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Comparative Biodepurative Potentials of Metadavinae Cestodes and Strongyloides Nematodes on Trace Metals in the Intestine of whe-bellied Pangolin (*Phataginus tricuspis*)

Akeredolu Excellence[1], Soladoye Iwajomo[1], Omole Damilola Adewunmi[1],Fatsuma Olaleru[1] ; Isibor Patrick Omoregie[2] and Akinsanya Bamidele[1]
[1]Department of Zoology, University of Lagos, Akoka, Nigeria.
[2]Department of Biological Sciences, Covenant University, PMB 1023, Ota, Ogun State, Nigeria*.
***Email :** bamidele992@gmail.com

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ABSTRACT

The white-bellied pangolins (*Phataginus tricuspis*) harbour ecto- and endo-parasites. In this study we compared the bioaccumulation potentials of metadavinae cestode and *stongylondes* nematode parasites for trace metals in the intestine, and the lipid profile in the liver of infected and uninfected *P. tricuspis* sampled from Epe Local Government Area, Lagos State, Nigeria. Trace metal concentrations were determined in the pangolin and its intestinal parasites using a Flame Atomic Absorption Spectrometer. Total cholesterol levels in the infected and uninfected pangolin were determined using the enzymatic endpoint method. The concentrations of Al, Cd, and Cr were higher in the infected intestines, while Ba, Fe, and Zn were higher in the uninfected intestines. The levels of lipid profile in the infected intestine were comparatively low. The average level of cholesterol (CHOL) in the infected intestine was 0.87 mg/dL, while the levels of triglycerides (TRIG), high-density lipoproteins (HDL), and low-density lipoproteins (LDL) were all below 0.4 mg/dL. The concentrations of the lipid profile CHOL and HDL in the uninfected intestines were higher than the concentrations observed in the infected counterparts. The concentrations of CHOL, HDL, and LDL were 2 mg/dL, 1.7 mg/dL, and 0.85 mg/dL respectively, while TRIG below 0.35 mg/dL. The concentrations of trace metals detected in the tissues of strongylondes nematodes showed significant bioaccumulation factors in the order of Mn (28.6)> Zn (9.7)> Ba (5.2)> Cd (3.5)> Cr (2.9)> Al (1.3). Cestode parasites are good biodepurative agents. The nematodes in this study exhibited notable biodepuration superiority. *Strongyloides spp*. may be a reliable bioindicator of the metal burden in *P. tricuspis*. This provides a reliable ecotoxicological prognosis for proactive remediations and decisions by lawmakers to make pragmatic plans and policies toward sustainable conservation of *P. tricuspis*.

INTRODUCTION

Increased demand for pangolin scales and meat in Asia has driven the illegal trafficking of these animals from Africa (Challender, 2011). The ongoing trade in pangolins poses a severe threat to their survival and has resulted in a significant decline in their population (Abayomi *et al*., 2009; Challender, 2011).

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Evidence shown by Challender and Hywood (2012) suggests that the intercontinental trade in African pangolins, primarily to meet the demand in the Asian market, especially China, could potentially lead to the extinction of the taxon (Akeredolu *et al*., 2018). Pangolin trafficking from Africa to Asia has been documented since 2008 (Challender and Hywood, 2012).

In West Africa, research consensus on the bushmeat trade and traditional medicinal use of pangolins suggests that these activities contribute to population declines in the three tropical African species (Soewu and Adekanola, 2011; Boakye *et al*., 2014; Soewu and Adekanola, 2011). The unsustainable exploitation of pangolins can also lead to biodiversity loss (Zanvo *et al*., 2021). Three decades ago, Sodeinde and Adedipe (1994) reported that hunters described white-bellied pangolins (*Phataginus tricuspis*) as rarer compared to previous years. In interviews with traditional medicine practitioners, Soewu and Adekanola (2011) found that pangolins had decreased in number and average body size over time. In Central Africa, available evidence indicates that local use and trade of pangolins are also likely unsustainable. As a result, all eight pangolin species are listed in CITES Appendix I, effectively banning international trade in pangolins and their derivatives.

The role of parasites in biodiversity conservation has received little attention until recent times. Parasites can cause infections that affect fecundity (Dobson *et al*.,1992; Akinsanya and Otubanjo, 2006), and damage or impair the functioning of the body systems of wildlife (King and Li, 2018). Certain parasites exhibit symbiotic relationship by accumulating contaminants such as heavy metals and organic pollutants from their hosts into their own tissues (Akinsanya *et al*., 2020). Goutte and Molbert (2022) reported reduced contamination levels, oxidative stress, histological alterations, improved survival rates, and better body condition in infected individuals compared to non-infected counterparts of the same species.

Pangolins, in general, are known to be entomophagous organisms whose diet primarily consists of ants and termites (Karawita *et al*., 2018). As a result, they are vulnerable to the trophic transfer of pollutants. Other characteristics of pangolins, such as their ability to inhabit diverse habitats, including farmland, their feeding mechanism involving burrowing in the ground and climbing trees, and even their ability to swim (Oguntuase and Oni, 2018), all contribute to the potential exposure of these endangered wildlife species to environmental contaminants.

Pangolins are consumed in Asian countries, particularly in the southern parts of China, such as Guangdong Province and Guangxi Zhuang Autonomous Region, since 1900 (Pantel and Chin, 2009). They are also consumed in Africa (Bräutigam *et al*., 1994; Dickman and Richer, 2001; Drury, 2009; Challender and Hywood, 2012; Boakye *et al*., 2015; Bobo *et al*., 2015; Boakye *et al*., 2015; Boakye, 2016; Akeredolu *et al*., 2018; Yasmeen *et al*., 2021). In Africa, pangolins are also used in traditional medicine practices, where the whole animal or its body parts are utilized in various concoction preparations, as stated by Soewu *et al*. (2020). The extensive documentation of various utilization and consumption practices that have increased the vulnerability of pangolins to extinction has emphasized the need for research on sustainable protection of these wild animals (Sodeinde and Adedipe, 1994; Gaudin and Wible, 1999; Gaubert and Antunes 2005; Gaudin *et al*., 2009; Pantel and Chin, 2009; Soewu and Ayodele, 2009; Isaksson, 2010; Soewu and Adekanola, 2011; Kingdon and Hoffman, 2013; Mahmood *et al*., 2013; Edet *et al*., 2014; Baillie *et al*., 2014; Pietersen *et al*., 2014; Waterman *et al*., 2014; Baiyewu, 2016; Liu *et al*., 2016; Nash *et al*., 2016; Karawita *et al*., 2018; Kumar *et al*., 2018; Willcox *et al*., 2019; Jansen *et al*., 2020; Soewu *et al*., 2020; Nguyen *et al*., 2021; Sexton *et al*., 2021;Sandri *et al*., 2022).

Several studies have examined the presence of gastrointestinal parasites in pangolins and their impact (Sist *et al*., 2021; Barton *et al*., 2022). Additionally, Mohapatra *et al*. (2016) compiled a checklist of ecto and endo parasites found in pangolins. However, there have been no reports on the bioaccumulation of trace metals in parasites recovered from pangolins. While studies have investigated the bioaccumulation of trace metals in tissues of various mammals and amphibians (Ali and Khan, 2019; González-Gómez *et al*., 2021; Khairy *et al*., 2021; Okeagu *et al*., 2022), it is challenging to draw similar conclusions for pangolins due to the limited amount of research available on this aspect for the species (Atkins, 2004). It is necessary to understand the extent of bioaccumulation in their tissues and the potential impact on their health and conservation.

It is crucial to understand the parasite fauna of pangolins as a prerequisite for establishing facts about their health status, zoonotic potential, and conservation measures, such as captive breeding (Liumsiricharoen *et al*., 2008). Generally, pangolins often harbor both ectoparasites and endoparasites, including ticks, mites, helminths, bacteria, and protozoa (Ayodele and Akinsanya, 2022). Parasites found in both captive and wild pangolins include *Amblyomma javanense* in Chinese pangolins (*Manis pentadactyla*), *Amblyomma copressum* in Giant ground pangolins (*Manis gigantea*), *Amblyomma javanense, Aponomma gerviasi*, and *Rhipicephalus sp*. in Indian pangolins (*Manis crassicaudata*), *Amblyomma cordiferum, Amblyomma javanense,* and *Aponomma varanensis* in Malayan pangolins (*Manis javanica*), *Amblyomma compressum, Ixodes rasus, Ornithodorus moubata, Rhipicentor longus, Rhipicentor muhsamae*, and *Rhipicephalus simus* in Temminck's ground pangolins (*Manis temminckii), Amblyomma compressum, Aponomma exornatum, Aponomma flavomaculatum, Aponomma latum, Haemaphysalis parmata*, and *Rhipicentor muhsamae* in Tree pangolins (*Manis tricuspis*), *Amblyomma arcanum, Amblyomma cordiferum, Amblyomma geoemydae*, , Dermacentor (Indocentor) *atrosignatus*, Dermacentor (Indocentor) *steini*, and Ixodes oldi in an unidentified pangolin species (*Manis sp*.) (Ezenwaji *et al*., 2005; Opara and Fagbemi, 2008; Mohapatra *et al*., 2016; Wang *et al*., 2016; Simo *et al*., 2020; Sist *et al*., 2021; Barton *et al*., 2022).Pangolins are often heavily infested with ticks, and according to Jacobsen (1991), mites (*Manitheronyssus heterotarsus*) and tampans (*Ornithodorous moubata*) were believed to induce progressive paralysis in adult male pangolins, eventually leading to death. *Ambloyomma compressum* (Baiyewu, 2016) is almost exclusively found in the other three African pangolin species.

Parasites are known to be useful bio-indicators of contaminants in various trophic levels of an ecosystem (Akinsanya *et al*., 2019; Ayodele *et al*., 2022). Several studies have shown the effectiveness of different parasite taxa in accumulating environmental pollutants, such as persistent heavy metals (Amzat *et al*., 2008; Le *et al*., 2014; Nachev and Sures, 2016). Sures *et al*. (2017) stated in a review that four major endohelminth taxa, namely Acanthocephala, Cestoda, Digenea, and Nematoda, have been considered indicators of metal pollution. They further mentioned that the location and developmental stage of parasites are crucial in determining the concentration and type of pollutants that can be bioaccumulated. While some parasites can aggravate symptoms of pollutant toxicity in certain organisms (Marcogliese *et al*., 2010), others can help mitigate the impacts of pollutants in their hosts (Heinonen *et al*., 2001).

Trace metals can be introduced into ecosystems not only through anthropogenic activities, such as mining, smelting, and agriculture, but also through natural means (Dube *et al*., 2001). They are classified as environmental pollutants and can persist in the environment (Sharma and Agrawal,2005; Sharma *et al*., 2021). Since heavy metals cannot be destroyed by heat (Mohamed *et al*., 2016), they can be transported across ecosystems, depending on the physicochemical properties of the metal and the soil (Dube *et al*.,2001). They are largely present in soil and water bodies, while being found in the atmosphere in minute proportions (Sharma and Agrawal,2005). They can enter organisms through dermal contact, inhalation, and ingestion of contaminated water and food (Fu and Xi, 2020).

While some heavy metals, such as manganese, zinc, copper, and iron, are required in small quantities for optimum growth and activation of various enzymes (Wintz *et al*., 2002), others, such as arsenic, lead, aluminum, mercury, and cadmium, are extremely detrimental to human health even at low concentrations (Sharma and Agrawal, 2005; Fu and Xi, 2020). Due to their persistence and bioavailability, they pose a threat to humans and wildlife, causing various health complications and metal toxicity (Mohamed *et al*., 2016).

It is an established fact that the application of agrochemicals can help improve agricultural yield (Oyinloye *et al*., 2021) by curbing the effects of pest and disease outbreaks in farmland. In addition to this source, contaminants such as trace metals are incorporated into the food chain through a plethora of anthropogenic activities, such as the use of automobiles, generators, and the application of many factory-made products, which have been implicated in ecological and health risk analyses (Gwary *et al*., 2011). Hence, there is a need to evaluate the effect of trace metals on pangolins and explore the roles of endoparasites in protecting the animal from metal toxicity.

The study aimed to compare the bioaccumulation potentials of Metadavinae, Cestodes and Strongylondes nematodes for trace metals in the intestine of Phataginus tricuspis (white-bellied pangolin) sampled from Epe local government, Lagos. It sought to compare the lipid profile of the liver of infected and uninfected pangolins.

MATERIALS AND METHODS

This study was carried out in the Oluwo market area in Epe local government, Lagos, Nigeria. Epe is situated in the coastal territory of Lagos. Oluwo market is a popular bushmeat market where the buying and selling of various bushmeat, both live and carcasses, takes place. The market is located close to the Lekki lagoon, which is between longitude 40001 and 40151E and latitude 60251 and 60371N. The surface area of the lagoon is about 247 km square with a maximum depth of 6.4m, occupying about 900 hectares (Akinsanya *et al*., 2019). The surroundings of the market are sparsely covered with a few trees, shrubs, and a plantain plantation. Other buying and selling activities, such as fishing and basic daily needs and household items, are also conducted at the market.

1. Parasite Collection, Preservation and Identification:

Fresh pangolin specimens were dissected one by one, and the gastrointestinal tract was collected. The intestines were dissected longitudinally from the anterior to the posterior using sterile scissors and placed in a petri dish containing a normal saline solution (0.75% NaCl) to facilitate the release of parasites that adhere to the lumen. A hand magnifying lens was used to inspect for tiny parasites and distinguish them from small strands of tissue. Parasites that were found were collected using forceps.

All the parasites that were discovered were preserved and transferred to vials. The vials were carefully sealed and labelled with code names for identification purposes. Standard morphological characteristics were used to identify the parasites, and photomicrographs of the parasites were taken for further identification. For ethical compliance, 85 deceased but fresh pangolins were dissected one by one, and their gastrointestinal tracts were collected. The procedure followed the same steps described above, including the use of sterile tools and a normal saline solution. Parasites were collected for study and identification using forceps.

2. Parasite Collection, Preservation and Identification:

All the parasites that were found were preserved and transferred to vials after being thoroughly sealed and labelled. Standard morphological characteristics were used to identify the parasites, and photomicrographs of the parasites were taken for identification purposes. In total, 238 enteric parasites were recovered. These parasites were identified as 120 Metadavinae cestodes and 118 Strongyloidiasis nematodes, according to Akinsanya *et al*. (2007).

3. Determination of Trace Metals and Lipid Profile:

The intestines of the sampled pangolins were excised and weighed. The organs were homogenized with 0.1 phosphate buffer (pH 7.2) and then pulverized with a mortar and pestle. The resulting homogenate was centrifuged at 2500 rpm for 15 minutes, and the supernatant was decanted and stored at -20°C.Frozen tissues were thawed, and samples of two (2) grams wet weight from infected and uninfected intestines were weighed. The enteric parasites were placed separately in a beaker and digested with a 1:1 ratio of hydrogen peroxide and nitric acid (25 mL). The mixture was heated until it reduced to about 5 mL and then allowed to cool. It was then filtered and diluted with distilled water to a final volume of 50 mL. The concentrations of the elements were analysed using a flame Atomic Absorption Spectrometer (Philips model PU 9100). The analytical procedures followed were strictly in compliance with the guidelines of Whiteside (1981). The total cholesterol in the infected and uninfected intestines of pangolins was determined using the enzymatic endpoint method described by Roeschlau *et al*. (1974). High-density cholesterol (HDL) was measured spectrophotometrically using a series of coupled reactions as described by Burstein *et al*. (1980). Low-density cholesterol (LDL) was determined using the method of Assman *et al*. (1984), which combines polyvinyl sulfate precipitation and an enzymatic method for analysing low-density lipoprotein-associated cholesterol.

4. Statistical Analysis for Specimens:

The descriptive statistics of the parasite abundance and trace metals in the parasites and intestines of infected and uninfected pangolins were entered into a Microsoft Excel spreadsheet. The data was then exported into SPSS to establish the relationship between each variable. The prevalence rates of each species of parasite found in pangolins were calculated separately using the following formula.

$$\text{Prevalence} = \frac{\text{Number of infected pangolin}}{\text{Number of examined pangolins}} x100$$

RESULTS

Although there was no significant difference in the concentrations of all the trace metals between the infected and uninfected pangolins, some observable differences were noted that may have implications for the infection status of the animals (Fig. 1). The concentrations of Al, Cd, and Cr were higher in the infected compared to the uninfected pangolins. Conversely, the concentrations of Ba, Fe, and Zn were higher in intestine samples collected from uninfected indivuduals compared to the infected ones.

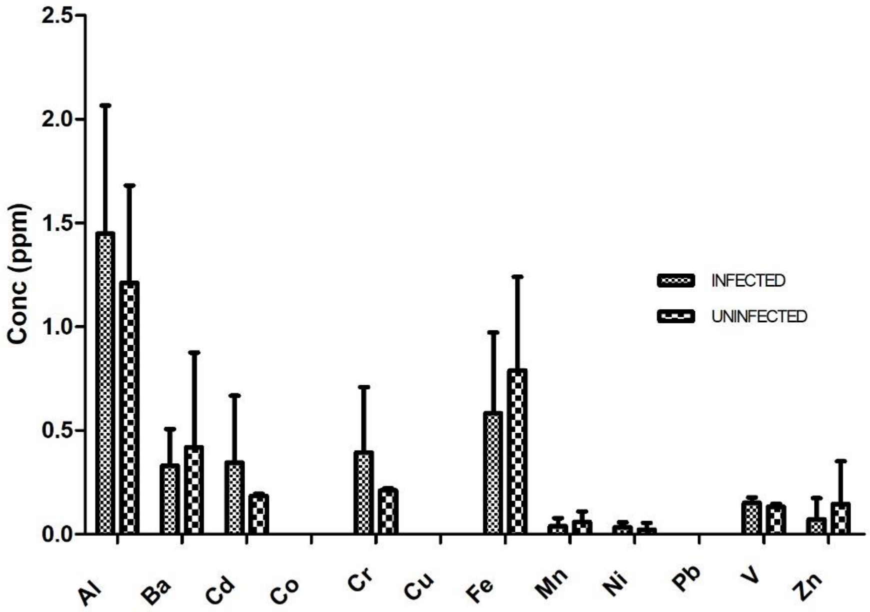

Fig. 1: Comparative concentrations of trace metals in the infected and uninfected intestines of *P. tricuspis* (sample size = 85)

The levels of lipid profile in the infected individuals (Fig.2) were comparatively low. The average level of cholesterol (CHOL) in the infected pangolins was approximately 0.87 mg/dL, while the levels of triglycerides (TRIG), high-density lipoproteins (HDL), and low-density lipoproteins (LDL) were all below 0.4 mg/dL. On the other hand, the concentrations of the lipid profile in the uninfected pangolins were notably higher than those observed in the infected counterparts, particularly in cholesterol and high-density lipoproteins (Fig. 3). The concentration of cholesterol was 2 mg/dL, the level of high-density lipoproteins was 1.7 mg/dL, low-density lipoproteins were 0.85 mg/dL, and triglycerides were below 0.35 mg/dL.

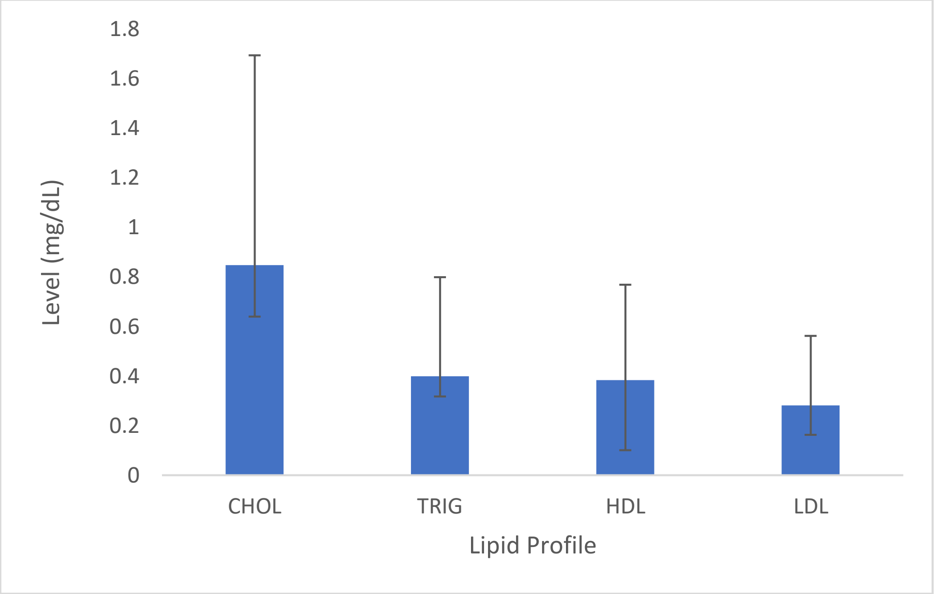

Fig. 2: Lipid profile for the intestine of infected *P. tricuspis* (sample size = 85)

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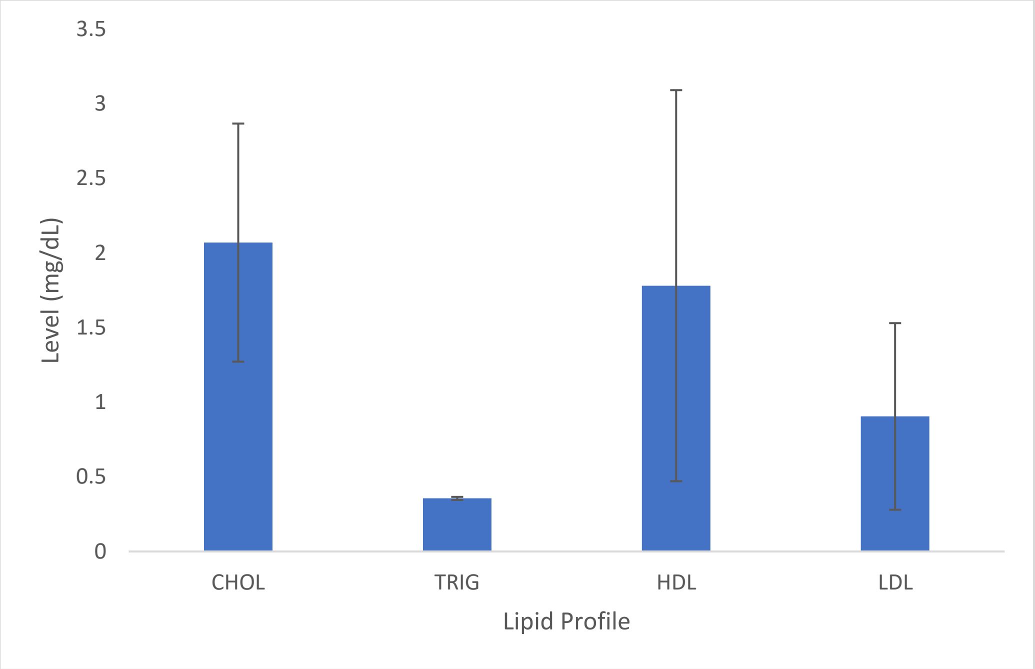

Fig. 3: Lipid profile for the intestine of the uninfected *P. tricuspis* (sample size = 85)

The observed disparities in the patterns of lipid profiles in the intestines of infected and uninfected pangolins warranted further investigation into the actual levels of trace metals in the enteric parasites of the animals (Fig. 4). The concentrations of trace metals (except Co, Cu, Ni, Pb, and V) in the Strongylondes nematodes were significantly higher ($p<0.005$) than the concentrations in the metadavinae cestode. Markedly higher concentrations were particularly observed in Al, Ba, Cd, Cr, Fe, and Mn. These observations prompted an investigation into the actual bioaccumulation of trace metals from the intestines of pangolins into the sampled enteric parasites. Figures 5 and 6 further support the differential depurative potentials of the two enteric parasites of *P. tricuspis.*

The bioaccumulation factor indicates the rate at which each enteric parasite accumulates or depurates trace metals from the intestines of the pangolins. In line with the concentrations of trace metals detected in the parasite tissues, the significant bioaccumulation factors of trace metals in strongyloides nematodes were in the order of Mn (28.6) > Zn (9.7) > Ba (5.2) > Cd (3.5) > Cr (2.9) > Al (1.3). Although Al had the highest concentration in the enteric parasite, the bioaccumulation factor was the lowest (Fig. 5).On the other hand, much lower bioaccumulation factors of the same trace metals were observed in *metadavinae cestodes* in the order of Zn (5.5) > Ni (5) > Mn (2) > Ba (1.6). Al also showed a high concentration in the parasite tissue, but the bioaccumulation factor did not correspond with the concentration (Fig. 6).

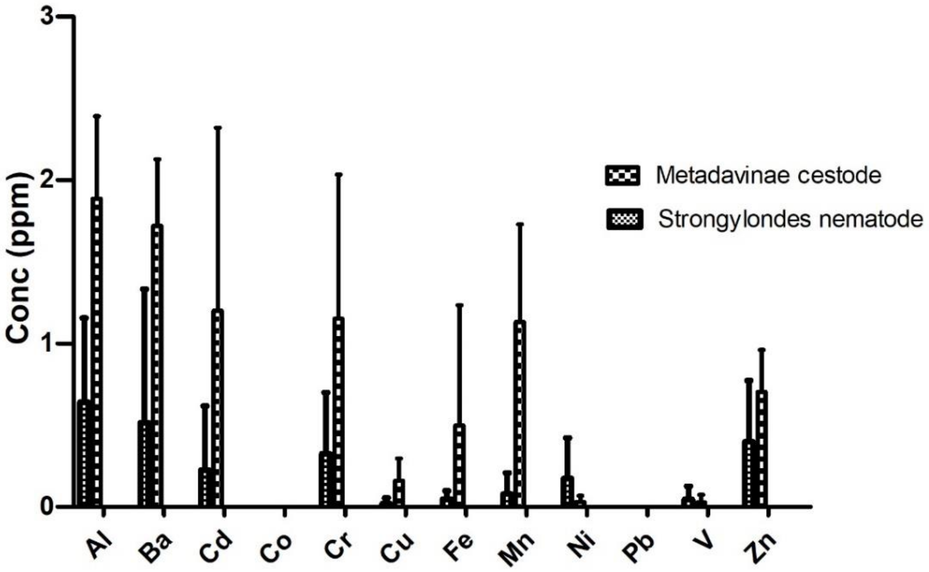

Fig. 4: Comparative concentrations of trace metals in metadavinae cestodes (N= 120) and strongylondes nematodes (N=118)

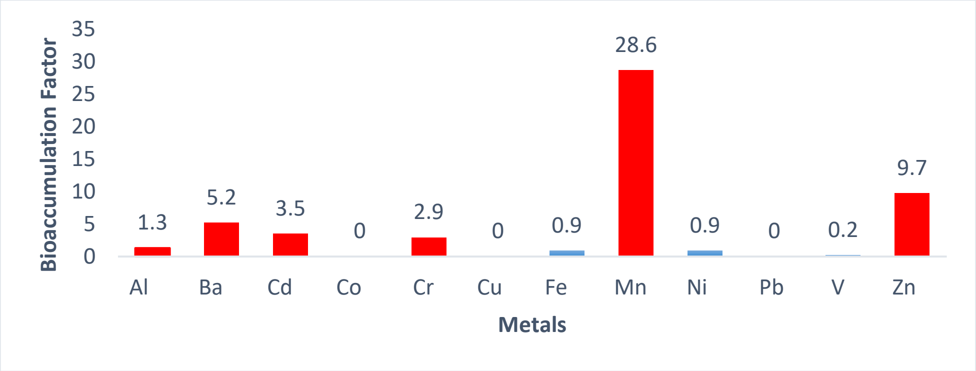

Fig. 5: Bioaccumulation of trace metals in strongylondes nematodes.

Key: red bars indicate significant bioaccumulation factor, blue bars indicate insignificant bioaccumulation factor

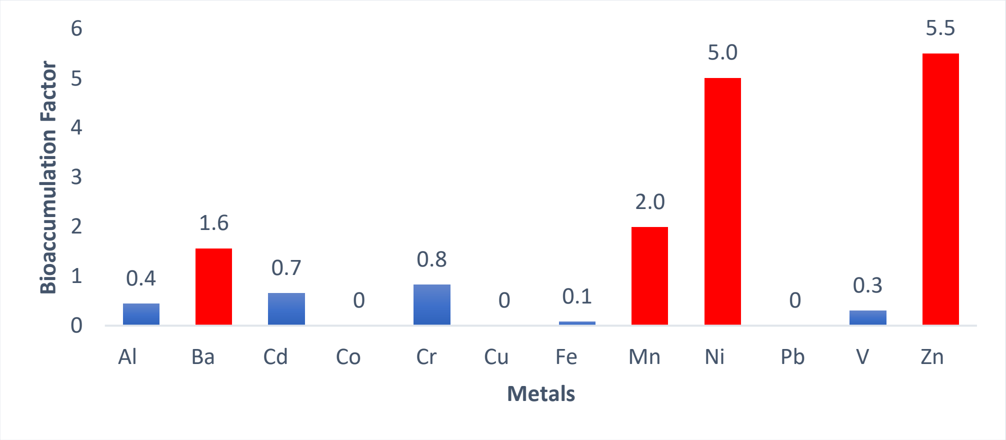

Fig. 6: Bioaccumulation of trace metals in metadavinae cestodes.

Key: red bars indicate significant bioaccumulation factor, blue bars indicate insignificant bioaccumulation factor

DISCUSSION

The arithmetic difference between the infected and uninfected was considered a prognostic measure that warranted further investigation into the differential roles of the parasites in either mitigating or synergizing the trace metals in the host's intestine. Another prognostic indicator that warranted investigation into the roles of the intestinal parasites was the differential lipid profile in the infected and uninfected intestines. The latter shows high levels of lipid profiles, particularly cholesterol and high-density lipoproteins. The elevated levels of cholesterol detected in the liver and intestine of the pangolins may have resulted from their slow metabolism and/or their consumption of termites. The high density of lipids found in the intestine of the uninfected pangolin is more than the low-density lipid, which is an indication of the cardiovascular health of the examined pangolins, probably due to the absence of interference from the parasite (Marcogliese *et al*., 2010).

Results indicated that the enteric parasite metadavinae cestodes not only accumulated higher concentrations of the trace metals from the host's intestine than their strongyloidiasis nematode counterparts, but they also showed superior depurative capacity. A marked biodepurative potential of metadavinae cestodes was exhibited for Mn. The occurrence of Al in high concentration in both infected and non-infected pangolins could have been due to the versatility in the use of Al for various anthropogenic activities such as construction, transportation, and packaging, which has made it readily available in the environment and easy for the animal to ingest. The *strongyloides* nematode exhibited a high depurative capacity for Mn (28.6) > Zn (9.7) > Ba (5.2) > Cd (3.5) > Cr (2.9) > Al (1.3) in the host pangolin, which may offer a dual advantage to the host. The concurrent interactions between the strongyloides nematode and trace metals exhibited mutual effects (Saaristo *et al.*, 2018). While the presence of strongyloides nematodes ameliorates the metal toxicity, the metals may, on the other hand, alleviate the adverse health impact of the parasite on the host. Furthermore, the strongyloides nematode in the pangolin is a reliable bio-depurative agent and bioindicator for trace metals. The superiority of nematodes observed in this study corroborates earlier observations of notable depurative potentials reported in previous literature (Akinsanya *et al*., 2022; Ayodele *et al*., 2022). Furthermore, the observations in this study conform to the findings of Azmat *et al*. (2008), who demonstrated the depuration of Pb, Cd, Cr, and Ni by enteric nematodes (*Echinocephalus spp.* and *Ascaris spp.*) in fish (*Liza vaigiensis*) of Karachi coast. This implies that there are several reliable depurative candidates in the community of nematodes. Nematodes are thus notable for accumulating metals in their soft body tissues from the host. The impacts of the bioaccumulated metals may elicit several toxicity effects in the nematodes, which may interfere with their parasitic effects (King and Li, 2018). Excessive bioaccumulation of manganese in the parasite may lead to a condition known as manganism, a neurodegenerative disorder that causes dopaminergic neuronal death (Avila *et al*., 2013), which may impair the parasitological effects on the host. This trend may thus protect the pangolin in the polluted environment in a more sustainable manner than conventional bioremediation methods (Sharma Agrawal, 2005; Zanvo *et al*., 2021; Goutte and Molbert, 2022). Notably, nematodes have been previously recommended as sentinel bioindicators of trace metals in aquatic and terrestrial ecosystems (Yen *et al*., 2013; Akinsanya *et al*., 2020; Isibor *et al*., 2020), sharing more burden of environmental pollutants than the initially exposed host. Similarly, it has been reported that intestinal Acanthocephalus of fish exhibit the capability to accumulate significantly higher concentrations of metal in their soft bodies than the host muscles (Rafia and Shahina, 2008).

The current findings are also corroborated by Ayodele *et al*. (2022), who discovered that *Strongloides spp*. are enteric parasites of roan antelope that serve as good biosequestration agents, alleviating the toxic load of cadmium and nickel from the antelope. They also suggested that the synergistic impacts of cadmium and nickel on the parasites might reduce the infection intensity in the host. Likewise, the synergistic effect of Mn, Zn, Ba, Cd, Cr, and Al may reduce the infection intensity of the strongyloides nematodes in the pangolin of the current study

Although some studies have also reported cestode parasites as good bio-depurative agents (Yen Nhi *et al*., 2013; Tammone *et al.,* 2019), the nematodes, however, exhibited notable superiority in that regard in the current study. Hence, Strongyloides spp. may be a reliable bioindicator of the metal burden in roan antelopes. This provides a reliable ecotoxicological prognosis for proactive remediations and decisions by lawmakers to make pragmatic plans and policies toward sustainable conservation of the white-bellied pangolin (Mohapatra and Panda,2014; Mohapatra *et al*.,2016; Maurice *et al*.,2019). Furthermore, this conforms to the study of Rafia *et al.* (2008), who demonstrated the metal sequestration potentials of two enteric nematodes, namely Echinocephalus sp. and Ascaris sp in *Liza vaigiensis* fish. More recently, Akinsanya *et al.* (2022) also demonstrated the biosequestration potential of enteric nematodes, *Amplicaecum africanum*, on trace metals in the toad host *Amietophrynus regularis.* As Strongyloides is a member of the phylum Nematoda, it indicates that members of the phylum may possess unique attributes that aid in the absorption of trace metals (Nachev and Sures,2016).

The strong indications that pangolins are highly parasitized suggest that consuming the animal poses a threat to the public, as consumers are at a high risk of parasitic infections or metal toxicity. Additionally, the concentration of trace metals that were bioaccumulated in the parasites at minimal levels implies that it is inevitable for consumers to ingest trace metals to a certain extent, which can consequently lead to metal toxicity. The consequences of trace metal toxicity, such as reproductive failure and reduced growth, can ultimately lead to the population decline of pangolins if not properly addressed. Therefore, it is recommended that strict laws and enforcement procedures be vehemently imposed on the harvesting of pangolins from the wild. The greatest impediment to the effective conservation of pangolins, which has been identified as a lack of biological knowledge of the species, must be addressed by creating awareness and enlightening the people about the health implications of consuming pangolins and the risk of extinction, which will ultimately have an impact on biological diversity (Maurice *et al*., 2019).

Conclusion

The dynamic interplay between the parasitic organism, Strongyloides nematode, and trace metals underscores a complex relationship characterized by bidirectional effects. On one hand, the presence of Strongyloides nematodes exerts a protective influence by ameliorating the toxicity associated with trace metals within the host organism. Conversely, the trace metals, in turn, demonstrate the capacity to mitigate the detrimental health consequences imposed by the parasitic infestation.

Additionally, within the context of pangolin hosts, Strongyloides nematodes emerge as dependable bio-depurative agents and reliable bioindicators for trace metals. The superior bio-depurative capabilities of nematodes highlighted in this study align with earlier findings that consistently underscore their notable potential for the removal of trace metals, as documented in prior scientific literature. This reaffirms the significance of nematodes in contributing to

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bioremediation efforts and environmental health, thereby adding to the growing body of knowledge on this subject.

Declarations:

Ethical Consideration: Permission and approval were sought from the Ethical Review Committee of Osun State Ministry of Health (OSHREC/PRS/569T/193) and the Planning, Research and Statistics Department of Osun State Ministry of Education (MOE/PR&S/SS 2/vol.vi/43).

Competing interests: The authors declare no conflict of interest.

Authors Contributions: I hereby verify that all authors mentioned on the title page have made substantial contributions to the conception and design of the study, have thoroughly reviewed the manuscript, confirmed the accuracy and authenticity of the data and its interpretation, and consent to its submission.

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Availability of Data and Materials: All datasets analysed and described during the present study are available from the corresponding author upon reasonable request.

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