acid concentration and distribution in meat parts. Bars represent mean arachidonic acid concentration ± standard deviation of triplicate determinations. Bars with identical alphabets do not differ significantly ($p>0.05$).

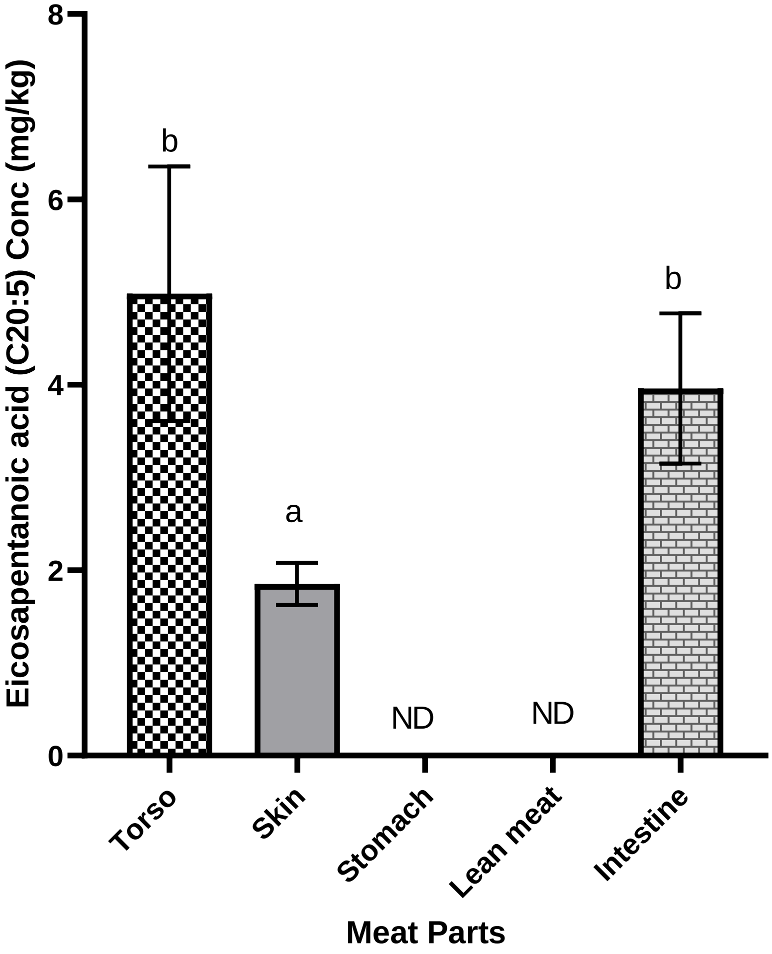


Figure 4.12: EPA concentration and distribution in meat parts. Bars represent mean EPA concentration ± standard deviation of triplicate determinations. Bars with different alphabets differ significantly ($p<0.05$). ND: Not Detected

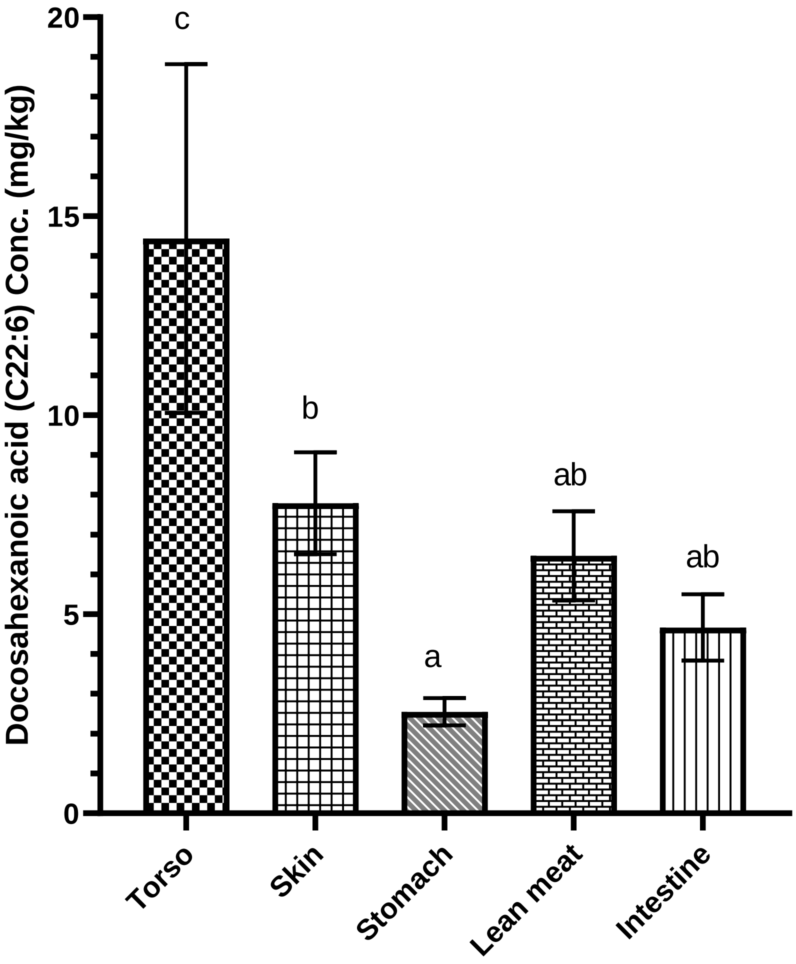


Figure 4.13: DHA concentration and distribution in meat parts. Bars represent mean DHA concentration ± standard deviation of triplicate determinations. Bars with different alphabets differ significantly ($p<0.05$).

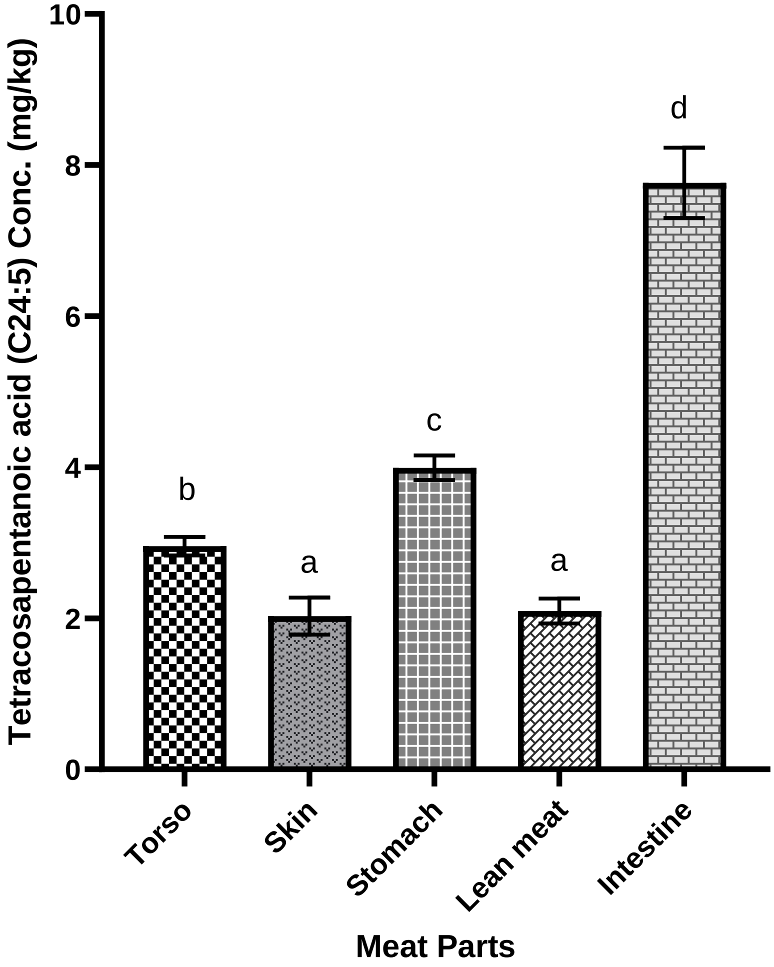


Figure 4.14: Tetracosapentanoic acid concentration and distribution in meat parts. Bars represent mean tetracosapentanoic acid concentration ± standard deviation of triplicate determinations. Bars with different alphabets differ significantly ($p<0.05$).

4.1.3 Micronutrients and heavy metal residue distribution in different meat parts of cattle

The distribution of micronutrients (Mn, Cu, Fe, Zn, Ni, Cr and Co) and heavy metals (As, Cd and Pb) in the different meat parts of cattle are presented in Figures 4.15 – 4.24. Among the studied metals, iron (Fe) was the most highly abundant metal, ranging from 0.333-1.052 mg/kg, followed by chromium (Cr) and arsenic which was the least. Heavy metals concentration were significantly different ($p<0.05$) in the various meat parts. The concentrations of the metals in the different meat parts are in the range; Mn (0.178±0.020 mg/kg – 0.348±0.025 mg/kg), As (0.004±0.002 – 0.037±0.001 mg/kg), Cu (0.042±0.029 – 0.385±0.009 mg/kg), Fe (0.333±0.113 – 1.510±0.042 mg/kg), Zn (0.173±0.007 – 0.406±0.086 mg/kg), Ni (0.035±0.016 – 0.154±0.028 mg/kg), Cr (0.314±0.067 – 0.734±0.234 mg/kg), Pb (0.021±0.002 – 0.089±0.009 mg/kg), Co (0.021±0.004 – 0.049±0.010 mg/kg), and Cd (0.019±0.003 – 0.092±0.002 mg/kg). Copper, zinc, nickel, cobalt, cadmium, and lead did not exceed the maximum permissible limits (MPLs) as set by FAO/WHO.

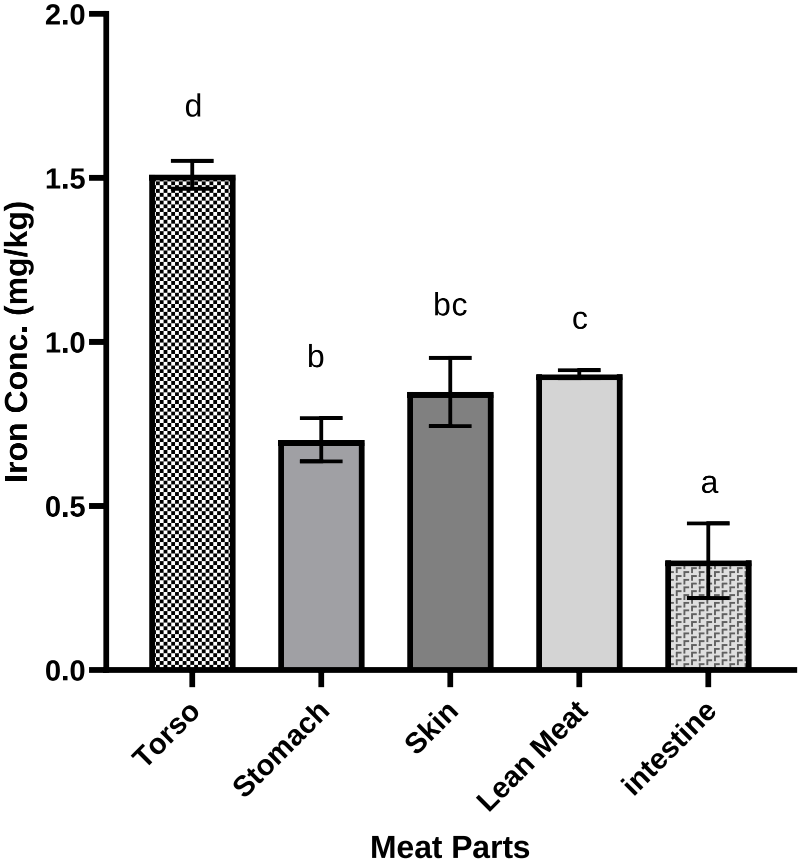


Figure 4.15: Iron concentration and distribution in meat parts. Bars represent mean iron concentration ± standard deviation of triplicate determinations. Bars with different alphabets differ significanty ($p<0.05$).

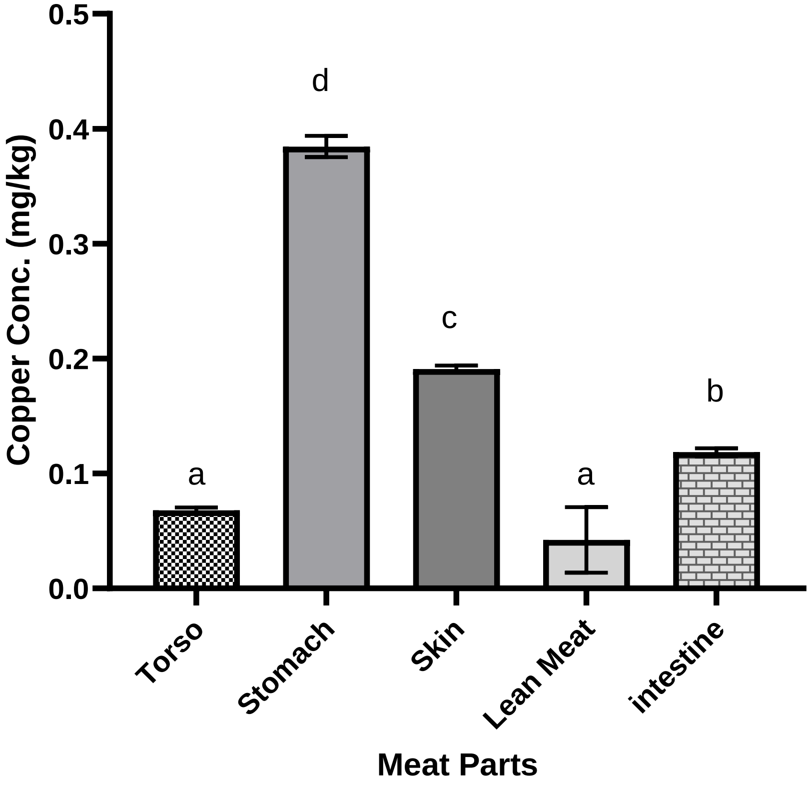


Figure 4.16: Copper concentration and distribution in meat parts. Bars represent mean copper concentration ± standard deviation of triplicate determinations. Bars with different alphabets differ significantly ($p<0.05$).

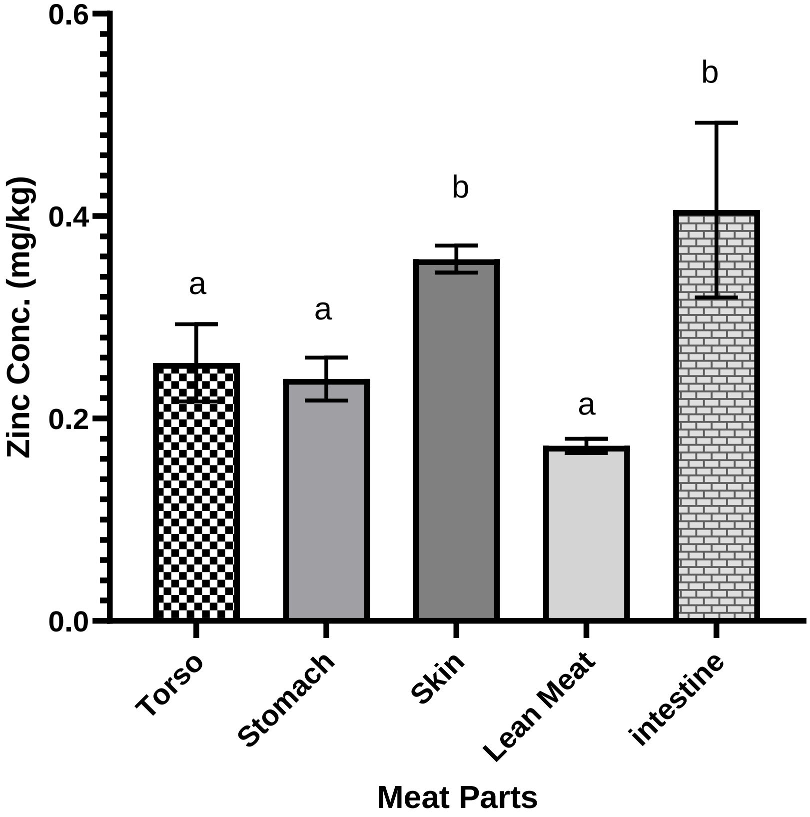


Figure 4.17: Zinc concentration and distribution in meat parts. Bars represent mean zinc concentration ± standard deviation of triplicate determinations. Bars with different alphabets differ significantly ($p<0.05$).

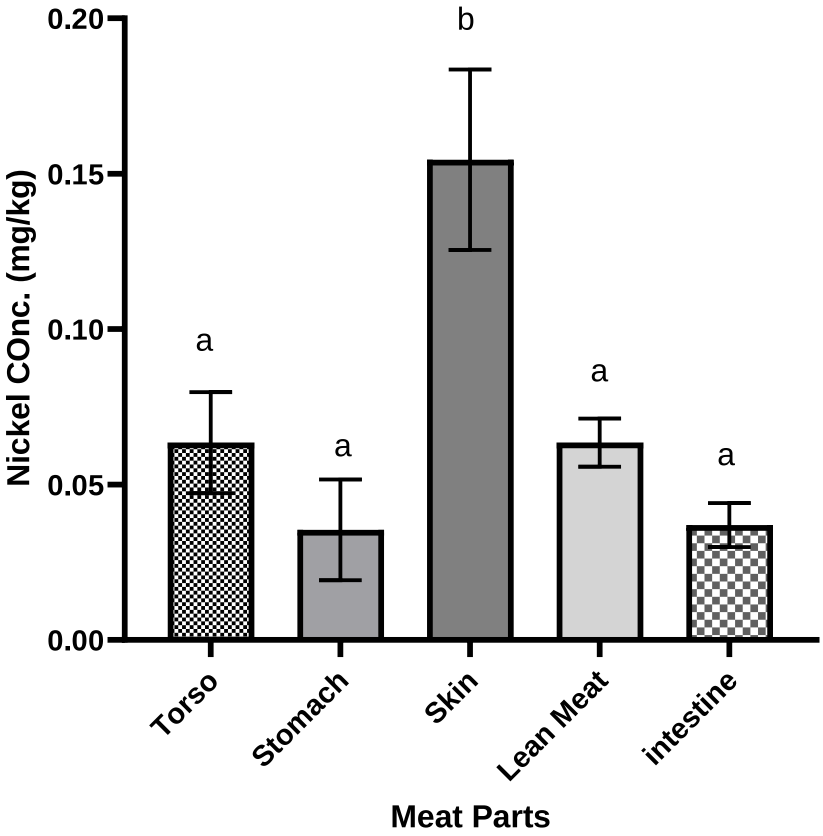


Figure 4.18: Nickel concentration and distribution in meat parts. Bars represent mean nickel concentration ± standard deviation of triplicate determinations. Bars with different alphabets differ significantly ($p<0.05$).

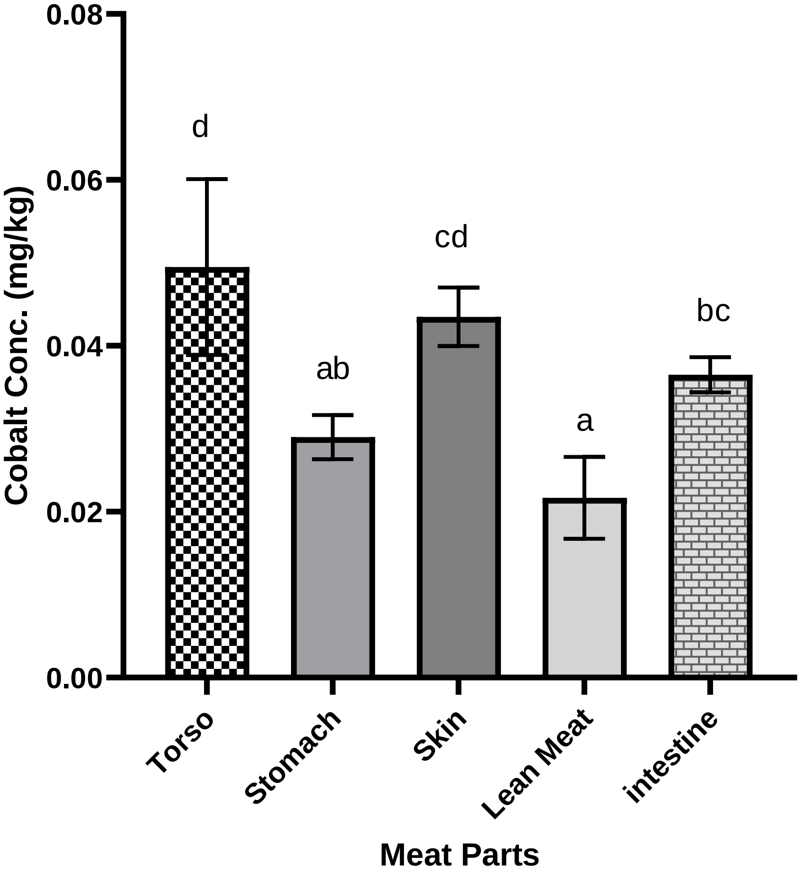


Figure 4.19: Cobalt concentration and distribution in meat parts. Bars represent mean cobalt concentration ± standard deviation of triplicate determinations. Bars with different alphabets differ significantly ($p<0.05$).

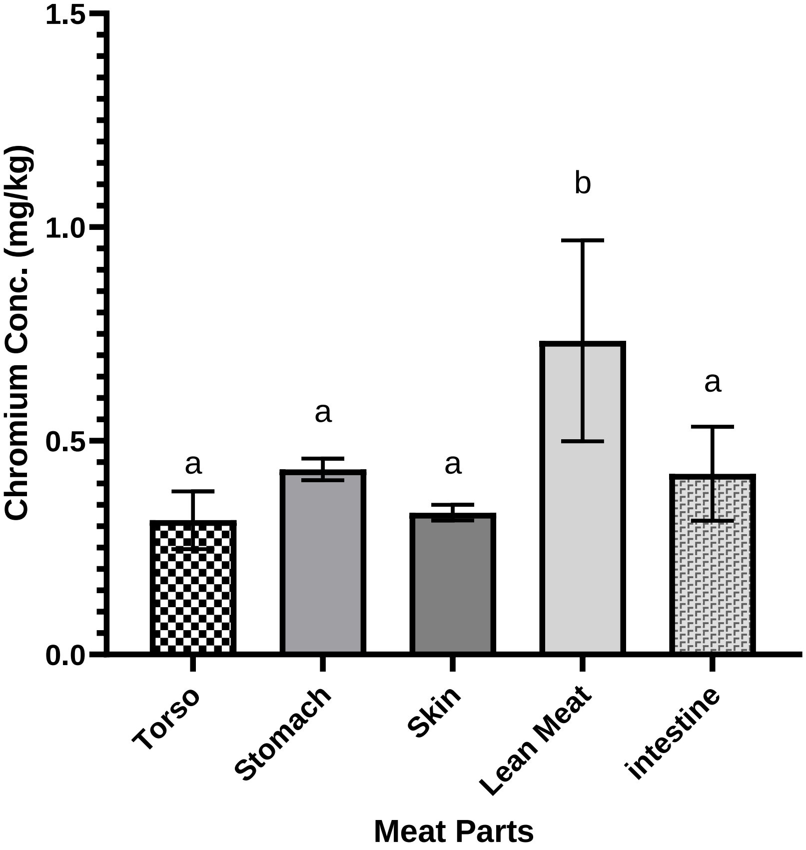


Figure 4.20: Chromium concentration and distribution in meat parts. Bars represent mean chromium concentration ± standard deviation of triplicate determinations. Bars with different alphabets differ significantly ($p<0.05$).

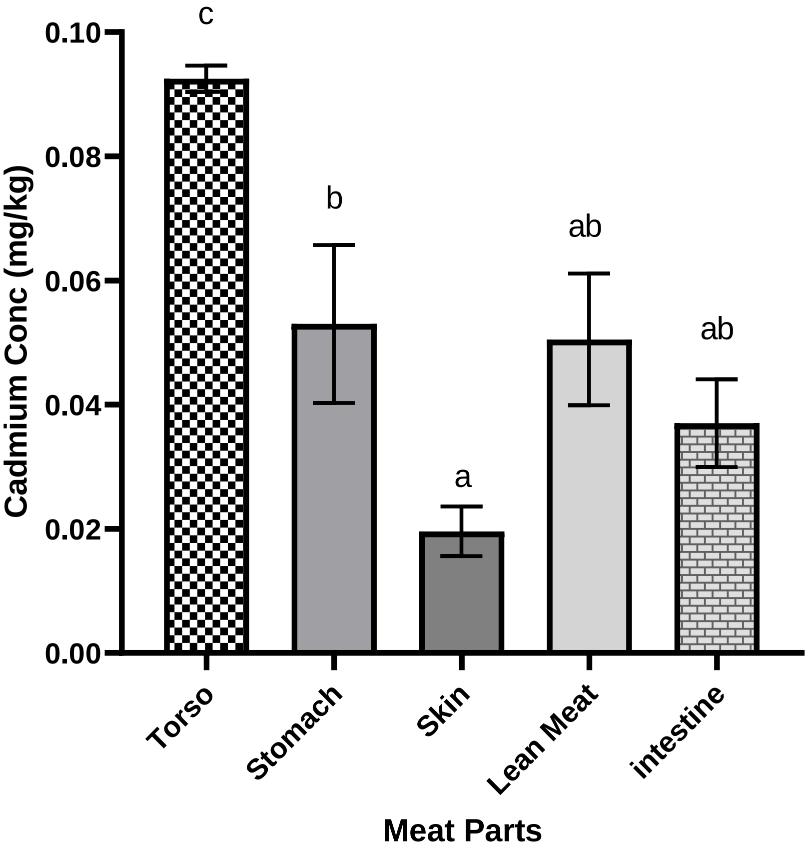


Figure 4.21: Cadmium concentration and distribution in meat parts. Bars represent mean cadmium concentration ± standard deviation of triplicate determinations. Bars with different alphabets differ significantly ($p<0.05$).

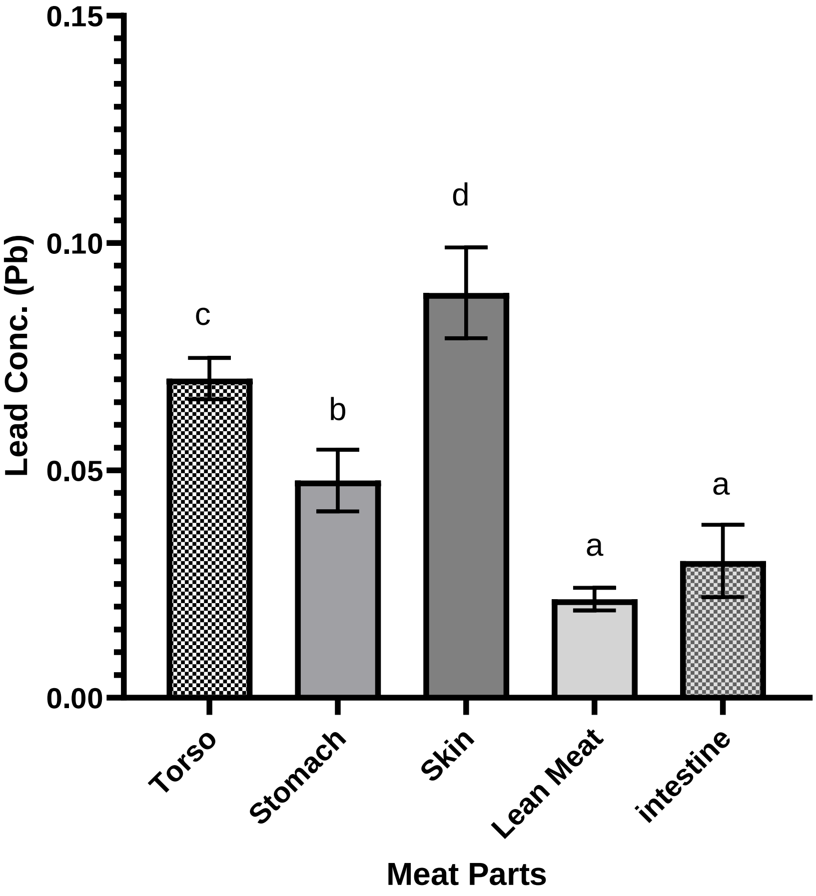


Figure 4.22: Lead concentration and distribution in meat parts. Bars represent mean lead concentration ± standard deviation of triplicate determinations. Bars with different alphabets differ significantly ($p<0.05$).

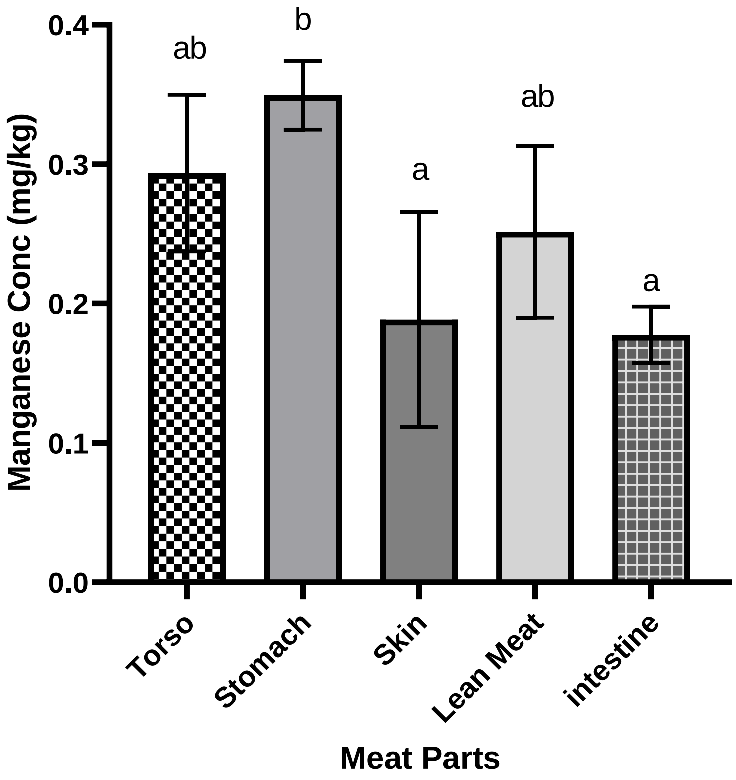


Figure 4.23: Manganese concentration and distribution in meat parts. Bars represent mean manganese concentration ± standard deviation of triplicate determinations. Bars with different alphabets differ significantly (p<0.05).

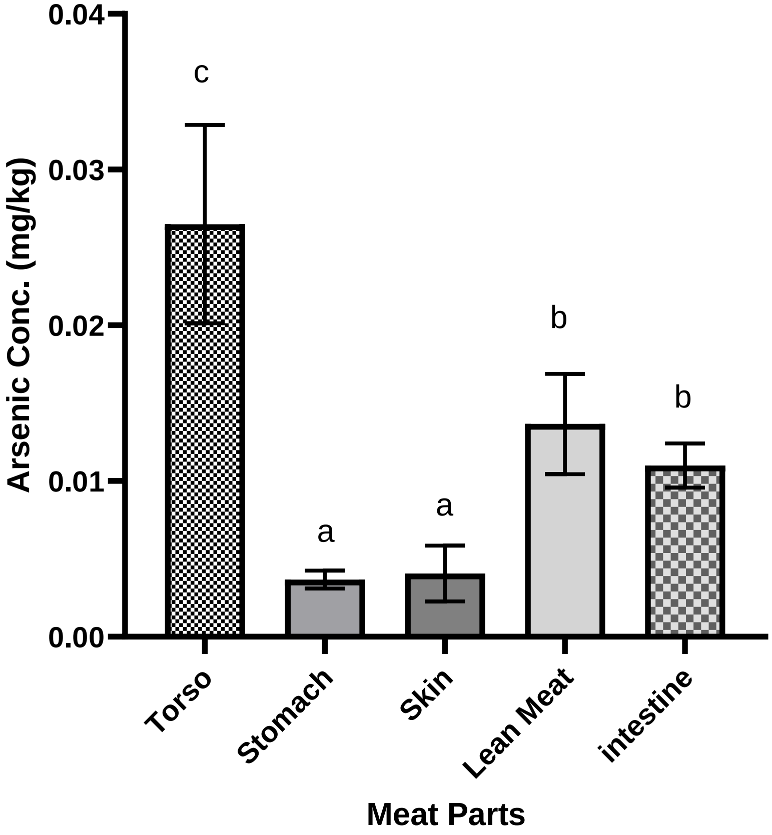


Figure 4.24: Arsenic concentration and distribution in meat parts. Bars represent mean arsenic concentration ± standard deviation of triplicate determinations. Bars with different alphabets differ significantly ($p<0.05$).

4.1.4 Pesticide residue distribution in the different meat parts of cattle

The concentration of pesticides residue levels were compared in the five samples and the mean ± standard deviation values (mg/kg) are presented in Table 4.1. A total of sixteen pesticide residues were detected across the studied samples. Organochlorine pesticides detected include DDT and its metabolites (p′p′-DDE and p′p′-DDD), chlordanes (gamma-chlordane and trans-nonachlor), heptachlor, lindane, endosulfan, hexachlorobenzene (HCB), biphenyl, dichlorobiphenyl and 4-4 bipyridinium dichloride while organophosphate pesticides detected are chlorpyrifos, dichlorvos and emamectin. Results presented inTable 4.1 shows that there was no statistical difference ($p<0.05$) across the meat parts for most of the pesticides detected.

Table 4.1: Pesticide residue distribution and concentration in the different meat parts of cattle

Pesticides (mg/kg)	Torso	Stomach	Skin	Lean meat	Intestine
Lindane	0.47 ± 0.25^{a}	0.56 ± 0.32^{a}	0.56 ± 0.14^{a}	0.58 ± 0.20^{a}	0.56 ± 0.22^{a}
Hexachlorobenzene	0.70 ± 0.65^{a}	0.17 ± 0.20^{a}	0.13 ± 0.14^{a}	0.10 ± 0.08^{a}	0.11 ± 0.12^{a}
Endosulfan	0.19 ± 0.22^{a}	0.19 ± 0.21^{a}	0.20 ± 0.16^{a}	0.18 ± 0.00^{a}	0.17 ± 0.02^{a}
g-Chlordane	0.11 ± 0.02^{a}	0.10 ± 0.03^{a}	0.09 ± 0.01^{a}	0.12 ± 0.06^{a}	0.08 ± 0.02^{a}
DDT	0.70 ± 0.63^{a}	0.74 ± 0.65^{a}	0.47 ± 0.41^{a}	0.41 ± 0.37^{a}	0.22 ± 0.19^{a}
p′p′-DDD	0.26 ± 0.10^{a}	0.25 ± 0.10^{a}	0.34 ± 0.51^{a}	0.47 ± 0.45^{a}	0.31 ± 0.50^{a}
p′p′-DDE	0.68 ± 0.60	0.61 ± 0.53^{a}	0.63 ± 0.54^{a}	0.03 ± 0.05^{a}	0.05 ± 0.04^{a}
Glyphosate	0.22 ± 0.19^{a}	0.22 ± 0.20^{a}	ND	ND	ND
Heptachlor	1.58 ± 1.38^{a}	0.74 ± 0.65^{a}	2.16 ± 1.88^{a}	0.46 ± 0.39^{a}	0.35 ± 0.30^{a}
Chloropyrifos	0.04 ± 0.04^{a}	0.04 ± 0.04^{a}	0.27 ± 0.24^{a}	0.28 ± 0.24	0.30 ± 0.26
t-nonachlor	1.05 ± 0.78^{a}	0.11 ± 0.04	0.09 ± 0.07	0.08 ± 0.05^{a}	0.07 ± 0.06^{a}
Dichlorvos	0.013 ± 0.01^{a}	0.023 ± 0.02^{ab}	0.04 ± 0.01^{ab}	0.04 ± 0.01^{a}	0.05 ± 0.01^{b}
Dichlorobiphenyl	0.67 ± 0.58^{a}	0.68 ± 0.59^{a}	0.72 ± 0.63^{a}	ND	0.74 ± 0.64^{a}
Biphenyl	0.67 ± 0.58^{a}	0.70 ± 0.61^{a}	0.14 ± 0.12^{a}	0.14 ± 0.12^{a}	0.09 ± 0.08^{a}
4-4 bipyridinium dichloride	0.31 ± 0.15^{a}	0.16 ± 0.09^{a}	0.77 ± 0.13^{a}	0.47 ± 0.36^{ab}	0.32 ± 0.33^{ab}
Emamectin	0.05 ± 0.04^{a}	0.01 ± 0.04^{a}	0.03 ± 0.02^{a}	0.06 ± 0.03^{a}	0.05 ± 0.04^{a}

Data represents the mean ± standard deviation of pesticide residue in the different meat parts. Values on the same row bearing different superscript letter are significantly different ($p<0.05$). ND = Not Detected.

4.2 DISCUSSION

The cholesterol content and fatty acid profile of some meat parts of cattle were determined. The American Heart Association (AHA) recommends a total fat intake in the range of 25 to 35% of calories, <7% of calories from saturated fatty acids, <1% of calories from trans fat and <300 mg/day of cholesterol (Ejike & Emmanuel, 2009). The result obtained shows that the cholesterol content in the meat parts under study are below the estimated daily serving recommended by AHA (2007) which means that consumption of these meat parts doesn't pose a risk for the development of cardiovascular disease.

The high cholesterol content observed in the torso meat may be due to fact that it is majorly a deposit of fat. In the study conducted by Madu and Yakubu (2018) on total cholesterol in selected tropical cow meat parts in Ogun state, Nigeria, the intestine had the highest amount of total cholesterol (138 mg/100g) followed by the muscle (136 mg/100g) and the skin with the least amount of total cholesterol (31mg/100g). The cholesterol content in this study are higher than those reported by Abonyi, Ogbu and Unigwe (2018) in muscle and edible offal of slaughtered pigs, goats and cattle at Nsukka Municipal abattoir.

The main SFAs in ruminant meat products are: myristic, palmitic and stearic acids. Some SFAs have been shown to have cholesterol-increasing properties, which are indicators of coronary heart disease (CHD) risks (Davis, Magistrali, Butler & Stergiadis, 2022). Stearic acid has a neutral effect on blood total and LDL-cholesterol levels because it is converted into oleic acid in the organism without affecting the blood cholesterol levels (Ladeira et al., 2014). Overall, our result showed that the prevailing individual saturated fatty acid were lauric, myristic, palmitic and stearic acids. The highest proportion of SFAs were recorded in lean meat and skin. The result of the study indicates lower levels of lauric and myristic acids compared to palmitic and stearic acid. Lauric and myristic acid concentrations were higher in lean meat compared to other meat samples. Myristic acid was undetected in torso and skin meat. Higher levels of palmitic acid were recorded in lean meat and stomach than was found in torso, skin and intestine. There were higher concentrations of stearic acid observed in skin and torso compared with other tissue samples in the study, the intestine had the least stearic acid concentration. Higher levels of SFAs (myristic, palmitic and stearic) have been reported by Dagne et al. (2021) ranging (11.75 ±1.21 – 42.51 ± 0.73 mg/kg)in a study on the proximate composition and fatty acid profile of beef from 3 cattle breeds in Ethiopia. The low level of saturated fatty acids observed in the study indicates a positive impact on human health.

Oleic acid was the only monounsaturated fatty acid detected in this study. Oleic acid reduces the level of LDL-cholesterol and increases the level of HDL-cholesterol (Igenbayev et al., 2019). Oleic acid is reported to regulate fatty acid and cholesterol biosynthesis by up-regulating AMP-activated protein kinase (AMPK), which readily phosphorylates and therefore inactivates acetyl-CoA carboxylase and 3-hydroxy-3-methyl-glutaryl CoA reductase two important enzymes of cholesterol biosynthesis. Activated AMPK stimulates the oxidation of fatty acids thereby reducing biosynthesis of cholesterol and triglycerides in hepatocytes and also prevent the development of fatty liver (Cheng et al., 2018; Zhang et al., 2021). The presence of oleic acid is associated with slow progression of heart diseases and promotes antioxidant activity (Hur et al., 2005). However, individual responses to dietary fats can vary, and other dietary and lifestyle factors may as well determine overall cardiovascular health.

The highest concentration of oleic acid was recorded in skin meat followed closely by torso. There were differences in oleic acid content in torso and skin meat compared to stomach and intestine, the intestine had the least oleic acid content.

Ruminant meat is characterized by its high content of saturated fatty acid due to the ruminal bio-hydrogenation phenomenon (Ben-Abdelmalek et al., 2020). However, studies have showed that it is possible to vary the FA composition by varying diet and the rearing system (Van-Harten et al., 2016; Margetin, Oravcová, Margetínová & Kubinec, 2018; Belhaj et al., 2020). Linoleic and alpha-linolenic were the predominant PUFAs in the study. Linoleic and α-linolenic acids are said to be essential as they cannot be synthesized by the human body and must be obtained from diet. There was no observed variation in linoleic acid content in all meat parts. The highest concentration of α-linolenic acid was detected in the skin meat. Lower levels for eicosadienic, arachidonic, docosahexaenoic (DHA), dihomo-γ-linolenic, eicosapentaenoic and tetracosapentaenioc were observed in this study.

Environmental pollutants including heavy metals are extensively dispersed into the environment along with industrial waste, and these accumulate and persist in the environment (Solomon, Nwaogu, Ujowundu, & Maza, 2019). In Nigeria, cattle rearing is mainly by nomadic open field grazing, where right from birth, cattle spend their entire life feeding on green pasture. This potentially exposes these cattle to ingesting toxic substances and leading to the bioaccumulation of these substances in cattle tissues.

Of the metals in this study, seven are essential trace elements (Mn, Ni, Fe, Cu, Cr, Co, Zn), needed in small concentrations for important metabolic, biochemical or biological reactions; three (Cd, As, Pb) are not known to mediate any biochemical reactions and are referred to as non-essential toxic metals (Prashanth et al., 2015; Dada et al., 2023). Iron (Fe) is an important element with significant role in haemoglobin synthesis, oxygen and electron transfer in the human body (Oyareme, Akpogheneta, Iloba & Ogidiagba, 2020). However, high iron burden in the body may increase the risk of colorectal cancer, cardiovascular disease, infection, neurodegenerative disease and inflammatory conditions (Usman et al., 2022). The concentration of Fe in this study was significantly higher and above the permissible limit for all tissues in the study. The highest iron (Fe) concentration was observed in the torso meat and the least detected in the intestine. The iron concentrations in all tissues studied were higher than the 0.01mg/kg recommended standard set by FAO/WHO (Kasozi et al., 2021).

The highest copper (Cu) concentration (mg/kg) was detected in the stomach meat, with the least concentration observed in lean meat. This study recorded higher Cu levels compared to the study of Sabuwa & Nafarnda (2020), who reported 0.0041mg/kg and 0.0009mg/kg in intestine and skin respectively, from cattle raised in the North (Zamfara). All the sampled meat parts recorded concentrations lower than maximum permissible limit of 0.5mg/kg (FAO/WHO). Although, Cu is an essential metal required for the formation of red blood cells as well as many oxidation and reduction reactions in humans and animals, elevated levels in tissues is toxic. The effect of high intake of copper in human body are increased blood pressure and respiratory rates, damage to kidneys and liver, convulsions, cramps, vomiting or even death (MathuMithra, Mohan, Sangeetha, Susan & Ragumaran, 2021).

The concentration of Zn in the sampled tissues was in the order intestine > skin > torso > stomach > lean meat. The observed values in all meat parts were below the 1.0 mg/kg MPLs of FAO/WHO (Kasozi et al., 2021). Jen and Jude (2018) in their study recorded higher levels of Zn (2.07mg/kg) and (3.19mg/kg), respectively, than observed in this study in the intestine and stomach of cows raised in Yola, Nigeria. Zinc plays a vital role in regulating many biochemical processes and physiological functions of living tissues. It is involved in DNA and RNA synthesis together with cell proliferation (Meche et al., 2010). Increased concentrations however, may cause skin irritations, vomiting, nausea, liver damage, respiratory and metabolic disorders (Gautam et al., 2016).

The mean concentration of Ni obtained from the different meat parts showed that the skin meat had the highest concentration while the least concentration was detected in the stomach. Sabuwa & Nafarnda (2020), in their study conducted in northern Nigeria recorded high levels of Ni in the intestine (0.109mg/kg) with lower levels in the skin (0.08mg/kg). Although, Ni plays a vital role in the body such as regulating prolactin and stabilization of RNA and DNA structures (Sabuwa & Nafarnda, 2020), it is considered as one of the trace elements that pose a major danger to public health and ecology (Sule, Umbsaar & Prenner, 2020; Jadaa & Mohammed, 2023). The concentrations of Ni in all sampled meat parts in this study were below the permissible limit of 1.0 mg/kg set by FAO/WHO (Kasozi et al., 2021).

Cobalt was detected in all the parts studied. The highest cobalt concentration was found in torso meat and the lowest concentration in lean meat. Milam, Dimas, Jang and Eneche (2015), reported the presence of heavy metals in vital organs of cows and bulls at Jimeta abattoir in Yola, that cobalt was undetected in most of the samples except for the liver which recorded a concentration of 0.01 ±0.01 mg/kg. Cobalt is a key constituent of vitamin B_{12}, excess in human body may cause overproduction of erythrocytes and hypothyroidism, occupational asthma and fibrosis in lungs and can lead to disturbance of iodine metabolism in the thyroid gland (Attar, 2020).

The recorded mean concentration of chromium in the meat samples were above the FAO/WHO maximum permissible levels of 0.05mg/kg. The highest concentration of chromium was detected in lean meat, followed by stomach meat. Torso meat recorded the least concentration of chromium. Sabuwa et al. (2019), detected higher residual levels of Cr in intestine, kidney, liver, muscle and skin. The levels of the current study were lower than the results obtained by Usman, Lawal & Olademeji (2022), conducted in Northern Nigeria. Chromium functions as a cofactor of insulin when in trace amounts but could be toxic when it exceeds the tolerable limit (Makanjuola, 2016).

The highest cadmium level was found in torso meat while the least in skin meat. Studies have shown that cadmium has no known function in human body but rather induces toxicity even at low concentrations due to its low excretion rate (Wu et al., 2016). Cadmium is primarily toxic to the kidneys, especially to proximal tubular cells (Njoku et al., 2023). Long-term exposure in humans is associated with renal dysfunction and high exposure can lead to obstructive lung disease and has been linked to lung cancer (Tuzen et al., 2016). Cadmium can mimic the function and behaviour of essential metals like zinc, which can lead to dysregulation of calcium, zinc and iron homeostasis (Schaefer et al., 2020). In this study concentrations of cadmium recorded in all meat parts poses no toxicological risks to consumers.

Lead is considered one of the most toxic heavy metals and has no benefits for humans or animals (Ujowundu et al., 2017). Lead residues were higher in skin meat than the intestine and lean meat (Figure 4.22). The least concentration was observed in the lean meat. Livestock contamination with Pb can come from air, water they drink and food they eat. All the meat samples analysed contained lead in low doses (below the tolerable limit), which might be a consequence of road traffic and Pb emissions from petrol engines in areas where these cattle grazed. Chronic lead toxicity has been linked to birth defects, renal failure, neurological impairments, allergies, mental disorders, learning disability, autism, muscle weakness, coma and even death (ohiagu et al., 2022).

No permissible limit for Manganese (Mn) has been published by FAO/WHO or European Food Safety Agency (Ali, Almashhadany, & Khalid, 2020). Manganese residues were higher in stomach, followed by torso and the least concentration in lean meat. Anuforo et al. (2020) recorded low levels of Mn in red meat, liver and kidney of cattle meat sold in Owerri Metropolis, Imo State, Nigeria. Manganese ions function as cofactors for a large variety of enzymes and are particularly essential in detoxification of superoxide free radicals. They also play roles in fat metabolism, calcium absorption, and blood sugar regulation (Henn et al., 2010). Manganese is known to block calcium channels and with chronic exposure result in central nervous system dopamine depletion. This duplicates almost all the symptomology of Parkinson's disease (Odon, Ogah & Ushie, 2016). Overexposure to Mn in the brain has been implicated in several neurodegenerative diseases such as Alzheimer's disease (Martins et al., 2019).

Arsenic is an environmental toxicant and is detected in all sampled meat parts in this study. Torso meat recorded the highest mean concentration (mg/kg) when compared to other tissues and exceeded the permissible limit as set by FAO/WHO. The concentrations of arsenic in stomach and skin were below WHO permissible levels of 0.01mg/kg, while the concentrations in intestine and lean meat were slightly above the permissible limit (Kasozi et al, 2021). High concentration of arsenic can cause nausea, vomiting, diarrhea, cough, headache and cardiovascular disease especially in livestock (ATSDR 2007a; Tchounwou et al., 2012), which in turn poses a great risk to humans.

DDT and its metabolites, namely dichlorodiphenyldichloroethylene (DDE) and dichlorodiphenyldichloroethane (DDD), are known to persist in the environment and can bioaccumulate in aquatic organisms (Mshelia et al., 2022). DDT, DDD and DDE have all been classified by NAFDAC as probable human carcinogens (Mshelia et al., 2022). The relative profile of these compounds was DDT > DDE > DDD. DDT was detected in all sampled meat parts with the highest concentration observed in the stomach. Values obtained in this study are also below the MRLs of 5 mg/kg set by Codex Alimentarius for ∑DDT (i.e., DDT + p′p′-DDD + p′p′-DDE). However, the residue concentrations of DDT and its metabolites in this study exceeded those reported in edible tissues of cattle in Benin City, Nigeria, by Tongo and Ezemonye (2015). Similarly, varying concentrations of these compounds have been observed in edible offal of buffalo in Egypt by Mahmoud et al. (2013), and in muscle and organs of cow, camel, and goat in Kebbi, Nigeria by Osesu and Fasiku (2022). These elevated residue concentrations could be attributed to the persistent presence of DDT in the environment or possibly due to recent illegal and indiscriminate use.

In the case of heptachlor, its relatively high residue concentration in this study may be attributed to its persistence in the environment, with the highest concentration observed in skin meat However, residue concentration in the various parts did not vary. Heptachlor is known to bind to soil particles and migrate slowly, possibly being ingested by cattle during their feeding (Blankson-Arthur et al., 2011; Osesua & Fasiku, 2022). The concentrations of heptachlor in this study are higher than those reported by Blankson-Arthur et al., (2011) in muscle (0.695 µg/kg wet) and kidney (0.403 µg/kg wet) in grasscutter. Similar studies to that of Blankson-Arthur et al. (2011) has been reported by Osesua and Fasiku (2022) in muscle, liver, kidney and heart of slaughtered cow, camel and goat in Kebbi State, Nigeria. Concentrations observed in this study exceeded the MRLs of heptachlor (0.2mg/kg) stipulated by FAO/WHO (2016) in the different parts.

Despite the ban on endosulfan, its prevalence in this study may be attributed to its continued use in the environment. The concentration of endosulfan in the various parts did not vary. Varying levels of endosulfan have been reported in muscle, liver, kidney and tongue tissues of cattle (Tongo & Ezemonye, 2015) and in cattle meat (Muhammad et al., 2010). The observed residue concentrations of endosulfan in this study were higher than the concentrations reported in grasscutter tissues (Blankson-Arthur et al., 2012). The result showed that the levels were however within the established MRLs (0.2mg/kg). Endosulfan is known for its toxicity to the nervous system, with high exposure resulting in hyperactivity, convulsions, and potentially death (Agency for Toxic Substances and Disease Registry (ATSDR), 2015).

The concentration of γ-HCH (lindane) in the meat parts followed the sequence lean meat > stomach > intestine > skin > torso, with the highest concentration in lean meat, the intestine, stomach and skin had similar concentrations of lindane, the torso meat had the least concentration. While γ-HCH is typically known for its lipophilicity, concentrations of lindane did not vary among the tissues. The observed residual levels of lindane in the meat parts from this study were higher than concentrations in reported studies on various parts of animal tissues (Osesua & Fasiku, 2022; Tongo & Ezemonye, 2015; Mahmoud et al., 2013; Pardio et al., 2012). Higher levels of lindane observed in this study indicates an upsurge in the use of technical HCH and lindane on pastures grazed by the cattle. The concentrations of lindane across meat parts in this study were relatively higher than the FAO/WHO (2016) permissible limit (0.001 and 0.01 mg/kg) in edible offal and meat respectively.

Hexachlorobenzene is a fungicide that has been banned globally under the Stockholm Convention on persistent organic pollutants (UNEP, 2004; Benson & Olufunke, 2011). The HCB is a known animal carcinogen causing increased incidences of lung, kidney and thyroid cancers (IARC, 2001; Benson & Olufunke, 2011). The concentrations of HCB observed in this study did not vary across the meat parts as seen in (Table 4.1). The residue levels of hexachlorobenzene observed in the meat parts in the study were higher than the maximum limit of 0.01mg/kg according to the European Union (2016). Mahmoud et al. (2013), in their report on organochlorine pesticides in edible offal of Egyptian buffalo detected lower levels of HCB in kidney and tongue (9.49 ± 3.11

and 23.18 ± 8.82 ng/g) from Ismailia and in livers and kidneys (10.15 ± 2.67 and 96.67 ± 30.19 ng/g) from Mansura city.

Chlordane is a cyclodiene insecticide that was used extensively in home and agricultural applications (Benson et al., 2011). g-Chlordane and t-nonachlor are two out of the four principal components of chlordane with t-nonachlor being the most bio-accumulative major constituent of the insecticide (WHO, 1984). The concentrations of both g-chlordane and t-nonachlor did not vary in the meat parts. The FAO/WHO Joint Meeting on Pesticide Residue evaluated chlordane and established tolerances in food of 0.02-0.5 for the sum of cis- and trans- isomers of chlordane. Similarly, extraneous residue limits established by Codex Alimentarius Commission for the sum of cis- and trans-chlordane and oxychlordane as 0.05 mg/kg.

Residue concentration of t-nonachlor in torso, skin, stomach, lean meat, and intestine were above the residue limits stipulated by the Codex Alimentarius Commission but within limits established by FAO/WHO in food with the exception of torso meat which recorded values way above the tolerance in food. Similar trend was also observed for residue concentration of g-chlordane. Mahmoud et al. (2013) detected residue concentration of chlordane in Egyptian buffalo with ∑CHLRs mean concentration of 19.08±8.53 ng/g and 45.09±6.38 ng/g in liver and kidney respectively. The mean concentrations observed in this study were higher than the values reported by Mahmoud et al., (2013). Chlordane is one of organochlorine that have been banned and high prevalence observed in this study means it’s still been used in this region.

Compared with the maximum limit of 0.01 mg/kg for biphenyl as stipulated by the European Commission (2011), the concentrations of biphenyl in the studied meat parts were above the safe limits. Biphenyl concentration was higher in stomach and torso meat. There were no differences in residual concentrations of biphenyl in the tissues. Biphenyl has been used as a fungistat, most commonly to preserve packaged citrus fruits or in plant disease control as dye carrier in polyester dyeing, and as a component in heat transfer fluids (Li, Hogan, Cai & Reith, 2016). Biphenyl is also found naturally in coal tar, crude oil and natural gas and may be released into the environment from incomplete burning of organic matters, coal, oil, fossil fuels, incinerators and agricultural waste, as well as from car exhaust, residential and industrial heating sources and cigarette smoke (European Food Safety Authority [EFSA], 2010). Literature on biphenyl residue in animal tissues are scanty but residue concentrations in food crops have been reported.

Dichlorobiphenyl represents either of the twelve isomers of the polychlorinated biphenyl (PCBs) containing two chlorine atoms. Dichlorobiphenyl residue abundance in the sampled meat parts were in the sequence intestine > skin > stomach > torso. The highest concentration of dichlorobiphenyl was observed in the intestine, but was undetected in lean meat. When compared with the maximum residue limit of 40 ug/mg of fat specified by the European Commission (Kuzukiran & Filazi, 2015), the concentrations of dichlorobiphenyl found in the meat parts were within safe limits. Varying concentrations of PCBs have also been reported in meat products.

PCBs are known for their hydrophobic, stable, lipid-soluble, and persistent nature. Their metabolites can pose various health challenges, including carcinogenicity, endocrine disruption, neurotoxicity, dermatological and pulmonary diseases, and developmental disorders in children (Kuzukiran & Filazi, 2015). Despite being globally banned under the Stockholm Convention, PCBs are still produced and used in many developing countries. One concerning aspect is the continuous release of PCBs from old equipment and waste sites. This poses a significant threat to both the environment and human health, as PCBs can persist in the environment for extended periods (EPSA, 2010; Yurdakok, Tekin, Daskin & Filazi, 2015). Official information on the PCB situation in Nigeria's environment is scarce, and there are no readily available formal regulatory limits or standards for PCBs. This highlights the need for proactive efforts by the Nigerian government and relevant agencies to develop food, water, and environmental monitoring programs for PCBs and related contaminants (Dada et al., 2023).

Chlorpyrifos is one of the organophosphorus residues analysed in this study. It was detected in all the meat parts. The levels of chlorpyrifos in the cattle meat parts are in the sequence intestine > lean meat > skin > stomach and torso meat. Concentrations of chlorpyrifos in the sample did not vary. Residual concentrations of chlorpyrifos in this study were higher than the reports of Dallergrave et al. (2018) and Osesua & Fasika, (2022). The concentration of chlorpyrifos in the study exceeded the MRLs (0.01mg/kg) in all the meat parts. Similar study reported in Faisalabad to compare the residue of chlorpyrifos and other pesticides in meat samples revealed high residue levels above the MRLs (Maitera et al., 2018, Muhammad et al., 2010; Ndahi, Maitera, Kubamarawa & Joseph, 2020).

Dichlorvos is an insecticide used on crops, stored products and animal or as pest control in homes (Ndahi et al., 2020). It is one organophosphate pesticide that is rarely detected in biological tissue despite their intensive use in agriculture for the control of insect pests, due to their high rate of degradation in biological tissues (Osesua & Fasika, 2022). Acute and chronic exposure of humans to dichlorvos can result in vomiting, diarrhoea, drowsiness, fatigue etc (Maitera et al., 2018). Dichlorvos was detected in all the meat parts studied. The concentration of dichlorvos was higher in the intestine than in other parts. The observed residual levels of dichlorvos in the tissues from this study were lower than the concentrations reported in beef, chevon and internal organs of cows and goats slaughtered in Yola, Adamawa State, Nigeria (Maitera et al., 2018). The detected levels of dichlorvos are below the MRLs value of 1mg/kg in all the meat parts in this study.

Glyphosate is a common herbicide used in agriculture that readily binds to soil particles and remains in the upper few centimetres of the soil which inevitably is consumed by cattle (Osesua & Fasiku, 2022). Glyphosate is classified in toxicity category III (i.e., non-carcinogenic to humans) (USEPA, 1993). The existence of glyphosate residues in animal feeds from pre-harvest glyphosate treatment of cereals or fodder may result in residual concentrations in meat, milk and eggs (JFCRF, 2016). In this study, glyphosate was detected in torso and stomach meat parts and their concentrations did not vary. The residual concentration observed in torso and stomach meat were below the MRLs (Codex Alimentarius). Similar levels below the MRLs was reported by Osesua & Fasiku (2022) in muscles and organs of cows, camel and goat in Kebbi State, Nigeria.

The concentrations of emamectin in the various meat parts did not vary. Emamectin is an avermectin class insecticide developed for the control of lepidopteron insects (e.g. butterflies and moths). It kills insects by disrupting neurotransmitters, causing irreversible paralysis and the target pests are numerous (USEPA, 2009). The residue concentration of emamectin in the meat parts in this study were lower than the permissible limit of 0.08 mg/kg stipulated by FAO/WHO (2012).

Paraquat (PQ, 1,1'-dimethyl-4-4'-bipyridinium dichloride) is a highly toxic quaternary ammonium herbicide widely used in agriculture, it exerts its toxic effects mainly because of its redox cycle through the production of superoxide anions in organisms, leading to an imbalance in the redox state of the cell. The maximum residue limit of paraquat in edible offal (mammalian) as stipulated by the FAO/WHO, (2006) is 0.05 mg/kg. Results of this study revealed varying levels of paraquat in cattle meat parts with the highest level observed in the skin meat. Higher residue levels in the skin may be attributed to direct contact with paraquat during grazing. Concentrations of paraquat obtained in this study were above the maximum residue limit across the meat parts.

Paraquat is a non-selective contact herbicide for broadleaf weed control and exposure can initiate oxidative stress, lipid peroxidation and liver damage through the generation of free radicals (Ujowundu, Nwaogu, Ujowundu, Oparaeche & Oyarebu, 2018). Studies on paraquat toxicity, have shown that chronic exposure can lead to lung and liver damage, kidney failure and Parkinsonian lesions in addition to fibrosis (Tanner et al., 2011; Ujowundu et al., 2018).

Comparing residues contamination in the different meat parts revealed that torso meat had the highest total pesticide contamination and lean meat had the least. The high prevalence of residual contamination observed in torso meat could be attributed to the fact that the torso meat is mainly a fat deposit and readily absorb these residues. The sequence of contamination is torso > skin > stomach > intestine > lean meat.

The differences in the levels of pesticides in the meat parts observed in the various studies could be due to the levels of contaminants in pastures where these cattle graze/drink, the type of husbandry practices, the quantity of contaminated fodder consumed, the physical and chemical properties of the pesticides and also the location or proximity of the slaughter houses or abattoir to pesticide contamination (Hiba, 2015; Osesua & Fasiku, 2022).

CHAPTER FIVE

CONCLUSION, RECOMMENDATIONS AND CONTRIBUTION TO KNOWLEDGE

5.1 CONCLUSION

The present study determined the lipid content, mineral and pesticide residues of cattle meats parts consumed in Nigeria. Owing to the fats and fatty acid profile composition of meat, concerns have been raised about the consumption of meat because of the presence of saturated fats that cause coronary heart diseases and elevated cholesterol level if taken in higher than normal amount. Cholesterol content lower than the reference value per daily serving, higher PUFA content than SFA observed in the study showed that these meat parts were suitable for incorporation in human diet and could improve overall diet in relation to healthy nutrition.

The study also revealed the accumulation of heavy metals and pesticide residues in cattle meat parts. The concentrations of heavy metals in the meat parts were below and within permissible limits with exceptions for Fe, Cr and As. Although the concentrations of most of the heavy metals were found to be generally low, it is important for the continuous evaluation of these metals in both animals and environment of the study area so as to reduce their accumulation in cattle and human tissues. The results of this study also revealed the persistence of organochlorine pesticides in the environment and subsequent accumulation in animal tissues. When compared with maximum residue limits stipulated by FAO/WHO, Codex Alimentarius Commission and the European Union, residue concentrations of heptachlor, lindane, hexachlorobenzene, chlordane, biphenyl and 4 – 4 pyridinium dichloride were above the safe limits. These findings reflected the quality and safety of cattle meat sold at Obinze Abattoir.

5.2 RECOMMENDATIONS FOR FURTHER STUDY

In light of the forgoing, this study concludes with the following recommendations:

i. Further investigations with larger sample size on the nutritional quality of cattle meat to reveal a clearer picture of the health implications of cattle meat consumption.
ii. Further research on residue concentration of other pesticides should be carried out to ascertain the span of pesticides in the environment as this study does not cover all pesticides.
iii. Ranching should be encouraged to reduce the exposure and accumulation of toxic substances in cattle tissues.

5.3 CONTRIBUTION TO KNOWLEDGE

The present study has shown that meat from cattle offer some benefits to human health, not only in terms of essential fatty acids such as linoleic and linolenic acids, but also polyunsaturated fatty acids such as arachidonic, eicosapentaenoic and docosahexanoic acids. However, the findings are significant as it highlighted the potential risk associated with the presence of heavy metals and pesticides above tolerable limits, which significantly diminished the nutritional advantages consumers may otherwise derive from the consumption of these meat parts. These findings provide preliminary baseline data on human health risks associated with consumption of edible cattle meat parts (torso, stomach, skin, lean meat and intestine) contaminated with heavy metal and pesticide residues from cattle slaughtered at Obinze Abattoir, Imo State.

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Appendix i

CALIBERATION CURVES FOR CHOLESTEROL