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ACARICIDAL ACTIVITY OF CURCUMA LONGA: A SYSTEMATIC REVIEW

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ABSTRACT

Curcuma longa L. is a plant of the Zingiberaceae family, popularly known as turmeric or golden ginger. Due to the fact that its rhizomes are rich in phytochemical compounds, this plant has several biological activities described, among them the activity against mites. Ectoparasites cause damage and losses in livestock, compromising the well-being of animals and reducing production. In addition, in agriculture, mites affect crops, suck essential nutrients from plants, and result in significant economic losses. In this context, the objective of this study was to analyze the scientific production on the acaricidal activity of C. longa, with a systematic review with a comprehensive search in the databases and using the PICO strategy to answer the research question: "Does Curcuma longa have acaricidal activity?". A total of 58 articles were identified, of which at the end of the screening stages, 10 were analyzed regarding the type of study, preparation of C. longa,

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species and its stage of development, activity, efficacy and aspects such as repellency, mortality, oviposition inhibition and in vivo studies. The analysis showed that C. longa can result in several preparations such as extracts and oils and these showed effectiveness in the control of mites, placing the plant as a potential sustainable alternative against mites and the growing resistance to synthetic acaricides. Therefore, the use of this vegetable may represent a complementary strategy to the commercially available arsenal.

Keywords: Turmeric. Curcumin. Ectoparasite. Tick. Mite.

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INTRODUCTION

Curcuma longa is a medicinal plant widely cultivated in tropical and subtropical regions and was introduced in Brazil during the colonial period. This plant is popularly known as turmeric or turmeric and belongs to the Zingiberaceae family (BRASIL. MINISTRY OF HEALTH, SECRETARIAT OF SCIENCE, 2020).

Due to the presence of bioactive compounds that confer unique sensory and functional characteristics, this plant is used in cooking and in the food industry as a natural coloring, preservative and condiment (BEZERRA *et al.*, 2013; OLIVE TREE; GHERARDI; ALMEIDA, 2024). In addition, its medicinal properties have been valued over the centuries, being recognized by traditional Asian medicine and by the growing application in modern pharmacological therapies (ALMEIDA *et al.*, 2022; MARMITT *et al.*, 2016).

Turmeric rhizomes concentrate chemical compounds such as curcuminoids (curcumin, demethoxycurcumin, and bisdemethoxycurcumin) and essential oils (turmerone, zingiberone, and borneol) (RAM; MACEDO, 2020). These components are responsible for antioxidant, anti-inflammatory, antimicrobial, antitumor, and neuroprotective activities, demonstrating efficacy in various pathophysiological conditions and expanding their potential for application in human and animal health (MORETES; GERON, 2019).

In particular, its bioactive composition has also aroused interest in agriculture and livestock, where the use of natural products has proven to be a sustainable alternative to the challenges faced by conventional pest control methods (CHAABAN *et al.*, 2019a, b; DAMALAS, 2011; PEAR TREE; CAMPOS JÚNIOR; COCCO, 2016).

Mites are ectoparasites belonging to the order Acari, represent a significant problem in several sectors, causing economic losses and compromising public and animal health (BARROS *et al.*, 2024; TORRES *et al.*, 2023). In livestock, ticks such as *Rhipicephalus (Boophilus) microplus* reduce animal productivity by affecting parasitized animals, causing inflammation and great discomfort, and chronic anemia and death. This scenario drastically reduces the production of milk, meat and wool, in addition to acting as vectors of serious diseases, such as babesiosis and anaplasmosis (SINGH *et al.*, 2022).

In agriculture, mites such as *Tetranychus cinnabarinus* are responsible for extensive crop damage to beans, cotton, and tomatoes. These mites have exacerbated reproduction rates and resistance to adverse environmental conditions (LEGWAILA; OBOPILE; TIROESELE, 2023).

Conventional methods of controlling these parasites are based on the intensive use of synthetic acaricides which, although effective, have important limitations, such as the development of resistance by the parasites and the negative impacts on the environment and human health (OBAID *et al.*, 2022). Chemical residues in animal products and soil and water contamination are problems often associated with the inappropriate use of these chemicals (PENAGOS-TABARES *et al.*, 2023).

Faced with the challenges of the growing demand for safer and more ecologically sustainable alternatives for the control of ecotoparasites (VERMA *et al.*, 2023), research into ecological management practices of natural products has gained prominence and in this context, *C. longa* emerges as a promising candidate, as it presents a wide range of activities associated with its various bioactive components.

Therefore, the present study evaluated, through a systematic review of the literature, the potential of *C. longa* and its by-products in the use for a sustainable management of ectoparasites, with a specific focus on mite control.

METHODOLOGY

PROTOCOL REGISTRATION

The protocol was registered in the OSF (*Open Science Framework*) repository and the protocol details can be accessed at http://OSF.IO/QG25Z (MOHER *et al*., 2015).

DATABASE AND GUIDING QUESTION

The systematic review was carried out in four databases for the search of articles: Virtual Health Library (VHL), *PubMed*, *Web of Science* and *ScienceDirect* to answer the guiding question: "Does *Curcuma longa* have acaricidal activity?"

The search was defined with the **PICO** **-** *Problem-Intervention-Comparison-Outcomes strategy* with the following elements: the acronym **P** refers to the control of mites, **I** to treatment with *Turmeric* extract or curcumin, **C** to comparison with untreated groups or treated with commercial products, **O** efficiency in inhibiting or killing mites (COCHRANE LIBRARY, 2000-2024).

The PICO system assists in the search for reference articles, with the definition of review strategies, formulation of questions and characterization of different studies to achieve a balance between desirable and undesirable results, showing with transparency the reasons behind each choice (ROEVER *et al.*, 2021).

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The search was performed with the following descriptors *MeSH Terms* (*Medical Subject Headings*): ("*Curcuma longa*" OR *turmeric* OR *curcumin*) AND (*acaricide* OR *acaricidal*) AND (tick OR *mite* OR *acari*)) in the chosen databases without the date limitation (KOLLER *et al*., 2014).

ELIGIBILITY AND EXCLUSION CRITERIA

The eligibility criteria for the systematic review on the acaricidal activity of *C. longa* were:

- Studies published in the form of articles evaluating the effect of *C. longa* against mites ;
- Research exploring the mechanisms of action of the phytochemical constituents of *C. longa*

against mites;

- Studies comparing the efficacy of *C. longa* with other commercial or known acaricides agents.

The exclusion criteria for this systematic review were defined as: unpublished monographs, dissertations or theses, literature reviews, conference abstracts, clinical case reports, case series and studies that do not address *C. longa* as the main agent.

STUDY SELECTION AND DATA EXTRACTION

The surveys carried out in each database were exported in the form of .ris or .csv files to the *Qatar Computing Research Institute*'s (QCRI) *Rayyan Systematic Review platform*. The selection and exclusion of duplicates and reading of the works were performed in pairs independently. Titles and abstracts were analyzed for the selection of potentially eligible articles and exclusion of those that did not meet the specifications (OUZZANI *et al*., 2016).

After the initial screening, the articles were read completely and whether they met the inclusion criteria for the construction of a flowchart following the PRISMA recommendation (*Preferred Reporting Items for Systematic Reviews and Meta-Analyses*), which consists of four steps: identification, selection, eligibility and inclusion, which allow the demonstration of the process of choosing studies (GALVÃO; PANSANI; HARRAD, 2015).

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After selecting and reading the articles, an evaluation of data from different studies investigating the acaricidal activity of *C. longa was carried out*. The forms of preparation (ethanolic extract and essential oil) were included in this analysis, as well as the types of mites evaluated in the studies.

The main characteristics evaluated in the articles were arranged in a table with data on the country of origin of the study, the type of bioassay, the concentration and preparation of *C. longa*, the species and stage of the mites, the activity performed in each article and the efficacy observed. Thus, items that met at least one of the following criteria were included in the research: (1) repellent effect, (2) toxicity, (3) oviposition, (4) mechanism of action, and (5) *in vivo tests*.

EVALUATION OF THE MOST USED TERMS IN THE EVALUATED STUDIES

The titles, abstracts and keywords of the selected articles were analyzed by the tool: *Word Art* available on the *website* <https://wordart.com/> through the "Word Cloud" tool to verify the co-occurrence of the terms in a visual way with the display of the most frequent terms in the set of texts evaluated.

ASSESSMENT OF RISK OF BIAS IN INDIVIDUAL STUDIES

Two independent researchers assessed the risk of bias in each study. The assessment items were adapted from previous systematic reviews. The following ten items were considered in all the publications reviewed:

- Item 1: Presence of control group
- Item 2: Description of the sample size calculation
- Item 3: Extraction of plant material using standard methods
- Item 4: Description of the bioactive compounds in the plant material
- Item 5: Identification of the mite or tick species studied
- Item 6: Specification of the stage of development of the species studied
- Item 7: Details of the methodology or type of study employed
- Item 8: Validation of the significance of the results with statistical tests
- Item 9: Comparison with commercial products or use of feasibility and technique controls
- Item 10: Observer Blinding

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Publications that reported less than four of these items were classified as having high risk of bias, while those that reported between four and six were considered to be at medium risk of bias and above six items were classified as low risk. Discrepancies were resolved through discussion among the researchers (ZHANG *et al.*, 2023).

RESULTS

A total of 58 publications were identified in the consulted databases, with the highest frequency of articles from *ScienceDirect* 33 (56.9%), followed by *Web of Science* with 14 (24.1%), *PubMed* with 8 (13.8%) and Virtual Health Library (VHL) with 3 (5.2%). After removing 10 duplicates, 48 studies moved on to the next phase of initial screening with analysis of titles and abstracts.

According to the eligibility criteria, 32 articles that did not address the theme of the review were excluded. Thus, 16 articles were selected for full reading. In the next step, 3 studies were excluded because they did not provide complete information, including those dealing with protective effect, simulations of studies and co-charged nanoparticles.

Thus, 10 articles were selected to compose the systematic review, which include 4 (33.3%) with *Tetranychus cinnabarinus* (red mite), 3 (25%) studies with *Rhipicephalus microplus* (cattle tick), 1 (8.3%) with *Ornithodoros savignyi* (sand cap), 1 (8.3%) with *Ixodes ricinus* (castor bean tick), 1 (8.3%) with the mites *Suidasia pontifica* Oudemans (mite), 1 (8.3%) with *Panonychus citri* (glitter mite) and 1 (8.3%) with *Tetranychus urticae* (two-spotted mite), and two authors reported the use of more than one species, as shown in the flowchart in Figure 1 and Table 1.

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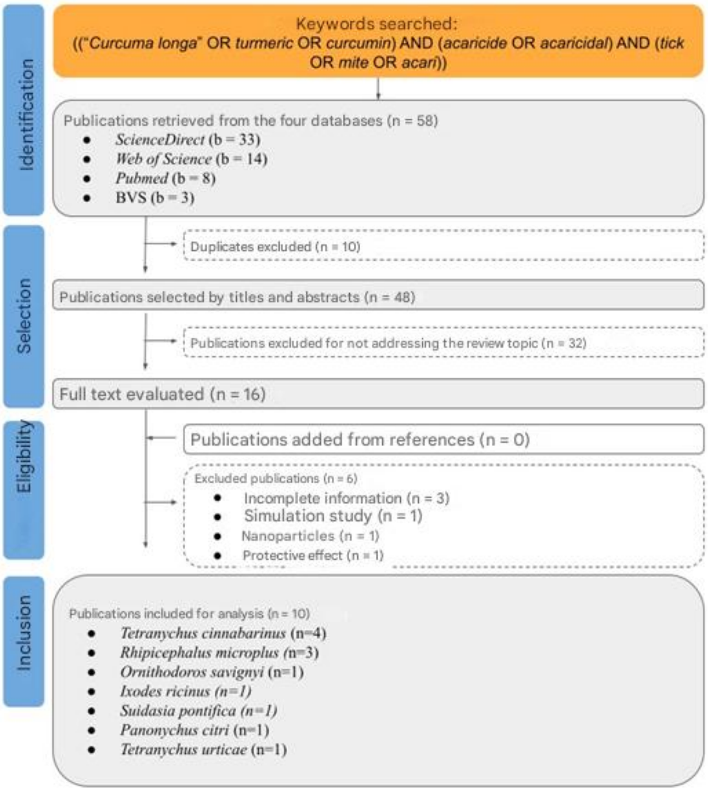
Figure 1. Screening, eligibility and inclusion of articles according to the PRISMA flow diagram (adapted)



Source: authors, 2025

Table 1. Summary of the main characteristics of the evaluated articles

No.	Authors, YEAR	Country	Type of study	Preparation of *C. longa*	Species	Internship	Activity	Effectiveness
1	GOODE; ELLSE & WALL, 2018	England	Immersion of the filter paper (*in vitro*) Direct spraying on the animals at specific anatomical sites (*in vivo*)	Commercially acquired essential oil extracted from the root of *C. longa* by steam distillation, the dilutions were carried out in ethanol at a concentration of 5%	Ticks *Ixodes ricinus*	Adults and nymphs	Mortality and repellency *(in vivo)*	Turmeric oil showed efficacy with a repellency rate of 93.03%
2	ABDEL-SHAFY *et al.*, 2020	Saudi Arabia	Direct immersion of the nymphs in the solution with ethanolic extract (*in vitro*). Oral administration of ethanolic extract in rabbits (*in vivo*)	Dry rhizomes of *C. longa.* The dry powder was treated with ethanol and diluted at concentrations of 10 to 0.625 mg mL-1	*Ticks Ornithodoros savignyi*	Nymphs	Mortality	The extract showed a strong acaricidal effect over time with LC50 and LC95 of 1.31 and 15.07 mg mL-1 on the first day and 0.81 and 6.97 mg mL-1 on the 15th day.

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3	OF SOUZA CHAGAS *et al.*, 2016	Brazil	Immersion of engorged females and modified larval pack testing	The oils from the rhizome of *C. longa* were obtained by hydrodistillation, and concentrations of 25 to 0.39 mg mL-1 were tested	Rhipicephalus microplus *ticks*	Adult females and larvae	Mortality	Oils of the Zingiberaceae family, which includes *C. longa*, proved to be effective, reaching 100% lethality at a concentration of 25 mg/mL.
4	ULLAH *et al.*, 2015	Pakistan	Modified larval immersion test	Plant material extracted from the rhizome of *C. longa* and the crude aqueous and methanolic extract was prepared in a solution of 0.2% triton X-100 and from concentrations of 50 to 3.125 mg mL-1.	Rhipicephalus microplus *ticks*	Larvae	Mortality	*C. longa* was observed at different concentrations and exposure times, although it showed acaricide activity, the combination of *C. longa* with other plants, such as *Citrullus colocynthis* and *Peganum harmala*, resulted in a higher efficacy.
5	NAZIM *et al.*, 2021	India	Larval Immersion Test	Extracts of *C. longa* were prepared from the rhizome using different solvents, such as acetone, chloroform and ethanol,	Rhipicephalus microplus *ticks*	Larvae	Mortality	The mortality of 100% of the larvae was achieved at 10% concentration (acetone and chloroform extracts), ethanolic extract reached 100% mortality from 7.5% concentration. The ethanolic extract showed the highest acaricide activity, with values of LC50, LC90, LC95 and LC99.
6	PUMNUAN & INSUNG, 2011	Thailand	Contact toxicity	Essential oil of the C. longa rhizome extracted by steam distillation, a glass tube was treated internally with 20 µL of essential oil at a concentration of 1.0% in 95% ethanol, and then other concentrations were studied.	Suidasia mites *pontificate*	Stage not specified	Mortality	Essential oils from some plants may be more effective at reducing the mite population in stored produce than turmeric essential oil, as well as others such as blueberry grass and betel vine.
7	CHENG *et al.*, 2020	China	Spraying turmeric oil solution on cowpea leaves	Use of the C. longa rhizome *extracted by hydrodistillation and for the preparation of the formulation in microemulsion, the oil of C. longa was extracted by hydrodistillation and*	*Tetranychus cinnabarinus mites*	Adult females	Mortality, repellency, inhibition of oviposition and behaviour	The microemulsion of *C. longa* oil has demonstrated superior efficacy compared to pure oil.

				for the preparation of the formulation in microemulsion, the oil of C. longa was combined with Tween 80 as surfactant and Isopropanol as co-surfactant, in a 2:1 ratio.				
8	LIU *et al.*, 2016	China	Spraying the curcumin solution on fresh cowpea leaves.	Curcumin dissolved in distilled water with 0.25% *Tween* 80.3% acetone, up to a concentration of 2.64 mg mL-1.	Mites *Tetranychus cinnabarinus* and *Tetranychus urticae*	Adult females	Transcriptional changes	There was differential expression in genes that are associated with insecticide/acaricide targets, as well as in genes that participate in the detoxification and metabolism processes of mites.
9	ZHOU *et al.*, 2021	China	Immersion method	Curcumin was diluted in dimethyl sulfoxide (DMSO) at concentrations of 40 to 1.25 μmol $^{L-1}$	*Tetranychus cinnabarinus mites*	Adult females	Mortality, Calmodulin Signaling, and Enzyme Activation	Exposure to curcumin resulted in an increase in TcCaM expression. The use of the anti-CaM drug TFP and the application of RNAi against the CaM gene decreased the sensitivity of *T. cinnabarinus* to curcumin.
10	LUO *et al.*, 2013	China	Slide immersion method	Compounds derived from bisdemethoxycurcumin (BDMC) were dissolved in water with 2% acetone, 0.8% of *Tween* 80 and 1% of laurocapram	Mites *Tetranychus cinnabarinus* and *Panonychus citri*	Adult females	Comparative mortality compounds derived from BDMC and pyridaben	BDMC derivatives showed significantly higher acaricidal activity than the parent compound, with compound 4 {(E)-2-vinyl}phenol having higher acaricidal activity.

Source: authors, 2025

The selected articles were published between 2011 and 2021 and the authors' countries were China, England, Brazil, Saudi Arabia, Pakistan, India, and Thailand. Among them, 5 (50 %) studied tick species and 5 (50 %) other mites. As for the stage of development, the researchers used adult ticks, nymphs and larvae, and two studies evaluated more than one stage with different methodologies and one of the articles did not specify the stage of development of the individuals.

The methodologies described were immersion, larval immersion test, spraying, contact toxicity and spraying. Three studies used two different methods during the

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research. The curcumin used was extracted from the rhizome of *C. longa* in 7 (70%) of the studies, but in the other 3 (30%) there was no specification of the extraction site. The essential oil of

C. longa was the most used preparation 4 (40%), among which one study also used the microemulsion system. In studies that used extract, curcumin was diluted in ethanol, water, methanol, acetone, chloroform and dimethyl sulfoxide.

The activity of the essential oils analyzed in the tick species resulted in a repellency of 93.03 % *in vivo* and lethality of 100 % *in vitro* (GOODE; ELLSE & WALL, 2018; DE SOUZA CHAGAS *et al*., 2016).

Curcumin extracts have been shown to be more effective when diluted in ethanol and have shown a strong tickicidal effect. However, in the aqueous and methanolic extracts, it was found that although they had tick activity, their effectiveness increased significantly when they were combined with other extracts, such as those of *Citrullus colocynthis* and *Peganum harmala* (ABDEL-SHAFY *et al*., 2020; ULLAH *et al*., 2015; NAZIM *et al*., 2021).

In studies with mites, microemulsion had a higher efficacy than oil and in another study some plants had greater results than *C. longa* when used in the preparation of essential oil, which may indicate that this preparation needs additional studies in mite species using additional technologies (PUMNUAN & INSUNG, 2011; CHENG *et al*., 2020).

The terms extracted from the studies in this systematic review were organized and analyzed in a thematic way to facilitate the critical and comparative interpretation of the results. The discussion was structured in topics that reflect the main aspects addressed by the selected studies, allowing a comprehensive view of the acaricidal activity of *C. longa*.

The thematic division sought to offer a clear and objective analysis, based on the available data, highlighting the relevance of the selected studies and their contributions to the knowledge on the application of *C. longa* in the control of mites.

Figure 2 is the overview of the literature reviewed in graphic representation that shows the co-occurrence of the words of the titles, abstracts and keywords, identifying the main terms and methodological approaches. The most used terms were: *TICK* and *OIL* are in greater evidence, repeated 30 times each, followed by *ACARICIDE* and *CURCUMIN* with 26, *ACTIVE* and *EXTRACT* with 25, *LONGA* with 19 and *AGAINST* with 15 repetitions.

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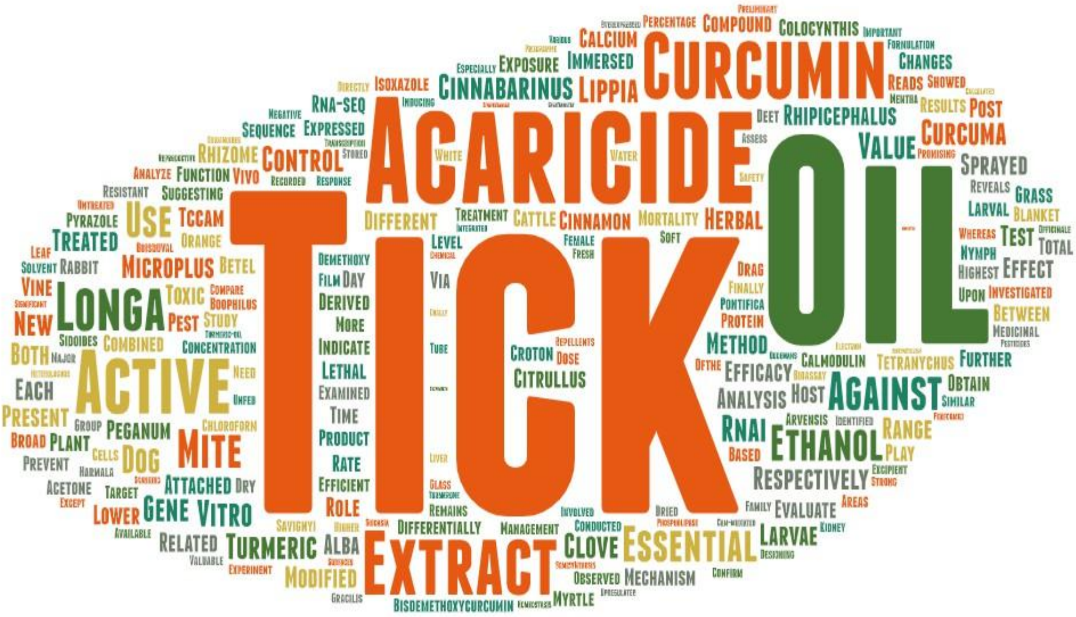
Figure 2: Co-occurrence of the terms present in the title, abstract and keywords of the selected works.



Source: authors, 2025

The quality of the studies was assessed through the analysis of the risk of bias based on items that covered the methodologies used in the selected studies. Table 2 shows the risk of bias in studies on *C. longa* activity against mites.

Half of the studies had a low risk and the rest had a medium risk, indicating that there is a need for improvement in studies regarding the acaricidal activity of curcumin. All studies described the presence of a control group, identification of the mite or tick species studied and validation of the significance of the results using statistical tests, and only one study did not specify the stage of development of the species studied and did not detail the methodology or type of study employed. This information guarantees the repeatability and reproducibility of the studies, although none of them reported the sample calculation and three of them did not specify the extraction of plant material using standard methods, because they acquired the compounds commercially.

A common point of improvement for all is the lack of blinding, an important bias in *in vitro* and in *vivo studies*, but which could bring a less significant p result (ZHANG *et al*., 2023).

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Table 2. Risk of bias in studies of the acaricidal activity of *C. longa*.

No.	Study Authors, ANO	Rated Item										Score	Risk of bias
		1	2	3	4	5	6	7	8	9	10		
1	GOODE; ELLSE & WALL, 2018	●	●	●	●	●	●	●	●	●	●	7	low
2	ABDEL-SHAFY *et al.*, 2020	●	●	●	●	●	●	●	●	●	●	7	low
3	DE SOUZA CHAGAS *et al.*, 2016	●	●	●	●	●	●	●	●	●	●	7	low
4	ULLAH *et al.*, 2015	●	●	●	●	●	●	●	●	●	●	6	medium
5	NAZIM *et al.*, 2021	●	●	●	●	●	●	●	●	●	●	8	low
6	PUMNUAN & INSUNG, 2011	●	●	●	●	●	●	●	●	●	●	4	medium
7	CHENG *et al.*, 2020	●	●	●	●	●	●	●	●	●	●	6	medium
8	LIU *et al.*, 2016	●	●	●	●	●	●	●	●	●	●	5	medium
9	ZHOU *et al.*, 2021	●	●	●	●	●	●	●	●	●	●	6	medium
10	LUO *et al.*, 2013	●	●	●	●	●	●	●	●	●	●	7	low

Legend: ● : Item included in the study; ● : Item not included in the study; Item 1 - presence of a control group; Item 2 - description of the sample size calculation; Item 3 - extraction of plant material using standard methods; Item 4 - identification of bioactive compounds in plant material; Item 5 - identification of the mite or tick species studied; Item 6 - specification of the stage of development of the species studied; Item 7 - details of the methodology or type of study used; Item 8 - validation of the significance of the results with statistical tests; Item 9 - comparison with commercial products or use of feasibility and technical controls; Item 10 - Observer blinding

Source: authors, 2025

DISCUSSION

REPELLENT EFFECT

The spray study carried out with *Tetranychus cinnabarinus* used a microemulsion of turmeric oil, in which the surfactant *Tween* 80 and the co-surfactant isopropanol were used, both selected based on the ternary phase diagram compared with different sublethal concentrations of turmeric oil (LC10, LC20 and LC30) after exposures of 3, 6, 12, 24 and 48 hours. The results indicated that the effectiveness of turmeric oil was greatest between 3 and 6 hours, reaching the peak at 12 hours. However, after this period, efficacy began to decrease, while the formulation stood out after 24 hours of exposure (CHENG *et al.*, 2020).

The fight against *Ixodes ricinus* performed by immersion using essential oil proved to be promising, as the sebaceous secretions extracted from canine hairs proved to be strong attractants, evidenced by the displacement of ticks towards the tip of the filter paper. When the material was treated with turmeric oil, no ticks reached the end. After drying the paper, the analysis was repeated and the results remained the same, with some mites reaching the tip only after 4 hours, for confirmation they dragged with blankets in a field that used turmeric, DEET (N,N-Diethyl-meta-toluamide) and orange oil tested at

2.5%. The treated groups had a lower fixation rate with DEET (89.42 %) and with oil 93.03 % (GOODE; ELLSE & WALL, 2018).

Turmeric demonstrated activity against ectoparasites in both studies, however the oil presented a disadvantage in relation to the microemulsion formulation that allowed a better stability and efficacy in the fight against *T. cinnabarinus*. In contrast, against *Ixodes ricinus* the essential oil obtained more favorable results. The difference can be attributed to the biological and behavioral characteristics of the species, the method of extracting the oil, and the optimization of the microemulsion, which has kept the results consistent over time, suggesting that an improved formulation may be crucial for efficacy in control.

TOXICITY

Three studies were conducted with *Rhipicephalus (Boophilus) microplus ticks*. Nazim *et al.* (2021) performed the Larval Immersion Test (LIT) on *C. longa* extract with 1% ethanol and triton X-100 at concentrations of 10.0 to 0.625%, the tubes were shaken with 0.5 mL ensuring immersion for 10 minutes, then it was taken to the filter paper at controlled temperature for 24 hours to analyze mortality.

HPLC analysis of the extract identified peaks of bisdemethoxycurcumin, demethoxycurcumin and curcumin, and the latter two showed higher yields in acetone and chloroform extracts. For these solvents, a concentration of 10 % resulted in 100 % mortality of tick larvae. In contrast, the ethanolic extract was effective from 7.5%, achieving significant results, especially compared to the negative control group, which had a mortality of only 1%. In comparison, deltamethrin achieved 100% mortality. Thus, the ethanolic extract showed the highest acaricide activity, with the following lethal concentration values: LC50 (2.43%), LC90 (9.12%), LC95 (13.26%) and LC99 (26.77%). This effectiveness can be attributed to the higher yield of curcumin, which interferes with the regulation of protein kinase C and calcium through increased reactivity. It is important to note that, although the ethanolic extract had a higher LC50 value, its LC90, LC95 and LC99 values were lower than those observed for the acetone and chloroform extracts. This indicates comparative efficiency at lower concentrations.

C. longa *extract* at concentrations of 10 to 2.5 mg mL-1 resulted in mortality rates between 73.30 % and 96.70 % after one week of exposure to the soft tick *O. savignyi*. In the evaluation, the values of LC50 (1.31, 1.07 and 0.81 mg mL-1) and LC95 (15.07, 8.56 and 0.81 mg mL-1) on the 1st, 7th and 15th days decreased, indicating toxicity of the extract. In addition, turmeric treatment caused morphological changes in the larvae, such as color changes in the cuticle and legs. Among the compounds identified, the most abundant were curcumene and tumerone, which may be the main responsible for the acaricidal activity (ABDEL-SHAFY *et al.*, 2020).

In another study, engorged females of *Rhipicephalus (Boophilus) microplus* were immersed in 5 mL of oils from various vegetables, including *C. longa* , at dilutions of 25 to 0.39 mg mL-1 for 5 minutes to observe the impact on the Reproductive Efficiency Index (SRI). Then the females were dried and placed in Petri dishes for oviposition, being weighed and placed in sealed syringes in the incubator. The IRE and the efficacy of the extracted product (EPE) were evaluated after its development. In the LPT bioassay, larvae aged 14 to 21 days were placed on oil-impregnated filter paper, sealed and incubated, with the results read after 24 hours (DE SOUZA CHAGAS *et al.*, 2016).

In the tests performed, a lower reproductive efficiency (SRI) of *C. longa* oil was observed, resulting in a LC50 lethality value of 10.24 mg mL-1. The concentration of 25 mg mL-1 showed no activity in LPT.

Mortality in the larval pack test was effective at a concentration of 25 mg mL-1 for plants of the families Zingiberaceae and Verbenaceae, except for *Lippia sidoides*. In addition, *C. longa* showed particularly remarkable results at the concentration of 6.25 mg mL-1. This efficacy was observed for both ticks and larvae, with LC50 values of 0.54 mg mL-1 and LC90 of 1.79 mg mL-1. These effects may be related to the presence of sesquiterpenes and ar-turmerone (DE SOUZA CHAGAS *et al.*, 2016).

The test conducted by Ullah *et al.* (2015) verified the action on the same tick species with the modified larvae immersion technique (syringe method). The eggs were incubated in a syringe, where the extracts were extracted in a triton X-100 solution. The syringe was treated with this solution for 30 seconds, allowing the removal of the extracts and leaving only the larvae. Evaluations were made after 24 hours and 6 days. The authors found that the acaricidal effect of the extracts increased with the concentration (50 mg mL-1), compared to the control groups, which had low mortality. The study did not evaluate the efficacy of *C. longa* alone, but rather the combination of *C. longa*, *Citrullus colocynthis* and *Peganum harmala*, which demonstrated 100% mortality and increased activity on day six.

Luo *et al.* (2013) evaluated the efficacy of 16 bisdemethoxycurcumin-derived compounds (BDMC) that were modified with the inclusion of isoxazole and pyrazole

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groups. The compounds were dissolved in water, 2% acetone, *0.8% Tween* 80 and 1% laurocapram and evaluated against T*. cinnabarinus* and *P. citri mites* after 48 and 72 hours of exposure. The results indicated that the acaricidal activity increased with the time of exposure, that some derivatives showed activity superior to or comparable to BDMC and that compound number 4 (4-{(E)2[5-((E)-4-hydroxystyryl)-1-methyl--1Hpyrazol-3-yl]vinyl}pheno) was as effective as the parent compound and the 95% pesticide pyridaben used as a control.

In another study, the contact toxicity of 28 essential oils was investigated against the mite *S. pontififica*. For this, a glass tube for confinement treated with 20 µL of each 1% essential oil in 95% ethanol was used for screening. Those who had high mortality were then evaluated at various concentrations (0, 0.05, 0.1, 0.5, 1.0 and 1.5 %) applied to the inner walls of the tube and allowed to dry in the open air. After the introduction of mites, mortality was observed after 24 hours of incubation. Initially, the essential oils of clove (*Syzygium aromaticum*), cinnamon (*Cinnamomum bejolghota*), blueberry grass (*Acorus calamus*), betel vine (*Piper betle*) and turmeric (*C. longa*) induced 70% mortality. The LD50 evaluation was 38.09 µg $^{cm-2}$, however, cinnamon oil presented the best evaluation, with LD50 of 24.05 µg $^{cm-2}$ (PUMNUAN; INSUNG, 2011).

These results demonstrated the acaricidal effect of *C. longa extract* and its active compounds. Therefore, its use can be a promising strategy in control, not only because of mortality, but also because of the possibility of affecting the reproduction and development of parasites, contributing to an integrated and sustainable management.

OVIPOSITION

Cheng *et al.* (2020) evaluated the inhibition of T*. cinnabarinus* oviposition by spraying with *C. longa*. No significant changes in inhibition rates were observed between 3 and 12 hours, however, as the exposure time increased, the inhibition rates showed an increase, with the formulation (turmeric oil, *Tween* 80 and isopropanol) proving to be more promising than turmeric oil, showing 52.61% inhibition compared to 44.83% for the oil. After 48 hours, the inhibition values continued to rise, maintaining the formulation as the most effective.

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MECHANISM OF ACTION

Zhou *et al*. (2021) investigated how curcumin affects the calmodulin gene (TcCaM) in *Tetranychus cinnabarinus* and intracellular calcium ([Ca^{2+}]) levels in Spodoptera *frugiperda Sf9* cells at concentrations of 2.6 μmol L^{-1} (LC30), 8.2 μmol L^{-1} (LC50), and 53 μmol L^{-1} (LC80), with 48-hour exposure. Calcium levels increased significantly in the cells exposed to curcumin, but were reduced when the cells were pretreated with trifluoperazine (TFP), a substance that inhibits calmodulin.

In the immersion method to evaluate toxicity at concentrations LC10 (0.21 mg L^{-1}), LC30 (1.23 mg L^{-1}) and LC50 (2.64 mg L^{-1}) with 0.1% *Tween* 80 and 3 % acetone. The cells were exposed for 48 hours and analyzed using RT-PCR and qRT-PCR, showing that tcCam had an increase in expression of 7.30 times in relation to LC50, 5.4 times in LC30 and 2.91 times in LC10. The transcription levels in the stages of development of the mite showed that the relative expression increased in larvae, nymphs and adults, with values of 2.48, 2.90 and 3.09 times higher than in eggs, which had the lowest levels. In addition, calmodulin was found to activate phosphodiesterase (PDE), showing significant results after 48 hours of curcumin treatment at lethal concentrations. Treatment with TFP resulted in decreased PDE activity, blocking the action of calmodulin and reducing the efficacy of curcumin (ZHOU *et al*., 2021).

Silencing the TcCam gene in mites resulted in a 62% reduction in silencing, a 45% decrease in phosphodiesterase (PDE) activity, and greater resistance to curcumin toxicity. Calcium measurement in the treated cells revealed elevated levels of TcCaM and PDE compared to GFP-expressing cells, indicating the importance of TcCaM in the process. Curcumin toxicity was more intense relative to TcCaM, with an associated LC50 value (Zhou *et al*., 2021).

In the RNA analysis performed by Liu *et al.* (2016) the mapping of *Tetranychus urticae* was used, as its sequencing is available in the database and presents genetic similarity with *Tetranychus cinnabarinus*. We identified 111 genes differentially expressed after 24 hours and 96 after 48 hours, with most of the *down* genes upregulated after 24 hours, indicating a stronger inhibitory effect of curcumin in this period, but after 48 hours more genes were activated indicating a defense response to the effect of turmeric. Enrichment analysis using *Gene Ontology* (GO) revealed that many affected genes were associated with biological processes, mainly cellular processes. KEGG *(Kyoto Encyclopedia of Genes and Genomes*) pathway analysis identified biochemical pathways focused on protein processing in the endoplasmic reticulum, in addition to MAPK (*Mitogen-Activated Protein Kinase) signaling*, Huntington's disease and focal adhesion, in addition to the 48-hour phosphatidylinositol signaling system.

Curcumin affected genes in the mite *Tetranychus cinnabarinus* related to detoxification and insecticide metabolism, including genes encoding the ABC transporter protein, which is important in pesticide resistance. The ABC gene was inhibited by curcumin and this reduces the mite's ability to eliminate toxins, promoting the accumulation of pesticides in cells and accelerating their death, curcumin influences signal transduction genes such as Ser/Thr protein kinase, gamma-aminobutyric acid, and calmodulin, initially activated but with reduced activity after 48 hours, indicating an adaptive response. Genes such as guanylate kinase and Ras GTPase, which are also targets of insecticides, reinforce the potential of curcumin as a natural and safe alternative for controlling ecotoparasites (LIU *et al.*, 2016).

Validation of RNA-Seq data by qRT-PCR confirmed the overexpression of phospholipase A2 and neuromedin-K receptor genes, causing the release of arachidonic acid and free radicals, dysregulating cellular calcium, and leading to cell death. In addition to the activation of signal transduction genes, which promotes the opening of calcium channels, resulting in high neuronal excitability and continuous contractions in the mites, until their exhaustion and death (LIU *et al.*, 2016).

Both studies reveal the action of curcumin on the calcium signaling system in the mite, with calmodulin at the center of this process. The study by Zhou *et al*. (2021) provided a more detailed understanding of the specific function of CaM, demonstrating that curcumin acts as a direct agonist of CaM, activating it and increasing calcium levels in mite cells. The study by Liu *et al*. (2016) expands this view by showing that curcumin affects other components of the calcium system and informs that the calcium and CaM complex acts on enzymes by altering conformations regulating apoptosis, muscle contraction, intracellular movement, nerve growth and immune response, in addition, it increases phospholipase activation causing increased calcium and excessive CaM activation, triggering death.

Thus, the study brings relevant information for the development of new acaricides that act not only on calmodulin, but also on other proteins of the calcium pathway, enhancing the acaricide effects and minimizing mite resistance.

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IN VIVO TESTS

The activity of turmeric oil was evaluated as a repellent of *Ixodes ricinus* and the authors found that there was a significant reduction in the presence of ticks in dogs treated on the paws and belly with a concentration of 2.5%, with only two dogs having ticks. It is worth mentioning that it is important to consider the owners' adherence to the treatment, since the efficacy of the product is affected by the owners' commitment and the response rate was only 61%, which indicated possible problems during the study (GOODE; ELLSE; WALL, 2018).

The study by Abdel-Shafy *et al.* (2020) presents the effects of ethanolic extract in rabbits for the treatment of *O. savignyi*, which proved to be safe after kidney analysis, as no abnormalities were detected. However, the liver showed dilation and congestion of the veins, although the study indicates that this does not constitute serious injury. Red blood cells, leukocytes, and other blood constituents were within normal limits in both groups.

Therefore, *C. longa* did not present significant adverse effects. However, kidney damage was considered not relevant at the concentrations studied, so it is necessary to pay attention to possible side effects.

CONCLUSION

The analysis of studies on the efficacy of *Curcuma longa* in the control of mites shows that extracts and oils derived from the plant have repellent and toxic properties and have shown significant results in terms of mortality and inhibition of oviposition in several species. The studies highlight the versatility of turmeric, which can be prepared in different formulations and concentrations, in addition to influencing gene expression related to pesticide resistance and the regulation of biological mechanisms, such as calcium metabolism. However, despite the promising results obtained *in vitro*, further research is needed, considering other species, methods and preparations, to validate the efficacy and safety of *in vivo use*. Thus, for its practical application in agriculture and livestock, additional research is needed to optimize formulations, standardize concentrations, evaluate long-term effects, and explore synergy with other compounds. In summary, turmeric emerges as a promising complementary solution, especially in view of the resistance to synthetic pesticides and the environmental and economic impacts associated with their use. Future studies should detail the mechanisms of action and validate their effectiveness under real-world conditions.

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