

# Efficacy of *Azadirachta indica* in the Treatment of Gastrointestinal Helminthiasis

## Abstract:

The study was carried out to assess the anthelmintic efficacy of *Azadirachta indica* commonly known as Neem (Dogoyaro). The phytochemical components of the leaf extract was accessed using Gas Chromatography Mass Spectrometry and the efficacy was carried out *in vitro* and *in vivo* using *Toxocara canis* (as worm model) of dogs. Twenty peaks of compounds were revealed in the GS-MS chromatogram, with Hexadecanoic acid which is saddled with anthelmintic effect as one of its major constituents. In the *in vitro* study, the lethal concentration was 92.48ml/mg at 6hrs. Percentage egg reduction of 76.2% and 83.9% from the Faecal Egg Count (FEC) at LC25 and LC50 respectively was recorded for the *in vivo* study. The overall blood count of all the puppies used for the experiment were  $4.46 \times 10^6/\mu\text{L}$  for RBC, 31.32% for PCV and  $11.23 \times 10^3$  for WBC. Puppies treated with *Azadirachta indica* leaf extract showed minimal alteration of the three hematological parameters (WBC, PCV and RBC) analyzed compared to the uninfected control group and group treated with Mbendazole. This indicates that *Azadirachta indica* leaf extract is effective in the treatment of gastrointestinal helminthiasis and also further investigations are recommended as it may be useful in the treatment of other diseases.

**Key words:** Efficacy, Gastrointestinal helminthiasis, phytochemical, anthelmintic

## Introduction

Gastrointestinal helminthiasis refers to helminth infections that primarily affect the gastrointestinal tract in humans and animals (Papaiakovou *et al.*, 2022; Kajero *et al.* 2022). These infections are caused by various types of parasitic worms, including roundworms, hookworms, whipworms, and tapeworms (Schafer and Skopic, 2007; Carlson *et al.*, 2020). Infections can lead to symptoms like abdominal pain, diarrhea, nausea, vomiting, anemia, digestive issues, weight loss, vitamin deficiencies and malnutrition and growth retardation in children (Bethony *et al.*, 2006; CDC, 2013; Hotez *et al.*, 2012), and in animals, loss of production through mortality, weight loss, reduced milk, meat and wool production (Ketzis *et al.*, 2002; Githiori *et al.*, 2006; Eguale *et al.*, 2007). In severe cases, a large number of worms can cause intestinal blockage both in animals (Wilcox *et al.*, 2009) and man (Otubajo, 2013).

Treatment for gastrointestinal helminthiasis involves administration of specific antiparasitic medications prescribed by healthcare professionals or veterinarians, depending on the species of helminth involved, and are referred to as anthelmintic medications or anthelmintics (CDC, 2013; Campbell and Soman-Faulkner, 2023). These medications are specifically designed to

target and eliminate the worms from the body (Rosenthal, 2017). There are different types of anthelmintic drugs available, depending on the specific type of helminth infection being treated. Some common classes of anthelmintics include: Albendazole, Mebendazole, Ivermectin, Praziquantel and Pyrantel Pamoate (CDC, 2013). The drug commonly used by control programmes targeting helminth infections in man and animals have different species efficacy (Papaiakovou *et al.*, 2022, Fernandes *et al.*, 2022), but the fact remains that a large proportion of the world's population affected by these parasites do not have access or cannot afford it, particularly in the rural communities of developing countries (WHO, 2012). Also, there is a growing concern about potential reduction in the effectiveness or even emergence of drug resistance through wide spread and frequent use of this anthelmintic chemotherapy (Jackson and Coop, 2000; Sangaster, 2008; Marsh and Lakritz, 2023). These have created an urgent need for newer, inexpensive and accessible drugs, and traditional herbal medicine based largely on medicinal plants offers an alternative, as it is reported to be a major and accessible source of health care to the people in remote parts of most developing countries (Tandon *et al.*, 2011). Therefore, there is a need for proper scientific documentation of the efficacy of some of the plants extracts used as anthelmintic.

The use of plant extracts as antihelminthic agents has been explored in traditional medicine systems for centuries due to various factors ranging from drug resistance to inability to access/purchase the prescribed drugs (Al-shaibani *et al.*, 2009; Fajmi and Taiwo, 2005). Various plants contain bioactive compounds that have shown potential in combating helminth infections (Egualé and Giday, 2009). However, it is important to note that while traditional knowledge and anecdotal evidence exist, the efficacy and safety of plant extracts as anthelmintics have not been extensively studied or confirmed through rigorous scientific research, which is the case with Neem plants.

Neem (*Azadirachta indica*) leaf extract has been traditionally used in various cultures for its potential anthelmintic properties (Athanasidou *et al.*, 2007). Neem, commonly known as Dogoyaro in Nigeria, is a tree native to the Indian sub-continent although in recent times it has naturalized and grown throughout the tropics and subtropical regions and is known for its medicinal properties which have been explored widely (Porter, 2006). Although, its leaf extracts

have shown some activity against certain helminths, it is important to note that the scientific evidence supporting its effectiveness as an anthelmintic is limited and this work is aimed at validating its use.

## Materials and Methods

The study was carried out in Akwa Ibom State, Nigeria which lies between latitude 4° 32' and 5° 53' North and longitude 7° 25' and 8° 25' East with total land area of 7.249 km<sup>2</sup>. The leaves of the *Azadirachta indica* plant (fig.1) were collected from matured plants identified and authenticated in the herbarium unit, Department of Botany and Ecological Studies, University of Uyo. The ethanolic extraction of the leaves was carried out using maceration method (Sujon *et al.*, 2008). Dogs (puppies) aged about 7 months weighing about 7 – 8 kg were bought from vendors and used for the studies. The crude leaf extract of *Azadirachta indica* commonly known in the area as neem (Dogoyaro) was screened for anthelmintic effects *in vitro* using adult worms (*Toxocara canis*) and also *in vivo* using experimentally infected dogs (puppies infected with *Toxocara canis*) according to the modified method of Sujon *et al.*, (2008).



**Figure 1:** Picture of *Azadirachta indica* A. Juss  
**Herbarium No:** ADAMS, UUH4432 (Eket)

GC-MS analysis of the plant extract was carried out on an Agilent technology 7890 GC system equipped with a mass spectrometric detector (MSD). Ms model was agilent technology 5975 ms, the column used was HP-5MS agilent technology, length of the column 30 m, internal diameter 0.320 mm, thickness of 0.25  $\mu$ m. Volume of sample injected was 1  $\mu$ L. Oven temperature

program with initial temperature of 80°C to hold for 2 minutes at 10°C/min to final temperature of 240°C to hold for 6 minutes with injector temperature of 250°C. The mobile phase was helium gas while the stationary phase was the column.

Detection of Components Analysis of mass spectrum GC-MS was conducted by the database of National Institute Standard and Technique (NIST) having more than 62,000 patterns. The spectrum of the unidentified components were compared with the spectrum of the identified components stored in the NIST library. The name, molecular weight, structure of the components in the test material were ascertained (Oshiobugie *et al.*, 2017)

**In vitro** analysis of the extract was carried out using the modified method of Sujon *et al.* (2008). All the dogs (except the reservoir host) were treated with anthelmintic drug administered orally and faecal analysis carried out to ascertain a worm free colony prior to the experiment. Faeces containing *Toxocara canis* eggs was obtained from a naturally infected puppy (reservoir host). Dogs (worm free colony of puppies) (Prior to the experiment, all the puppies were examined coprologically and treated accordingly, except for few of those that had only *Toxocara canis* eggs present in their faeces and was kept as the reservoir host). were infected with *Toxocara canis* (round worm species associated with dog) by contaminating their food and water with the infected faecal sample that was collected from the reservoir host and kept moist for some days at room temperature, and infection was confirmed through faecal analysis after three weeks. Some of the dogs that were passing eggs in faeces were slaughtered using appropriate humane method and the small and large intestine carefully extracted from the body of the dogs. The intestines were opened with a scissor and the content washed with tap water into a clean plastic container, then the adult worms were collected carefully with the aid of the blunt head of a needle into petri dishes containing physiological saline (buffered saline). Two sets each of 5 petri dishes (groups) containing 10 adult worms each (total of 100 worms) was prepared and the plant extract was diluted at various concentrations 10%, 20%, 50% and 100% and a control with only physiological saline. 0.1ml of each diluted plant extracts (extract of *Azadirachata indica*) at various concentrations were pipetted into the different petri dishes (groups) leaving a control and then allowed for 12hours at room temperature. The groupings were as follows:

Group 1: adult worms treated with 10% extract

Group 2: adult worms treated with 20% extract

Group 3: adult worms treated with 50% extract

Group 4: adult worms treated with 100% extract (crude extract)

Group 5: adult worms which received only physiological saline

The non-motile worms were counted from the various plates (groups) after 30 mins, 1 hour, 6 hours and 12 hours respectively and then percentage mortality calculated.

$$\text{Percentage death} = \frac{\text{Number of dead parasites}}{\text{Total number of parasites}} \times 100$$

Lethal concentration at 25 and 50% was calculated using probit analysis (AAT Bioquest Inc., 2022). The GC-MS Chromatogram of Ethanolic Extract of *A. indica* Leaf is presented in figure 2 and the identified phyto-component are presented in table 1.

The *in vivo* screening was carried out according to the modified method of Sujon *et al.* (2008), the plant ethanolic extract was tested using 4 groups of experimentally infected puppies and one group of worm free colony of puppies which were made up of two males and two females respectively i.e. in duplicate, (making a total of 40 puppies).

Three of the experimentally infected groups were treated orally with LC50 and LC25 of the extract and **Mebendazole**, all at the dosage of 50 mg/kg body weight divided into three doses for 3 consecutive days (as it is the recommended dosage of **Mebendazole** for therapeutic use in Nigerian dogs) and one group was left untreated (positive control). The groupings were:

Group 1: Infected puppies treated with LC25 obtained from the *in vitro* studies

Group 2: Infected Puppies treated with LC50 obtained from the *in vitro* studies

Group 3: Infected Puppies treated with Mebendazole

Group 4: Infected puppies without treatment

Group 5: Non-infected puppies

The efficacy of the extract on the experimental animals was determined by faecal egg count from direct smear faecal analysis using the formula:

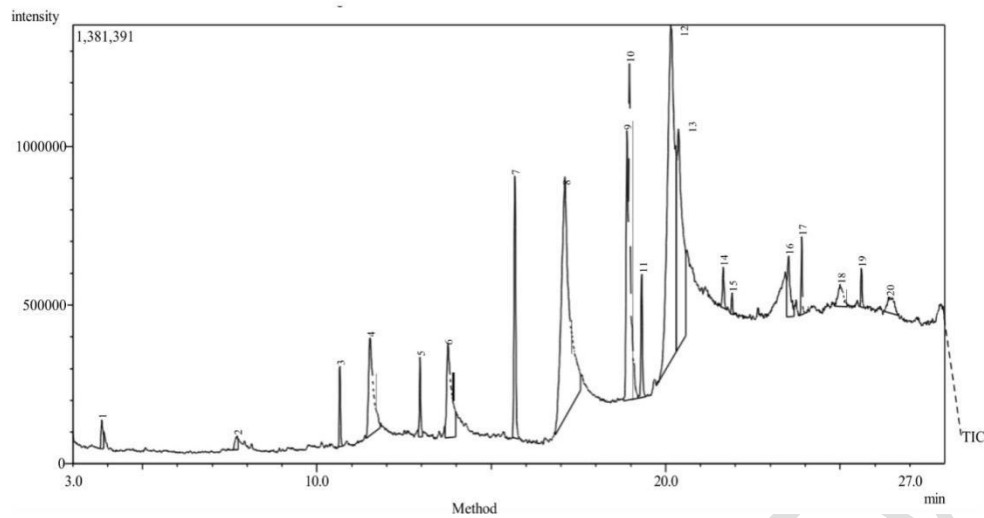
$$\text{Faecal Egg Count Reduction (\%)} = \frac{\text{Pre-treatment egg count} - \text{post treatment egg count}}{\text{Pre-treatment egg count}} \times 100$$

(Salien *et al.*, 2019).

Haematological test which included white blood cell count (WBC), packed cell volume (PCV) and red blood cell count (RBC) was carried out on the puppies before and after the experiment. Packed cell volume (PCV) was assessed by the method of Nweze *et al.* (2013). Blood was collected from the tail veins of the dogs into heparinized capillary tubes. One end of the tube was sealed using sealer. The tubes were placed on a capillary tube rack and centrifuged with a micro-hematocrit centrifuge at 5000 revolutions/min for 5 min. The PCV was then read using a hematocrit reader. White and red blood count was carried out using the Neubauer haemocytometer counting chamber. Behavioural changes observed from the experimental animals was noted. The *in vivo* screening results are presented in table 2 and figure 2.

All data obtained were subjected to analysis using Microsoft Excel and SPSS Version 21 data packages. Chi-square test was used to compare differences based on the level of statistical significance of  $P \geq 0.05$  with 95% confidence interval and results are presented in table 3.

Twenty peaks of compounds were revealed in the GS-MS chromatogram of *Azadirchta indica* (Fig 2), and the major constituents were Oleic acid (26.04%), Nonadecanoic acid (21.07%), Methyl-beta-D-Arabinopyranoside (12.82%), 11-Octadecenoic acid (8.04%), 9,12-Octadecadienoic (5.17%), n-Hexadecanoic acid (5.00%), while the minor compounds were Hexadecanoic acid (4.93%), Eicosanoic acid (4.85%), Pentadecanoic acid (2.04%), 3-n-Hexyltioslane S, S-dioxide (1.96%), 1-Hexacosanol (1.21%), 2H-Pyran, 2-(7-Heptadecyloxy) tetrahydro (1.19%), Octanoic acid (1.10%), Decanoic acid, methyl ester (1.04%), Docosanoic acid methyl ester (0.57%), Acetic acid (0.72%), Heneicosanoic acid methyl ester (0.57%), 1-Nonanol (0.55%) and Divalonic acid (0.72%) as shown in Table 3. The plant contained Hexadecanoic acid which is saddled with anthelmintic effect as one of their major constituent.



**Figure 2: GC-MS Chromotogram of Ethanolic Extract of *A. indica* Leaf**

**Table 1: Phyto- Components Identified in the *Azadirachta Indica* Leaf Extract**

Peak	Retention time	% Peak Area	Compound Analyzed	Molecular Weight	Molecular formular
1.	3.835	0.55	1-Nonanol	144	C <sub>9</sub> H <sub>20</sub> O
2.	7.713	0.45	Divalonic acid	130	C <sub>6</sub> H <sub>10</sub> O <sub>3</sub>
3.	10.656	1.04	Decanoic acid, methyl ester	186	C <sub>11</sub> H <sub>22</sub> O <sub>2</sub>
4.	11.524	5.00	n-Hexadecanoic acid	256	C <sub>16</sub> H <sub>32</sub> O <sub>2</sub>
5.	12.957	1.10	Octanoic acid	158	C <sub>9</sub> H <sub>18</sub> O <sub>2</sub>
6.	13.760	4.85	Eicosanoic acid	312	C <sub>20</sub> H <sub>40</sub> O <sub>2</sub>
7.	15.677	4.93	Hexadecanoic acid	270	C <sub>17</sub> H <sub>34</sub> O <sub>2</sub>
8.	17.111	21.07	Nonadecanoic acid	298	C <sub>19</sub> H <sub>38</sub> O <sub>2</sub>
9.	18.893	5.17	9,12-Octadecadienoic acid	294	C <sub>19</sub> H <sub>34</sub> O <sub>2</sub>
10.	18.932	8.04	11-Octadecenoic acid	296	C <sub>19</sub> H <sub>36</sub> O <sub>2</sub>
11.	19.314	2.04	Pentadecanoic acid	270	C <sub>17</sub> H <sub>34</sub> O <sub>2</sub>
12.	20.147	26.04	Oleic Acid	282	C <sub>18</sub> H <sub>34</sub> O <sub>2</sub>
13.	20.365	12.82	Methyl-.beta.-D-arabinopyranoside	164	C <sub>6</sub> H <sub>12</sub> O <sub>5</sub>
14.	21.650	0.72	Acetic acid	200	C <sub>12</sub> H <sub>24</sub> O <sub>2</sub>
15.	21.902	0.28	Pentanoic acid, 4-methyl-, methyl	130	C <sub>7</sub> H <sub>14</sub> O <sub>2</sub>

16.	23.521	1.96	3-n-Hexylthiolane, S,S-dioxide	204	C <sub>10</sub> H <sub>20</sub> O <sub>2</sub> S
17.	23.900	0.95	Docosanoic acid, methyl ester	354	C <sub>23</sub> H <sub>46</sub> O <sub>2</sub>
18.	25.001	1.21	1-Hexacosanol	382	C <sub>26</sub> H <sub>54</sub> O
19.	25.611	0.57	Heneicosanoic acid, methyl ester	340	C <sub>22</sub> H <sub>44</sub> O <sub>2</sub>
20.	26.384	1.19	2H-Pyran, 2-(7-heptadecyloxy)tetrahydro-	336	C <sub>22</sub> H <sub>40</sub> O <sub>2</sub>
<b>Total</b>		<b>100.0</b>			

**Table 2: *In vitro* screening of the *Azadirachta indica* extracts on adult worms**

**Percentage (%) of Dead Adult Worms**  
**N=100**

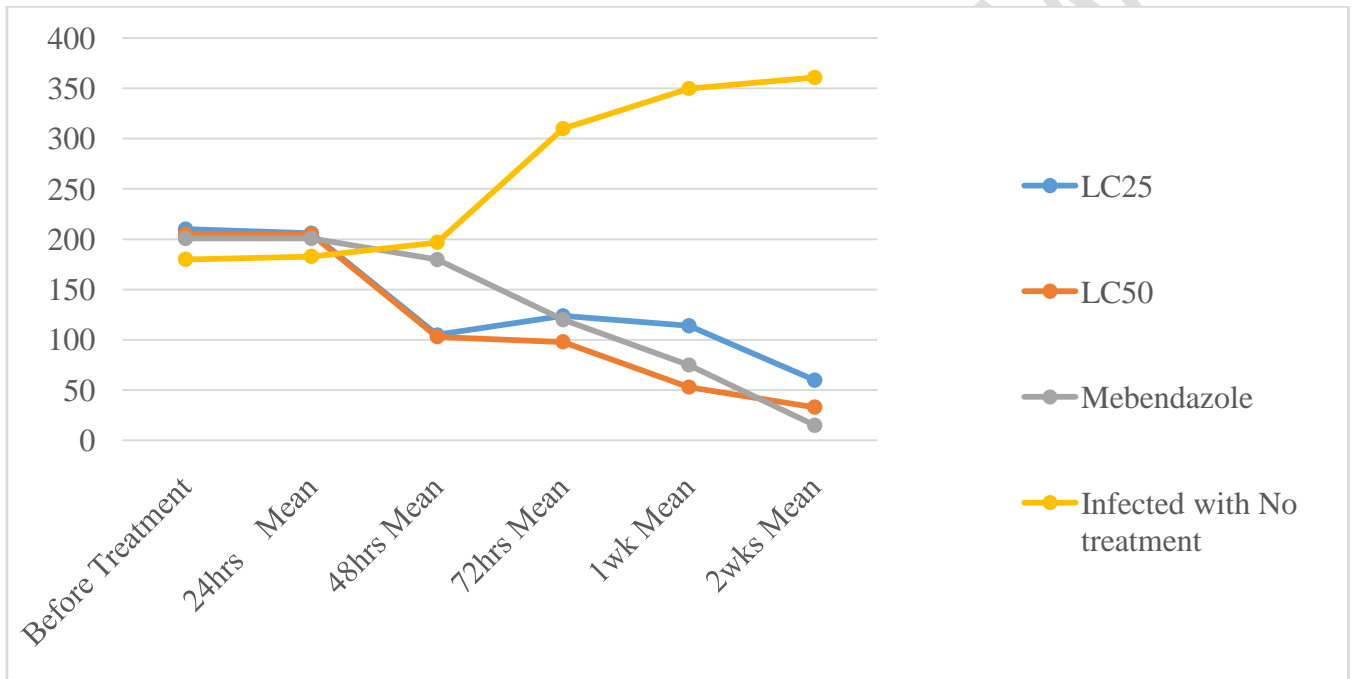
<b>Concentration (ml/mg)</b>	<b>30mins</b>	<b>1hr</b>	<b>6hrs</b>	<b>12hrs</b>
10ml/mg (10%)	–	–	–	60
20ml/mg (20%)	–	–	20	50
50ml/mg (50%)	–	–	40	100
100ml/mg (100%)	–	–	50	100
Control	–	–	–	–

LC25= 25.85ml/mg, LC50=92.48ml/mg

*Azadirachta indica* plant extract screening on adult *Toxocara canis* (Table 4) revealed that the extract was observed to be effective within 6-12 hrs. The percentage death at 6hrs was 20, 40 and 50% for 20ml/mg, 50ml/mg and 100ml/mg respectively, while no death was recorded for the

control. At 12 hours the percentage death was 60, 50, 100 and 100 at the dose of 10ml/mg, 20ml/mg, 50ml/mg and 100ml/mg respectively. The lethal concentration was observed at the 6hrs and was calculated to be 92.48ml/mg.

**In vivo** screening of *Azadirachta indica* leaf extract on puppies in Figure 3 shows a high percentage egg reduction of 76.2% and 83.9% from the Faecal Egg Count (FEC) at LC25 and LC50 respectively, while Mebendazole showed a 92.5% reduction.



**Figure 3:** **In vivo** screening of the *Azadirachta indica* extracts on puppies faecal samples

The overall blood count of all the puppies used for the experiment as shown in Table 5 were  $4.46 \times 10^6 \mu\text{L}$  for RBC, 31.32% for PCV and  $11.23 \times 10^3$  for WBC. A marked reduction was observed in the pack cell volume (PCV) and Red blood count (RBC) of the infected untreated puppies (23%,  $3.70 \times 10^6 \mu\text{L}$ ) and also those that were treated with Mebendazole (25.83%,  $4.40 \times 10^6 \mu\text{L}$ ) while those treated with LC25 and LC50 extracts of *Azadirachta indica* recorded 33,  $4.80 \times 10^6 \mu\text{L}$  and 32%,  $4.50 \times 10^6 \mu\text{L}$  respectively. The difference was statistically significant.

The WBC revealed an increase in the infected untreated (positive control) ( $14 \times 10^3 \mu\text{L}$ ) and also those treated with Mebendazole ( $11.63 \times 10^3 \mu\text{L}$ ) while those treated with LC<sub>25</sub> and LC<sub>50</sub> extract

concentrations of *Azadirachta indica* recorded 10 and 11x10<sup>3</sup>μL respectively. The difference was statistically significant (p<0.001). LC50 of *Azadirachta indica* revealed a minimal alteration of the three heamatological parameters (WBC, PCV and RBC) analyzed compared to the uninfected control group and group treated with Mbendazole.

**Table 3: Heamatological analysis of the puppies used for the *In vivo* screening**

Treatments	RBCs(μL)	PCV (%)	WBCs(μL)
	Mean±SD	Mean±SD	Mean±SD
Non-infected	5.30±0.12a	42.00±1.73a	9.33±0.17cd
Infected untreated	3.70±0.12f	23.77±0.62c	14.17±0.88a
Infected treated with Mbendazole	4.40±0.06de	25.83±0.83c	11.63±0.52b
Infected treated with LC25 OF <i>Azadirachta indica</i>	4.80±0.15b	33.00±1.53b	10.00±0.29bcd
Infected treated with LC50 of <i>Azadirachta indica</i>	4.10±0.06e	32.00±1.15b	11.00±0.50bc
<b>Total</b>	<b>4.46±0.11</b>	<b>31.32±1.17</b>	<b>11.23±0.47</b>
p Value	<0.001*	<0.001*	<0.001*

Means along the same column with different Alphabet(s) are statistically significant at p≤0.05, ns – Not significant at p>0.05, \* - significant at p≤0.05.

### Results and Discussion

The leaves of *Azadirachta indica* (Neem) in the study showed an anthelmintic efficacy of 76.2% and 83.9% egg reduction in faecal egg count (FEC) among the litters used for the experiment which agrees with the report of Sujon *et al.* (2008) who also reported a high percentage efficacy of 85% on the gastrointestinal nematodes of goats, but disagrees with the report of Nambiar *et al.* (2016) who reported that neem leaves had no anthelmintic effect on the test organisms (goats). The differences in the reports on neem leaves anthelmintic efficacy

could be attributed to the solvent used for extraction which was ethanol and water respectively and also time in which the leaves were harvested for the experiment (Dele *et al.*, 2020). Although, phytochemicals present in the plant such as phenols, alkaloids and **terpenoids** are said to be antioxidants and inhibitors of carcinogenic cell, microorganisms, parasites and other foreign bodies in the body thus revealing a high potential of the plant having an **anthelmintic** property but **its** use was justified by the presence of n-Hexadecanoic acid and decanoic acid which are nematocidal compounds in the leaf extract.

The reduction of egg count by the leaf extracts of *Azadirachta indica* in this study is a positive and welcomed development in our local helminths struggle because the plants are available year-round in Nigeria. The easy access to this plant and its availability might mean that the cost of medication would be drastically reduced.

The activities shown by the plant extract is of considerable importance and **justified its** use as anthelmintic in folklore traditional medicine as the use of medicinal herbs in treatment of infectious diseases has attracted the attention of scientist worldwide (Aswathi and Dhivya, 2017; Ujah *et al.*, 2021). Studies show that the plant contain alkaloids, saponins, tannin, glycosides, flavonoid, terpenoid and phenol which indicates that the plant could be useful in treatment of other diseases for example Alkaloid has antimalarial, analgesic value and can equally be used as stimulant, flavonoids for gastric infections (Arona and Tamrakar, 2017; Ujah *et al.*, 2021). GC-MS analysis revealed that the plant contained n-Hexadecanoic acid as one of its major compound which accounts for their anthelmintic effect and also anti-inflammatory compounds such as Octadecanoic acid and Decanoic acid. This agrees with the findings of Abirami and Rajendran, (2012), and Alzohairy (2016) who also reported the presence of n-Hexadecanoic in *Azadirachta indica*. Other compounds with bioactivities such as antibacterial, antifungal, antioxidant were encountered in the study which could be useful in the treatment of other ailments.

## **Conclusion**

Aside the use of medically prescribed drugs, enema/ drinking of various plant extracts (both water and ethanolic extract) have been used by traditional/herbal medicine in the treatment of gastrointestinal helminthiasis in both man and animals. The leaves of Neem (*Azadirachta indica*)

which is one of the most commonly used plants were collected, identified and anthelmintic efficacy on *Toxocara canis* as helminth model was tested *in vivo* and *in vitro*. LC50 of 92.48ml/mg at 6hours with percentage egg reduction of 83.9% was reported for *Azadirachta indica* respectively. This revealed that the plant leaves had anthelmintic potentials with minimal alteration of hematological parameters and could be attributed to the presence of flavonoids which is associated with treatment of gastric infections and also n-Hexadecanoic acid which accounts for their anthelmintic effect, alongside Octadecanoic acid and Decanoic acid which are anti-inflammatory compounds.

## References

AAT Bioquest Inc. (2022). *Quest Graph LC50 Calculator*. <http://www.aatbiio.com/tools/LC50-Calculator/23/06/2022>

Abirami, P. and Rajendran, A. (2012) GC-MS Analysis of Methanol Extracts of *Vernonia cinerea*. *European Journal of Experimental Biology*, 2 (1):9-12

Al-Shaibani, I.R.M., Phulan, M. S. and Shiekh, M. (2009). Anthelmintic Activity of *Fumaria parviflora* (Fumariaceae) against Gastrointestinal Nematodes of Sheep. *Int. J. Agric. Biol.*, 11(4): 431–436

Alzohairy, M. A, (2016) "Therapeutics Role of *Azadirachta Indica* (Neem) and their Active Constituents in Diseases Prevention and Treatment", *Evidence-Based Complementary and Alternative Medicine*, Vol. 2016, Article ID 7382506, 11 Pages, 2016. <https://doi.org/10.1155/2016/7382506>

Arona, C. and Tamakar, V. (2017). *Gmelina arborea*: Chemical Constituents, Pharmacological Activities and Applications. *Journal of Phytomedicine*, 9: 528-542

Aswathi, P. V. and Dhivya, R. (2017). Quality Phytochemical Screening and Mosquito Replelency of *Chromolaena odonrata* leaf extract against adult *Culex sp.* *Indo American Journal of Pharmaceutical Science*, 4(3): 698-705.

Athanasiadou, S., Githiori, J and I. Kyriazakis, I. (2007) Medicinal Plants for Helminth Parasite Control: Facts and Fiction. *Animal* 1(9): 1392–1400

Bethony, J., Brooker, S., Albonico, M., Geiger, S. M., Loukas. A., Diemert, D. and Hotez, P. J. (2006). Soil-Transmitted Helminth Infections: Ascariasis, Trichuriasis and Hookworm. *Lancet* 367: 1521-1532.

Campbell S and Soman-Faulkner, K. (2023) Antiparasitic Drugs. In: Statpearls [Internet]. Treasure Island (FL): Statpearls Publishing; 2023 Jan-. Available From: <https://www.ncbi.nlm.nih.gov/books/NBK544251/>

Carlson, C. J., Dallas, T. A., Alexander, L. W., Phelan, A. L. and Phillips, A. J. (2020) What Would It take to describe the Global Diversity of Parasites? *Proc. R. Soc. B* 287:

Centre for Disease Control (CDC) (2013). Soil Transmitted Helminths: causes, prevention and control. Available at <http://www.cdc.gov/parasites/sth/>. Accessed On January 10, 2013.

Dele, O. S., Arowosegbe, S. and Oyegun, B. A. (2020). Phytochemical Properties of *Azadirachta indica* (A. Juss) Harvested at Different Times of the Day. *International Journal of Herbal Medicine*, 8(2):7-11

Egualé, T. and Giday, M. (2009) *In vitro* Anthelmintic Activity of Three Medicinal Plants against *Haemonchus contortus*. *International Journal of Green Pharmacy* 29-34

Egualé, T., Tilahun, G., Debella, A., Fleke, A. and Makonnen, E. (2007). *Haemonchus contortus*: *in vitro* and *in vivo* Anthelmintic Activity of Aqueous and Hydro-alcoholic Extracts of *Hedera Helix*. *Experim. Parasitol.*, 116: 340–345

Fajmi, A. K. and Taiwo, A. A. (2005) Herbal Remedies in Animal Parasitic Diseases in Nigeria: A Review. *Afr J Biotec* 4:303-7.

- Fernandes, F. D., Guerra, R. R., Ries, S. A., Cargnelutti, F. J., Sangioni, A. L. and Vogel, F. S. F. (2022) Gastrointestinal Helminths in Dogs: Occurrence, Risk Factors, and Multiple Antiparasitic Drug Resistance. *Parasitology Research* <https://doi.org/10.1007/S00436-022-07599-0>
- Githiori, J.B., Athansiadou, S. and Thamsborg, S. M. (2006). Use of Plants Novel Approaches for Control of Gastro-Intestinal Helminths in Livestock with Emphasis on Small Ruminants. *Vet. Parasitol.*, 139: 308–320
- Hotez, P. J. Asojo, O. A. and Adesina, A. M. (2012). Nigeria: Ground Zero for the High Prevalence Neglected Tropical Diseases. *Plos Neglected Tropical Disease*, 6(7): 1600-1605.
- Jackson F. and Coop, R. I. (2000). The Development of Anthelmintic Resistance in Sheep Nematode. *Parasitology* 120: 95-107
- Kajero, O. T., Janoušková, E., Bakare, E. A., Belizario, V., Allen, D. B., Alonte J., Manalod, S. M., Paller, V. G., Betson, M. and Prada, J. M. (2022) Co-Infection of Intestinal Helminths in Humans and Animal in the Philippines. *Trans R Soc Trop Med Hyg.*, 116: 727–735
- Ketzis, J. K., Tayler, A., Brown, D. D., Brown, D. A., Warnick, L. D. and Erb, H. N. (2002). *Chenopodium ambrosioides* and its Essential oil as Treatments for *Haemonchus contortus* and Mixed Adult-nematode Infections in Goats. *Small Rumin. Res.*, 44: 193–200
- Marsh, A. E. and Lakritz, J. (2023). Reflecting on the Past and Fast Forwarding to Present Day Anthelmintic Resistant *Ancylostoma Caninum*: A Critical Issue We Neglected To Forecast. *International Journal of Parasitology; Drugs and Drug Resistance* 22: 36-43

- Nambiar, B.K., Premaalatha, B., Chandrawathani, P. and Zary, S. T. (2016). Efficacy of Neem and Sbah Snake Grass Leaves Water Extract and Decoction against Gastrointestinal Parasites in Local Goats. *Malaysian Journal of Veterinary Research*, 7(2): 91-101
- Nweze, N. E., Arine, O. and Ngongeh, L.A. (2013). Anthelmintic Potential of Three Plants Used in Nigeria Ethnoveterinary Medicine. *Pharmaceutical Biology* 5(3): 311-315
- Oshiobugie, M. J., Olaniyi, A. M. and Raphael, A. O. (2017) AAS and GC-MS Analysis of Phytocomponents in the Leaf, Stem and Root of *Azadirachta indica* A. Juss (Dongoyaro). *British Journal of Pharmaceutical Research* 15(4): 1-12
- Otubanjo, O. (2013). *Parasites of Man and Animals*. First Edition. Concept Publication Limited. Lagos, Nigeria
- Papaiakovou, M. Timothy, D., Littlewood, J., Doyle, S. R., Gasser, R.B. and Cantacessi, C. (2022) Worms and Bugs of the Gut: The Search for Diagnostic Signatures Using Barcoding, and Metagenomics–Metabolomics. *Parasites & Vectors* 15(118): 2-13
- Porter, A. H. (2006) *Neem: India's Tree of Life*. BBC News. [http://news.bbc.co.uk/2/hi/south\\_asia/4916044.stm/](http://news.bbc.co.uk/2/hi/south_asia/4916044.stm/)(Retrieved 09/06/2022)
- Rosenthal P. J. (2017). Clinical Pharmacology of the Antihelminthic Drugs. Katzung B.G. (Ed.), *Basic and Clinical Pharmacology*, 14e. Mcgraw Hill. <https://Accessmedicine.Mhmedical.Com/Content.aspx?Bookid=2249&Sectionid=175224314>
- Salien, A. M., Kassuku, A. A., Magwisha, H., Edward, C., Marisa, J. and Ngovi, C. (2019). Determination of Anthelmintic Resistance in Goats and Sheep Using Faecal Egg Count Reduction Test At Luguruni Farm, Dares Salaam, Tanzania. *Tanzania Veterinary Association Proceedings*, 34:87-90
- Sangaster, N. C. (2008) Anthelmintic Resistance: Past, Present and Future. *International Journal of Parasitology* 29:115-124

- Schafer, T. W. and Skopic, A. (2007) Parasites of the Small Intestine. *Curr Infect Dis Rep* **9**, 60–68. <https://doi.org/10.1007/S11908-007-0024-1>
- Sujon, M. A., Mostofa, M., Jahan, M. S., Das, A. R. and Rob, S. (2008). Studies on Medicinal Plants against Gastrointestinal Nematodes of Goats. *Bangl. J. Vet. Med.*, **6** (2): 179–183
- Tandon, V., Yadav, A. K., Roy, B. and Das, B. (2011) *Emerging Trends in Zoology: Phytochemicals as Cure for Worm Infections in Traditional Medicine System*. Narendra Publication House, New Delhi. 351-378
- Ujah, I., Nsude, C., Ani, O., Alozieuwa, U., Okwor, A. and Okpako, I. (2021). Phytochemicals of Neem Plant (*Azadirachta Indica*) Explains Its Use in Traditional Medicine and Pest Control. *GSC Biological and Pharmaceutical Sciences*. **14**. 10.30574/Gscbps.2021.14.2.0394.
- WHO (2012) Research Priorities for Helminth Infections. *Technical Report Series*, No 972. Geneva. <https://www.who.int/publications-detail-redirect/WHO-TRS-972/retrieved> on 09/06/2022
- Wilcox, R. S., Bowman, D. D., Barr, S.C. and Euclid, J. M. (2009) Intestinal Obstruction Caused by *Taenia Taeniformis* Infection in Cat. *J Am Anim Hosp Assoc* **45** (2): 93–96