CHAPTER 2

2.0 REVIEW OF LITERATURE

Mankind has been primarily dependant on the stored cereals for survival since thousands of years. These demands are continuous and require supply to the consumers without fail. However, their management in the storage is a major challenge for almost all the nations due to their viability to different kinds of factors. The list is dominated by insect pests which thrives more on account of indecorous management of the grains (Gawande & Patil, 2015). Sinha (1994) in his report has discretely cited the loss of grains in the storage with a figure of 50% in developing nations. The survey has reported that the USA experiences 9% yield loss of grains every year. The loss incurred is no doubt a major concern for developing nations which suffers tremendously in the form of malnutrition (Berg, 1968). But the ambiguity lies with the developed nations which too find it difficult to sustain the loss due to exponential growth in population. To overcome the phase, the hunt for finding a competent management practices across the research labs is continued.

Fumigants of synthetic varieties are popular in the warehouses (Bell, 2000) to control stored grains pests like red flour beetles and many. *Tribolium casteneum,* the primary pest of wheat flour, could attract maximum human attraction for being the major competitor of the wheat grains and flour. History witnessed the incidence of the pest almost a century ago and in no time they won the tag of most disastrous being (Good, 1933). Their control measure has taken the use of fumigants in peak. However, the later had to delist from the category of "most preferred choices" as it imposes a wide range of negative effects in the environment and human health (Daft, 1991). Moreover, bioaccumulation of pesticides have added to their fitness and boosted the resistance which led to the emergence of highly resilient pest variety.

The above discussed problems has deviated the research interest towards eco-friendly alternatives. The very room for fumigants is taken over by environmentally sound options in order to reduce the deleterious impact. Among all, pesticidal plants gained considerable attention due to their high

reliability and better results with no toxicity towards humans. One of its major products, EOs, have set the era of green revolution in modern agriculture and was found efficient in controlling different varieties of insect pest (Hernandez-Lambraño et al., 2015). As reviewed by Pandey et al. (2017) the area of research, "pest management with the EOs", is observed to flourish in the last five decades. The positive results have further promoted upcoming researchers to work in the same trail (Lee et al., 2004) (Lee et al., 2001) (Chaubey, 2007). Globally countless number of research has been conducted with the different varieties of indigenous plant species (Mossa, 2016). Still record shows only 10% of the plant species of the total existed is known for their insecticidal attributes. The factual data throws light into the scope remaining in the aspect.

2.1 Literature documented from the state: Gujarat

With these baseline reports, I started the literature survey by delimiting the search to the efficacy of essential oils against *Tribolium casteneum*. While reviewing the literature in the state, unfortunate yet surprising fact of "no previous studies" came into light. Only a few preliminary works on the antifeedant properties of pulverised leaves of a few plants viz. *Annona squamosa*, *Moringa oleifera* and *Eucalyptus globulus* against *T. casteneum* have been published in the decade (Anita, 2012). However, extension of these works was needed in the form of EOs isolation and their characterisation for the presence of novel plant compounds with insecticidal and repellent properties. The state lacks any report on the EOs of plant origin against any stored grain pest.

With great curiosity, I extended my search on the national reports to find out the plant variants used for drawing EOs and their insecticidal properties. Moreover, these works carried out in the nation would form a framework and hence help me to evade the difficulties associated with the proper designing of the work.

2.2 Literature documented from the nation: India

Scientist from different corners of India has documented a number of plant species whose EOs were efficient against *T. casteneum.* Majority of the

reports were from the early 20th century. However, with time the graph shows a downfall in the number of reports on EOs. An interesting finding was the state Uttar Pradesh, majorly CSIR lab, which has documented maximum works on EOs from the nation.

In a recent report by Brari & Thakur (2018) from Department of Biosciences, Himachal Pradesh University, ShimLa, HP, the larvicidal potency of eight different plants EOs viz. *Artemisia maritima, Cinnamomum zeylanicum, Citrus hystrix, Colebrookea oppositifolia, Pelargonium hortorum, Rabdosia rugosa, Thuja occidentalis* and *Zanthoxylum armatum* against larval *Tribolium casteneum* has been tested. Among all, *R. rugosa* EOs was most efficient against the *T. casteneum* larvae. However, the live individuals of treatment groups have showed resistance towards the EOs at the previously documented lethal concentration as they mature to the successive stage. Upadhyay et al. in the same year (2018) from K.N. Govt. P.G. College, Uttar Pradesh has evaluated the bioefficacy of two other species namely *Mentha* and *Citrus* EOs against the agents which causes wheat deterioration. Though the major focus of the paper was fungus management but the control of *T. casteneum* through fumigation was also studied. The results have shown that the *Mentha* oil was more effective than the *Citrus* oil. The pest was completely checked at the concentration of 500 µl/mL and 1000 µl/mL of *Mentha* and *Citrus* oil and respectively. Moreover, the rate of seed germination was found to increase due to the control of damage causing agents. Hence, the positive effect of the EOs could be concluded.

Another work published recently Haider et al. (2017) from Department of Botany, Gorakhpur University, Gorakhpur, UP, has discussed about the insecticidal and repellent efficacy of *Tanacetum tomentosum* and *T. dolichophyllum* EOs against *T. casteneum*. The work emphasised on the *T. tomentosum* as the better plant variant than *T. dolichophyllum* in both the fumigantion and repellency bioassay. Presence of β-bisabolene as the major component of *T. tomentosum* was considered to be the reason of its insecticidal properties. Moreover, both the EOs were reported to possess grain protectant potential thus accelerates the germination rate. With increasing emphasis on active components of EOs, research interest has deviated to

analyse the efficacy of each isolates of the oil against the beetle. Such a work has been presented by Kanda et al. (2017) from Insect Biopesticide Research Centre, Jalandhar, Punjab. Kanda has checked the effect of monoterpenoids and phenylpropanoids, a common isolate of most of the EOs, against the beetle. The scientists have found that thymol, the monoterpenoids, to be most effective amongst all the treatment sets. Moreover, the synergic effect of various compounds was proven most effective in the work. In a similar work published from the Department of Zoology, University of Calicut, Kerala has evaluated the efficacy of methanol and petroleum ether extracts of *Vitex negundo* against *T. casteneum* (Haridasan et al., 2017). Results showed that the both the solvent derived EOs have significantly reduced the growth rate & food consumption of the pest with petroleum ether derived EOs being the best. Hence, scientists claimed its use as a grain protectant against various stored grains pests.

Similar work in the previous year by Jeyasankar et al. (2016), Department of Zoology, Arignar and Anna Government Arts College, Musiri, Tamil Nadu, has documented the larvicidal activities of five native plants viz. *Corymbia citriodora, Cymbopogon nardus Syzygium aromaticum, Gaultheria procumbens* and *Cymbopogon citratus* against the beetle. Though all the EOs was efficient compared to control but *C. citriodora* derived EOs was found to be the most effective with 81.86% pest mortality at the low concentration of 20µl/mL. A study carried out by Singh et al. (2016), Botany and Pharmacognosy Department, CSIR-Central Institute of Medicinal and Aromatic Plants, Lucknow, U.P., has tested four different EOs viz. *Mentha spicata, Cymbopogon citratus, Cymbopogon nardus* and *Eucalyptus hybrid* for their insecticidal properties against the flour beetle. *M. spicata* was most effective among all the EOs in the fumigant toxicity assay. The species has a history of medicinal significance which could justify the presence of potent chemical group in it. This rationalise its efficacy against the pest. Mishra et al. (2016) from Department of Zoology, Gorakhpur University, Gorakhpur has taken the work one step ahead by evaluating the enzymatic activity of the treated groups. In the study, EOs of *Syzygium aromaticum* was found efficient in controlling the beetle. Also, the AChE activity of the beetle treated with the

sub-lethal concentrations was reduced significantly compared to the control group.

In a relevant work, Haider et al. (2015) from Centre for Aromatic Plants, Dehradun, Uttarakhand, insecticidal activity of *Tanacetum nubigenum* collected from three different locations viz. TNG, TNB and TNM was evaluated for controlling *T. casteneum*. TNG was most effective in controlling the red flour beetle. Moreover, it was grain protectant too among all the three EOs of *T. nubigenum* collected from three different locations. This study presents an insight into the influence of climatic variations on the efficacy of different plant species. Nattudurai et al. (2015), Entomology Research Institute, Loyola College, Chennai, in the same year has reported the insecticidal activities of *Toddalia asiatica* eluted with different solvents viz. hexane, diethyl ether and methanol against *T. casteneum*. Diethyl ether derived EOs have drawn highest insecticidal activity compared to hexane and methanol. This study depicted the importance of solvent selection in drawing EOs and hence guides the upcoming scientists to work in the same path.

Jaya et al. (2014), Laboratory of Herbal Pesticides, Centre of Advanced Study in Botany, Banaras Hindu University, Varanasi, in her work has demonstrated the pesticidal efficacy of two more plant species namely *Ageratum conyzoides* and *Hyptis suaveolens* against the flour beetle. The EOs of *H. suaveolens* was comparatively stronger fumigant than *A. conyzoides.* Moreover, the EOs posed no negative effect on the rate of seed germination. Pant et al. (2014) from Centre for Rural Development and Technology, Indian Institute of Technology, New Delhi has worked on the interesting aspect of waste management for controlling *T. casteneum*. Pant tried to increase the efficiency of Eucalyptus oil as a pesticide by combining the aqueous filtrates of Karanja and Jatropha cakes which are left after oil extraction for biodiesel. In the study, pesticidal effect was validated through nanoemulsions containing filtrates. Results have shown the higher efficacy of nanoemulsions compared to conventional Eucalyptus oil in pest management.

Mishra et al. (2012) from Department of Zoology, M.G.P.G. College, Gorakhpur, have worked and established the bioefficacy of *Mentha arvensis*

leaves against the red flour beetle. The duo (Bhaskar & Tripathi, 2011) has also established the insecticidal properties of well-known plants namely *Aegel marmelos, Corriandrum sativum, Schyzygium aromaticum, Citrus reticulate* against the beetle. Though all the EOs was effective but highest activity was reported from *S. aromaticum*. Another study reported from the Department of Zoology, Annamalai University, Annamalainagar has demonstrated the bioefficacy of three different plants viz. *A. mexicana, P. juliflora* and *T. purpurea* against *T. casteneum* (Pugazhvendan et al., 2009). Among the three plant powders, *T. purpurea* was most effective in controlling the pest.

Another work reported in early twentieth century by Kumar et al. (2006) in the Laboratory of Herbal Pesticides, Centre of Advanced Study in Botany, Banaras Hindu University, Varanasi, has depicted the grain protective activity of *Cymbopogon martinii* by controlling the *T. casteneum*. Scientist has reported the stronger activity of the EOs than its major constituent, which is an exception. This work justifies the role of secondary metabolites in the effect of EOs. The scientists have also reported the insecticidal properties of *Aegle marmelos* EOs (Kumar et al., 2008). Upadhyay & Jaiswal (2007), Department of Zoology, Deen Dayal Upadhyay Gorakhpur University, have demonstrated the biological activity of *Piper nigrum* against the pest beetle. The EOs were equally effective in both the repellency and acute toxicity assays.

A similar work by Tripathi et al. (2002) have recoded the effect of *Curcuma Longa* leaves on the progeny production of *Tribolium casteneum*. Though the beetle was highly resistant but significant reduction in oviposition and egg-hatching capacity has been witnessed. Varma & Dubey (2001) from Department of Botany, Banaras Hindu University, Varanasi, working with the two different plant species viz. *Caesulia axillaris* and *Mentha arvensis* have reported *M. arvensis* as the better variant.

The literatures cited above have beautifully portrayed the positive correlation of EOs against the *Tribolium casteneum.* Though the figures vary in terms of percent repellency and mortality but all the EOs were effective against the pest.

2.3 Literature documented across the globe: International platform

While extending the search further, the essential oils and its work was found to hit the global platform every now and then. Moreover, a few studies have also worked on the biomolecular profiling other than the conventional testing of bioefficacy of the EOs. This could be reasoned due to the fact that *T. casteneum* is a global pest and its management studies are majorly taken up by the developed nations equipped with modern technology to find a better alternative towards the development of green revolution.

In the isolation of EOs and their effect against *T. casteneum*, China is reported to excel in the aspect. The Laboratory of Traditional Chinese Medicine Protection and Utilization, Beijing Normal University, Beijing, China, is seen to be deeply engrossed in the research of EOs which is transparent from the number of publications from the lab. A recent work has evaluated the efficacy of *Artemisia dubia* and its major compounds against the flour beetle (Liang et al., 2018). The result shows the stronger efficacy of active compounds over crude EOs in the repellency as well as acute toxicity assays.

Another species of *Artemisia, A. ordosica* native to china were analysed for their insecticidal activity (Zhang et al., 2017). The study conducted in the lab has reported that the isolated compounds i.e. capillin, capillinol, capillene, and cis-dehydromatricaria ester was efficient than the EOs. However, among the four isolates, cis-dehydromatricaria ester was highly efficient against the pest. The conclusion was majorly revolved round the correlation of insecticidal properties of the isolates with the presence of acetylenic bonds. The more the number of acetylenic bonds the more insecticidal potency would be seen. Another work conducted in the same laboratory has worked on the efficacy assessment of the isolated compounds of *Juniperus formosana* against *T. casteneum* (Guo et al., 2016). Results demonstrated the efficacy of EOs in controlling the pests. However 4-terpineol, one of the isolates, has showed strongest activity against the pest. Down the line, reports on bioactivity of EOs of *Zingiber purpureum* Rhizomes against *T. casteneum* was found during the literature search from the same lab (Wang et al., 2015).The study has

demonstrated the efficacy of active compounds over the EOs. Among the isolates viz. Sabinene, terpinen-4-ol, and γ-terpinene, terpinen-4-ol showed the strongest activity against the pest in both the repellency and fumigant bioassay. The crude EOs and Sabinene was found moderately effective whereas γ-terpinene was reported with the weakest effect. This work forms the baseline for understanding the pros of crude EOs over the isolates as all the compounds together work simultaneously in the oil. Another work from the lab (You et al., 2015) have analysed six different species of *Murraya* genus namely *M. tetramera, M. euchrestifolia, M. koenigii, M. kwangsiensis, M. exotica,* and *M. alata*. EOs of *M. tetramera* and *M. kwangsiensis* showed strong activity against the pest. This report confirms the efficacy of the genus with moderate to high insecticidal property depending on the species.

The other parts of the world are also taken over by the work of EOs. As different agricultural, pest management labs are working on the aspect of eco-friendly measure, the first interest of all is plant based EOs. While reviewing the work of Hu et al. (2019), School of Food Science and Technology, South China University of Technology, China, efficacy of *Artemisia brachyloba* EOs and its major constituents against *T. casteneum* could be recognised. The biochemical estimation has proved the reduction in the enzymatic level in the treatment groups. Authors have concluded the possibility of synergy in the effect of EOs.

In a recent survey conducted in the Department of Agriculture, Food and Environment, University of Pisa, Italy, EOs of *Pimpinella anisum* were tested against *Tribolium casteneum* (Hashem et al., 2018). The scientist have modified and made use of nanoemulsions to mediate the toxicity of EOs on the pest. Results depicted the efficacy of EOs based nanoemulsions which was confirmed by the SEM and light microscopy analysis of the progeny.

Salem et al. (2017) from Tunisia has documented the insecticidal properties of two well-known species viz. *Ricinus communis* and *Mentha pulegium* EOs against the adult beetles. *R. communis* EOs, rich in oxygenated monoterpene, was found more effective than the *M. pulegium*. Hence, oxygenated monoterpene draws interest for being the reason of insecticidal properties.

Another shade of component isolation and their potency evaluation was depicted by Lee & Lee (2016), Department of Bioenvironmental Chemistry, College of Agriculture & Life Science, Chonbuk National University, Republic of Korea. Scientists established the efficacy of 2-isopropyl-5-methylphenol, a major component of *Thymus vulgaris* flowers and its derivatives. Result depicted the stronger activity of 2-isopropylphenol over other derivatives in the order of decreasing efficacy, 4-isopropylphenol, 2-methylphenol, 3-methylphenol, and phenol. The work followed the same trend and isolates win the race due to the functional groups present in it. Lee described the possibility of methyl and isopropyl group inclusion into the phenol skeleton, which is the key for the activity.

Scientists from Zoology Department, Faculty of Science, Kafrelsheikh University, Egypt, has work on three different species of *Achillea* for insecticidal potential against *T. casteneum*. *A. santolina* showed strongest activity and affected the progeny of the animal by disrupting the normal developmental course (Nenaah, 2014). In a relevant work carried out in the Department of Biology, Kyungsung University, Republic of Korea, commercialised form of two well-known plants namely *Ocimum basilicum* and *Citrus sinensis* EOs and their active constituents were tested. Results depicted the efficiency of basil EOs over the orange against the flour beetle in acute toxicity assays (Kim & Lee, 2014).

Documentation of five different Columbian native plants as an insecticide was found recently in the literature (Olivero-Verbel et al., 2013). EOs of *Cananga odorata*, *Tagetes lucida* and *Cymbopogon citratus* was found to repel the pest strongly compared to the commercial IR3535 at the highest concentration of 5µl/gm. However, the significant finding was the *Eucalyptus citriodora* which was best even at the lowest concentration of 0.0005µl/gm. Licciardello et al. (2013) has worked on the aspect of food packaging with the three different EOs viz. citronella, oregano and rosemary. The pests were strongly repelled in the coated packages with rosemary being the strongest EOs. Another work reported from Columbia, toxicity of *Cymbopogon martinii*, *Cymbopogon flexuosus* and *Lippia origanoides* has been documented against the flour beetle (Caballero-Gallardo et al., 2012).

Liu et al. (2011) from Department of Entomology, China Agricultural University, Beijing, China has reported the chemical composition and toxicity of *Ostericum sieboldii* towards the flour beetle. The EOs possessed a wide array of chemical constituents which thought to be responsible for insecticidal properties of the plant. The scientists have also reported the insecticidal properties of *Schizonpeta multifida* EOs and its isolates against the flour beetle. Among all, Pulegone depicted strongest activity among the isolates (Liu et al., 2011).

Zapata & Smagghe (2010) from the Department of Crop Protection, Ghent University, Belgium, have reported the insecticidal potential of EOs eluted from the leaves and bark of *Laurelia sempervirens* and *Drimys winteri* against the beetle. Results documented the efficacy of EOs derived from the leaves and bark of *L. sempervirens* over *D. winteri*. Another work published in the same year has documented the insecticidal properties of *Cymbopogon citratus* over *Eucalyptus citriodora* against red flour beetle (Olivero-Verbel et al., 2010). Moreover, both the EOs were effective than the IR3535 at the same concentration range.

The body of literature reviewed has point towards the efficiency of different plants EOs against *T. casteneum*. Whether it is the report from India or Global, all the works have claimed the strong efficacy of the oils. However, the fact of *T. casteneum* being the most resistant pest cannot be denied upon. Hence, evaluation of different plant variants for better result is the need of the hour. The lacuna which was sensed during review of literature is that most of the studies unfortunately end in the preliminary level. Reports rarely extend beyond the strata of antifeedant, repellency, and insecticidal potential of EOs. This shortcoming is majorly due to the fact that majority of the reports focus on the indigenous species which is difficult to replicate in other parts of the ecosphere.

One added difficulty is the widely practiced studies on isolation of major components of the EOs which delimits the probability of different secondary metabolites working in synergy. Though studies have already established the role of secondary metabolites on the activity of active compounds still isolates

are the choice of present era. This lacuna can be addressed by giving equal weightage to all the components of the EOs which are unique to the plant instead of focusing on the major component only. One more forthcoming difficultly is the rapid resistance development towards a single component. Moreover, role of EOs in modulating biomolecular pathways is a field which is poorly understood. Hence, the literature needs to be strengthened with the studies deciphering the effect of EOs till the biomolecular pathways of treatment groups. Moreover, no works from the state has inspired me to frame a piece of work in the same trail with an environmental friendly plant variety.

"Nobody is qualified to become a statesman who is entirely ignorant of the problem of wheat."

— Socrates