Use of Essential Oils for the Treatment of Cryptosporidiosis

Shamreza Aziz[1,*], Wenqiang Tang[2], Ayah Talal Zaidalkilani[3], Ammar AL-Farga[4] and Muhammad Mobashar[5]

[1]Department of Epidemiology & Public Health, University of Veterinary & Animal Sciences, Lahore, Pakistan
[2]Institute of Animal Husbandry and Veterinary Medicine, Tibet Academy of Agriculture and Animal Husbandry Sciences, Lhasa 850009, China
[3]Faculty of Pharmacy and Medical Sciences, Department of Nutrition, University of Petra, Amman, Jordan
[4]Department of Biological Sciences, College of Science, University of Jeddah, Jeddah, Saudi Arabia.
[5]Department of Animal Nutrition, The University of Agriculture Peshawar, Pakistan
*Corresponding author: shamrezaaziz@gmail.com

Abstract

Cryptosporidiosis is a global zoonotic disease of the gastrointestinal tract of both humans and animals. In an immuno-competent host, this disease is self-limiting but in case of immunocompromised individuals, the disease has devastating impacts. The disease spreads through the direct or indirect contact with the infected host or contaminated environment as the infectious oocysts of the parasite shed through the feces in the surroundings. The oocysts can survive in harsh environments due to its robustness and tiny size, which makes parasites resistant to usually available disinfectants and makes it tough to eradicate them. The pathogenesis of the parasite includes infection of the microvillus epithelial cells of the small intestine of its host and causes severe diarrhea. This diarrheal condition is known as cryptosporidiosis which is ranked as fifth leading cause of diarrhea in children. The therapeutic drugs available for the treatment of cryptosporidiosis are very few and also the efficacy of these drugs are very low. The only FDA approved drug used for the treatment of cryptosporidiosis is Nitazoxanide (NTZ) which also has varying efficacy in immunocompromised patients (having co-infection of HIV) and children. The emergence of resistance in parasites to available drug therapies highlights the need of alternatives for better treatment options. Plant essential oils discovered as a novel agent to fight against different types of parasites. Due to the unique properties of essential oils and their active components, these essential oils have been studied to be used against different parasitic agents such as Cryptosporidium. The increased research and use of the essential oils against different parasitic infections indicates the potential of essential oils as an alternative treatment. This chapter aims to explore different types of essential oils used for the treatment of cryptosporidiosis.

Keywords: *Cryptosporidium parvum*, Oocysts, Antiparasitic drugs, Essential oils, Carvacol, Oregano, Mint oil,coconut oil, Onion and cinnamon oils, and thyme essential oil

Cite this Article as: Aziz S, Tang W, Zaidalkilani AT, AL-Farga A and Mobashar M, 2025. Use of essential oils for the treatment of cryptosporidiosis. In: Kun Li (ed), Protozoan Zoonoses: Advances in the Diagnosis, Prevention, and Treatment of Cryptosporidiosis and Toxoplasmosis. Unique Scientific Publishers, Faisalabad, Pakistan, pp: 37-42. https://doi.org/10.47278/book.HH/2025.399

A Publication of Unique Scientific Publishers

Chapter No: 25-06

Received: 20-Jan-2025
Revised: 02-March-2025
Accepted: 21-Apr-2025

Introduction

Cryptosporidium parvum (*C. parvum*) is an intracellular intestinal protozoan which causes a zoonotic disease named cryptosporidiosis. The host range of this parasite is wide which include humans, ruminants and many other species of animals (Craighead et al., 2021). Cryptosporidiosis causes severe diarrhea especially in mal-nourished children and adults with compromised immune systems (El-Ashkar et al., 2022). Cryptosporidiosis mainly invades enterocytes and innate immunity plays a vital role in the control of this cryptosporidiosis (Gullicksrud et al., 2022). Currently available drug for the treatment of cryptosporidiosis is Nitazoxanide (NTZ) which is approved by the Food and Drug Administration (FDA). But there are few drawbacks associated with this drug such as it does not give satisfactory results in immunocompromised individuals and the cure rate is also very low in mal-nourished children (Taha et al., 2017). Other than NTZ, there are few other drugs such as azithromycin, roxithromycin, and paromomycin available for the treatment of *C. parvum* (Table 1) (Gargala, 2008). In developing countries, there have been reports regarding drug toxicity, antimicrobial resistance, low efficacy, and less availability of drugs. All the challenges demand for novel, innovative, inexpensive, safe and effective treatment options (Abdelmaksoud et al., 2020). This situation led the scientists to investigate traditional methods such as use of natural herbs and plants to deal with parasitic infections (Mendonça et al., 2021).

Transmission and Life Cycle

The oocysts of *C. parvum* are present all over the surroundings but there are also many ways through which the oocysts get entry into the host such as through fecal-oral route via direct or indirect contact (Robertson & Robertson, 2014). The direct or indirect transmission of the *C. parvum* between susceptible and infected hosts is mainly due to high density of population and close contact with infected environment or individuals (Cacciò et al., 2005) justifying the record of transmission within family members such as children and sexual partners (Robertson & Robertson, 2014). Another way of transmission is through contaminated food handled by infected individuals or exposed to contaminated water known as food borne transmission (Ramirez et al., 2004). The life cycle of *C. parvum* ends up in feces and produces thick outer wall oocysts which then release in the feces (Gunasekera et al., 2020). These infectious oocysts result in the contamination of the soil, water, and

grazing land. When a susceptible host graze on this contaminated land, come in contact with the oocysts, ingested by the host, oocysts come in contact with the bile salts, acid in the stomach, and enzymes such as trypsin and expression of the receptors present on the surface of the oocysts, which facilitate the process of excystation and ends up into the release of four motile sporozoites in the intestinal tract of its host (Borowski et al., 2008). Secretary apical organelles are important as they help in the adherence, invasion, and insertion of the parasite into the epithelial cells of the host. After that parasite nestles into a parasitophorous vesicle for its shelter and nutrition. The parasite goes through merogony, asexual, and sexual phases of its life cycle. In the process of merogony, parasites go through the differentiation and form trophozoites, type I meront, and merozoites. Some of these merozoites form Type II meronts while others penetrate the surrounding enterocytes (asexual life cycle) (Ali et al., 2024a). Type II meronts then attach themselves to the neighboring cells of the host and go through the sexual phase of life cycle called gametogony and produce microgamonts and macrogamonts. After maturation microgamonts form microgametes which fertilize macrogamonts, once they are released, and form zygote. After the process of meiosis, zygote produced four naked sporozoites and some of these sporozoites developed into oocysts with thin walls, causing autoinfection in its host. The other oocysts develop with thick walls which are resistant to harsh environments, and are released into feces (Figure 1) (Ali et al., 2024b).

Table 1: Conventional treatment options for Cryptosporidiosis

Previously used drug	Status of drug	Drawbacks	References
Nitazoxanide (NTZ)	FDA approved drug for Cryptosporidiosis, ineffective in patients with co-infection (HIV)	Expensive, low availability, less effective in children and immuno-compromised individuals	(Amadi et al., 2009; Khalil et al., 2018)
Azithromycin	Use in other infections	Use in combination with other drugs in HIV patients	(Diptyanusa & Sari, 2021; Khan & Witola, 2023)
Rifabutin		Used to prevent cryptosporidiosis	(Khan & Witola, 2023)
HIV protease inhibitors		Causes suspension of Cryptosporidiosis in HIV patients	(Khan & Witola, 2023)
Paromomycin		Less effective in HIV patients	(Diptyanusa & Sari, 2021)
Rifaximin		Effective in HIV patients	(Diptyanusa & Sari, 2021)
Miltefosine	Use in animals	Low efficacy and adverse side effects	(Diptyanusa & Sari, 2021)
Halofuginone lactate		Cause toxicity in host	(Khan & Witola, 2023)

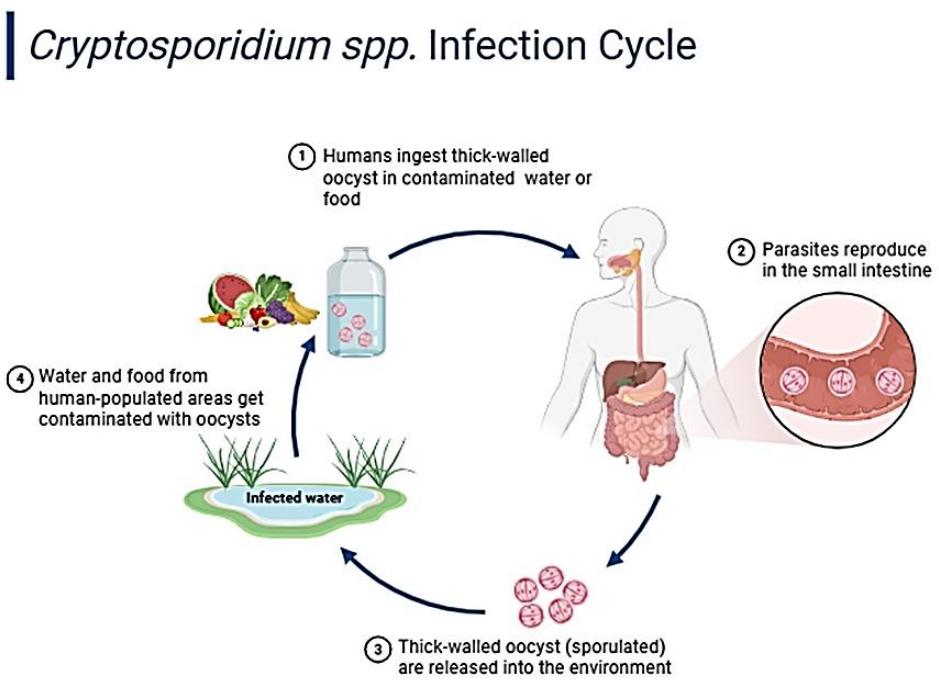

Fig. 1: After ingestion, *Cryptosporidium* oocysts complete their asexual and sexual life cycle in the small intestine and release thick-walled oocysts in the environment to infect susceptible hosts.

Essential Oils

NTZ has been used as a drug of choice for the treatment of cryptosporidiosis. Other than NTZ, many other drugs have been tested to check their efficacy levels against the infection of cryptosporidiosis in mammals (Hikal & Said-Al Ahl, 2017). But the emerging threat of resistance in parasites to the treatment currently available for the *C. parvum* highlights the significance of herbal products including plants and their extracts. Attributed to their activity against intestinal parasites, essential oils are recently used as a novel strategy against parasitic agents for instance *C. parvum* (Figure 2) (Benchaar et al., 2008).

Carvacrol (CV) and Oregano (*Origanum vulgare*) Essential Oils

There is still need of research about the exact mechanism of action of antiparasitic activity of carvacrol (CV) and oregano essential oils (OEO). In a study, the effect of CV and OEO on cell viability and infectivity was studied by introducing the oocysts of *C. parvum* into HCT-8 cell

(human ileocecal colorectal adenocarcinoma cells) monolayers (Gaur et al., 2018). The results of this study reveals the anti *C. parvum* activity of both CV and OEO. CV being a monoterpene, can affect several functions of the parasite including modification of the calcium-dependent protein kinase 1(CDPK1) and also have an influence on the Ca2+ mediated signalling (which is required for the invasion, differentiation, and regulation of other major functions) (Ultee et al., 2002; Murphy et al., 2010). Other than that the hydrophobicity and presence of hydroxyl groups in CV (Ultee et al., 2002; Burt, 2004) help phenol to penetrate the parasitic cell membrane which in turn decreases the infection rate (Turina et al., 2006; Santoro et al., 2007). In case of children having infection of *C. parvum*, the CV and OEO act as a bioactive substance to fight and lower the infection rate (Thakur et al., 2024). According to Ayurvedic and ethnopharmacological literature, OEO is recognized and used as antiparasitic agent (Burt, 2004) but there is limited evidence on the working of OEO and CV as antiparasitic agents.

Mint (*Mentha* × *piperita*) Oil

The chemical composition of mint oil consists of various minerals and nutrients such as iron, manganese, folate, magnesium, potassium, copper, calcium, omega-3 fatty acids, vitamin A and vitamin C. It also contains several volatile bioactive compounds for example menthol, menthyl acetate, menthone, piperitone, pulegone, carvone, and limonene (McKay & Blumberg, 2006; Kligler & Chaudhary, 2007). Mint oils is an important essential oil due to its anti-inflammatory, anti-diarrheal, antiemetic, spasmolytic, anti-bacterial, anti-depressive, diaphoretic, analgesic, antioxidant, hepato-protective, keto-protective and anti-parasitic characteristics (İşcan et al., 2002; Kiran & Patra, 2003; Farzaei et al., 2017). Mint oil also shows its unique activity in relieving irritable bowel syndrome and shows significant effects against both Gram-positive and gram-negative bacteria (Mahadevappa et al., 2014). In addition, mint oil is also used as mosquito repellent, strengthening the immune system, and shows choleretic effect that is why it has great use in the medical field (İşcan et al., 2002; Mahadevappa et al., 2014). The use of mint oil against *C. parvum* infection shows significant results as it improves the histopathological damage of the intestinal villi of the host's intestinal tract. There has been significant improvement in the small intestinal histopathological changes of the host cell. Mint oils have great therapeutic potential to inhibit the production of pro-inflammatory cytokines and limit the inflammatory response (Hejna et al., 2021). Due to the presence of flavonoids and phenolic constituents, mint oil donates electrons or hydrogen to the free radical which result in the inhibition of the production of hydroxyl peroxide ultimately control the damage due to oxidative stress (Djeridane et al., 2006; Krzyzanowska et al., 2011). The antioxidant properties of mint oil have been confirmed by many researchers (Nikavar et al., 2008; Teixeira et al., 2013; Wu et al., 2019; Hejna et al., 2021).

Coconut (*Cocos nucifera*) Oil

Essential coconut oil is chemically composed of triglycerides having a large number of medium chain saturated fatty acids. Among these fatty acids a large amount of Lauric acid, almost 50% of the total fatty acids, is present in coconut oil (Dayrit, 2014). The beneficial therapeutic effects of coconut oils include antimicrobial activity, anti-inflammatory action, and antioxidant properties (Benchaar et al., 2008; Srivastava et al., 2016). Coconut oil has significant activity against the oocysts of *C. parvum* as it decreases the oocysts count and also causes the amelioration of the histopathological changes in ileal tissue of the host intestinal tract (Naggar et al., 2023). There is a significant decrease in the apoptotic index after the treatment with coconut oil in case of cryptosporidiosis.

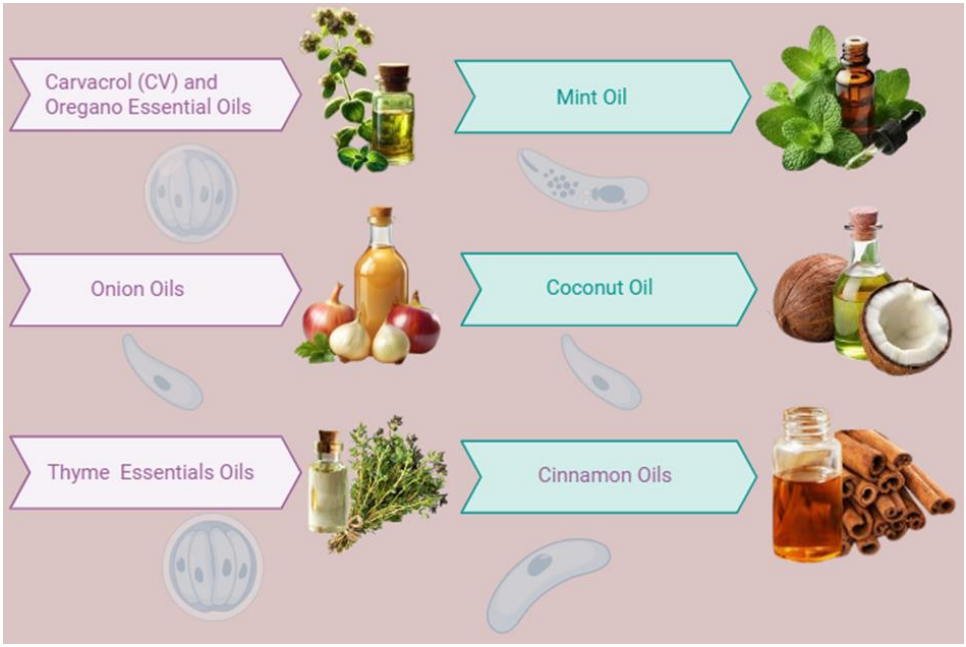

Fig. 2: Different essential oils used against Cryptosporidiosis.

Onion (*Allium cepa*) and Cinnamon (*Cinnamomum zeylanicum*) Oils

The antiparasitic activity and therapeutic benefits of the *A. cepa* oil is attributed to the presence of the flavonoids and sulphoid components which also provide protection against cell damage (Hodges et al., 1999). *C. zeylanicum* oil has been used as an immune stimulant (GT et al.,

2010). *C. zeylanicum* oil is composed of eugenol, a member of phenylpropanoids, which is known for its antiphagocytic and local antiseptic properties (Mallavarapu et al., 1995). Onion oil and cinnamon oil has great importance due to their anti *C. parvum* activity as the use of onion oil and cinnamon oil decrease the oocysts count at a significant level. These oils are also reported to improve the appearance of villi of ileum of the host's cell, as the parasite colonized in the villi. The administration of onion oil and cinnamon oil has beneficial therapeutic effects against the zoonotic *C. parvum* infection in both humans and animals (El Ezz et al., 2011).

Thyme (*Thymus vulgaris*) Essentials Oils

Thyme (*Thymus vulgaris*) is an important essential oil composed mainly of thymol (2-isopropyl-5-methylphenol) which is a monoterpene (Youssefi et al., 2019). Thymol is a famous therapeutic agent because of its antibacterial (Kachur & Suntres, 2020), antifungal (Wang et al., 2019), larvicidal (López et al., 2018), and acaricidal (Araújo et al., 2015) properties. But there is limited data about the antiparasitic characteristics of thymol. Thymol is easily available in many natural sources and frequently used because of its low toxicity to mammalian cells. Due to these properties, thymol has a great potential to be used as an antiparasitic agent (Chauhan & Kang,2014). In a study thymol and thyme have significant activity against *C. parvum* when used in HCT-8 cell (human ileocecal colorectal adenocarcinoma cells) culture model. The knowledge about the activity of both the thyme and thymol is scarce and there is need for further research (Dominguez-Uscanga et al., 2021).

Conclusion

Essential oils appeared as a promising alternative for the treatment of cryptosporidiosis, especially in the current situation of development of drug resistance and limited treatment options. Essential oils as one of the best plant extracts have been experimented in both in vitro and in vivo studies while they show efficacy against cryptosporidiosis. The essential oils such as Carvacrol, Oregano, Mint, Coconut, Onion, Cinnamon, and Thyme contain bioactive compounds that are mainly responsible for the antiparasitic activity of these essential oils. The in vivo and in vitro studies of animal models represent compelling evidence of the antiparasitic efficacy of different essential oils, more research needed and human trials are important for the application of clinical use of these oils in human cryptosporidiosis treatment. The introduction of essential oils as an alternative of NTZ (current treatment regimen against cryptosporidiosis) increases the therapeutic effects and less side effects. There is a need for research in perspectives of preparation techniques of the essential oils, their mode of action, and combination of essential oils to enhance their efficacy. Essential oils hold great potential as an alternative treatment for the management of cryptosporidiosis in the current situation of evolution of resistance in various parasitic diseases.

References

Abdelmaksoud, H. F., El-Ashkar, A. M., Elgohary, S. A., & El-Wakil, E. S. (2020). Potential therapeutic and prophylactic effects of Asafoetida in murine cryptosporidiosis. *Journal of Parasitic Diseases*, *44*, 646-653.

Ali, M., Ji, Y., Xu, C., Hina, Q., Javed, U., & Li, K. (2024a). Food and waterborne cryptosporidiosis from a One Health perspective: A comprehensive review. *Animals: An Open Access Journal from MDPI*, *14*(22), 3287.

Ali, M., Xu, C., Nawaz, S., Ahmed, A. E., Hina, Q., & Li, K. (2024b). Anti-Cryptosporidial drug-discovery challenges and existing therapeutic avenues: A "One-Health" Concern. *Life*, *14*(1), 80.

Amadi, B., Mwiya, M., Sianongo, S., Payne, L., Watuka, A., Katubulushi, M., & Kelly, P. (2009). High dose prolonged treatment with nitazoxanide is not effective for cryptosporidiosis in HIV positive Zambian children: a randomised controlled trial. *BMC Infectious Diseases*, *9*, 1-7.

Araújo, L. X., Novato, T. P. L., Zeringota, V., Matos, R. S., Senra, T. O. S., Maturano, R., & Monteiro, C. M. O. (2015). Acaricidal activity of thymol against larvae of Rhipicephalus microplus (Acari: Ixodidae) under semi-natural conditions. *Parasitology Research*, *114*, 3271-3276.

Benchaar, C., Calsamiglia, S., Chaves, A. V., Fraser, G. R., Colombatto, D., McAllister, T. A., & Beauchemin, K. A. (2008). A review of plant-derived essential oils in ruminant nutrition and production. *Animal Feed Science and Technology*, *145*(1-4), 209-228.

Borowski, H., Clode, P. L., & Thompson, R. A. (2008). Active invasion and/or encapsulation? A reappraisal of host-cell parasitism by Cryptosporidium. *Trends in Parasitology*, *24*(11), 509-516.

Burt, S. (2004). Essential oils: their antibacterial properties and potential applications in foods—a review. *International Journal of Food Microbiology*, *94*(3), 223-253.

Cacciò, S. M., Thompson, R. A., McLauchlin, J., & Smith, H. V. (2005). Unravelling cryptosporidium and giardia epidemiology. *Trends in Parasitology*, *21*(9), 430-437.

Chauhan, A. K., & Kang, S. C. (2014). Thymol disrupts the membrane integrity of Salmonella ser. typhimurium in vitro and recovers infected macrophages from oxidative stress in an ex vivo model. *Research in Microbiology*, *165*(7), 559-565.

Craighead, S., Huang, R., Chen, H., & Kniel, K. E. (2021). The use of pulsed light to inactivate Cryptosporidium parvum oocysts on high-risk commodities (Cilantro, mesclun lettuce, spinach, and tomatoes). *Food Control*, *126*, 107965.

Dayrit, F. M. (2014). Lauric acid is a medium-chain fatty acid, coconut oil is a medium-chain triglyceride. *Philippine Journal of Science*, *143*(2), 157-166.

Dev, S. (2023). *Prime Ayurvedic Plant Drugs*. Springer Nature.

Diptyanusa, A., & Sari, I. P. (2021). Treatment of human intestinal cryptosporidiosis: A review of published clinical trials. *International Journal for Parasitology: Drugs and Drug Resistance*, *17*, 128-138.

Djeridane, A., Yousfi, M., Nadjemi, B., Boutassouna, D., Stocker, P., & Vidal, N. (2006). Antioxidant activity of some Algerian medicinal plants extracts containing phenolic compounds. *Food Chemistry*, *97*(4), 654-660.

Dominguez-Uscanga, A., Aycart, D. F., Li, K., Witola, W. H., & Laborde, J. E. A. (2021). Anti-protozoal activity of Thymol and a Thymol ester against Cryptosporidium parvum in cell culture. *International Journal for Parasitology: Drugs and Drug Resistance*, *15*, 126-133.

El-Ashkar, A. M., Mahmoud, S., Sabry, H., Guirguis, N., El Komi, W., Ali, E., & Abdelmksoud, H. F. (2022). Nitazoxanide, Ivermectin, and

Artemether effects against cryptosporidiosis in diabetic mice: parasitological, histopathological, and chemical studies. *Journal of Parasitic Diseases*, *46*(4), 1070-1079.

El Ezz, N. A., Khalil, F. A., & Shaapan, R. M. (2011). Therapeutic effect of onion (Allium cepa) and cinnamon (Cinnamomum zeylanicum) oils on cryptosporidiosis in experimentally infected mice. *Global Veterinaria*, *7*(2), 179-183.

Farzaei, M. H., Bahramsoltani, R., Ghobadi, A., Farzaei, F., & Najafi, F. (2017). Pharmacological activity of Mentha longifolia and its phytoconstituents. *Journal of Traditional Chinese Medicine*, *37*(5), 710-720.

Gargala, G. (2008). Drug treatment and novel drug target against Cryptosporidium. *Parasite*, *15*(3), 275-281.

Gaur, S., Kuhlenschmidt, T. B., Kuhlenschmidt, M. S., & Andrade, J. E. (2018). Effect of oregano essential oil and carvacrol on Cryptosporidium parvum infectivity in HCT-8 cells. *Parasitology International*, *67*(2), 170-175.

GT, W., Villeneuve, N. F., Lamore, S. D., Bause, A. S., Jiang, T., & Zhang, D. D. (2010). The cinnamon-derived dietary factor cinnamic aldehyde activates the Nrf2-dependent antioxidant response in human epithelial colon cells. *Molecules*, *15*(5), 3338-3355.

Gullicksrud, J. A., Sateriale, A., Engiles, J. B., Gibson, A. R., Shaw, S., Hutchins, Z. A., & Hunter, C. A. (2022). Enterocyte–innate lymphoid cell crosstalk drives early IFN-γ-mediated control of Cryptosporidium. *Mucosal Immunology*, *15*(2), 362-372.

Gunasekera, S., Zahedi, A., O'Dea, M., King, B., Monis, P., Thierry, B., & Ryan, U. (2020). Organoids and bioengineered intestinal models: potential solutions to the Cryptosporidium culturing dilemma. *Microorganisms*, *8*(5), 715.

Hejna, M., Kovanda, L., Rossi, L., & Liu, Y. (2021). Mint oils: In vitro ability to perform anti-inflammatory, antioxidant, and antimicrobial activities and to enhance intestinal barrier integrity. *Antioxidants*, *10*(7), 1004.

Hikal, W. M., & Said-Al Ahl, H. A. (2017). Anti-cryptosporidium activity of essential oil: A review. *American Journal of Food Science and Health*, *3*(3), 35-40.

Hodges, D. M., DeLong, J. M., Forney, C. F., & Prange, R. K. (1999). Improving the thiobarbituric acid-reactive-substances assay for estimating lipid peroxidation in plant tissues containing anthocyanin and other interfering compounds. *Planta*, *207*, 604-611.

İşcan, G., Ki ri mer, N., Kürkcüoğlu, M., Başer, H. C., & Demirci, F. (2002). Antimicrobial screening of Mentha piperita essential oils. *Journal of Agricultural and Food Chemistry*, *50*(14), 3943-3946.

Kachur, K., & Suntres, Z. (2020). The antibacterial properties of phenolic isomers, carvacrol and thymol. *Critical Reviews in Food Science and Nutrition*, *60*(18), 3042-3053.

Khalil, I. A., Troeger, C., Rao, P. C., Blacker, B. F., Brown, A., Brewer, T. G., & Mokdad, A. H. (2018). Morbidity, mortality, and long-term consequences associated with diarrhoea from Cryptosporidium infection in children younger than 5 years: a meta-analyses study. *The Lancet Global Health*, *6*(7), e758-e768.

Khan, S. M., & Witola, W. H. (2023). Past, current, and potential treatments for cryptosporidiosis in humans and farm animals: A comprehensive review. *Frontiers in Cellular and Infection Microbiology*, *13*, 1115522.

Kiran, U., & Patra, D. D. (2003). Medicinal and aromatic plant materials as nitrification inhibitors for augmenting yield and nitrogen uptake of Japanese mint (Mentha arvensis L. Var. Piperascens). *Bioresource Technology*, *86*(3), 267-276.

Kligler, B., & Chaudhary, S. (2007). Peppermint oil. *American Family Physician*, *75*(7), 1027-1030.

Krzyzanowska, J., Janda, B., Pecio, L., Stochmal, A., Oleszek, W., Czubacka, A., & Doroszewska, T. (2011). Determination of polyphenols in Mentha longifolia and M. piperita field-grown and in vitro plant samples using UPLC-TQ-MS. *Journal of Association of Official Agricultural Chemists International*, *94*(1), 43-50.

López, V., Cascella, M., Benelli, G., Maggi, F., & Gómez-Rincón, C. (2018). Green drugs in the fight against Anisakis simplex—larvicidal activity and acetylcholinesterase inhibition of Origanum compactum essential oil. *Parasitology Research*, *117*, 861-867.

Mahadevappa, N., Hanumantharaju, D. K., Suvarna, P. V., Moses, V., Chandrashekar, S., & Gowda, S. (2014). Study on advanced application of mint oil. *Journal of Advanced Scientific Research*, *5*(04), 1-3.

Mallavarapu, G. R., Ramesh, S., Chandrasekhara, R. S., Rajeswara Rao, B. R., Kaul, P. N., & Bhattacharya, A. K. (1995). Investigation of the essential oil of cinnamon leaf grown at Bangalore and Hyderabad. *Flavour and Fragrance Journal*, *10*(4), 239-242.

McKay, D. L., & Blumberg, J. B. (2006). A review of the bioactivity and potential health benefits of peppermint tea (Mentha piperita L.). *Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives*, *20*(8), 619-633.

Mendonça, F. L., Carvalho, J. G., Silva, R. J., Ferreira, L. C., Cerqueira, D. M., Rogge, H. I., ... & Facury-Filho, E. J. (2021). Use of a natural herbal-based feed additive containing isoquinoline alkaloids in newborn calves with cryptosporidiosis. *Veterinary Parasitology*, *300*, 109615.

Murphy, R. C., Ojo, K. K., Larson, E. T., Castellanos-Gonzalez, A., Perera, B. G. K., Keyloun, K. R., & Maly, D. J. (2010). Discovery of potent and selective inhibitors of CDPK1 from C. parvum and T. gondii. *ACS medicinal chemistry letters*, *1*(7), 331-335.

Nagamune, K., Moreno, S. N., Chini, E. N., & Sibley, L. D. (2008). Calcium regulation and signaling in apicomplexan parasites. *Molecular Mechanisms of Parasite Invasion: Subcellular Biochemistry*, 70-81.

Naggar, H.M.E., Mohammed, B.O., Aboushousha, T. (2023). Study on the Therapeutic Effect of Coconut Oil Extracts as An Alternative Medicinal Plant in *Cryptosporidium* Infected Mice. *Turkish Journal of Parasitology*, 47(3), 136-143.

Nikavar, B., ALI, N. A., & KAMALNEZHAD, M. (2008). Evaluation of the antioxidant properties of five Mentha species.

Ramirez, N. E., Ward, L. A., & Sreevatsan, S. (2004). A review of the biology and epidemiology of cryptosporidiosis in humans and animals. *Microbes and Infection*, *6*(8), 773-785.

Robertson, L. J., & Robertson, L. J. (2014). Occurrence of Cryptosporidium oocysts in Different Food Matrices: Results of Surveys. *Cryptosporidium as a Foodborne Pathogen*, 39-56.

Santoro, G. F., das Graças Cardoso, M., Guimarães, L. G. L., Salgado, A. P. S., Menna-Barreto, R. F., & Soares, M. J. (2007). Effect of oregano (Origanum vulgare L.) and thyme (Thymus vulgaris L.) essential oils on Trypanosoma cruzi (Protozoa: Kinetoplastida) growth and

ultrastructure. *Parasitology Research*, *100*, 783-790.
Srivastava, Y., Semwal, A. D., & Majumdar, A. (2016). Quantitative and qualitative analysis of bioactive components present in virgin coconut oil. *Cogent Food & Agriculture*, *2*(1), 1164929.
Taha, N. M., Yousof, H. A. S. A., El-Sayed, S. H., Younis, A. I., & Negm, M. S. I. (2017). Atorvastatin repurposing for the treatment of cryptosporidiosis in experimentally immunosuppressed mice. *Experimental Parasitology*, *181*, 57-69.
Teixeira, B., Marques, A., Ramos, C., Neng, N. R., Nogueira, J. M., Saraiva, J. A., & Nunes, M. L. (2013). Chemical composition and antibacterial and antioxidant properties of commercial essential oils. *Industrial Crops and Products*, *43*, 587-595.
Thakur, S., Yadav, R., Kaur, U., Thakur, J. S., & Sehgal, R. (2024). Efficacy of medicinal plants in cryptosporidiosis treatment: a comprehensive review. *Journal of Parasitic Diseases*, 1-8.
Turina, A. D. V., Nolan, M. V., Zygadlo, J. A., & Perillo, M. A. (2006). Natural terpenes: self-assembly and membrane partitioning. *Biophysical Chemistry*, *122*(2), 101-113.
Ultee, A., Bennik, M. H. J., & Moezelaar, R. J. A. E. M. (2002). The phenolic hydroxyl group of carvacrol is essential for action against the food-borne pathogen Bacillus cereus. *Applied and Environmental Microbiology*, *68*(4), 1561-1568.
Ultee, A., Bennik, M. H. J., & Moezelaar, R. J. A. E. M. (2002). The phenolic hydroxyl group of carvacrol is essential for action against the food-borne pathogen Bacillus cereus. *Applied and Environmental Microbiology*, *68*(4), 1561-1568.
Wang, K., Jiang, S., Yang, Y., Fan, L., Su, F., & Ye, M. (2019). Synthesis and antifungal activity of carvacrol and thymol esters with heteroaromatic carboxylic acids. *Natural Product Research*, *33*(13), 1924-1930.
Wu, Z., Tan, B., Liu, Y., Dunn, J., Martorell Guerola, P., Tortajada, M., & Ji, P. (2019). Chemical composition and antioxidant properties of essential oils from peppermint, native spearmint and scotch spearmint. *Molecules*, *24*(15), 2825.
Youssefi, M. R., Moghaddas, E., Tabari, M. A., Moghadamnia, A. A., Hosseini, S. M., Farash, B. R. H., & Sut, S. (2019). In vitro and in vivo effectiveness of carvacrol, thymol and linalool against Leishmania infantum. *Molecules*, *24*(11), 2072