ORIGINAL ARTICLE

# Phytochemical, Antioxidant, and Anthelmintic Potential of *Cinnamomum verum* J. Presl Bark Extracts Against *Eudrilus eugeniae*

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**ABSTRACT**

**Introduction:** Helminthic infections, or soil-transmitted helminths (STHs), are a significant global health concern, particularly in livestock production, leading to economic losses in farming communities. Although anthelmintic drugs are essential for controlling helminthiasis, the emergence of drug resistance presents a significant challenge. *Cinnamomum verum* (*C. verum*) has a rich history of medicinal use and exhibits promising therapeutic properties. **Materials and Methods:** This study investigated the phytochemical composition and anthelmintic activity of various *C. verum* bark extracts against earthworms (*Eudrilus eugeniae*) and their antioxidant capacity. Antioxidant activity was evaluated using the DPPH radical scavenging and FRAP assays, with acetone and ethyl acetate extracts demonstrating significant antioxidant properties. **Results:** Phytochemical screening revealed the presence of phenols, alkaloids, flavonoids, glycosides, and steroids in the extracts. In anthelmintic assays, all extracts exhibited superior paralytic and lethal effects compared to the standard drug mebendazole at all concentrations. **Conclusion:** These findings suggest that *C. verum* bark extracts possess potent antioxidant and anthelmintic activities, making them promising candidates for alternative anthelmintic treatments.
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**Keywords:** *Cinnamomum verum*, Anthelmintic activity, Antioxidant capacity, *Eudrilus eugeniae*, Phytochemical composition

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## INTRODUCTION

Helminthic infections caused by parasitic worms, particularly soil-transmitted helminthiasis (STH), pose significant global health challenges, affecting approximately 1.5 billion individuals, particularly in underprivileged communities lacking adequate sanitation and hygiene facilities (1). Roundworms (*Ascaris lumbricoides*), whipworms (*Trichuris trichiura*), and hookworms (*Necator americanus* and *Ancylostoma duodenale*) are the three primary parasite species that infect humans. These infections can cause various health problems, including malnutrition, gastrointestinal issues, anaemia, and delayed cognitive development in children.

The conventional approach to combating these infections involves the use of synthetic anthelmintic drugs. Anthelmintic drugs kill parasites by starving or paralysing them since they lack energy storage and must consume food constantly to survive (2). However, the emergence of drug resistance in helminths offers a significant challenge to the efficacy of conventional anthelmintic therapies. The extensive use of anthelmintic drugs has contributed to the development of resistance in gastrointestinal nematodes, particularly in cattle, sheep, goats, and equines (3). There is an increasing interest in discovering alternative treatments derived from natural sources.

Since ancient times, traditional medicine has used medicinal plants to treat disease and preserve health due to their abundance of bioactive compounds. The World Health Organisation highlights integrating diverse cultural knowledge and practices in traditional medicine for disease prevention, diagnosis, improvement, or treatment (4). *Cinnamomum verum* (*C. verum*) is a plant native to Sri Lanka and is part of the *Lauraceae* family. It is commonly known as kayu manis or Ceylon cinnamon in Malaysia. It grows naturally in forests in Sri Lanka and is cultivated in Malaysia. This species often grows up to 700 meters high in its native habitat.

*C. verum* is a widely used medicinal herb known for its diverse applications and potent active compounds. The key bioactive components include cinnamaldehyde, eugenol, cinnamic acid, and proanthocyanidins, which contribute to its therapeutic effects. Numerous cultures worldwide use *C. verum* extensively for culinary purposes (5). Numerous studies have proven the therapeutic benefits of *C. verum*, including containing anticancer agents against various types of cancer lines (6, 7, 8), antibacterial activity (9, 10, 11, 12), and antidiabetic activity (13). *C. verum* is also known for its antioxidant effects that help counteract the damaging effects of oxidative stress and its anti-inflammatory effect (14, 15, 16). Other studies have identified that *C. verum* exhibits remarkable neuroprotective effects in Alzheimer's disease (17), antianxiety and antidepressant activity (18, 19), along with wound healing activity (20). Based on recent studies into *C. verum*'s advantages in treating various ailments, there is still more to discover about this plant's maximal efficacy.

The emergence of resistance in helminths to currently available synthetic anthelmintic drugs is a major concern. *T. trichiura* (21.6%) is the most common STH, followed by *A. lumbricoides* (6.4%) and hookworms (2.3%) (21). The incidence of parasite infection is highest in cattle (43.13%), followed by buffalo (40.8%), sheep (29.4%), and goats (21.4%). Numerous helminth species have developed drug resistance due to prolonged use of anthelmintic medications. As a result, new alternative therapeutic agents for helminthic infection treatment and control are crucial due to minimal adverse effects. Therefore, the ultimate objective of this study is to evaluate the phytochemical constituents, antioxidant capacity, and anthelmintic activity of *C. verum* bark extract against Eudrilus eugeniae. The present discovery regarding the bark extract of *C. verum* provides initial insights into its therapeutic potential, serving as a reference point for researchers conducting similar studies. Hence, further comprehensive studies on this plant's potential as an alternative treatment to current pharmaceuticals can be carried out.

## MATERIALS AND METHODS

The primary material used in this study was the bark of *C. verum*. The plant was extracted using acetone (R&M Chemicals, Malaysia) and ethyl acetate (HmbG, Malaysia), followed by dilution with distilled water. Furthermore, Ferric Chloride (MP Biomedicals, USA), Sodium hydroxide (Merck, Germany), Sulphuric acid (SPL Life Science, Korea), Chloroform (Merck, Germany), and Wagner's Reagent (R&M Chemicals, Malaysia) were used in the phytochemical analysis test on *C. verum* bark extracts. The 2,2-diphenyl-1-picrylhydrazyl (DPPH) reagent (TCI, USA) and Ascorbic acid (R&M Chemicals, Malaysia) were used to conduct the DPPH assay. 2,4,6-tris (2-pyridyl)-1,3,5-triazine (TPTZ) (Sigma-Aldrich, USA), Gallic acid (Merck, Germany), Sodium acetate trihydrate (Amresco, USA), Hydrochloric acid (R&M Chemicals, Malaysia), and Glacial acetic acid (MP Biomedicals, USA) were used to perform FRAP assay. Mebendazole was the positive control for evaluating the anthelmintic activity of the Eudrilus eugeniae earthworm.

### Worm selection

The *Eudrilus eugeniae* (*E. eugeniae*) earthworm was used to investigate the anthelmintic activity. Adult earthworms were selected for this study because they resemble human gastrointestinal roundworm parasites in anatomical and physiological ways. Adult earthworms were collected from a local provider and morphologically identified based on the International Journal of Research in Pharmacy and Life Sciences. The earthworms ranging from 6 to 10 cm were selected in this study.

### Preparation of *C. verum* extract

The surface of *C. verum* bark was washed thoroughly with distilled water to remove debris or dust, and it was air-dried for 1-2 weeks. The dried bark was ground to a fine powder using an electronic blender and stored in an airtight container at 4°C before further extraction (22).

### Extraction of *C. verum* bark

100 g of bark powder was dissolved into 1000 ml each of acetone and ethyl acetate solution in a Schott bottle, respectively, and then covered with aluminium foil to prevent the solution from evaporating (23). The extracts were then agitated for three days at room temperature with a 120 rpm orbital shaker shaking. After three days, the extract solvents were filtered using four layers of gauze and Whatman No. 1 filter paper and then transferred to a flask. The filtrate was concentrated at 40°C using a rotary evaporator at 250 mbar pressure for ethyl acetate and 400 mbar pressure for acetone to obtain crude extract. The bark extracts were weighed, labelled, and stored at 4 °C until further use.

### Preparation of different concentrations of each *C. verum* extract

The working solutions were produced by dissolving the powder obtained from each extraction with distilled water and stored in a separate container with appropriate labelling.

### Anthelmintic activity

The earthworms were rinsed with normal saline to eliminate particles or faecal matter. The earthworms were then separated into five groups of six worms, each approximately the same size of 6-10 cm, and were released in a Petri dish. Three groups of earthworms were tested with different extracts at different concentrations (40, 60, 80 mg/ml) of different extraction solvents; one group was used as a positive control with 50 mg/ml of mebendazole, and one group was treated with normal saline as a negative control. The time taken for the

paralysis and death of the earthworms was recorded after different concentrations of each extract were applied to Petri dishes. Time taken for paralysis was noted when there was no movement of the worm except when shaken vigorously, and the time taken for death was noted when the worm lost its motility and faded in body colour (24).

**Qualitative phytochemical analysis**

A preliminary phytochemical screening test was performed on *C. verum* bark extracts at 1000 mg/ml concentration. The test used the standard method from previous studies (25, 26, 27).

**Tests for phenols**

A ferric chloride test was used to determine the presence of phenols. One ml of bark extract was mixed with two ml of distilled water. 0.5 ml ferric chloride solution ($FeCl_3$) was then added to the solution and mixed thoroughly. The presence of bluish or green colours indicates phenol compounds (25).

**Tests for flavonoids**

The presence of flavonoids was performed using an alkaline reagent test. One ml of sodium hydroxide (NaOH) solution was mixed with two ml of bark extract. The presence of yellow colour suggests the presence of flavonoids (25).

**Tests for saponins**

The froth test was used to determine the presence of Saponins. 0.5 ml of bark extract was mixed with approximately 0.5 ml of distilled water and was shaken vigorously. Stable emulsion formation indicates the presence of Saponins (25).

Tests for glycosides

The presence of glycosides was determined by performing Salkowski's test. Two ml of chloroform was mixed with one ml of bark extract. After that, two ml of concentrated sulphuric acid ($H_2SO_4$) were added to the mixture and shaken vigorously. The reddish-brown colour demonstrates the presence of glycosides (26).

**Tests for steroids**

The presence of steroids was detected using Salkowski's test. Two ml of bark extract was dissolved with two ml of chloroform. Then, two ml of concentrated sulphuric acid ($H_2SO_4$) was added. The appearance of red colour and yellowish-green fluorescence signifies the presence of steroids (27).

**Tests for alkaloids**

Wagner's test was used to detect the presence of alkaloids. A few drops of Wagner's reagent were added to a ml of bark extract and mixed. A reddish-brown precipitate suggests the presence of alkaloids (27).

**DPPH Radical Scavenging Assay**

The DPPH radical scavenging assay was performed using a 96-well plate according to the method from a previous study (28). In this method, 180 µL of DDPH solution (150 µmol L−1) in methanol-water (80:20, v/v) was mixed with 20 µL of the diluted sample (acetone and ethyl acetate extract of *C. verum* bark with 31.25 -1000 µg/ml) in 96-well plates and was shaken. The mixture was incubated at room temperature in the dark for 30 minutes. Then, a plate reader was used to measure the absorbance of the mixture at 517 nm. The standard control for this test was ascorbic acid, ranging from 3.125 – 100 µg/ml, and all measurements were made in triplicate. The formula used to calculate the DPPH assay is shown below:

DPPH inhibition (%)=
[1-((Abs sample-Abs blank))/(Abs control)]x100%

Where:
Abs sample= absorbance of extract or standard with DPPH solution
Abs blank = absorbance of water with methanol-water
Abs control = absorbance of water with DPPH solution

**Ferric Reducing Antioxidant Power (FRAP) assay**

The FRAP analysis was done using the method from a prior study with a slight modification (29). Firstly, the FRAP reagent was prepared by mixing 300 mM sodium acetate buffer (pH 3.6), 10mM 2,4,6-tris(2-pyridyl)-1,3,5-triazine (TPTZ) solution in 40 mM HCl, and 20 mM ferric chloride solution in the following ratios (10;1;1), respectively. 10 µL of acetone and ethyl acetate extract of *C. verum* bark (1 mg/ml) were then mixed with 190 µL freshly prepared FRAP reagent in the 96-well plate. The mixture was incubated at 37 °C for 10 minutes, and the absorbance was measured at 593 nm using a plate reader. Gallic acid with different concentrations (0-100 µg/ml) was used to produce a standard calibration curve, and the result was converted to mg of gallic acid equivalents per g (mg GAE/g) of the sample. Gallic acid equivalent per gram of dry weight (mg GAE/g dry weight) was used to calculate FRAP, as shown below:

C=cv/m

Where:
C = antioxidant power in mg GAE/g of extract
c = concentration of gallic acid obtained from the calibration curve
v = volume of *C. verum* bark extracts
m = the weight of pure extracts of *C. verum* bark

**RESULTS**

Using 1000 ml of acetone and ethyl acetate to extract 100 g of *C. verum* bark powder resulted in a dark brown crude extract.

**Table I** shows that the acetone had the highest crude

extract percentage yield, 6.3%, followed by the ethyl acetate extract, 4.2%.

**Table I: Extraction yields of *C. verum* bark.**

| Solvent | Weight of *C. verum* bark powder (g) | Weight of crude (g) | Percentage of weight extract (%) |
|---|---|---|---|
| Acetone | 365 | 22.88 | 6.3 |
| Ethyl acetate | 488 | 20.67 | 4.2 |

**Figure 1** illustrates the anthelmintic activity of the negative, positive control (standard drug), acetone, and ethyl acetate extracts of *C. verum* bark against *E. eugeniae* earthworms. The crude acetone and ethyl acetate extracts of *C. verum* bark were tested for anthelmintic activity against the *E. eugeniae* earthworms. Each extract was tested at different concentrations (40 mg/ml, 60 mg/ml, 80 mg/ml) against selected worms in a duplicate manner to ensure reliable results. Six earthworms were used at each concentration for each extraction solvent. Commercial mebendazole was used as a positive control, while distilled water was used as a negative control.

**Table II** shows the phytochemical tests of the acetone extract of *C. verum*, which demonstrated the presence of phenols, flavonoids, glycosides, steroids, and alkaloids. In contrast, the ethyl acetate extract of *C. verum* displayed the presence of phenols, flavonoids, saponins, glycosides, steroids, and alkaloids.

**Table II: Phytochemical contents of *C. verum* extracts.**

| Phytochemical content | AECV | EAECV |
|---|---|---|
| **Phenols** | + | + |
| **Flavonoids** | + | + |
| **Saponins** | - | + |
| **Glycosides** | + | + |
| **Steroids** | + | + |
| **Alkaloids** | + | + |

**Table III** summarises the results of the DPPH radical scavenging assay for different extracts of *C. verum* bark. All the extracts showed dose-dependent scavenging activity, with the acetone extract exhibiting the highest activity. However, the scavenging activity of standard ascorbic acid was more significant than that of all extracts.

**Table III: DPPH radical scavenging activity of ascorbic acid, acetone, and ethyl acetate extracts of *C. verum* bark.**

| Samples | Concentrations (µg/ml) | Percentage inhibition (%)/ Scavenging activity (Mean ± SD) |
|---|---|---|
| Positive control (Ascorbic acid) | 3.125 | 6.37 ± 1.62 |
| | 6.25 | 9.13 ± 2.15 |
| | 12.5 | 13.21 ± 1.11 |
| | 25 | 28.34 ± 1.91 |
| | 50 | 52.54 ± 4.31 |
| | 100 | 95.85 ± 0.13 |
| AECV | 31.25 | 29.30 ± 1.95 |
| | 62.5 | 37.94 ± 0.72 |
| | 125 | 42.13 ± 0.57 |
| | 250 | 54.15 ± 2.70 |
| | 500 | 69. 30 ± 0.51 |
| | 1000 | 87.78 ± 0.27 |
| EAECV | 31.25 | 28.91 ± 0.45 |
| | 62.5 | 39.62 ± 0.64 |
| | 125 | 45.21 ± 0.70 |
| | 250 | 49.24 ± 1.00 |
| | 500 | 64.18 ± 5.89 |
| | 1000 | 84.32 ± 2.07 |

**Table IV** demonstrates that the AECV exhibited superior scavenging activity with a lower IC50 value of 270.88 ± 15.36 µg/ml, followed by the EAECV with an IC50 of 292.03 ± 25.83 µg/ml. All extracts demonstrated significant scavenging ability ($P < 0.05$) compared to the standard ascorbic acid (IC50 = 49.68 ± 0.73 µg/ml).

The acetone and ethyl acetate extracts of *C. verum* bark displayed a linear calibration curve against gallic acid, which served as the standard. The antioxidant activity of *C. verum* bark in acetone and ethyl acetate extract was estimated using gallic acid. The calibration equation is $y = 0.0176x + 0.0345$, and the coefficient of determination is $R2 = 0.9989$, as indicated by the calibration curve.

**Table IV: The half maximal inhibitory concentration (IC50) and statistical interpretation of ascorbic acid, acetone, and ethyl acetate extracts of *C. verum*.**

| Samples | $IC_{50}$ ± SD | P-value |
|---|---|---|
| Ascorbic acid | 49.68 ± 0.73 | P < 0.012 |
| AECV | 270.88 ± 15.36 | |
| EAECV | 292.03 ± 25.83 | |

**Table V** shows that the ethyl acetate extract of *C. verum* bark exhibited the highest reducing power, with a higher FRAP value (291.08 ± 52.40 mg GAE/g), followed by the acetone extract of *C. verum* bark (159.70 ± 3.86 mg GAE/g).

The time for paralysis and death of the *E. eugeniae* earthworm were measured and expressed as mean ± standard deviation (SD). A one-way ANOVA was conducted to compare the effects of *C. verum* bark extracts and the standard drug (mebendazole). The mean results showed significant differences ($P < 0.05$) compared to the standard drug. Antioxidant studies were conducted three times, and the results were reported as mean ± standard deviation (SD). The one-way ANOVA indicated statistically significant differences ($p < 0.05$) between the sample mean values and the standard.

**Table V: Ferric reducing antioxidant power of *C. verum* bark extracts (expressed as gallic acid equivalents) and statistical interpretation.**

| Extractions | Concentration (mg GAE/g) | P-value |
|---|---|---|
| Acetone | 159.70 ± 3.86 | P < 0.012 |
| Ethyl acetate | 291.08 ± 52.40 | |

## DISCUSSION

Helminthiasis, a prevalent public health concern, particularly in children, poses a substantial economic burden due to its impact on livestock and domestic animals. The emergence of anthelmintic drug resistance (3) has necessitated the exploration of alternative treatments, including those derived from medicinal plants such as *C. verum*. However, alternative therapies, particularly those derived from medicinal plants like *C. verum*, are becoming increasingly popular.

The yield of *C. verum* bark extractions throughout the current study varied significantly. Table I shows that the

acetone extract of *C. verum* bark had the highest crude extract yield at 22.88 g (6.3%), followed by the ethyl acetate extract of *C. verum* bark at 20.67 g (4.2%). This finding is consistent with a study that found the highest extraction yield with acetone extract of Limnophila aromatica (30). The solvent choice significantly determines the obtained extract's composition and extraction efficacy. Acetone, a moderately polar solvent, efficiently extracts various phytochemicals by forming hydrogen bonds with polar compounds. Conversely, ethyl acetate, possessing intermediate polarity, selectively extracts specific classes of compounds. This highlights the importance of carefully selecting solvents based on their polarity to optimize extraction and isolate targeted bioactive compounds (31).

The acetone extract of *C. verum* bark demonstrated considerable dose-dependent anthelmintic activity against *E. eugeniae*. A significant increase in extract concentration correlates with a decrease in the paralysis and death times of the earthworm. Based on **Figure 2**, the acetone extract of *C. verum* bark at the highest concentration (80 mg/ml) exhibited the strongest anthelmintic activity, with paralysis occurring in 1.21 minutes and death occurring in 4.55 minutes. Moreover, at a concentration of 40 mg/ml, the earthworm was paralysed at 2.08 minutes and died 6.63 minutes later. Furthermore, when exposed to 60 mg/ml acetone extract, *E. eugeniae* was paralysed in 1.8 minutes and died 5.27 minutes later. The presence of bioactive compounds within the acetone extract may influence anthelmintic activity, such as tannin, which can bind to glycoprotein on the cuticle of the parasite and free proteins in the gastrointestinal tract of the host animal, leading to the death of the worm (32). Hence, further phytochemical analyses are needed to identify the specific compounds responsible for the anthelmintic action.

In addition, the ethyl acetate extract from *C. verum* bark revealed significant anthelmintic activity at 40 mg/ml, 60 mg/ml, and 80 mg/ml. The time required for paralysis and death of *E. eugeniae* at 40 mg/ml was 3.42 minutes and 10.5 minutes, respectively. Furthermore, ethyl acetate extract at a concentration of 60 mg/ml paralysed *E. eugeniae* in 2.30 minutes, while death took 6.80 minutes. The highest concentration of the ethyl acetate extract (80 mg/ml) showed the shortest time for paralysis and death at 1.50 minutes and 5.91 minutes, respectively. The ethyl acetate extract results showed that the time taken decreased as the concentration of the extraction solvent increased. These findings are similar to those of the previous study, which also found that an extract of Urochloa distachya has anthelmintic action in a concentration-dependent manner (33). Another study also found that the extracts from Majoon Sarakhs exhibited a notable anthelmintic effect at higher concentrations than the standard albendazole (2).

In contrast to the positive control (mebendazole), all *C. verum* bark extracts demonstrated superior efficacy in paralyzing and killing *E. eugeniae*. Mebendazole inhibits beta-tubulin polymerization, a critical process for parasite glucose uptake and cytoplasmic microtubule formation. This disruption ultimately leads to immobilization and death. Additionally, degenerative changes within parasite cells result in decreased glucose uptake, ATP production, and glycogen depletion, contributing to parasite mortality (34, 35).

The potential mechanism of anthelmintic action in *C. verum* bark could be explained by proanthocyanidin tannins, particularly trans-cinnamaldehyde (36). Besides that, bioactive compounds in the plant extract, such as glycosides, interfere with sodium and potassium ion transport, causing helminth death, while flavonoids promote allelopathy and hinder auxin transport (37, 38). As a result, *C. verum* bark extract may have used its anthelmintic effects on *E. eugeniae* in the same way as mebendazole.

The anthelmintic efficacy of *C. verum* bark extracts varied significantly based on the solvent used. The acetone extract of *C. verum* bark demonstrated superior anthelmintic activity compared to the ethyl acetate extract of *C. verum* bark. Figure 2 revealed that the acetone extract of *C. verum* bark at a concentration of 80 mg/ml caused paralysis and death of *E. eugeniae* at 1.21 and 4.55 minutes, respectively. In contrast, the ethyl acetate extract of *C. verum* bark showed lower anthelmintic potency, with the highest concentration (80 mg/ml) requiring *E. eugeniae* earthworm for paralysis and death at 1.5 and 5.91 minutes, respectively. These findings suggested that acetone might be the best solvent for extracting anthelmintic compounds from *C. verum* bark. The enhanced activity of the acetone extract could be due to the differential extraction of bioactive compounds based on the polarity of the solvent. Similar results were observed where the acetone extract of Teucrium sandrasicum exhibited stronger anthelmintic effects, potentially due to its polyphenolic compounds (39).

The qualitative phytochemical analysis found various bioactive compounds, such as phenols, flavonoids, saponins, steroids, glycosides, and alkaloids, within the *C. verum* bark extracts. The presence of these compounds is consistent with the previous studies that found various phytochemicals in this plant species. Meanwhile, saponins were absent in the acetone extract of *C. verum* bark, suggesting that solvent polarity significantly impacts the phytochemical extraction (31). In addition, a previous study using gas chromatography-mass spectrometry (GCMS) detected the highest quality compounds, like hexadecanoic acid, pentadecanoic acid, cinnamaldehyde, 3-phenyl-, oxime-, 2-methyl-benzofuran, and Tridecanoic acid, methyl ester contributing to anthelmintic action (9). These high-quality compounds, particularly cinnamaldehyde, may

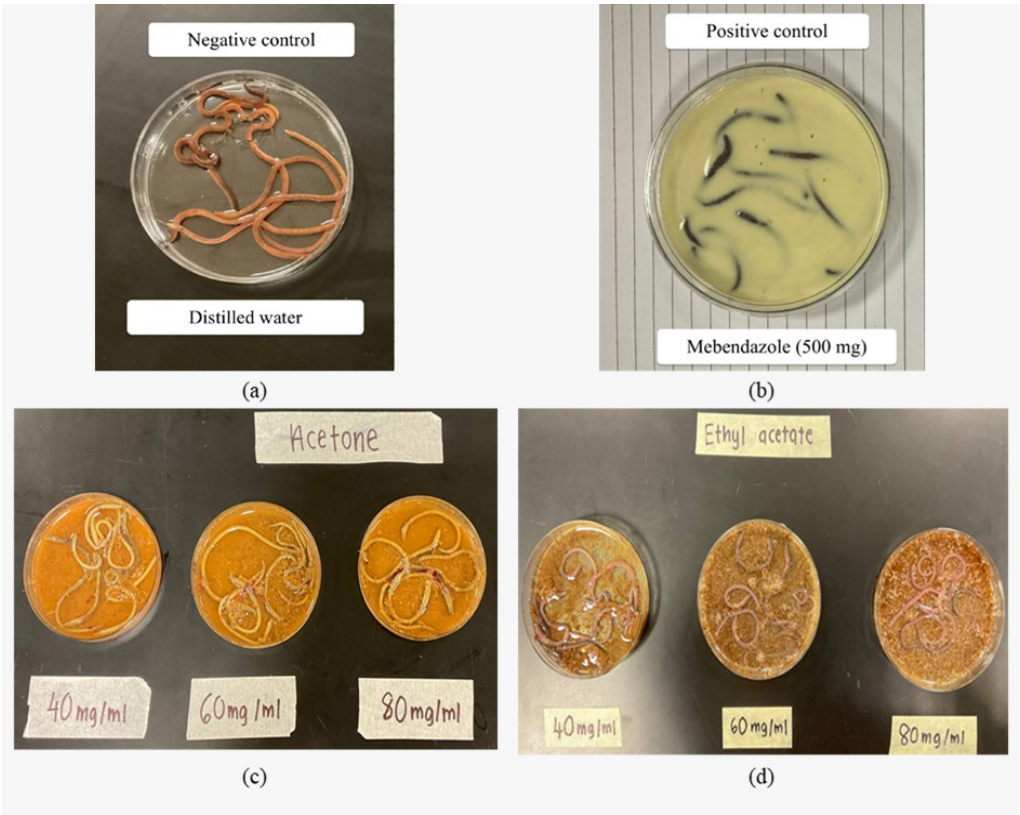


**Fig. 1: Anthelmintic activity of the negative control and positive control against *E. eugeniae* earthworms. (a) Distilled water was used against *E. eugeniae* as a negative control. (b) 50 mg/ml of mebendazole was used against *E. eugeniae* as a positive control during this study. (c) Anthelmintic activity of acetone extract of *C. verum* bark against *E. eugeniae* at concentrations of 40 mg/ml, 60 mg/ml, and 80 mg/ml. (d) Anthelmintic activity of ethyl acetate extract of *C. verum* bark against *E. eugeniae* at concentrations of 40 mg/ml, 60 mg/ml, and 80 mg/ml.**

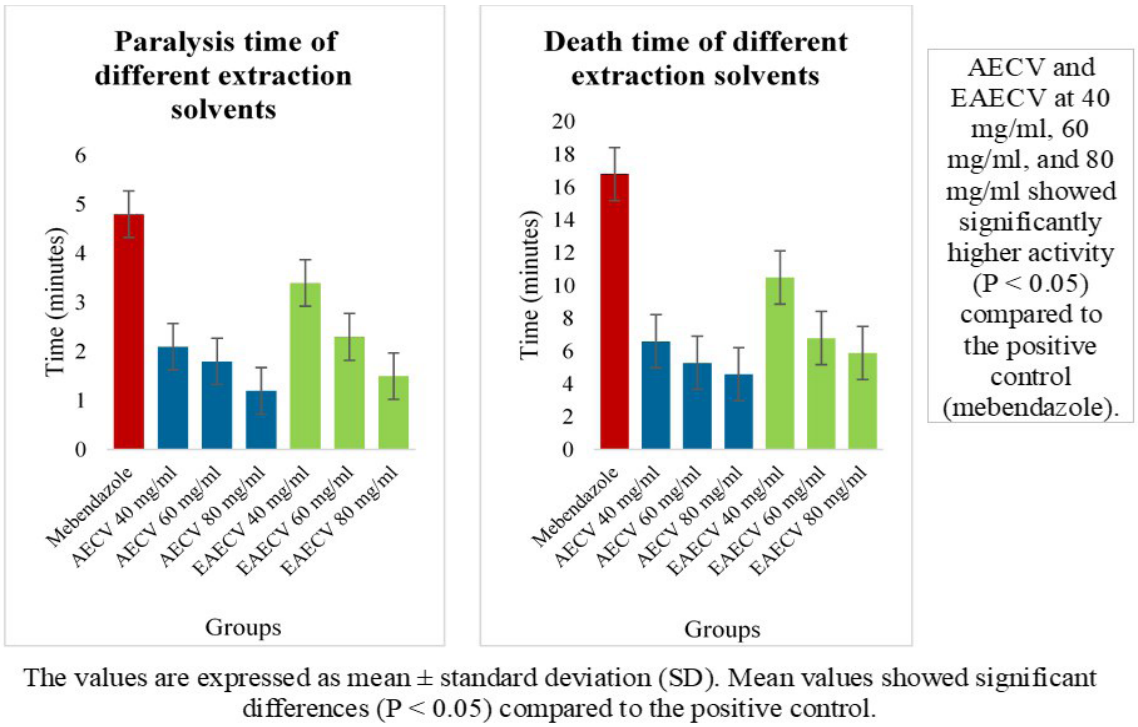


**Fig. 2: The time taken for paralysis and death of the *E. eugeniae* earthworm was compared between the acetone extract of *C. verum* (AECV) and the ethyl acetate extract of *C. verum* (EAECV) and the positive control (mebendazole). The shortest paralysis occurred at 1.2 mins, at 80 mg/ml of AECV, compared to the positive control and EAECV. The shortest death time occurred at 4.6 mins, at 80 mg/ml of AECV, compared to the positive control and EAECV.**

contribute to the anthelmintic action.

The antioxidant capacity of *C. verum* bark extracts was evaluated using two standard assays: the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay and the ferric reducing antioxidant power (FRAP) assay. To ensure the reliability of the results, all measurements were conducted in triplicate. The acetone extract of *C. verum* bark and ethyl acetate of *C. verum* bark exhibited antioxidant activity with a significant difference. The presence of phenols and flavonoid compounds is likely responsible for the antioxidant activity. These compounds are known for their excellent antioxidant, which acts as free radical scavengers capable of protecting biomolecules from oxidative damage (40).

The inhibition percentage of the extracts and positive control by DPPH assay was determined spectrophotometrically. The increase in inhibition percentage indicates that the higher dose enhances free radical scavenging activity. The results of the DPPH assay showed that both acetone and ethyl acetate extracts of *C. verum* bark possessed antioxidant potential, with a dose-dependent increase in DPPH radical scavenging activity. These suggest the presence of compounds with hydrogen-donating ability within the extracts that can stabilise DPPH radicals.

The acetone extract of *C. verum* bark showed a higher radical scavenging activity (87.78 ± 0.27%) than the ethyl acetate extract of *C. verum* bark (84.32 ± 2.07%) at 1000 µg/ml. This result suggests that the acetone extract of *C. verum* bark has better antioxidant activity than the ethyl acetate extract of *C. verum* bark, indicating that acetone extract has a higher concentration of compounds like phenols and flavonoids with a hydroxyl group. Furthermore, ascorbic acid used as a positive control exhibited the highest radical scavenging activity (95.85 ± 0.13 at 100 µg/ml) compared to the extracts, ensuring the validity of the assay. Antioxidant activity exhibited by *C. verum* bark extracts might be due to the phenolic and flavonoid compounds known for their potent antioxidant activity (41).

The half maximal inhibitory concentration (IC50) values for the DPPH radical scavenging activity of ascorbic acid, acetone, and ethyl acetate extracts of *C. verum* bark were determined using the percent inhibition (%), as presented in Table IV. The acetone extract of *C. verum* bark had an IC50 value of 270.88 ± 15.36 µg/ml, and that for the ethyl acetate extract of *C. verum* bark was 292.03 ± 25.83 µg/ml. These findings clearly show that acetone extract has greater antioxidant efficacy. The IC50 value for ascorbic acid was 49.68 ± 0.73 µg/ml, showing a significant scavenging ability than the plant extracts. Several studies have indicated that cinnamon's antioxidant activity is associated with higher amounts of eugenol and E-cinnamaldehyde (42).

Moreover, the IC50 values determined for DPPH radical scavenging activity revealed a concentration-dependent antioxidant capacity for acetone and ethyl acetate extracts of *C. verum* bark. The structure-activity relationship between flavonoids and antioxidant capacity is already established, where the presence of hydroxyl groups, especially in the ortho 3, 4-dihydroxy configuration, contributes to their free radical scavenging potential (43). *C. verum* leaf extract possesses antioxidant activity as it can prevent reactive oxygen species and free radicals and possesses hydrogen donor ability (44).

The ferric-reducing antioxidant power assay (FRAP) was used to assess the reducing capacity of the *C. verum* bark extracts. Based on Table V, the ethyl acetate extract of *C. verum* bark showed a higher FRAP value (291.08 ± 52.40 mg GAE/g) compared to the acetone extract of *C. verum* bark (159.70 ± 3.86 mg GAE/g). These results indicate that the ethyl acetate extract of *C. verum* bark has superior reducing power and contains a higher concentration of compounds capable of reducing ferric ions to ferrous ions through electron transfer. Furthermore, the standard calibration curve obtained using gallic acid showed excellent linearity, R = 0.9989, thus confirming that the FRAP assay was reliable. The results were consistent with the previous findings that showed the potential antioxidant of *C. verum* bark extracts (15, 22, 42, 45). Cinnamaldehyde, eugenol, and other phenolic constituents likely contribute to the observed antioxidant activity.

## CONCLUSION

The current study demonstrated the anthelmintic and antioxidant potential of *C. verum* bark extracts. The acetone extract revealed significant anthelmintic activity compared to the ethyl acetate extract, with a dose-dependent response observed. On the other hand, the ethyl acetate extract exhibited stronger antioxidant capacity, as proven by the FRAP assay. Qualitative phytochemical analysis revealed the presence of bioactive compounds such as phenols, flavonoids, glycosides, and potentially more compounds that contribute to anthelmintic and antioxidant activity. Cinnamaldehyde, a recognised bioactive component found in cinnamon, is believed to contribute to the anthelmintic and antioxidant activities of the extracts. However, further study is needed to isolate and characterise the particular bioactive components responsible for the observed effects, while these findings provide exciting insights into the therapeutic potential of *C. verum* bark. In vivo studies are also required to test the anthelmintic and antioxidant activity of the extracts in relevant animal models, as well as their safety and pharmacokinetics.

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## COMPETING INTEREST

The authors declare that they have no competing interests.

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