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Controlling vector-borne health issues and *in-vitro* effects of Nanoemulsion of essential Oils: A Review

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A B S T R A C T

Controlling the parasitic and infectious diseases is a permanent health issue worldwide, requiring innovative methods for the prevention & treatment of illness triggered by parasites. Controlling vector and its intermediate hosts is an effective method for anticipation of human and animal's diseases. It is essential to have bioactive components that act competently on the agents which produce the illnesses. Synthetic agents have strong surplus effects in humans & other animals, and they cause biological toxicity, affecting animals, plants and disturbing the local environment. Many studies have reported the effect of the Essential Oils (EOs). Essential Oils extracted from the medicinal plants are generally used as insect repellents worldwide. They are very safe and favorable to the environment with minimum ill-effects on animals and public health. It helps to control the vectors and also applicable against pathogens. Commonly Essential Oils easily degrade and cause less environmental pollution. Problems associated to solubility as well as stability lead to the improvement of effective carriers for formulations containing Essential Oils that is nanoemulsion. Nanoemulsion is a colloidal dispersion system, thermodynamically stable, prepared by two different non-miscible liquids assorted with emulsifying agents such as surfactants and co-surfactants, to form a single phase. Nanoemulsion a novel drug delivery system can be formulated by using two different techniques, the persuasion technique and the brute force technique. This review describes some studies accomplished with nanoemulsions as carriers of Essential Oils that have repellent, larvicidal, acaricidal, insecticidal and antiparasitic activities. Thus it can be used as substitutes in the vector control of parasitic and communicable diseases.

Keywords: Nanoemulsion; essential oils; vector control; infectious diseases, insecticidal.

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INTRODUCTION

The Essential Oils (EOs) are complex combinations of unstable organic components which are obtained from the secondary metabolites in plants. They are constituted by two main compounds that are hydrocarbons (such as terpenes & sesquiterpenes) and oxygenated components (such as alcohols, aldehydes, esters, ethers, ketones, lactones, phenols and phenol ethers) [1]. These compounds are commonly responsible for the typical odor of plants. More than three thousands essential Oils are identified, and about 10 to 15% of them have commercial significance in different fields such as cosmetics, nutrition, and pharmaceutical industries [2]. Hence, they are generally known as safe by the United State Food and Drug Administration (USFDA) [3]. Their conformation can vary significantly with plant species and biodiversities [4]. The aromatic plants with essential oils shows several effects such as repellents, low-risk insecticides, antifungals, antivector growth regulators, oviposition deterrents and antifeedants. The use of essential oils for these activities had increased due to its popularity among organic farmers and environmentally conscious consumers [5-8]. The production of essential oils is done generally by distillation techniques (such as hydro, steam & dry) and/or mechanical cold pressing of plants [9]. Mostly the "Clavenger steam distillation apparatus" is used for production of essential oils globally. It has been developed and extended for large scale production of essential oils in industries. In recent times, contemporary essential oil isolation techniques have been initiated such as microwave-assisted processing (MAP) & supercritical fluid isolation (SFI) techniques [10]. Essential oils could cover, on usual, among 25 and 90 different compounds. The constituents of essential oils are usually designated to two different phytochemical groups: terpenoids, example monoterpenes and sesquiterpenes of low mol. wt. and to a smaller range, Phenyl-propanoids example volatile phenolic compounds. Terpenoid is the chief component of the essential oils. Monoterpenes are present in the essential oils which may contain terpenes such as hydrocarbons (α-pinene and D-limonene), ethers (1, 8-cineol), aldehydes (cinnamaldehyde & citronellal), lactones (artemisin), alcohols (cadinol) and ketones (thujone). Wide variety structures of sesquiterpenes have more than 100 skeletons and enlargement of the series to fifteen carbons may enhance the quantity of potential cyclizations. Less common aromatic compound includes Phenyl-propanoids like p-allylanisole & phenolic components like thymol. The composition of essential oils may vary in different plant species. For example eucalyptus *Eucalyptus globulus*, belonging to family Myrtaceae with chief component of the essential oil monoterpene 1, 8-cineol, whereas coriander *Coriandrum sativum* belonging to family Umbelliferae, has sesquiterpenes linalool as the main component. The oil isolated from leaves of *Eucalyptus globules* have allelopathic & insecticidal property which acts as a natural pesticides [11-12]. In various studies, with fumigation effects [13] and repellency [14], the effectiveness of these oils had been validated [15]. The mixture and growth of essential oils in plants are linked with the occurrence of compound and to very specific structures like glandular trichomes (*Lamiaceae*) and secretary cavities (*Myrtaceae, Rutaceae*). Depending on the species, the essential oils could be stored in many plant organs such as, in flowers, fruits, leaves, seeds, wood, roots and rhizomes [16]. Biologically, the essential oils have various effective properties such as insecticidal effects, and reduce growth of insects and repellent activity. They are efficiently significant to regulate phytophagous insects and also regulate local and plot insects. The mechanism of action (MOA) of the components present in essential oils on pests are generally through neurotoxic effects, through the inhibition of acetylcholinesterase (AChE) [17], functionality disruption of gamma-aminobutyric acid (GABA) receptors [18], and as agonist of octopaminergic system [19]. Even though the biological effects of specific chemical components of essential oils are commonly known, the toxic effect of their mixtures is a very difficult aspect to evaluate. The most attractive features of essential oils are that they are, in general, low-risk products on animals, and their environmental determination is short. Their toxicity for mammals is low, having values of oral LD_{50} that varies from 1000 to 1950 mg kg^{-1} in rats. In addition, due to their use as medicines, some essential oils are relatively well studied experimentally and clinically. The toxic effects of essential oil components are classified into three basic classes based on the toxicological measures [20]. Class 1 with low functionality and less oral toxicity like limonene, Class 2 with some functionality & midway toxicity for example menthofuran and Class 3 with sensitive functionality & high possible toxicity for example elemicin. Based on classification and other toxicological measures, a different procedure has industrialized to estimate the protection from essential oils [21]. The essential oils can be promising antiprotozoal agents. The compounds like terpinen-4-oland/or thymol & camphor the chief component have antiprotozoal activity [22, 23].

2. NANOEMULSION AND NANOTECHNOLOGY:

An emulsion is a combination of two or more liquid which are generally non-miscible. Macroscopic separation of both liquid phases is measured by accumulation of non-ionic surfactant. When the emulsion size ranges between 10 to 200 nm, it is called as “Nanoemulsion”. Nanoemulsion can be formed through dispersion of the oil-in-water (o/w) and/or water-in-oil (w/o) and allow the incorporation of different active substances. They have some individual characteristics, like transparency when observed by the naked eye, with bluish reflection, owing to the diffusion of light b/w the nanoparticles [24]. The very lesser extent of particles also discusses greater resistance to the effects of incineration and sedimentation, because the effect of gravity is smaller on them [25]. Surfactants have an essential role in the formulation of Nanoemulsion systems. Interfacial tension produced owing to the immiscibility of mixture, liquid systems is made compact by the use of surfactant. The formulation process of the Nanoemulsion is passed out b/w the lower to higher energy emulsification method. Lower energy method includes the “phase inversion method”, but higher energy method includes ultrasound and “high-pressure homogenization”. In addition the system displays lower interfacial tension that simplifies the diffusion of other ingredients and the major advantage is when the combination of extremely lipophilic substances like essential oils, into the aqueous systems is compulsory [26]. The nanoemulsions have various applications in numerous areas like medications, cosmetics, agriculture, etc. [27]. In recent development, different methods are being accepted in the advancement of Nanoemulsion for repellent activity, larvicidal effects and insecticidal effects using essential oils. Nanotechnology is a trans-disciplinary and promising area of science owing to its miscellaneous potential of application, belonging to the field of electronic and mechanical engineering, telecommunications, industrial chemistry, civil construction, Health, development of nanostructure drugs, biological carriers and devices for diagnosis [28, 29]. Advancement of technologies in electron microscopy dates back to 1980s, beneficial to observe study, manipulate and develop nanostructure systems, which led to technical revolution in various fields of science [30]. Nano-metric materials have a size in the range between 0.1-200 nm. [31]. Nanotechnology had provided substitute for the research and development of novel drug delivery systems in the biological area and health sciences. A field that delivers a number of patient benefits like dose reduction, lower number of administrations, improved therapeutic efficacy and reduction in side effects. Nano-systems have an advantage of protecting active materials against mechanisms of inactivation and degradation, also providing the combination of materials with different polarity in relation to matrix, to promote sustained release and/or targeting of drug action in a definite tissue [32, 33].

3. NANOEMULSION OF ESSENTIAL OIL:

In recent years, various scientific studies have been described for the use of nanoemulsions as appropriate carriers of active essential oils. They are mainly classified into 3 types which are formed depending on the composition such as:

a) Oil in water Nanoemulsions wherein oil droplets are dispersed in the continuous aqueous phase
b) Water in oil Nanoemulsions wherein water droplets are dispersed in the continuous oil phase
c) Bi-continuous Nanoemulsions wherein micro domains of oil and water are interdispersed within the system [34, 35].

Their composition and preparation is very easy with high thermodynamic stability with low production cost and the possibility of production on an industrial level provide a significant advantage to this technology over the biological and pharmacological usage of the essential oils [36, 37]. Nanoemulsions are encouraging tools to fight with vector-borne diseases in public control of communicating mediators. It is probably owing to the characteristic physico-chemical possessions of the Nano-metric emulsion system [38]. The dimension of the nanoemulsion in nanometer increases its specification and distribution target, resulting in more efficiency than marketed pesticides. Moreover, nanoemulsions pesticides has lesser surfactant concentration than microemulsion, and surfactants are significantly more eco-friendly & economically feasible. Essential oils dispersed in various nano-formulations include numerous MOA and de-regulation of the growth-hormone which inclines to stopover the insect flaking that leads to its deaths and also enzymatic inhibition, between others [39–41]. According to the recent studies, the organic effects of nanoemulsions on etiological mediators of parasitic source had reported that the use of nanoemulsions have potentially increased in the control of infectious/parasitic diseases.

4. BIOLOGICAL ACTIVITIES OF ESSENTIAL OIL NANOEMULSIONS

4.1. LARVICIDAL & PUPICIDAL ACTIVITY

The mosquito species, *Culex quinquefasciatus* are substitute as repeated vector for *Wuchereria bancrofti*, a humanoid filarial roundworm which originate filariasis. It is a disease which generally causes lymphedema that leads to patient illness and are potentially lethal [42]. Eucalyptus oil loaded Nanoemulsion developed showed larvicidal activity as well as pupicidal activity against *Culex quinquefasciatus*. The treated larvae/pupa exhibited lower protein levels, as well as significant fall in the stages of AChE and acid/basic phosphatase. The nanoemulsions could be used as a nontoxic and active substitute in restraint of vectors [43]. The nanoemulsions of essential oils (*Ocimum basilicum*) exhibited larvicidal effects in 3rd instar larvae and pupicidal activity on *Aedes aegypti* (dengue-transmitting mosquitoes). Essential Oil compositions contained about 89% of methyl chavicol (estragole), Phenylpropanoids with insecticidal property [44]. The study reported that about 100 fold dilution of Nanoemulsions initiated larvicidal effects of 60 to 70% after period of 60 to 75 minute, separately. Complete losses of larval at this concentration were observed after a submission period of 90 minute. While, diluted (about ten-fold) Nanoemulsion induced 100% larvicidal effects on *Aedes aegypti* in 15 minute [43]. Brazilian scientists established Nanoemulsions using *Rosmarinus officinalis e*ssential oil as an active component for 4th instar larvae of *Aedes aegypti*, in 2015. The mortality ratios were found after 24 to 48 hours of interaction with the Nanoemulsion, which induced 85 to 90% mortality, respectively [45]. 1, 8-cineol is the chief component of *Rosmarinus officinalis* which showed potent larvicidal activity [46, 47]. The validated non-emulsified *R. officinalis e*ssential oil showed a DL_{95} of 409 ppm after 24 hours of interaction indicates the greater larvicidal efficiency of the Nanoemulsion [48].

The Nanoemulsions of *Cinnamomum zelanycum e*ssential oil (5% conc.) with chief component cinnamaldehyde caused 70% death of mealworm (*Alphitobius diaperinus*) larvae at the L8 stage after two days, and had three times more stronger effects as compared to un-emulsified essential oil within 3 days. Besides, the nanoemulsions exhibited no harmful effects on existence and imitation tests of springtails (*Folsomia candida*), indicated that nano-encapsulation of cinnamon oil meaningfully reduced its harmful effects without changing the efficiency in controlling *Aedes diaperinus*. Botas et al., (2017) reported larvicidal bioassays against *Aedes aegypti* in a study [49], wherein nanoemulsions based on essential oils of *Baccharis reticulate* was studied. D-limonene the chief component (25%) of *Baccharis reticulate* and the nanoemulsions of these essential oils showed larval mortility against *Aedes aegypti*, with LC_{50} values of 120.10 μg/mL & 80.95 μg/mL, respectively [50]. Balasubramani et al., in a study reported the Nanoemulsions of *Vitex negundo* L. essential oils with larvicidal activity for 2nd & 3rd instar larvae, after 12 to 24 hour contact times. After 12 hour exposure period, the LC_{50} values of both 2nd & 3rd instar larvae was 65.54 and 71.12 ppm, respectively when compared to the values of the non-emulsioned Essential Oils which was 120.13 and 91.94 ppm, respectively. Similarly, after a 24 hour exposure period, the Nanoemulsion LC_{50} values were 29.10 and 42.93 ppm, although the non-emulsioned essential oil values were 76.65 and 55.87 ppm, respectively. Osanloo et.al., (a) worked on control of anopheles species, which causes malaria worldwide, by the application of Nanoemulsion loaded essential oils from *Artemisia dracunculus* belonging to family *Asteraceae*. The activity of Nanoemulsions on both 3rd & 4th instar larvae were done, with LC_{50} or LC_{90} of 12.13 or 16.98 ppm, respectively. P-allylanisole is the main component of *Artemisia dracunculus* [51]. Osanloo et al., (b) evaluated larvicidal activity on *Anopheles stephensi* by the act of nano-emulsionated essential oils from *Anethum graveolens* which mainly consists of p-cymene and α-phellandrene as chief components. After one hour of contact with nanoemulsions, larvicidal effects of 50 and 90% were found at 40.1 and 64.9 ppm, individually, against 3rd & 4th instar larvae [52], in comparison to *Anethum graveolens* non-emulsified essential oils, the Nanoemulsion exhibited more efficiency, since the oil LD_{50} without nano-emulsification was 100 ppm after the same contact time [53-54]. The nanoemulsions of *Ocimum basilicum* essential oils showed larvicidal effects on 2nd & 3rd instar larvae of *Culex quinquefasciatus*, trans- β-Guaiene (16.89%) and α-Cadinol (15.66%) the chief components of Essential Oil. Following table enumerates various essential oil Nanoemulsions with larvicidal activity (Table 1):

Table: 1. Essential Oil Nanoemulsion with Larvicidal activity:

S. no.	Common Name	Chief constituent of essential oil	Emulsifying agent	Insect
1.	Tarragon	p-Allylanisole	Tween 20	*Anopheles stephensi*
2.	True cinnamon Tree	Cinnamaldehyde	Tween 80	*Alphitobius diaperinus*
3.	Dill	p–Cymene and α-phellandrene	Tween 20	*Anopheles stephensi*
4.	Eucalyptus	1,8-cineole	Tween 80	*Culex quinquefasciatus*
5.	Sand-Rosemary	D-limonene	Tween 80	*Aedes aegypti*
6.	Cumin	Pinene and cymene	Tween 20	*Aedes aegypti* & *Anopheles stephensi*
7.	Chinese chaste tree	β-caryophyllene	Tween 80	*Aedes aegypti*
8.	Basil	*Trans*-β-Guaiene and α-Cadinol	Tween 80	*Culex quinquefasciatus*
9.	Rosemary	Caffeic acid and betulinic acid	Polysorbate 20	*Aedes aegypti*
10.	Basil	Methyl-chavicol	Tween 20	*Aedes aegypti*
11.	Sucupira	γ-muurolene and biciclogermacrene	Polysorbate 20	*Aedes aegypti*

4.2. MOSQUITO REPELLENT AND INSECTICIDAL ACTIVTY OF ESSENTIAL OILS

Some monoterpenes (such as α-pinene, cineole, thymol, limonene, camphor, citronellol, terpinolene, citronellal and eugenol) are common components of different essential oils, which showed mosquito repellent activities [55-58]. Among sesquiterpenes like β-caryophyllene showed strong repellent effects on *Aedes aegypti* [59]. However repellent effects of some essential oils commonly appear to be linked with the occurrence of monoterpenoids and sesquiterpenes [60-63]. Further authors have reported that phytol, a linear diterpene alcohol, have greater repellent activity for *Anopheles gambiae*. Also, the oxygenated components such as cinnamyl alcohol, geraniol, phenyl ethyl alcohol, β-citronellol and α-pinene, extracted from the essential oil of *Dianthus caryophyllum*, exhibited strong repellent effects for ticks (*I. ricinus*) [64,65]. The repellent effects of 12 to 16 essential oils from natural and striking Argentine plants and 21-isolated metabolites; 3-alcohols (thymol, benzyl alcohol and menthol) were reported as the most active towards *Pediculus humanus capitis* [66]. The repellent effects of 10 to 12 different Kenyan plants species against *Anopheles gambiae* belonging to family *Diptera*, and about 5 to 10 pure metabolites were isolated from them, the most effective chemicals such as citronellal, geraniol, caryophyllene oxide, carvacrol, perillyl alcohol, cisverbenol, cis-carveol, 4-isopropyl benzene methanol, 3-carene, thymol and myrcene showed strong repellent activity. This constituent belongs to different categories such as diterpenoid, sesquiterpenoid and acyclic, monocyclic & bicyclic monoterpenoids. Many components have shown activity on adult insects, as well as on other insect development stages [67]. The effect of several nanoformulations of *Ocimum sanctum* essential oils on *Culex quinquefasciatus* & *Aedes aegypti* has been reported. By the use of filter paper impregnation technique, the preparation containing essential oils (30%) showed 98% effect on *Aedes aegypti* and 100% effect on *Culex quinquefasciatus* [68]. The Nanoemulsion loaded citronella oil showed the repellent activity against *Aedes aegypti*, using the human-bait method, based on standard test of World Health Organization (WHO). The Nanoemulsions containing 20% of citronella oil and glycerol-water (1:1) ratio were reported to be more protective (about 2.7 hour), which can be measured high in contrast with essential oils diluted to 10% in olive oil exhibited protection (about 56.30 min.). d-limonene & citronellal were the chief component of the essential oils (40% each) and had greater repellent effects [69]. The repellent activity of Nanoemulsions from different essential oils on adult mosquito (*Aedes aegypti*), 7 nano-formulations were prepared using different concentration of oils from hairy basil (*Ocimum americanum*), Vetiver (*Vetiveria zizanioides)* belonging to family Poaceae & citronella oil (*Cymbopogon nardus*). Using the human-bait method, the preparation with ratio 5:5:10 (vetiver, hairy basil and citronella) showed repellent effects with a protection time of 4.8 hours. Citronellal (citronella) & limonene, vetiveric acid (vetiver) and 3-carene & caryophyllene (hairy basil) were the chief components in the essential oils, and possibly represented the activity through synergic mechanisms (Table 2) [70].

4.3. ACARICIDAL ACTIVITY:

Rhipicephalus microplus is an Ixodidae tick which causes severe financial damages on livestock. It is defined as vector of tick-transmitting agents like *Babesia bigemina*, *Anaplasma-marginale* & *Babesia bovis.* Some groups of researchers had described the acaricidal effects of essential oils loaded Nanoemulsion against this species [71]. The study assessed the effects of the Nanoemulsions-based *Cinnamomum verum* (5%) that induced 96% and 64% of oviposition inhibition, *in-vitro* & *in-vivo*, correspondingly. In comparison, additional study presented that the non-emulsioned essential oils didn't cause oviposition inhibition. Furthermore, after 25 days, the cows which were previously invaded and treated with the Nanoemulsion were free of the parasites [71,72]. Similarly, the Nanoemulsion of *Eucalyptus globules* essential oils exhibited that the preparations at 1% & 5% inhibited parasite reproduction by 52% and 60.8%, individually [73]. The various essential oils formulated in Nanoemulsion with acaricidal activity are shown in Table 2.

Table: 2. Essential Oil Nanoemulsion-Insecticidal, repellent and acaricidal activity:

S. No.	Common Name	Main Essential Oil Compound	Emulsificant	Parasite/Insect
1.	Eucalyptus	1,8-cineole	Tween 80	*Rhipicephalus microplus* (Acaricidal activity) *Culex quinquefasciatus*
2.	Cinnamomum	Cinnamaldehyde	Tween 80	*Rhipicephalus microplus* (Acaricidal activity) *Aedes aegypti*
3.	Citronella	D-limonene and Citronellal, D-limonene and citronellal (*C. nardus*),	Montanov 82	Aedes aegypti (Repellent activity)
4.	Cumin	Cymene	Tween 20	*Aedes aegypti/Anopheles stephensi* (Repellent activity)
5.	Nutmeg	Pinene and camphene	Montanov 82	*Aedes aegypti* (Repellent activity)
6.	Holy Basil	Ursolic acid & β-caryophyllene	Tween 20	*Culex quinquefasciatus* and *Aedes ae* (Insecticide activity)

4.4. ETIOLOGICAL AGENTS FOR ANTIPARASITIC ACTIVITY

Trypanosoma evansi are flagellated parasite & the etiological agent of the disease called "Surra" & "Mal das Cadeiras" mainly affects in Brazilian horses and hardly affects humans [74]. The *in-vitro* trypanocidal effects of the nano-emulsified *Schinus molle* essential oils had been evaluated. The Nanoemulsions (0.5% and 1% concentration) were able to decrease the number of living parasites in 79% and 100%, correspondingly. The study outcomes were compared with the non-emulsified essential oils, showed a minor death ratio, with 64% and 70%, correspondingly [75]. The *in-vitro* effect of essential oils (*Lavanudula officinalis*) Nanoemulsions against *Trichomonas vaginalis* were observed. The Nanoemulsion (100 μg/mL concentration) showed 82% of growth resistance and demonstrated low toxicity & macrophages (about 91% viability) [76]. In an study for antiparasitic effects of nano-emulsionated essential oils of *Lavanudula* class, the Nanoemulsion of this oil and also *Rosmarinus officinalis* (rosemary), exhibited an antileishmanial effect for *Leishmania major*. In Iran, it is one of the most etiological agents of cutaneous leishmaniasis. Linalool (11.22%) and 1, 8-cineol (21.98%) were the chief components of *Lavandula angustifolia* (lavender) essential oils. The Nanoemulsion of *Lavandula angustifolia* and *Rosmarinus officinalis* exhibited antileishmania effects on promastigote with IC_{50} = 0.12 μL/mL & IC_{50} = 0.07 μL/mL, correspondingly. The study was compared with similar non-emulsioned essential oils of *Rosmarinus officinalis*, which showed IC_{50} = 2.5 μL/mL respectively [77]. The study reported that a greater strength of the Nanoemulsion kills parasites. The effects of *Zataria multiflora* essential oil on *Echinococcus granulosus*, caused cystic echinococcosis, a zoonotic contamination with financial and human health importance globally [78]. The *in-vivo* results presented that the scolicidal effect of the Nanoemulsion (1 mg/mL concentration) were 90% and 100% after 12 to 22 min, correspondingly, although the Nanoemulsions (2 mg/mL concentration) exhibited 100% of scolicidal effect after 10 minute [79]. Thymol is the chief component of *Zataria multiflora* essential oil involved in the scolicidal activity [80-82]. It also exhibited negative effect on the germinal layer of hydatid cysts [83]. The following table shows some of the Nano emulsion essential oils with antiparasitic activity (Table 3).

Table: 3. Essential Oil Nanoemulsion for antiparasitic activity

S.No.	CommonName	Main Essential Oil Compound	Emulsificant	Parasite
1.	Avishan Shirazi	Thymol	Tween 80	Protoscoleces of the hydatid cysts
2.	Lavander and Rosemary	1,8-cineole and linalool	Tween 80	Leishmania major
3.	Lavender	1,8-cineole	Tween 80	*Trichomonas vaginalis*

The Nanoemulsions with essential oils have been used as active mediators in control of illnesses caused by several agents. The study reported the variety of targets and effectiveness of nanoemulsions when compared to additional agents already used, as well as their easiness of production [84, 85]. Technology of Nanoemulsion formulations provide various benefits with respect to the active principle and their stability, such as:

a) Better protection of the active constituent against chemical or biological degradation
b) Lower probability of creaming or sedimentation of droplets
c) Greater contact surface of the target with the droplets that contains the active agent
d) Possibility of dispersion of immiscible substances in a certain solvent, which in the case of Essential Oils is usually water, besides the simplicity of production,
e) Low cost of reagents.
f) Less residual damage to the environment when compared to synthetic products, widely used in modern times [85].

These facts could be verified through related studies made with nanoemulsified oils in which the essential oils alone were not able to balance the activity propagation of the nano-formulations. The variety of the components of the essential oils such as monoterpenes, sesquiterpenes and Phenylpropanoids, contributes to the diversity of mechanisms of action for controlling the vectors & etiological agents of infectious/parasitic diseases which increase the possible action of synergistic effect [86–88].

5. CONCLUSIONS:

Nanomodification of essential oils, is hydro-immiscible in nature, expressively improves life value and efficiency as a pesticide and/or antiparasitic. Nanoformulations require a lesser amount of essential oils to develop/prepare nanoemulsions, and the use of water & nonionic surfactants also makes these Nano-formulations favorable & ecofriendly. In case of pesticide preparation, removal of the unpredictable chemical components increases their biological effects and makes "greener" method to the control of vectors of pathogenic illness. The properties of essential oil Nano-formulations such as a greater degree of delivery to the target of action, water dispersion, and stability of formulation, cost-effective and low toxicity are very effective and highly ecological.

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