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Comparative Nematocidal Efficacy of Coriander Oils Against *Haemonchus Contortus*

Omnia M Kandil[1*], Hatem A Shalaby[1], Noha M F Hassan[1], Seham H M Hendawy[1], Amira H El Namaky[1], Hanan A A Taie[2], Bassma S M Elsawy[1], Mohamed A Helal[1] and Omaima M Kandil[3]

[1]Parasitology and Animal Diseases Department, Veterinary Research Institute, National Research Centre, Dokki, Cairo, 12622, Egypt
[2]Plant Biochemistry Department, Agriculture and Biology Research Institute, National Research Centre, Dokki 12622, Giza, Egypt
[3]Animal Reproduction and Artificial Insemination Department, Veterinary Research Institute, National Research Centre, Accredited (ISO 17025) Embryo and Genetic Resources Conservation Bank in National Research Centre (NRC), Egypt
***Corresponding author:** kandil_om@yahoo.com

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ABSTRACT

This study aimed to define the active phytochemical constituents of extracted oil and, commercially available one of *Coriandrum* and to investigate the anthelmintic impacts of its major components against the diverse stages of *Haemonchus contortus.* The compositional analysis of the extracted and commercial oil of *Coriandrum* was carried out via GC/MS. The chromatography revealed the poor quality of commercial oil available in local markets than the extracted ones because of trace content of major component, linalool. Detection of the anthelmintic effect of crude extracted coriander essential oil, and the pure components of geraniol, linalool, and eugenol, at six concentrations (0.25, 0.5, 1, 2, 4 and 8mg/mL) were evaluated employing egg hatch assay against *H. contortus* eggs. The coriander and geraniol showed higher and reproducible inhibitory egg hatching activity even at the lowest concentrations (0.25 mg/ml) up to 86 and 100%, respectively. Both essential oils exhibited a marked inhibitory activity against adult and larval motility in a dose-dependent manner. The nematocidal effect of the coriander essential oil on treated adult worms was indicated by cuticular changes induced with concentration of 4mg/mL on the histological examination compared to the untreated worms. The safety results of the body and organ weights, oxidative stress and biochemical parameters confirmed that the administration of coriander and geraniol oils (50mg/kg) is a great extent biologically safe. Our findings showed that the coriander and geraniol have potential anthelmintic activity against *H. contortus* and can be taken for a long time with no side effects.

Key words: Botanicals**,** Coriander Essential Oil, Phytochemicals, *Haemonchus Contortus*, Anthelmintic, Sheep.

INTRODUCTION

Gastroenteritis caused by infection with a gastrointestinal nematode (GIN), particularly Haemonchus contortus, has negatively influenced animal health and productivity through mortalities, reduced weight gains, and milk production **(**Fthenakis and Papadopoulos 2018). Current control measures of GIN infections in small ruminants rely exclusively on regular treatment using anthelmintics. This approach has led to the emergence of resistant parasites to the commonly used broad-spectrum anthelmintics (Dubois et al. 2019) which is considered as ubiquitous phenomenon with a massive challenge to sheep production systems and global food security (Beleckė et al. 2021). Also, the vaccination is not a 'silver bullet' and has not provided satisfactory protection in clinical trials (Kandil et al. 2018). Therefore, recent trends toward non-chemical approaches are markedly growing for integrated parasite control programs and organic livestock productions (Reyes-Guerrero et al. 2021). Medicinal plants are deemed one of the most remarkable natural and biodegradable anthelmintics (Ferreira et al. 2016). A high potency of some medicinal plants was confirmed through i*n vitro* and *in vivo* anthelmintic action against *H. contortus* (Helal et al. 2022; Kandil et al. 2023).

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The anthelmintic impacts of bioactive phytoconstituents especially the essential oils have been extensively evaluated (Panda et al. 2022). These plant-derived oils are generally composed of a mixture of terpenes and terpenoids (Masyita et al. 2022), and have been shown to possess a wide range of therapeutic properties making them popular in the field of natural medicine (Abidi et al. 2020; Hassan et al. 2020). Coriander (*Coriandrum sativum* L.) is one of the essential oil-bearing plants that are local to the Mediterranean region including Egypt (Aelenei et al. 2019) and rich in antioxidants with well-known antibacterial and anthelmintic properties (Sriti Eljazi et al. 2017). Identification of essential oil components with the greatest anthelmintic activity may provide alternative treatment options to the commercially available drugs (Helal et al. 2020). The potential anthelmintic components such as linalool, citronellal, eugenol, geraniol, thymol, limonene, citral, and carvacrol (Katiki et al. 2017; Jimayu 2022) can be fractionated from the crude essential oil and used individually or in a blend formulation to achieve the powerful effect against parasitic stages However, it's important to note that essential oils should be used with cautions as a result of their narrow safety margin that may cause adverse reactions to the treated host (Ebani and Mancianti 2020; Batool et al. 2023). Therefore, the toxicity of used essential oil must be addressed and clarified before the start of clinical trials.

In the current study, the chemical composition of extracted and commercially available oil of *Coriandrum* was assigned and the anthelmintic activates of its major components were investigated against the diverse stages of *H. contortus* with reference to histological changes of treated adult worms with the crude oils. Also, the *in vivo* toxicity study was employed to detect the safety margins of candidate essential oils.

MATERIALS AND METHODS

The Ethics Committee for the Care and Use of Laboratory Animals of the National Research Centre, Giza, Egypt approved the procedures (EX060717082022) and experimental protocols of the current study.

Extraction, Determination and Analysis of Essential Oil

A weight of 1000g of *Coriandrum* seeds was exposed to hydro-distillation for over 4h utilizing a modified Clevenger apparatus as adopted by Bousbia et al. (2009).

GC/MS Analysis

The GC/MS analysis was carried out according to the methodology of Al-Sayed et al. (2021).

Experimental Infection of Sheep with *H. Contortus*

A group of three sheep was experimentally infected with the third larval stage of *H. contortus* (oral dose of 20,000 L_3) to get donor sheep for monospecific infection as a source of eggs and larval stages as mentioned by Schallig et al. (1995). The infection was monitored by daily fecal examination and clinically examined until the animals began to pass eggs in feces and cultured afterwards for preparation of larval isolate (Soulsby 1986).

In Vitro Effects of Essential Oils on *H. Contortus* Egg Hatchability

The egg stages used in this study were collected from experimentally infected and monospecific sheep with *H. contortus*. *H. contortus* eggs were incubated for 24h in Ringer solution (37°C atmosphere 5% CO2). Then, the collected eggs were incubated in a Ringer solution containing different concentrations of essential oils; coriander, eugenol, linalool, and geraniol (0.25 to 8mg/mL) and using albendazole as a reference drug at a concentration of 0.0063mg/mL. Following incubation, the percentage of the reduction of *H. contortus* egg development resulting from the tested essential oils were determined utilizing the following formula:

$$\text{Inhibitory egg hatching activity} = \frac{\%\ \text{control egg hatching} - \%\ \text{exposed egg hatching}}{\%\ \text{control egg hatching}} \text{ X } 100$$

In Vitro Impacts of Coriander Essential Oil on Larval and Adult *H. Contortus* Motility

Collection of Larval and Adult Stages

The third larval stage used in this study was collected from fecal cultures of monospecific and experimentally infected sheep with *H. contortus*. The adult *H. contortus* worms were collected from slaughtered animals in local abattoir houses (El-Moneib, Giza, Egypt). The larval and adult stages were subjected to several washes by double distilled water, saline, then centrifugation was done for 5min at 700×g and washed three times with PBS containing streptomycin and penicillin at concentration of 4% and only active motile adults and larvae were utilized. Both larval and adult worm motility tests were carried out in accordance with the procedure of Santos et al. (2018). The larvae and adults were treated with different concentrations of essential oils (coriander, eugenol, linalool and geraniol) (0.25 to 8mg/mL in Ringer solution) and albendazole was used as a reference drug at concentration of 0.0063mg/mL. Then, the parasite stages were incubated at 37°C for 24h (5% CO2) and the number of movable and immovable worms was calculated for each concentration. The Immobility Index (%) was calculated according to the following equation:

Immobility Index (%) = No. of immobile worms/Total No. of worms x 100.

The experiments were carried out in three replicates and three times.

Light Microscopic Examination

Whole fresh motile adult worms, under sterile conditions, were moved to Ringer solution having different concentrations of Coriander essential oil. Following incubation, the mid-body region of *H. contortus* worms under experiment was dissected, then fixed and processed for light microscopy examination. The mid-body wall was photographed utilizing an Olympus CX41 microscope.

Experimental Animals for Safety Study

Fifteen Wistar male rats (155-170g) were obtained from the animal house of the National Research Centre-Giza -Egypt. The animals were divided into three groups

(five rats for every group) and kept in suitable cages at a 25°C with 12h/12h darkness photoperiod and with free access of rodent pellets and water. Each group was administered the investigated oil treatment orally via oral gavages (50mg/kg) once a day during the period of the experiment.

Body and Organ Weight

Each rat was weighed at the beginning and the end of the experiment (28 days). At the end of the period, animals were scarified, and blood samples were collected. Serum samples were prepared and stored at -20°C for biochemical parameters. Different organs of rats were closely removed and weighed.

Assigning of Oxidative Stress Biomarkers

Determination of antioxidant enzymes of serum were carried out according to Bio-diagnostic kit's guidelines. Serum Superoxide dismutase (SOD) and catalase enzyme activities were detected as adopted by Nishikimi et al. (1972) and Aebi (1984), respectively. Serum malondialdehyde (MDA) content was defined by a colorimetric technique as described by Kei (1978).

Determination of Serum Biochemical Parameters

All biomarkers and kits were applied according to Bio-diagnostic kit's instructions (Bio-diagnostic Company, Dokki, Giza, Egypt). Serum AST and ALT were measured as claimed by the methods of Young (1990), HDL was measured as stated by the method of Lopez-Virella et al. (1977). While LDL cholesterol was determined according to Wieland and Seidel (1983). Total cholesterol was determined according to Richmond (1973). However, Triglyceride was determined according to Fassati and Prencipe (1982). Creatinine and urea were determined according to Tietz (1990) and Tobias et al. (1962).

RESULTS

GC/MS Analysis of the Extracted and Commercial Essential Oil of *Coriandrum*

A volume of 5ml/kg essential oil was obtained from Coriandrum seeds. Five major components were obtained with total peak areas 63.23%. Fig. 1 shows the probabilities of the compounds' identified structures. Linalool (33.01%), decanal (7.42%), and 3-tetradecyn-1-ol (18.16%) make up the majority of the components and account for 92.66% of the total peak areas identified through computer search using user-generated reference libraries that included mass spectra. While 19 components were obtained by GC/MS analysis of commercial Coriandrum essential oil with total peak areas 92.51% (Fig. 2). The main compounds are N-[1-(2-Pyridyl) propyl]-(S)-1- phenylethylamine (31.79%), camphene (6.98%), adamantane (14.48), 3-Cyano-spiro[2-pyrazoline-5,1'-cyclopropane] (4.18%), 1-methyl, 4- piperidinone (8.27%), benzene sulfonic acid, 4-methyl-, (1-methylethylidene) hydrazide (15.23%) and 3,3'-oxybis, propane nitrile (4.32%), which made up (92.15%) of all the peak areas. Peaks were investigated by single-ion chromatographic reconstruction to emphasize their homogeneity. In some cases, only the structural type of the corresponding compound was proposed according to its mass spectral fragmentation. Reference compounds were co-chromatographed, when possible, to emphasize GC retention times. Generally, GC/MS analysis clearly indicated that there were many differences between the extracted and commercial volatile oil of Coriandrum which caused the variation in the biological activity of the two volatile oils.

Clinical Investigation of Sheep

The clinical inspection of donor sheep revealed that they were infected with hemonchosis three weeks post the experimental infection. Animals showed signs of restless, inappetence and pale mucous membranes. The infection was proven through detection of *H. contortus* eggs in feces.

Egg Hatch Assay

The obtained egg hatch assay showed the great inhibitory egg hatching activity of tested essential oil samples against *H. contortus* eggs (Fig.3). The three pure principles of coriander oil; eugenol, linalool, and geraniol, resulted in 100% inhibition of egg hatchability at high concentrations (2-8mg/mL). Also, coriander oil was highly effective with an egg hatching inhibition of 100% at concentration of 8mg/mL, showing a similar inhibitory egg hatching activity of albendazole. However, concentrations 0.25, 0.5 and 1mg/mL of coriander,

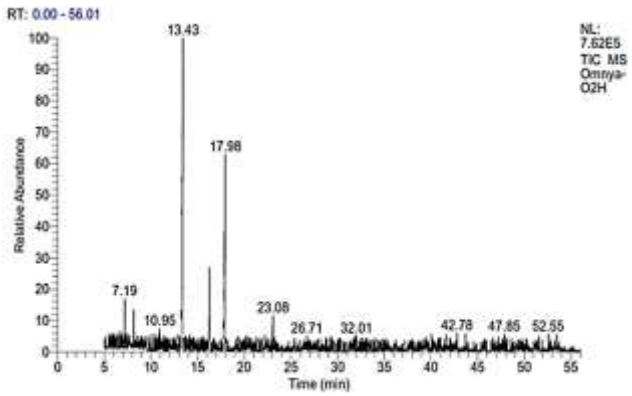

Fig. 1: GC/MS analysis of the extracted essential oil of *Coriandrum* seeds.

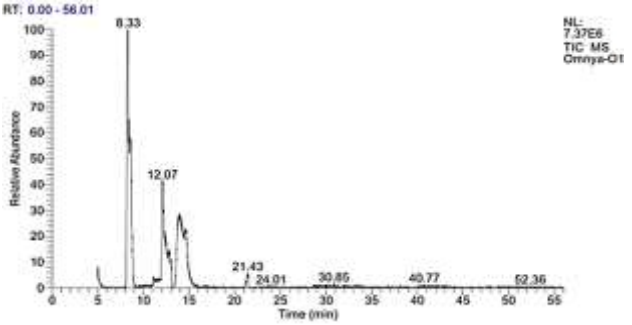

Fig 2: GC/MS analysis of the commercial essential oil of *Coriandrum* seeds.

eugenol, and linalool oil showed dose-dependent inhibitory egg hatching activity ranged from 86-98, 29-98 and 59-97%, respectively. At the meantime, geraniol exhibited the highest inhibitory egg hatching activity at all tested concentrations and the cell division stage was arrested (Fig.4).

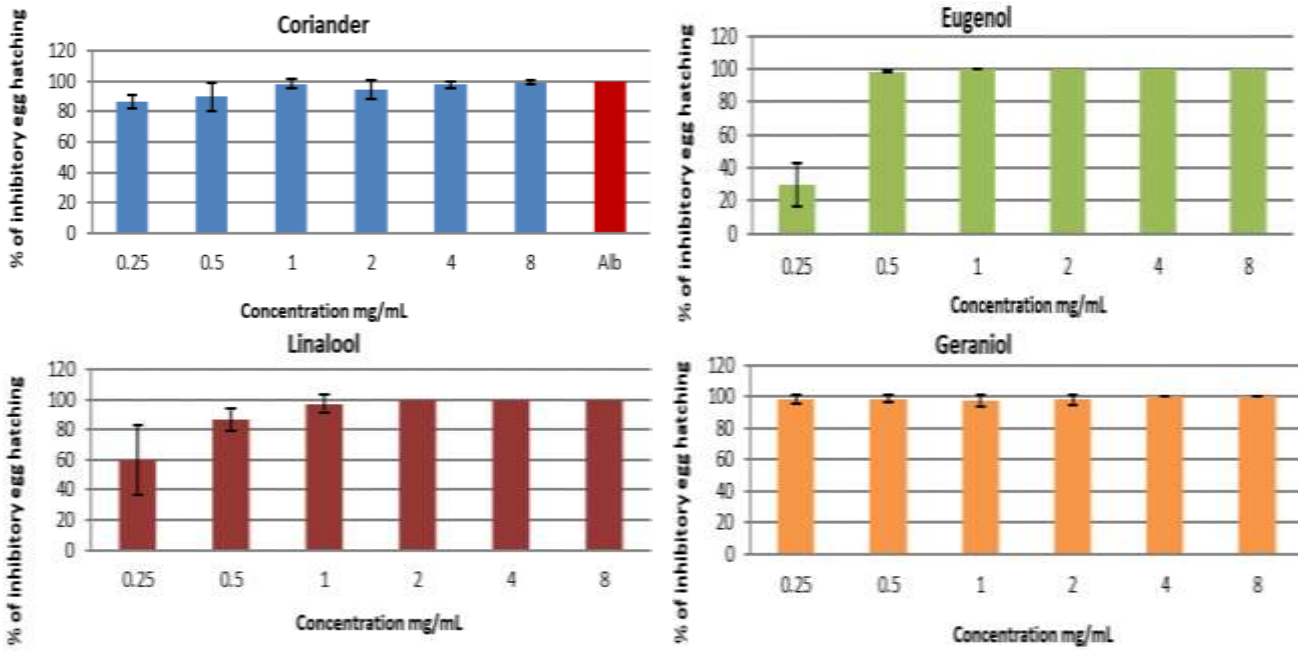

Fig. 3: Inhibitory activity of coriander (A) and its three pure essential oils (B=Eugenol; C= Linalool and D= Geraniol) at different concentrations against *H. contortus* egg hatching and Alb= Albendazole (0.0063mg/mL).

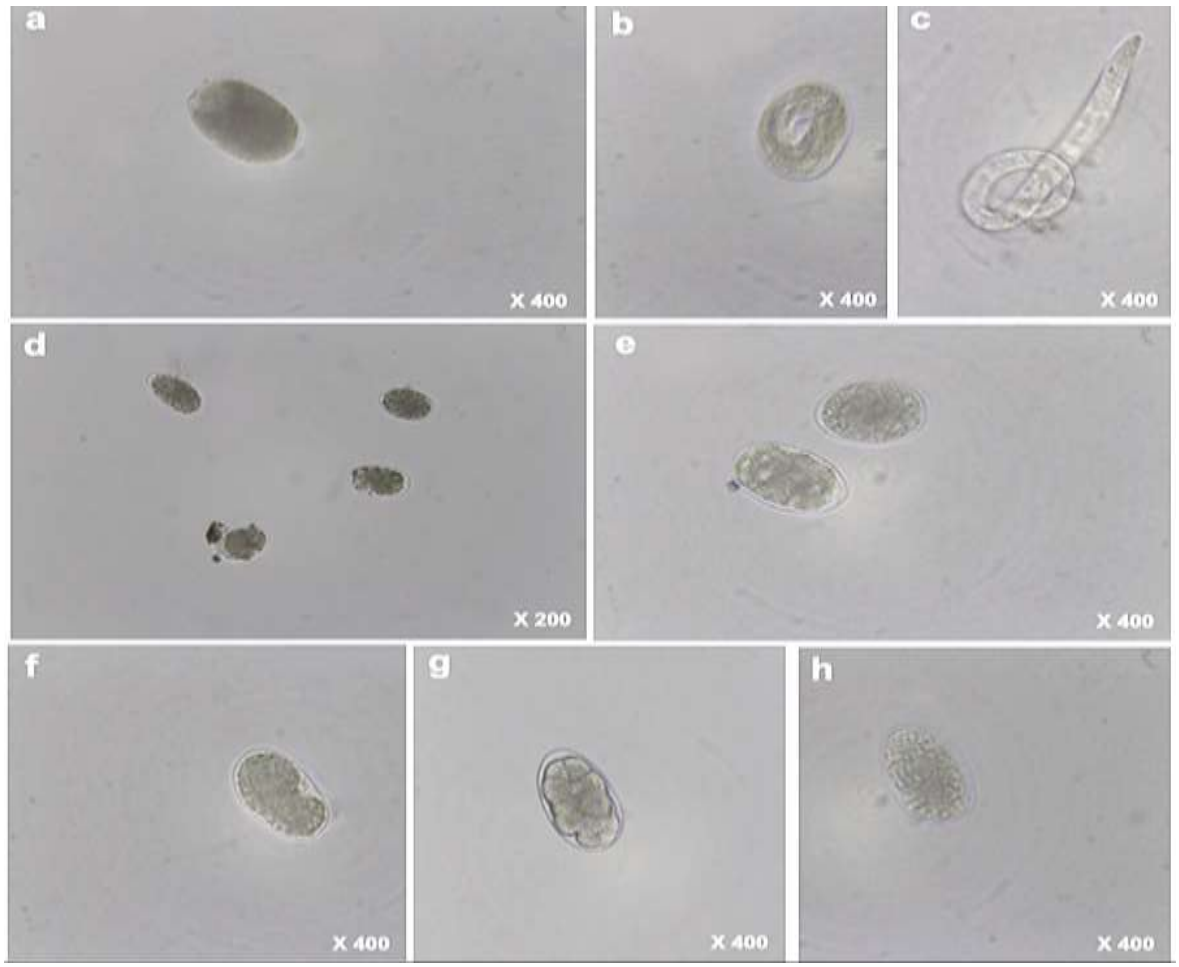

Fig. 4: *H. contortus* eggs. (a) Immature egg (b) Egg containing larva (c) Larva (d - h) After exposure to essential oils. Note the egg development was arrested at cell division stage.

Adult Worm Motility Assay

During the period of incubation (2h), the untreated *H. contortus* adult worms remained alive and active at the same time, coriander and geraniol essential oils revealed inhibitory activity on adult worm motility. At the start of exposure, the treated worms revealed strong movement that decreased gradually with time till 100% of the treated worms became completely immotile or even paralyzed in the test medium post 2h of incubation. In this experiment, coriander and geraniol oils at high concentrations ranged from 2-8mg/mL completely inhibited adult worm motility in the first hour of observation. While coriander and geraniol oils showed dose-dependent inhibition of the adult worm motility ranged from 22.3-77.8% and 44.5-55.6% at concentrations 0.25, 0.5 and 1mg/mL, respectively, (Fig. 5).

Larval Motility Assay

The results showed a marked inhibitory effect of coriander and geraniol oils versus *H. contortus* L3 motility at 4-8mg/mL. Both caused L3 motility suppression of >85 and 100% at concentrations of 4 and 8mg/mL, respectively. While at the lower concentrations ranged from 0.25 – 2mg/mL, coriander and geraniol oils showed dose-dependent inhibitory larval motility ranged from 54.3-75.0 and 47.0-90.6%, respectively (Fig. 6).

***In Vitro* Effects of Coriander Essential Oil on *H. Contortus* Adult Worms**

Cuticular features of adult worms utilizing light microscopy was important to define how coriander oil extract could impact the adult worm vitality. The tissue deterioration observed post treatment was assessed through histological examination of the cuticle of the treated adult worms.

Light Microscopic Observations

The cuticle of untreated *H. contortus* adult worm (Fig. 7a-d) comprises of 3 layers (outer cuticle, thin hypodermis, and inner muscle cells). A thin hypodermis is under the cuticle and consists of a syncytium of cells followed by several layers of longitudinally arranged striated muscles. The adult worms incubated for 24h at concentrations of 0.25, 0.5, 1 and 2mg/mL coriander oil showed no alteration in the integrity of the cuticle. The first appearance of cuticular changes appeared with concentration of 4mg/mL coriander oil at which the cuticle appeared to be thinner and pale than the untreated control and tiny areas for connection loss between the cuticle and the muscle layer could be detected. Some specimens showed disarrangement of the cuticular musculature (Fig. 7e-h). With concentration of 8mg/mL coriander oil, the cuticular distortion changed to be more remarked and showed large, isolated regions of cleavages. Besides, degenerative changes in the underlying muscle cells could be observed in some areas of the cuticle accompanied with small, isolated parts of cuticular damage (Fig. 7i-l).

Safety Study

Effect on Body and Organ Weights

Results (Table 1) revealed that the mean body weight of the rats in control group was 161±6.18g at 1st day of experiment and 283.5±16.92g at the end of the

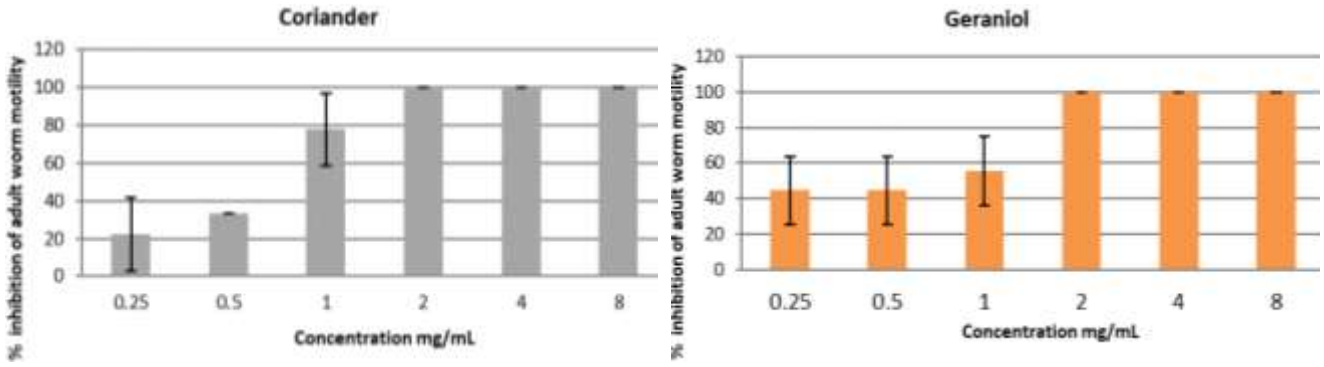

Fig. 5: Inhibitory effect of coriander oil and its pure essential oil geraniol at different concentrations against *H. contortus* adult worm motility after 1hr of exposure

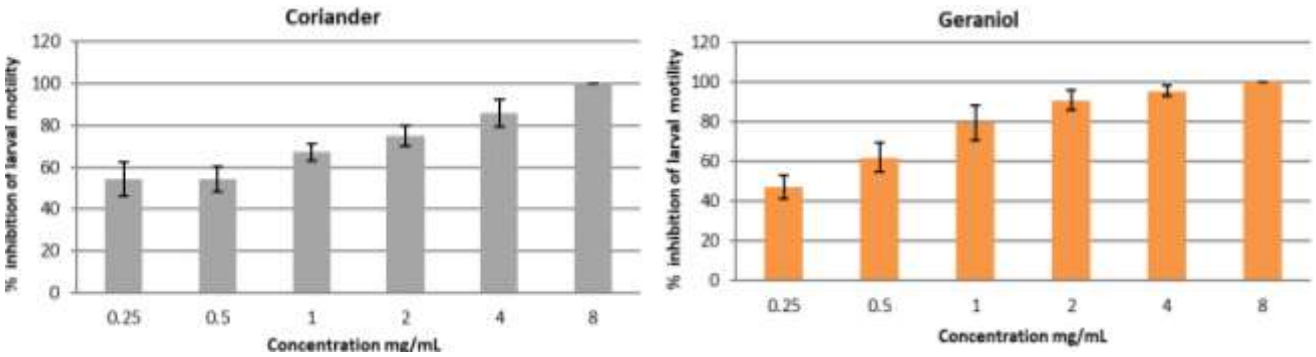

Fig. 6: Inhibitory effect of coriander oil and its pure essential oil geraniol at varies concentrations against *H. contortus* larval motility after 24h of exposure.

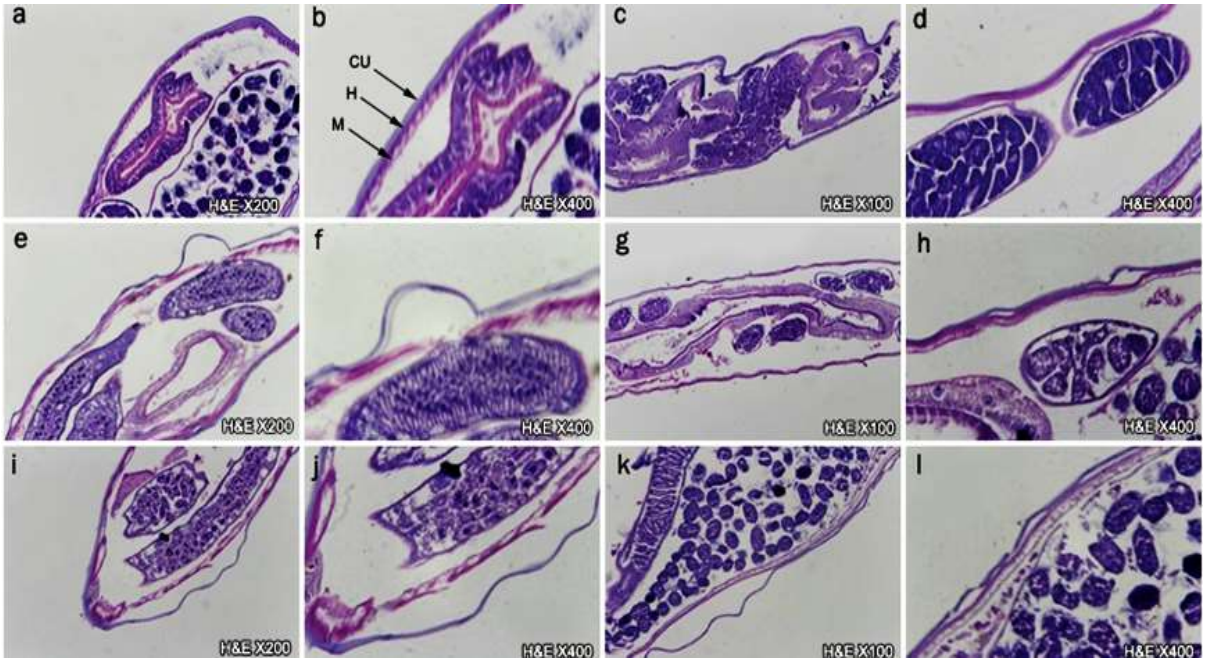

Fig. 7: Light microscopy of the body wall of adult *H. contortus* (a - d) Untreated control worm. Transverse (a, b) and longitudinal (c, d) sections revealing three layers of the body wall; cuticle, hypodermis, and an inner layer of muscle cells. (e - h). After 24 h incubation with 4mg/mL coriander oil. Transverse (e, f) and longitudinal (g, h) sections showing areas of lack of link between the cuticle and the muscle layer. (i – l). Following 24 h incubation with 8mg/mL coriander oil. Transverse (i, j) and longitudinal (k, l) sections revealing degenerative alterations in the underlying muscle cells and small isolated parts of cuticular damage. *CU* cuticle, *H* hypodermis, *M* muscle layer.

Table 1: Effect of administration of Coriander and geraniol oils (50mg/kg) on body and organs weights (grams) of male Wistar Rats.

Oils	Body weight	Brain	Liver	Kidney	Spleen	Lungs	Testes	Heart
Control	283.5±16.92a	1.71±0.04a	8.80±0.32b	2.50±0.050a	1.10±0.05a	1.75±0.10a	3.32±0.13a	1.09±0.03a
Coriander	284±10.10a	1.67±0.06a	8.67±0.29b	2.46±0.045a	1.08±0.06a	1.79±0.03a	3.35±0.05a	0.99±0.04b
Geraniol	284.5±15.33a	1.68±0.02a	9.40±0.16a	2.53±0.065a	1.06±0.06a	1.77±0.06a	3.37±0.04a	1.01±0.02b

Values (Mean±SD) are for five animals per group. Values bearing different alphabets in a column differ significantly ($P<0.05$).

experimental period. A similar weight was recorded with all the treated groups. No effect was noticed on the mean body weight of the rats (284±10.10 and 284.5±15.33) using both Coriander and geraniol oils. Additionally, there were no significant findings in the weights of the rats' organs after 28 days, so the variation was too small to be taken into account.

Effect on Oxidative Stress Biomarkers and Lipid Profile

Oxidative stress biomarkers in serum of administrated rats with Coriander and geraniol oils (50 mg/kg) and control group are illustrated in Table 2. MDA, SOD, and catalase were determined in the serum of the administrated rats. Results clearly indicated that no changes were noticed in the administrated groups in comparison to the control after 28 days of administration. The obtained results confirmed that coriander and geraniol oils (50mg/kg) had no harmful effect on all the determined oxidative stress biomarkers. Concerning the serum lipid profile of the administrated rats with coriander and geraniol oils (50mg/kg), there were no considerable changes in the total cholesterol and triglycerides levels they found to be as near as for the values of the control group. Total cholesterol was 141±0.51, 141±0.35 and 141±0.92mg/dL in serum of the administrated rats with coriander, geraniol oils and control group, respectively. Meanwhile, the administration of the investigated oils exhibited increasing effect on HDL cholesterol to reach 61.63±0.62, 63.31±0.11mg/dL for coriander, geraniol oils respectively, while the control group recorded 52.49±0.87mg/dL. In a parallel direction, it seems clear that LDL cholesterol values decreased after the administration of coriander and geraniol oils (32.75±0.30 and 33.06±0.16mg/dL) in comparison to the control (42.16±0.35mg/dL), which means that the administration of the investigated oils enhanced the lipid profile of the serum of the treated rats.

Effect on Liver, Kidney Functions and Serum Glucose

Liver, kidney functions and serum glucose level are illustrated in Table 3. No considerable changes were noticed in values of serum ALT, AST, creatinine, and urea of the administrated rats with of coriander and geraniol oils (50mg/kg). All the measured parameters seemed in the normal ranges and like those of the control group after 28 days of administration. Serum glucose found to have a slight decrease after the administration of investigated oils; it reached to be 98±0.94 and 97±0.80mg/dL for coriander and geraniol respectively, while serum glucose of the control group found to be 103±1.0mg/dL at the end of the experimental.

Table 2: Effect of administration of Coriander and geraniol oils (50mg/kg) on oxidative stress biomarkers and lipid profile in male Wistar Rats

Groups	MDA (nmol/mL)	SOD (U/mg)	Catalase (U/mg)	T. Cholesterol(mg/dL)	HDL-C (mg/dL)	LDL-C (mg/dL)	Triglyceride (mg/dL)
Control	2.08±0.06a	120±0.17a	14.69±0.25ab	141±0.92a	52.49±0.87a	42.16±0.35a	101±0.89a
Coriander	2.14±0.08a	119±0.30b	14.70±0.44a	141±0.51a	61.63±0.62b	32.75±0.30b	96±0.16b
Geraniol	2.09±0.02a	119±0.27c	14.56±0.17b	141±0.35a	63.31±0.11c	33.06±0.16b	97±0.38b

Values (Mean±SD) are for five animals per group. Values bearing different alphabets in a column differ significantly (P<0.05).

Table 3: Effect of administration of Coriander and geraniol oils (50mg/kg) on liver, kidney functions and serum glucose of male Wistar Rats.

	Liver function		Kidney function		
	AST (U/L)	ALT (U/L)	Urea (mg/dL)	Creatinine (mg/dL)	Glucose(mg/dL)
Control	137±0.16a	30.48±0.16a	6.60±0.38a	0.39±0.01a	103±1.0a
Coriander	138±0.41a	30.86±0.66ab	6.57±0.3a	0.41±0.01b	98±0.94b
Geraniol	138±0.97a	30.93±0.25b	6.55±0.20a	0.41±0.01b	97±0.80ab

Values (Mean±SD) are for five animals per group. Values bearing different alphabets in a column differ significantly (P<0.05).

DISCUSSION

Plant oils have drawn consideration as a potential normal source of anthelmintic compounds, owing to the event of anthelmintic resistance in sheep gastrointestinal nematodes and the increased public demand for drug-free meat products (Salman and Imran 2022; Kandil et al. 2023). The anthelmintic potential of crude extracted coriander essential oil, and the pure components of geraniol, linalool, and eugenol, at six concentrations (0.25, 0.5, 1, 2, 4 and 8mg/mL) were assessed utilizing egg hatch assay against *H. contortus* eggs. The coriander and geraniol showed higher and reproducible inhibitory egg hatching activity even at the lowest concentrations (0.25mg/mL) up to 86 and 100%, respectively. Few available studies have been interested at the ovicidal effects of essential oil components on *H. contortus*. Macedo et al. (2013) reported that *C. sativum* essential oil exhibited a dose-dependent effect in the egg hatch test, inhibiting 99% of *H. contortus* larvae hatching at a concentration of 2.5mg/mL; the results that appeared to be in line with the current findings. Another essential oil of *Eucalyptus staigeriana* (73% limonene, 9.5% cineole, 4.5% cimene) had a 99.96% efficacy in the egg hatch test, at 1.0mg/mL (Ribeiro et al. 2013). Besides, Katiki et al. (2017) assessed ten essential oils individually or in mixtures combinations utilizing the *in vitro* egg hatch test using eggs obtained from resistant strain of *H. contortus* worms. The authors reported that cinnamaldehyde and anethole were the superior active essential oils and the least ones were cineole and limonene. The binary combinations of cinnamaldehyde + carvacrol and anethole + carvone exhibited a potent inhibition of egg hatching. On the other hand, crude aqueous and hydro-alcoholic extricates of the seeds of *C. sativum* suppressed hatching of *H. contortus* eggs completely at a concentration less than 0.5mg/mL (Eguale et al. 2007). Variation in egg hatching inhibitory activity between the previous extracts and the essential oil might be due to differences in the proportion of the active components responsible for the tested inhibitory activity (Macedo et al. 2013).

In this study, the coriander and geraniol were furtherly investigated for inhibition of adult and larval motility of *H. contortus* and the results indicated that the coriander and geraniol displayed a marked inhibitory activity against adult and larval motility in a dose-dependent way with up to 77.8 and 90.6% inhibition at concentration of 1mg/mL within 2hrs of exposure, respectively. The suppression of adult and larval motility, as a sign of worm vitality after incubation with the treatments, is still the most widely accepted method for testing anthelmintics (Ritler et al. 2017). Studies had demonstrated anthelmintic effect of both crude aqueous and hydro-alcoholic extracts of *C. sativum* on the motility of *H. contortus* adults, with 45 and 85% inhibition, respectively, at concentration of 8mg/mL (Eguale et al. 2007). The low density of plant oils and their fast diffusion over cell membranes could improve the targeting of the dynamic constitutes of essential oils into endoparasites (Leja et al. 2019). The fact that might explain the superior activity of *C. sativum* essential oil to the other extracts tested previously. In the previous study by Helal et al. (2020), the anthelmintic impacts of extracted coriander oil were examined utilizing larval motility assay, on the third-stage larvae (L3) of gastrointestinal nematode species. They reported that coriander oil and linalool, a major component of tested coriander oil, exhibited a vigorous inhibitory impact and structural damage of L3 larvae against different species, except *Cooperia oncophora*. The coriander essential oil disrupted the membrane function through strong lipolytic action and inhibition of acetylcholine receptors, causing neurotoxicity and loss of motion in nematodes (Helal et al. 2020).

Within the current consideration, the possible tissue injury of the cuticle of the treated adult worms was assessed. The first appearance of cuticular changes appeared with concentration of 4mg/mL coriander oil and became more remarkable and displayed large, isolated areas of cuticular distortion with concentration of 8mg/mL. The nematodes' cuticle is responsible for selective entrance of nutrients. It has also been revealed that this route is dominant for the uptake of major broad-spectrum anthelmintics. So, the main cause for destructive changes and malformation of the helminthes' body surface might be the passive diffusion of anthelmintics via the worm body wall (Alvarez et al. 2007; Schmahl et al. 2007). The current observations appeared to be parallel with that demonstrated by previous histomorphological studies about the nematodes' cuticle where this was detected to be a main target organ for many synthetic and natural anthelmintics (Martin et al. 1997; Kandil et al.

2023). The cuticular distortion of the adult *H. contortus* induced by coriander essential oil had been reported for these nematodes by a number of anthelmintics (Shalaby et al. 2014). Taken together, our data showed that coriander and geraniol had potential anthelmintic activity and could be used against gastrointestinal nematodes particularly *H. contortus*.

Essential oil content and chemical composition of the oils significantly differ according to the geographical locations, maturity, seasonal variation, varieties, ecological conditions and also extraction conditions (Al-Khayri 2023). The results of our analysis were as near as to previous literatures that confirmed linalool as highest constituent in the essential oil of coriander, it found to be 37.7% (Bhuiyan et al. 2009). GC analysis of the commercial and coriander seed oils clearly indicated the high variation in the chemical composition which might be due to the industrial additives.

The body and organs weight results were in parallel with those recorded by Jayachandran et al. (2014), who confirmed that relative organ weight of the control and Hamsters treated with geraniol did not display any measurably critical contrast within the relative organ weights in comparison with that of the controls. The results of lipid profile of serum clearly indicated that the administration of the investigated oils enhanced the lipid profile of the serum of the treated rats. The recorded changes in lipid profile might be attributed to the strong antioxidant activity of the used oils which highly related to the accumulation of fat in arteries. Our results were following the results investigated by Jayachandran et al. (2014), they reported that the oral dosing of 100mg/kg body weight of geraniol was very effective in lowering the risk of hyperlipidemia in hamsters. Also, Eskandari et al. (2021) found that the treatment of geraniol and glibenclamide significantly increased HDL cholesterol in the rats as compared to the diabetic group to be almost within the normal ranges. The LDL level in diabetic rats increased compared to the normal group and decreased in the group treated with geraniol and glibenclamide, as a standard drug, to near the normal level. This slight decrease in serum glucose values may be attributed to the enhancement of lipid profile which occurred after the administration of coriander and geraniol oils. Our results agreed with the findings of Burdock and Carabin (2009), they confirmed that coriander extract and its oil were already in dietary use, with no data of harm or side effects due to the consumption of these ingredients. Previous study by Mandal and Mandal (2015) concluded that the main component of the essential oil of coriander is Linalool which is already used as spices and in medicines with proven safety. Our results supported by those obtained by Eskandari et al. (2021) which confirmed that the consumption of geraniol for diabetic rats clearly reduce the level of serum glucose.

Conclusion

Our data showed that coriander and geraniol have potential anthelmintic activity and can be used against gastrointestinal nematodes in particular *H. contortus*. Besides, all the obtained results of the weight, organ weights, oxidative stress parameters and biochemical markers confirmed that the administration of coriander and geraniol oils (50mg/kg) is to a great extent biologically safe. Moreover, enhances the level of HDL cholesterol and reduces LDL cholesterol, it may be used for a long time with no side effects.

Conflict of interest

The authors confirm that there is no conflict of interest regarding this manuscript.

Authors contributions

HAS and OMK: Conceptualization, methodology, resources, funding acquisition, project administration, writing – review and editing. OMK, HAS, NMFH, AHE, SHMH and KOM: Conceptualization, methodology, formal analysis, visualization, writing – review and editing. OMK and HAAT: GC/MS analysis**,** biochemical and safety methodology, roles/writing-original draft. BSME and MAH: Laboratory work and drafted the manuscript. All authors have read, reviewed, and approved the final manuscript.

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