

Comparative Study of Two Monoterpenes Effect on *Rhipicephalus microplus* Tick

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Abstract

The cattle tick *Rhipicephalus microplus* is one of the most important ectoparasites for livestock in tropical and subtropical areas worldwide. This tick hurts the economy of the milk and meat production chain. In addition, it constitutes a vector for the transmission of Anaplasmosis and Babesiosis pathogens. The control of *R. microplus* populations is mainly based on the use of synthetic acaricides. However, using this control method presents a danger to humans and the environment and leads to the emergence of resistant tick populations. In this situation, searching for ecological and effective control alternatives is essential. Thus, plant extracts constitute a promising solution, particularly essential oils and their active compounds.

Thus, the present study aims to assess the acaricidal activity of two monoterpenes (Thymol and 1.8 cineole) abundantly found in essential oils to find an alternative to synthetic acaricides. The acaricidal activity was determined according to the method of larval immersion test (LIT). Eight concentrations were tested and R software version 4.0.3 was used for data analysis. Results showed 100 % larval mortality rates for the two monoterpenes with LC50 and LC90 values of (0.28 and 0.64) and (0.64 and 2.66) respectively, for thymol and 1.8 cineole for the immersion time of 5 min. For 10 min of immersion, all LC values decreased for the two monoterpenes. These findings highlight the potential of the thymol and 1.8 cineole as an alternative for managing *R. microplus* tick.

Keywords: Acaricidal activity, Thymol, 1.8 cineole, Ticks, *Rhipicephalus microplus*

Introduction

Rhipicephalus microplus is an endemic important tick specie causing significant loss and damage to livestock production in tropical and subtropical regions of the world (Rodriguez-Vivas *et al.*, 2018; Diaz *et al.*, 2019). This tick affects animal welfare, resulting in stress, anemia due to blood spoliation, reduction of productive and reproductive performance, and transmits hemiparasites causing bovine babesiosis and anaplasmosis (Chagas, 2012). The main method of controlling ticks is the use of synthetic acaricides (Quadros *et al.*, 2020 ; Obaid *et al.*, 2022). However, this control method has led to the emergence of resistant tick populations (Gupta *et al.*, 2021 ; Dzemo *et al.*, 2022). In searching for alternatives to synthetic acaricides, plant extracts in particular essential oils (EOs) appear promising (Rodriguez-Vivas *et al.*, 2018 ; Selles *et al.*, 2021). Indeed, EOs are particularly advantageous because of their low toxicity, low persistence, and their complex chemistry that hinders the development of resistance in parasites (Mello-Peixoto *et al.*, 2013). Furthermore, previous work has shown that the biological activity of EOs is closely related to their chemical composition (Adenubi *et al.*, 2016 ; Djebir *et al.*, 2019). In addition, other studies have shown that this activity is mainly due to monoterpene compounds in essential oils (Zielińska-Błajet *et al.*, 2020 ; Liu *et al.*, 2022).

Thymol and 1,8-cineole are monoterpenes in several EOs. Thymol (2-isopropyl-5-methylphenol) is mainly present in EOs of plants of the *Lamiaceae*, *Verbenaceae*, *Scrophulariaceae*, *Ranunculaceae* and *Apiaceae* families (Marchese *et al.*, 2016). Many biological properties have been reported on this compound, including antioxidant, anti-inflammatory, antibacterial and antifungal properties (Marchese *et al.*, 2016 ; Kowalczyk *et al.*, 2020).

1.8 cineole (1,8-Epoxy-*p*-menthane) or eucalyptol is mainly derived from the EOs of plants in the *Lamiaceae*, *Myrtaceae* and *Zingiberaceae* families (Cai *et al.*, 2021). Many pharmacological properties have been reported on thymol, including anti-inflammatory, antioxidant, antimicrobial, mucolytic, broncholytic, anticancer, etc. (Cai *et al.*, 2021).

The present study aims to evaluate the acaricidal activity of thymol and 1.8 cineole on *R. microplus* larvae to find a natural and effective bio-acaricide.

2. Materials and methods

2.1 *Origin of ticks and chemical material*

The Adult females of *R. microplus* ticks were collected from Kimini (10.100000, -4.783330), a locality located in the Southwest region of Burkina Faso. The strain has been identified in the laboratory of CIRDES (Walker *et al.*, 2003). These were immediately oviposited under optimal temperature (28 ± 1 °C) and relative humidity ($85 \pm 5\%$) to produce eggs and then larvae after approximately 14 and 22 days of incubation, respectively. Fourteen days after the first observation of larvae, bioassays were performed. Thymol and 1.8 cineole standards were purchased from Sigma-Aldrich (St. Louis, MO, USA).

2.2 *Acaricidal activity*

The LIT test was used to evaluate the acaricidal activity of thymol and 1.8 cineole against *R. microplus* larvae with minor modifications according to the protocol described by Klafte *et al.* (2012). Eight concentrations (0.25, 0.5, 1, 1.75, 2.5, 3.75, 4.25 and 5 mg/mL) were used and the experiment was carried out in three replicates for each treatment. A solution (positive control) containing 1.0% of ethanol and the tween 20 at 3 % was used to dilute the standards. Thus, larvae (approximately 300 to 500) aged 14 days were previously placed with a brush between two pieces of Whatman paper N°1. 3 ml of the control solution was first applied to these larvae, which remained immersed for 5 minutes. They were then transferred to filter-paper packages (Whatman N°1) and sealed with “Bulldog” clips. This process was done in triplicate for all the treated larvae and controls. The test is repeated with a larval immersion time of 10 minutes. Both packages containing control and treated groups with thymol and 1.8 cineole were placed in the incubator under 27-28°C and 80-95% relative humidity for 24 hours. After this period, dead and live larvae were counted to calculate mortality rates according to the following formula :

$$\text{Mortality (\%)} = \frac{\text{dead larvae}}{\text{total of larvae}} \times 100$$

The Abbott formula has corrected the mortality rate of control groups when this rate exceeds 5 % (Abbot, 1925). Larvae without movement were diagnosed dead, and only larvae that could move around were recorded as alive (Perez-Cogollo *et al.*, 2010).

2.3 Statistical analysis

Statistical analysis was performed using R software version 4.0.3. The mean values for each treatment were subjected to an analysis of variance (one-way ANOVA) followed by Tukey's test at the 5% significance level. The lethal LC₅₀ and LC₉₀ concentrations were determined with their respective 95% confidence intervals by probit analysis with GraphPad prism 7.0.

3. Results

Results of larval mortality rates of thymol and 1.8 cineole at different concentrations during 5 and 10 minutes were recorded in Table 1.

Table 1. Larval mortality rates of thymol and 1.8 cineole

Concentrations (mg/mL)	5 min		10 min	
	Mortality rate (% ± SD)		Mortality rate (% ± SD)	
	Thymol	1.8 cineole	Thymol	1.8 cineole
0.25	42.3 ± 0.11 ^d	18.6 ± 0.07 ^d	51.3 ± 0.11 ^c	27.6 ± 0.01 ^d
0.50	60.4 ± 0.70 ^c	44.3 ± 0.21 ^c	68.4 ± 0.70 ^b	48.3 ± 0.52 ^c
1.00	88.7 ± 0.56 ^b	65.2 ± 0.53 ^b	93.7 ± 0.56 ^a	71.2 ± 0.26 ^b
1.75	96.7 ± 0.56 ^a	73.6 ± 0.61 ^b	98.3 ± 0.56 ^a	82.6 ± 0.22 ^a
2.50	100 ^a	81.3 ± 0.46 ^b	100 ^a	88.3 ± 0.83 ^a
3.75	100 ^a	94.1 ± 0.73 ^a	100 ^a	97.6 ± 0.83 ^a
4.25	100 ^a	100 ^a	100 ^a	100 ^a
5.00	100 ^a	100 ^a	100 ^a	100 ^a

a, b, c, d: Letters indicating different statistical groups. Identical letters in the same column indicate homogeneous statistical groups. Different letters indicate different statistical groups; **SD:** Standard deviation.

Both monoterpenes caused 100% mortality rates on the larvae of the *R. microplus* tick. Thymol caused more larval mortality compared to 1.8 cineole. The lethal concentrations LC₅₀ and LC₉₀ were determined and results have been reported in Table 2.

Table 2. LC₅₀ et LC₉₀ of thymol and 1.8 cineole

		5 min		10 min	
		LC (mg/mL ± SD)	CI	LC (mg/mL ± SD)	CI
Thymol	LC ₅₀	0.28 ± 0.03	[0.11- 0.50]	-	-
	LC ₉₀	1.21 ± 0.01	[1.01- 3.02]	0.95 ± 0.07	[1.01- 2.07]
1.8 cineole	LC ₅₀	0.64 ± 0.05	[0.50 -0.83]	0.52 ± 0.01	[0.36 - 0.73]
	LC ₉₀	2.66 ± 0.02	[2.50 - 3.81]	- 2.53 ± 0.03	[1.40 - 2.91]

LC : Lethal concentrations ; CI : Confidence intervals; LC₅₀: dose causing the mortality of 50% of larvae; LC₉₀: dose causing the mortality of 90% of larvae, SD: Standard deviation.

4. Discussion

In the current study, the LIT test was carried out twice. The larvae were immersed for 5 min the first time, and the second time, they were immersed for 10 min. For the 5 min immersion time, the effect of 1.8 cineole caused larval mortality rates ranging from 18.6 at the concentration of 0.25 mg/mL to 100% at 4.25 mg/mL. Thymol's lowest concentration caused 42.3% mortality; at 2.5% concentration, all larvae were eliminated. For the 10 min immersion time, 27.6 % mortality was recorded by 1.8 cineole at the lowest concentration, and at 4.25 mg/mL, this compound caused 100% larval mortality. As for thymol, larval mortality rates ranged from over 50% at the lowest concentration (0.25 mg/mL) to 100% mortality from 2.5 mg/mL.

Only a few studies have been realized on the acaricidal activity of 1.8-cineole. However, its acaricidal activity against *Sarcoptes scabiei* has been reported (Hu *et al.*, 2015). In addition, It has been demonstrated that 1.8 cineole was active on the reproductive parameters of the tick *R. microplus* (Queiroz *et al.*, 2020). Indeed, these authors showed that this compound caused an inhibition of the oviposition and hatching rates. Also, other authors have reported the acaricidal activity of an essential oil of *Eucalyptus globulus* with 1.8 cineole as the most abundant compound against the tick *Rhipicephalus (Boophilus) annulatus* (Adenubi *et al.*, 2021).

For thymol, several previous studies have reported its acaricidal effects on the tick *R. microplus*. Indeed, it has been shown that the thymol was effective on the tick *R. microplus* with an LC₅₀ value of 1.81 mg/mL (Lima *et al.*, 2017). Similarly, a study showed that this compound was active on *R. microplus* tick with an LC₅₀ of 4.46 mg/mL (Cruz *et al.*, 2013). In addition, another study found over 99% mortality of *R. microplus* larvae due to thymol (Scoralik *et al.*, 2012). Furthermore, acaricide and ovicide activities of thymol on engorged females and eggs of *R. microplus* have been proven (De Oliveira Monteiro *et al.*, 2010).

In the current study, the value of the lethal concentration LC_{50} was 0.28 mg/mL for thymol. This value was lower than those obtained in the previously mentioned studies performed on *R. microplus* larvae. This shows that the thymol used in the present study was more active. The sensitivity of the larvae to the product can explain this. Indeed, some larvae can be more sensitive than others when faced with a given product.

The lethal concentrations (LC_{50} and LC_{90}) of 1.8 cineole were higher than that of thymol, indicating that thymol was more active on *R. microplus* larvae than 1.8 cineole. Indeed, numerous studies have been reported on the activity of thymol as an insecticide, acaricide, and animal repellent (Escobar *et al.*, 2020). The acaricidal efficacy of thymol compared to 1.8 cineole could also be linked to the fact that thymol is a phenolic compound. A hydroxyl group on its aromatic ring confers a high reactivity to this compound compared to 1.8 cineole which is chemically more stable from a structural point of view.

Furthermore, the results showed that the larval mortality rates of thymol and 1.8-cineole differed when the larvae were immersed for 5 or 10 min. Indeed, for 1.8 cineole, the LC_{50} concentration increased from 0.64 to 0.52 mg/mL, and the LC_{90} concentration increased from 2.66 to 2.53 mg/mL. For thymol, the LC_{50} concentration could not be determined because mortality rates at the lowest concentration exceeded 50% mortality. As for the LC_{90} concentration, its value decreased from 1.21 to 0.95 mg/mL. These results indicate that the mortality rates increased with increasing immersion time of the larvae under both compounds.

Previous studies have revealed the molecular targets of 1.8-cineole and thymol on the tick *R. microplus*. Indeed, it has been shown that these two compounds act on *R. microplus* larvae as acetylcholinesterase inhibitors (Cardoso *et al.*, 2020). For thymol, another study showed that this compound induces the increased activity of antioxidant and detoxifying enzymes in *R. microplus* larvae (Tavares *et al.*, 2022). The acaricidal effect observed by thymol and 1.8 cineole in our study may be related to these mechanisms of action. However, further investigations are needed.

Conclusion

The present study has permitted us to compare the acaricidal activity of 1.8 cineole and thymol on the larvae of the tick *R. microplus*. Thymol was more active than 1.8 cineole but both compounds showed interesting mortality rates. The efficacy of thymol could probably be explained by its chemical structure making it more active than 1.8 cineole. The results of this study could lead to the development of new effective contact acaricide formulations based on these two monoterpenes. However, studies need to be carried out to increase the residual lifetime of these formulations but also

questions relating to the mechanisms of action of these products and their toxicity need to be addressed.

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Author's contributions: All authors jointly planned the study and analysis. The acaricidal activity was evaluated by Anass COULIBALY and Delphine M. HEMA. Anass COULIBALY and Delphine M. HEMA drafted the first version of the manuscript. Martin KIENDREBEOGO and Roger C.H NEBIE revised it. All authors approved the final version of the manuscript.

Data Availability

The data used to support the findings of this study are included in this article. Any required further information can be provided by the corresponding author upon request.

Conflicts of Interest: The authors declare no conflicts of interest.

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References:

1. Abbott, W.S. (1925). A method of computing the effectiveness of an insecticide. *J Econ Entomol*, 18, 265–267. <https://doi.org/10.1093/jee/18.2.265a>.
2. Adenubi, O.T., Abolaji, AO., Salihu, T., Akande, F.A., Lawal, H. (2021). Chemical composition and acaricidal activity of Eucalyptus globulus essential oil against the vector of tropical bovine piroplasmiasis, *Rhipicephalus (Boophilus) annulatus*. *Exp Appl Acarol*, 83(2), 301-312. [https://doi : 10.1007/s10493-020-00578-z](https://doi.org/10.1007/s10493-020-00578-z).
3. Adenubi, O.T., Fasina, F.O., McGaw, L.J., Eloff, J.N., & Naidoo, V. (2016). Plant extracts to control ticks of veterinary and medical importance: A review. *South African Journal of Botany*, 105, 178–193. <https://doi.org/10.1016/j.sajb.2016.03.010>.
4. Cai, Z.M., Peng, J.Q., Chen, Y., Tao, L., Zhang, Y., Fu, L., Long, Q., & Shen, X. (2021). 1,8-Cineole: a review of source, biological activities, and application. *J Asian Nat Prod Res*, 23(10), 938-954. [http://doi: 10.1080/10286020.2020.1839432](http://doi:10.1080/10286020.2020.1839432).
5. Cardoso, A.D.S., Santos, E.G.G., Lima, A.D.S., Temeyer K.B., Adalberto, Perez de Leon A.A., Costa L.M.J., & Soares, A.M.D.S. 2020. Terpenes on *Rhipicephalus (Boophilus) microplus* :

- Acaricidal activity and acetylcholinesterase inhibition. *Veterinary Parasitology* 280, 109090. [https://doi : 10.1016/j.vetpar.2020.109090](https://doi.org/10.1016/j.vetpar.2020.109090).
6. Chagas, A.C.S., Barros, L.D., Cotinguiba, F., Furlan, M., Giglioti, R., Oliveira, M.C. S., & Bizzo, H. R. (2012). In vitro efficacy of plant extracts and synthesized substances on *Rhipicephalus (Boophilus) microplus* (Acari: Ixodidae). *Parasitol Res*, 110 (1), 295–303. [https://doi :10.1007/s00436-011-2488-z](https://doi.org/10.1007/s00436-011-2488-z)
 7. Cruz, E.M.O., Costa, J.L.M., Pinto, J.A.O., Santos, D.A., De Araujo, S.A., Arrigoni-Blank, M.F., Bacci, L., Alves, P.B., Cavalcanti, S.C.A., & Blank, A.F. (2013). Acaricidal activity of *Lippia gracilis* essential oil and its major constituents on the tick *Rhipicephalus (Boophilus) microplus*. *Vet Parasitol* ,195(2013),198-202. [https://doi: 10.1016/j.vetpar.2012.12.046](https://doi.org/10.1016/j.vetpar.2012.12.046).
 8. De Oliveira Monteiro, C.M., Daemon, E., Silva, A.M., Maturano, R., & Amaral, C. (2010). Acaricide and ovicide activities of thymol on engorged females and eggs of *Rhipicephalus (Boophilus) microplus* (Acari: Ixodidae). *Parasitol Res*, 106(3), 615-9. [https://doi : 10.1007/s00436-009-1709-1](https://doi.org/10.1007/s00436-009-1709-1).
 9. Díaz, E.L, Camberos, E.P., Herrera, G.A.C., Espinosa, M.E., Andrews, HE., Buelnas, N.A.P., Ortega, A.G., & Velázquez, M.M., (2019). Development of essential oil-based phyto-formulations to control the cattle tick *Rhipicephalus microplus* using a mixture design approach. *Experimental parasitology*,201, 26-33. [https://doi : 10.1016/j.exppara.2019.04.008](https://doi.org/10.1016/j.exppara.2019.04.008).
 10. Djebir, S., Ksouri, S., Trigui, M., Tounsi, S., Boumaaza, A., Hadeif, Y., & Benakhla, A.(2019). Chemical composition and acaricidal activity of the essential oils of some plant species of lamiaceae and myrtaceae against the vector of tropical bovine Theileriosis: *Hyalomma scupense* (syn. *Hyalomma detritum*). *BioMed Research International*. <https://doi.org/10.1155/2019/7805467>.
 11. Dzemo, W.D., Thekiso, O., Vudriko, P. (2022). Development of acaricide resistance in tick populations of cattle: A systematic review and meta-analysis. *Heliyon*, 8 (1), e08718. <https://doi.org/10.1016/j.heliyon.2022.e08718>.
 12. Escobar, A., Pérez, M., Romanelli, G., & Blustein, G.(2020).Thymol bioactivity: A review focusing on practical applications. *Arabian Journal of Chemistry*, 13(12), 9243-9269. <https://doi.org/10.1016/j.arabjc.2020.11.009>.
 13. Gupta, S., Surbhi., & Kumar, S., (2021). Detection of Deltamethrin Resistance in Cattle Tick, *Rhipicephalus microplus* Collected in

- Western Haryana State of India. *J Arthropod Borne Dis* 15 (4), 389-396. <http://doi: 10.18502/jad.v15i4.10503>.
14. Hu, Z., Chen, Z., Yin, Z., Jia, R., Song, X., Li, L., Zou, Y., Liang, X., Li, L., He, C., Lin, L., Lv, C., Zao, L., Su, G., Ye, G., Shi, F. (2015). In vitro acaricidal activity of 1,8-cineole against *Sarcoptes scabiei* var. *cuniculi* and regulating effects on enzyme activity. *Parasitol Res*, 114(8), 2959-67. <https://doi: 10.1007/s00436-015-4498-8>.
 15. Kowalczyk, A., Przychodna, M., Sopata, S., Bodalska, A., & Fecka, I.(2020). Thymol and thyme essential oil—new insights into selected therapeutic applications. *Molecules*, 25(18), 4125. <https://doi: 10.3390/molecules25184125>.
 16. Klafke, G.M., Castro-Janer, E., Mendes, M.C., Namindome, A., & Schumaker, T.T.S. (2012). Applicability of in vitro bioassays for the diagnosis of ivermectin resistance in *Rhipicephalus microplus* (Acari: Ixodidae). *Vet Parasitol*, 184 (2-4), 212-20. <https://doi.org/10.1016/j.vetpar.2011.09.018>.
 17. Lima, A.S., Milhomem, M.N., Monteiro, O.S., Arruda, A.C.P., De Castro, J.A.M., Fernandes, Y.L.M., Maia, J.G.S., & Costa-Junior, L.M. (2017). Seasonal analysis and acaricidal activity of the thymol-type essential oil of *Ocimum gratissimum* and its major constituents against *Rhipicephalus microplus* (Acari: Ixodidae). *Parasitology Research*, 117(1), 59-65. <https://doi.org/10.1007/s00436-017-5662-0>.
 18. Liu, Z., Li, Q.X., & Song, B.(2022). Pesticidal Activity and Mode of Action of Monoterpenes. *J Agric Food Chem*, 70(15), 4556-4571. <https://doi : 10.1021/acs. java.2c00635>.
 19. Marchese, A., Orhan, I.E., Daglia, M., Barbieri, R., Di Lorenzo, A., Nabavi, S.F., Gortzi, O., Izadi, M., Nabavi, S.M. (2016). Antibacterial and antifungal activities of thymol: A brief review of the literature. *Food Chem*, 210, 402-14. <https://doi : 10.1016/j.foodchem.2016.04.111>.
 20. Mello-Peixoto, E.C.T., Figueiredo, A., Novo, S.M.F., Porto, E.P., Valadares, F., Da Silva, L.P., & Da Silva, R.M.G. (2013). Application of *Cymbopogon winterianus* Jowitt and *Azadirachta indica* A. Juss in the control of *Rhipicephalus (Boophilus) microplus*. *J. Med. Plants Res*, 7(32), 2392–2398. <https://doi.org/10.5897/JMPR12.1218>.
 21. Obaid, M.K., Islam, N., Alouffi, A., Khan, A.Z., Vaz, Jr, I.D.S., Tanaka, T., & Abid Ali. (2022). Acaricides Resistance in Ticks: Selection, Diagnosis, Mechanisms, and Mitigation. *Front Cell Infect Microbio* 12, 941831. <http://doi: 10.3389/fcimb.2022.941831>.
 22. Perez-Cogollo, L.C., Rodriguez-Vivas., R.I., Ramirez, C.G.T., Miller, R.J. (2010). First report of the cattle tick *Rhipicephalus*

- microplus* resistant to ivermectin in Mexico. *Vet Parasitol*, 168 ,165–169. <https://doi.org/10.1016/j.vetpar.2009.10.021>.
23. Quadros, D.G., Johnson, T.L., Whitney, T.R, Olivier, J.D., & Chávez, A.S.O., (2017). Plant-Derived Natural Compounds for Tick Pest Control in Livestock and Wildlife: Pragmatism or Utopia? *Insects*, 11(8), 490. <https://doi.org/10.3390/insects11080490>.
 24. Queiroz, D.V.T., Campos, N.C., Nunes, E.T., Costa, A.V., Coelho, J.D., Trivilin, L.O., De Melo, D.C.A., Morais, P.A.B., Martins, I.V.F. (2020). 1,8-cineole and castor oil in sodium lauryl ether sulfate disrupt reproduction and ovarian tissue of *Rhipicephalus (Boophilus) microplus*. *Med Vet Entomol* , 34(3), 316-326. <https://doi.org/10.1111/mve.12444>.
 25. Rodriguez-Vivas, R.I., Jonsson, N.N., & Bhushan, C. (2018). Strategies for the control of *Rhipicephalus microplus* ticks in a world of conventional acaricide and macrocyclic lactone resistance. *Parasitol Res*, 117(1), 3-29. <https://doi.org/10.1007/s00436-017-5677-6>.
 26. Selles, S.M.A., Koudri, M., González, M. G., González, J., Sánchez, M., González-Coloma, A., Sanchis, J., Elhachimi, M., Olmega, S., Tercero, J.M., & Valcárcel, F. (2021). Acaricidal and repellent effects of essential oils against ticks: A review. *Pathogens*, 10 (11), 1379. <https://doi.org/10.3390/pathogens10111379>.
 27. Scoralik, M.G., Daemon, E., de Oliveira Monteiro, C.M., & Maturano, R.(2012). Enhancing the acaricide effect of thymol on larvae of the cattle tick *Rhipicephalus microplus* (Acari: Ixodidae) by solubilization in ethanol. *Parasitol Res*, 110(2), 645-8. <https://doi.org/10.1007/s00436-011-2539-5>.
 28. Tavares, C.P., Sabadin, G.A., Sousa, I.C., Gomes, M.N., Soares, A.M.S., Monteiro, C.M.O., Vaz Jr, I.S., & Costa-Junior, L.M. (2022). Effects of carvacrol and thymol on the antioxidant and detoxifying enzymes of *Rhipicephalus microplus* (Acari: Ixodidae). *Ticks and Tick-Borne Diseases*, 13(3), 101929. <https://doi.org/10.1016/j.ttbdis.2022.101929>.
 29. Walker, A.R., Bouattour, A., Camicas, J.L., Estrada-Peña A., Horak, I.G., Latif, AA., Pegram, R.G., & Preston, P.M. Ticks of domestic animals in Africa : a guide to identification of species. Bioscience Reports ; Edinburgh, p.221, 2003.
 30. Zielińska-Błajet, M., & Feder-Kubis, J.2020. Monoterpenes and Their Derivatives-Recent Development in Biological and Medical Applications. *Int J Mol Sci*, 21(19,7078. doi: 10.3390/ijms21197078