INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE
ISSN: 2067-533X Volume 13, Issue 2, April-June 2022: 565-578 www.ijcs.ro

# BIOACTIVITY OF THREE INDIGENOUS MEDICINAL PLANTS (*FERULA ASAFOETIDA*, *SYZYGIUM AROMATICUM*, AND *MENTHA X PIPERITA*) AS FUMIGANTS FOR THE CONTROL OF THE SKIN AND SKIN-PRODUCT PEST (*ANTHRENUS VERBASCI*) IN MUSEUMS, LIBRARIES AND ARCHIVES

Fatma FAHEEM[1*], Abdurraheem K[1]

[1]Department of Museology, Aligarh Muslim University, Aligarh – 202002, India

***Abstract***

*Biodeterioration of cultural property is a major problem in almost all parts of the world. This paper focuses on the major biodeteriogens, the relative effects of the errant and uncontrollable environmental conditions, and the threat, vulnerability, and risk cause due to biodeterioration to the skin and skin-products most commonly found in the museum collections. The present paper was aimed to assess the investigation of three indigenous medicinal plants for their toxic and insecticidal activity against the Anthrenus verbasci, the stored product, and skin and skin-product pests. It also demonstrated a comparative study between the toxicities of three essential oils such as Ferula asafoetida, Syzygium aromaticum, and Mentha x piperita as fumigants against the larvae of Anthrenus verbasci after the 7 days of exposure under laboratory conditions (23ºC ± 5 ºC and 58% ± 6%RH). Probit analysis was done by SPSS software and then the transformed data were used to draw regression line graphs for determining LC90 values in each case of tests. The futuristic aspect of this study is to identify the active molecules from promising plant sources and evaluate them for application at the commercial level to develop environmentally friendly and human safe biopesticides with high efficiency and recyclability.*

***Keywords****: Biodeterioration; Biopesticide; Essential oil; Medicinal plant; Probit analysis; Skin and skin-product; Stored product.*

## Introduction

Museum preserves cultural and natural property of the past for future generations. The natural history collections in museum consist of astounding richness and full of immense significance. They act as an indispensable source for primary information on the diversity of life on earth, for today and for our coming next generation. The natural history collections comprise diverse fields such as botany, zoology, geology, archaeology, ethnography, anthropology, archives etc [1, 2]. Items made up of skin, wools, furs, feathers, bones, ivory, parchment membranes, as well as leather objects, books, journals, manuscript, stuffed birds, animal specimens, and dried insect collections etc., are made from natural materials especially derived from the animal skins (skin and skin-products) are some of the most versatile and durable collections found in museum [3, 4]. The natural history collections play very crucial role in disseminating knowledge regarding evolution, biodiversity, genetics, population and the environmental impacts of climate change, uses of pesticides and so on. Without proper care and control, these valuable collections of cultural heritage will be easily deteriorated [5]. The recognition of biodeterioration in the preservation and conservation of museum collections and the potential effects of pesticides on museum staff have gained prominence from the last thirty

* Corresponding author: fatmafaheem92@gmail.com

to thirty-five years. At the same time laws and regulations were also altered the landscape of pest control activities inside the museums [6-8].

Primarily, the pest control of skin and skin-products (skin, hide, leather, and fur items), and stored products, depends upon the use of gaseous synthetic fumigants and residual insecticides, both of which may possess serious hazards to warm blooded animals and the environment. Although, pesticides were used initially to benefit the human life for increasing the agricultural productivity by controlling infectious disease, but their adverse effects have overweighed the benefits associated with their use [9, 10]. The environmental problems caused due to the overuse of pesticides and other non-decomposing chemicals as well as products have been the matter of serious concern for both the scientists and public in recent years. Consequently, the use of chemical synthetic pesticides for pest management has become highly controversial. The continuous use of synthetic chemical insecticides causes, toxicity to non-target organisms, pest resistance, and environmental pollution around the world. The production of xenobiotic compounds by the application of synthetic chemicals results in the increase of human health and environmental risks, therefore the goal should be to use such compounds carefully for the least negative impact on the human and the environment [10-12]. The exposure of insects to an insecticide for long duration may develop resistance against a specific insecticide, or group of insecticides by the way of cross-resistance. A closely related phenomenon, multiple resistance may also occur in insect populations that resist two or more insecticide classes with unlike modes of action. Insects develop this type of resistance by expressing multiple-resistance mechanisms. This can happen if one insecticide is used until insects display a resistance and then another is used and the insect population becomes resistant to that one also, and so on. Multiple resistance is less common than cross-resistance but is potentially of greater concern because it drastically reduces the number of insecticides that can be used to control the insect [13, 14]. To overcome these problems, attempts were made to develop alternate methods of pest control including the use of cultural and traditional practices, biological control, anti-feedants, hormonal insecticides, plant extracts etc. Despite many synthetic chemicals are commonly used to control the propagations and multiplication of pest population and thus, certainly protecting the proteinecious objects or specimens, but simultaneously manifest many side effects as well [15, 16].

Nowadays the conservation fraternity is again turning towards traditional materials to look for the alternative to these toxic chemicals. However, now the scientific evaluation as regards their advantages and disadvantages became a part of consideration of their suitability for a particular purpose. Fumigants are the mode of action which acts or may kill the target insect by producing vapor. These insecticides produce poisonous gases when applied against insects. The vapor formed from insecticides enters the body of insects via their tracheal system through spiracles and causes death by poisoning. Some of their active ingredients are liquids when packaged under high pressure but change to gaseous when they are released. Other active ingredients are volatile liquids when enclosed in an ordinary container and are not formulated under pressure. Fumigants are used to remove stored product pests from museum, archives and libraries. In agriculture fumigants are used on very large scale to protect crops and animal products from being prone to pests. Fumigation remains a common method of stored product insect pest management in many developing countries and at present the fumigation is generally done by methyl bromide ($CH_3Br$) and phosphine ($PH_3$) [17, 18]. In preliminary fumigation trials with phosphine on baled skins, it was noted that the fumigant did not cause any noxious effect on the skins. Baled sheepskins in large containers have been successfully fumigated with methyl bromide at a dosage of $15g/m^3$ + 220g/tonne of animal skins with a 48h exposure period at 10ºC. In laboratory tests, the efficacy of insecticides such as chlorpyriphos and chlorpyriphos-methyl were compared with that of sodium arsenate treatment for the protection of sheep skins against *D. maculatus* [19]. Chlorpyriphos was found effective against the larvae of *D. maculatus* at the dosage of $49mg/m^2$ and gave proper protection to the skins even after 3 months [20]. It was revealed that the larvae were also controlled, when hides are treated by the solution containing 125mg of diflubenzuron/l of water [21, 22].

Methyl bromide has been divulged for its deleterious effect on the ozone layer and phosphine causes serious health problems in humans and also causes pesticide resistance in the target pests [23]. Stored products pests control mainly depends on fumigation by methyl bromide (CH3Br) or phosphine [24]. Due to ozone-depleting properties, application of methyl bromide is being restricted [25, 26]. Insect resistance to phosphine has been reported from many countries and using of this fumigant may become limited [27-29].

Treatment strategies from broad-based biostats in storage units to single dose fumigation had paralleled the growth of climate-controlled museum environments. Pest management inside museums was largely practiced by in-house technicians on a routine basis. It is reported that the use of the fumigant ethylene oxide ($C_2H_4O$) became widespread. It kills all stages of an insect and sterilizes mold as well [30]. Policies were casual, and procedures, somewhat haphazard, as seen in Table 1 taken from a 1980 pesticide survey of zoos and science museums [31, 32], it was reported that ethylene oxide was used by only 5% of responding institutions.

**Table 1.** Represented the percentage of responding institutions taking precautions while dealing with pesticides, after the survey of museums done in 1980

| S. No | Safety precaution Tak en | (%) | S. No | No precaution taken | (%) | S. No | Ventilation | (%) | S. No | Air quality monitoring | (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Minimize exposure | 49 | 1. | No perceived | 25 | 1. | Considered adequate | 63 | 1. | Human Senses | 84 |
| 2. | periods | 21 | 2. | hazard | 10 | 2. | Considered | 37 | 2. | Gas | 5 |
| 3. | Gloves worn | 12 | 3. | Too time- | 4 | | inadequate | | 3. | detection | 11 |
| 4. | Gas mask worn | 13 | | consuming | | | | | | None | |
| | Other | | | Not specified | | | | | | | |

Whereas, in another survey of 75 large libraries and archives showed 36% usage of ethylene oxide [33]. From 2010 to present time, another problem encountered with Smithsonian collections has been organic residual fumes of paradichlorobenzene (PDB) and of naphthalene. It was found that some staff has proven to be more sensitive to these fumes than the threshold limiting value (TLV) or the perceptible odor minimum would indicate [34-38].

Eventually, Integrated Pest Management stressed towards the use of non-chemical and natural products or chemicals methods, rather use of conventional synthetic chemical methods, as a primary defense against insect damage. The broad-spectrum insecticides like organophosphates, cyclodienes, and carbamates are being canceled due to their negative impacts on human, environment and as well as the valuable museum collections. There is an utmost need of creating awareness of the existing traditional conservation practices in India. Hence, scientists, conservators and collection managers have to consider the integration and incorporation of traditional wisdom and scientific information of the materials and methods into the development of conservation strategies [39-41]. It has been reported that phytochemicals are naturally occurring bioactive compounds that lead to low toxicity to mammals, biodegradability and high volatility of essential oils posses these compounds as alternatives to conventional fumigants [42]. Plant-derived products found effective against pests and diseases of spices and condiments have not been adequately tested in medicinal plants in India. There are no apparent environmental hazards through pollution of plant products in water and air. In soil, residue of plant products degrades and mobility is fast and residual toxicity is negligible. Some plant products have systemic action, but no ill effects were found from consumption of treated plants.

The objective of this study was to evaluate the performance of three botanicals as fumigants, against the larval stage in the life cycle of one recognized pest (*Anthrenus verbasci*) of skin and skin-product collections under the conditions of practical usage. It can be demonstrated if such chemicals are found effective against the pest selected, then it is proposed that such information could be used to provide reference guidelines on its application rates, exposure periods required, and effectiveness of these chemical treatments, specifically for infested material requiring fumigation in the museums, libraries, and archives environment [43].

While doing this research, a survey of several museums was also conducted pertaining to the prevention and control of biodeterioration for skin and skin-products collections including, National Museum of Natural History (New Delhi) and National Museum (New Delhi), State Museum (Lucknow), Departmental Museum of Zoology (AMU, Aligarh) and Musa Dakri Museum (AMU, Aligarh) in 2019, shown in below Table 2.

**Table 2.** Represented the sample of questionnaire used for the survey of different museums in order to collect information related to pest control and management adopted in museums and the feedback of the respondents shown in percentile

| Questions | The respondent feedbacks (%) |
|---|---|
| Is there any animal origin collection present in your museum? | 100.0 |
| Does the pest problem persist in your museum collection? | 100.0 |
| Are there any evidence of damage and debris caused by insect in your animal originated collections? | 100.0 |
| Are you satisfied with your cleaning management of museums? | 50.0 |
| Which of the following insect problem do you have in your museum and their collections? | |
| a) Cockroaches | 75.0 |
| b) Moths | 25.0 |
| c) Dermestid beetles | 100.0 |
| d) Termites | 100.0 |
| e) Common ants | 75.0 |
| f) Silver Fish | 50.0 |
| g) Others | 25.0 |
| 6. If there is any specimen infested, what is the duration of infestation? | |
| a) Few Weeks | 25.0 |
| b) Few Months | 50.0 |
| c) 1 year | 25.0 |
| d) More than a year | 25.0 |
| 7. Is there any climate control of your museum is maintained regularly? | 25.0 |
| 8. Which types of treatment are you using in your museum to control insects? | |
| a) Mechanical and Physical Control | 50.0% |
| b) Traditional and Cultural Control | 0.0% |
| c) Synthetic Chemical Control | 100.0% |
| d) Natural herbal control | 50.0% |
| e) Non-Chemical Control | 50.0% |
| 9. Are the chemicals used in your museums is toxic to staff and visitors? | 75.0% |
| 10. Will you be interested to incorporate herbal pesticides in your museum as control methods in future? | 100.0% |

It was observed that the problem of pest (insect) particularly in skin and skin-product collections causes due to dermestid beetles in their museums and the control methods they used were mainly synthetic in nature, which is extremely being toxic to their staff and visitors as well. In the survey it was also seen that the Museum stewards were interested to prefer indigenous and herbal pesticides for insect control over synthetic chemical control in the future.

## Experimental part

### *Materials*

Following materials and methods were used in this study and described as follows.

*Collection of insect pest*

The initial source of beetle culture was infested "Bull horn", which was collected from the Natural History collections of Musa Dakri Museum of the Aligarh Muslim University, India. The infested bull horn was kept in a rearing box covered with a muslin cloth, which is shown below by figure 1.

*Identification of test organism*

The rearing beetles were found to be the species of *Anthrenus verbasci*. It was identified based on the morphological characters in the entomology section of the Zoology Department, Aligarh Muslim University, India. The following figure 2 is demonstrating the dorsal and ventral view of an adult *Anthrenus verbasci* and dorsal view of its larva.

**Fig. 1.** Represent the severe infestation done by dermestid beetles in a bull horn

**Fig. 2.** Represent the dorsal; and ventral views of an adult *Anthrenus verbasci*, and dorsal view of its larva

*Rearing of insect culture*

During April 2014, the identified beetle along with the infested bull horn was kept in a rearing box covered with muslin cloths in the dark storage area. The culture of insects was carried out in the rearing box (48x27x34) to obtain a homogeneous and sufficient population of *Anthrenus verbasci* larvae for various biological tests.

*Collection of test botanicals*

Different essential oils and herbs were purchased from an herbal pharmacy in Aligarh. Each botanical was kept in proper air tighter glass container and placed in a cooled place for applying in the experiments.

***Methods***

*Characterization of botanicals*

The botanicals which have been used in the present study were first characterized through FTIR (Fourier Transform Infrared Spectroscopy) spectra. FTIR study analyzes the

chemical structure, the present group, and the existence of hydrogen or covalent bonding between the phases. This was done by "Interspec-2020, FTIR spectrometer" spectrolab-UK.

*Bioassay for fumigation toxicity (FT) test*

The bioassay test for the fumigation toxicity was determined by conducting a pilot study. Initially, a pilot study was done for range finding tests to determine the concentration and variation range of each botanical which is to be used for the bioassay test. This was done by applying randomly four nominal concentrations in each case of botanicals against larvae of *Anthrenus verbasci*. The contents of the setup were observed after a period of 7 days to establish total and zero mortality range in each case of botanicals. Finally, four different concentrations between the total and zero mortality range were revealed in every case of botanicals and were chosen for the bioassay test. Series of five experiments were conducted to evaluate the fumigant toxicity of seven botanicals against larvae of *Anthrenus verbasci*. In this case, three experiments were done with a single botanical and the next two experiments were done with four botanicals in two sets for identifying their synergistic or combinatorial effect. From the pilot study conducted, the selection of different formulations and variations were determined. Firstly, the concentrated essential oils or the extract so were diluted with distilled water to make the different required concentrations of (v/v) solutions. With the help of a micropipette, the quantity of formulation was measured and stored in different three test tubes. Then three different formulations were taken in 3 jars (15cm×8cm×5cm) A, B, and C respectively with some feathers in them for feeding larvae. Each jars containing ten larvae of *Anthrenus verbasci* inside it. Later those jars were kept in a fumigation chamber of dimension (34.5cm×29.5cm×29.0cm). The contents of the jars were examined after a period of 7 days to assess the level of larval mortality. The entire experimental setup and the controls were arranged in a laboratory with temperature fluctuating between 23±5ºC and 58±6% RH in a Completely Randomized Design (CRD). Each experiment, in this case, was repeated 3 times with the same concentration of the intoxicant exposed for the same duration of time.

## Results and discussion

The toxic and insecticidal effects of different botanicals as fumigants may rely on their chemical composition and the level of insect sensitivity. Therefore, the botanicals are first characterized by FTIR analysis for evaluating their important bioactive constituents. The FTIR analysis of asafoetida essential oil is shown in the figure 3**.**

The IR band in region 3287cm$^{-1}$ is corresponding to O–H vibration of polysaccharide or associated water molecule. The band in 2924cm$^{-1}$ region indicates the C–H stretching vibration. The band at 1598.1cm$^{-1}$ is due to asymmetrical stretching of carboxylate groups of uronic acid residue. Moreover, the band observed in area 820 to 400cm$^{-1}$ was due to symmetrical and asymmetrical ring breathing vibration (C–C–O and C–O–C). The wave number at 1030.51cm$^{-1}$ arose from the C–C function of carbohydrate. The bands lying from 1490 to 1200cm$^{-1}$ can be ascribed to amide III functional groups suggesting the presence of protein in its structure.

The next characterization of *Syzygium aromaticum* essential oil was done through FTIR analysis, which is clearly indicated in the below figure 4.

The peak in the graph is nearly 3400-2800cm$^{-1}$ represents OH group vibrations, the peak around 1600-1500cm$^{-1}$ shows C-H finger printing and C-C stretching vibrations respectively. While peaks nearly 1400-1200cm$^{-1}$ shows C=H bending vibrations of the present organic compounds.

The third and the last examination of *Mentha x piperita* essential oil was also done with FTIR spectrometer, which is clearly shown in the following figure 5.

The peak in the graph shows the absorption band or frequency nearly 3000-3300 cm$^{-1}$ ascribed the presence O-H stretching vibrations of alcohol, phenol and methyl group bonded compounds. The peak nearly 2800-3000 cm$^{-1}$ indicate the C-H stretching vibrations of alkane. The absorbance band at 1500-1600 cm$^{-1}$ revealed the presence of C=O bond aldehyde group in compound. The strong absorption bands nearly 600-1000 cm$^{-1}$ indicated the presence of aromatic C=C bond.

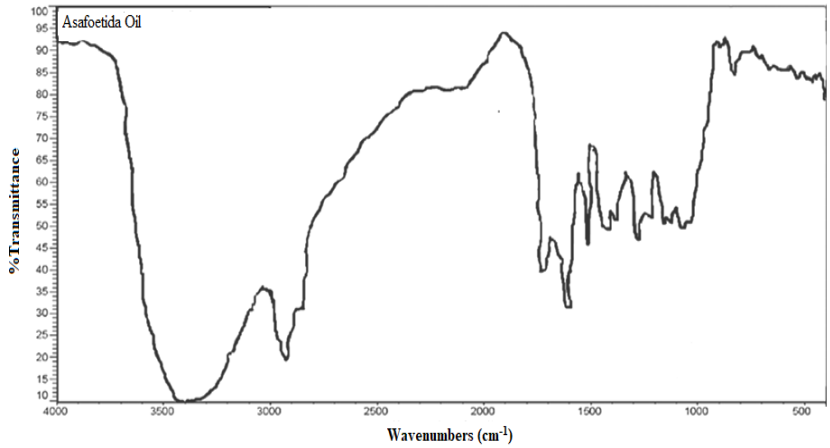


**Fig. 3.** Represents the FTIR spectra of *Ferula asafoetida* essential oil

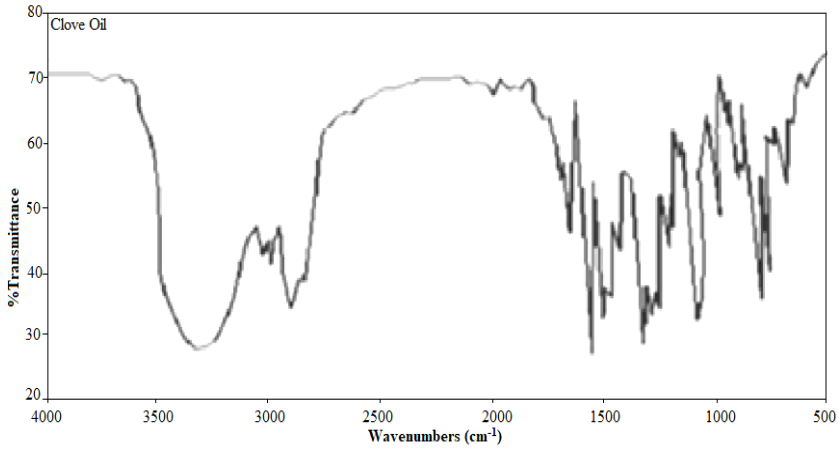


**Fig. 4.** Represents the FTIR spectra of *Syzygium aromaticum* essential oil

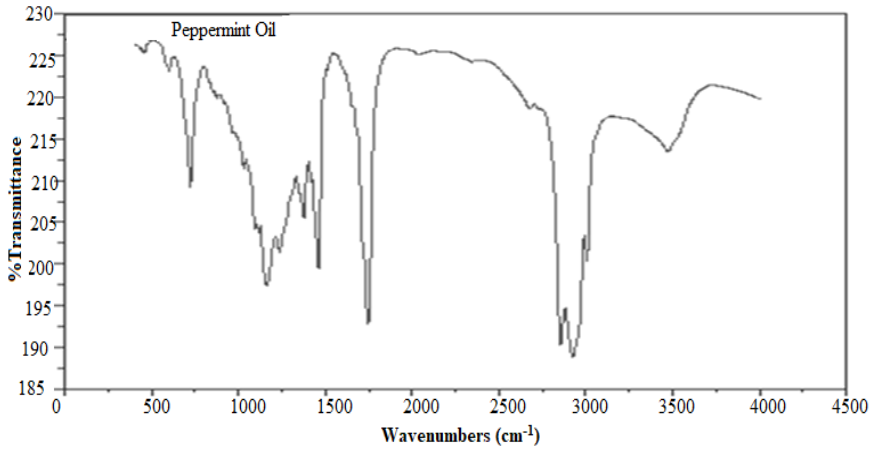


**Fig. 5.** Represents the FTIR spectra *of Mentha x piperita* essential oil

The results of experiments through fumigation mechanism reveal that the toxic efficacy of different botanicals at different formulation was assessed by the mortality percent counts of the larvae during the given specific exposure of periods. In case of essential oils of *Mentha x piperita* (peppermint) and *Syzygium aromaticum* (clove) fumigation mechanism were evident to be more effective comparatively to *Ferula asafoetida* essential oil. The data of mortality rate is shown below in Table 3.

**Table 3.** Represents mortality percent (X %) against *Anthrenus verbasci* larvae at the interval of 7 days exposure at three different concentrations through fumigation toxicity (FT) by *Ferula asafoetida* (asafoetida), *Syzygium aromaticum* (clove) and *Mentha x piperita* (peppermint) essential oils

| Treatment (concentrations of essential oils, mL /cm$^3$) | Total no. of larvae | Mortality percent (X%) against *Anthrenus verbasci* larvae at 7 days of intervals through fumigation toxicity | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 | Day 7 |
| ***Ferula asafoetida*** | | | | | | | | |
| 0.5 | 20 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.0 | 20 | 0.0 | 0.0 | 0.0 | 10.0 | 20.0 | 30.0 | 30.0 |
| 2.0 | 20 | 0.0 | 0.0 | 10.0 | 20.0 | 30.0 | 50.0 | 50.0 |
| ***Syzygium aromaticum*** | | | | | | | | |
| 0.5 | 20 | 0.0 | 0.0 | 0.0 | 10.0 | 10.0 | 10.0 | 20.0 |
| 1.0 | 20 | 0.0 | 10.0 | 20.0 | 30.0 | 30.0 | 40.0 | 50.0 |
| 2.0 | 20 | 0.0 | 10.0 | 20.0 | 40.0 | 60.0 | 70.0 | 80.0 |
| ***Mentha x piperita*** | | | | | | | | |
| 0.5 | 20 | 0.0 | 10.0 | 10.0 | 10.0 | 10.0 | 20.0 | 30.0 |
| 1.0 | 20 | 0.0 | 10.0 | 20.0 | 30.0 | 50.0 | 60.0 | 80.0 |
| 2.0 | 20 | 0.0 | 10.0 | 30.0 | 50.0 | 60.0 | 80.0 | 90.0 |

While the percent of mortality through fumigation mechanism is shown in the line graphs, which are also clearly indicated by following figures 6-8. In case of treatment with *S. aromaticum* oil, 50-80% mortality rate was revealed at dose of 1.0-2.0mL/cm$^3$ against larvae of *Anthrenus verbasci* after 7 days of exposure.

The lowest mortality percent was observed in case of *F. asafoetida* (hing) essential oil. It was recorded that the mortality percent with F. asafoetida (hing) essential oil against larvae of *Anthrenus verbasci* was 30-50% at dose of 1.0-2.0mL/cm$^3$ after 7 days of exposure. The highest mortality rate was observed in case of *Mentha x piperita* (peppermint) essential oil through fumigation mechanism against larvae of *Anthrenus verbasci* after 7 days of exposure. It was observed that 80-90 % mortality rate was achieved on treatment with dose of 1.0-2.0mL/cm$^3$ of conc. against larvae *Anthrenus verbasci*.

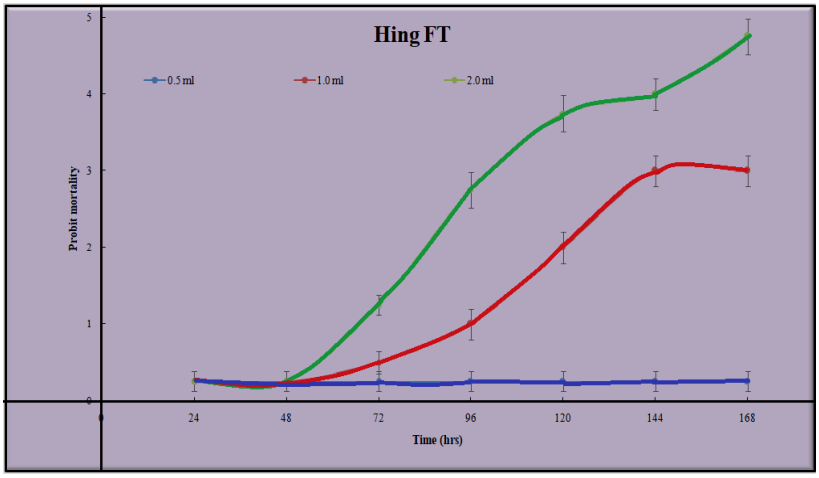


**Fig. 6.** Represents the percent mortality in case of fumigation toxicity with *Ferula asafoetida* (asafoetida, hing) essential oil against *Anthrenus verbasci* (larvae) after 7days of treatment

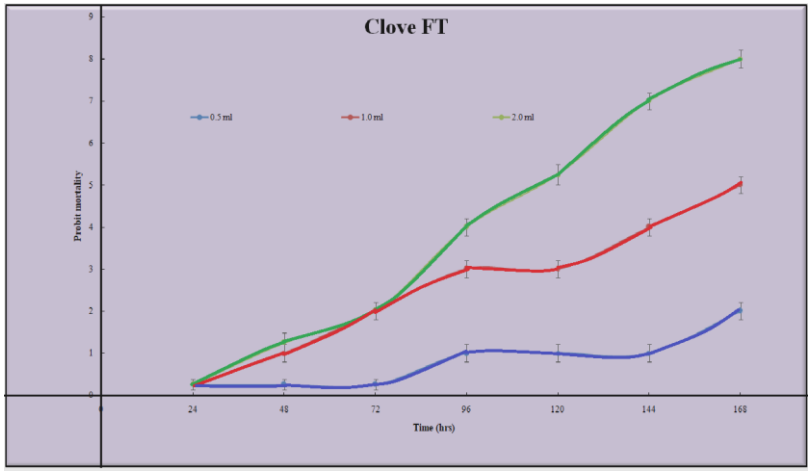


**Fig. 7.** Represents the percent mortality in case of fumigation toxicity with *Syzygium aromaticum* (clove) essential oil against *Anthrenus verbasci* (larvae) after 7days of treatment

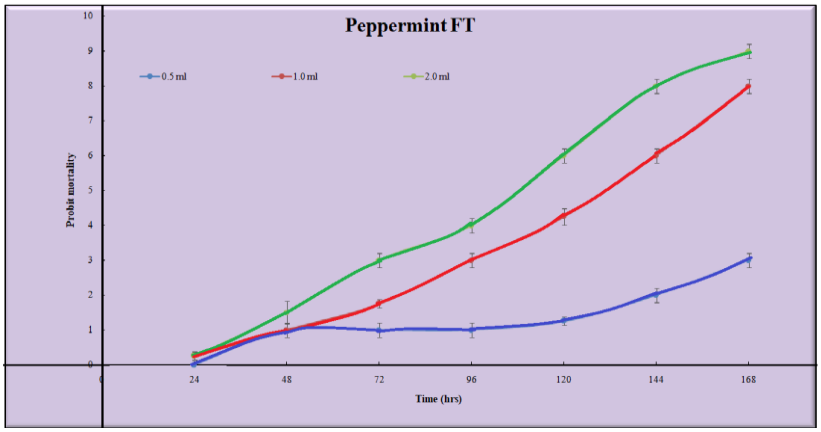


**Fig. 8.** Represents the percent mortality in case of fumigation toxicity with *Mentha x piperita* (peppermint) essential oil against *Anthrenus verbasci* (larvae) after 7days of treatment

Further, the mortality data were corrected by using the given below Abbott's formula:

***Corrected mortality (%) = [1- ((n in T after treatment)/(n in Co after treatment))]×100***

where: n = insect population, T = treated and Co = control.

Thus, the obtained data of fumigation toxicity were first subjected to probit analysis using SPSS software and then later the transformed data were used to draw regression line graphs. The output of the probit analysis is used to comprehend the LC90 by comparing the amount of the chemical required to create the same response in each of the various chemicals. The LC90 represents the lethal concentration (LC90) at which 90% of the population responds. The values of chi square, regression coefficient, LC90, fiducial limits and regression equation of each botanical for obtaining 90% mortality of larvae *Anthrenus verbasci* at 7 days of fumigants exposure are given below in Table 4. This can be also seen in the given figures 9-11.

In the case of F. asafoetida essential oil, the required lethal concentration (LC90) for killing the 90% of the population of larvae of *Anthrenus verbasci* was 3.35mL/cm$^3$, which was comparatively higher dose than other essential oils. Furthermore, the other values were, such as $\chi 2$ value is 8.83, $R^2$ value is 0.796, upper and lower fiducial limits are 5.16 and 2.67, and y is

0.282x + 0.414. Probit analysis done in case of essential oil *Mentha x piperita*, the LC90 value revealed was 1.76 ml/cm$^3$. Whereas $\chi 2$ value is 12.71, $R^2$ value is 0.671, upper and lower fiducial limits are 1.48 and 2.35, and y is 0.188x-0.086. Lastly, in case of *S. aromaticum* essential oil, the LC90 value was obtained at 2.34 ml/cm$^3$, which was slightly more than *Mentha x piperita* LC90 value but found less than *F. asafoetida* LC90 value.

**Table 4.** Represents values of x2, R2, LC 90 in case of fumigation toxicity through different botanicals for control of larvae of *Antrenus verbasci* at particular given period of exposure

| Insecticide mode of action | Name of botanicals (essential oils) | $x^2$ | $R^2$ | LC90 (ml/cm$^3$) | Fiducial Limits upper | lower | Regression equation(y) |
|---|---|---|---|---|---|---|---|
| Fumigation Toxicity (FT) | *Ferula asafoetida* | 8.83 | 0.796 | 3.35 | 5.16 | 2.67 | 0.282x + 0.414 |
| | *Syzygium aromaticum* | 4.42 | 0.890 | 2.34 | 3.13 | 1.95 | 0.230x + 0.012 |
| | *Mentha x piperita* | 12.71 | 0.671 | 1.76 | 1.48 | 2.35 | 0.188x - 0.086 |

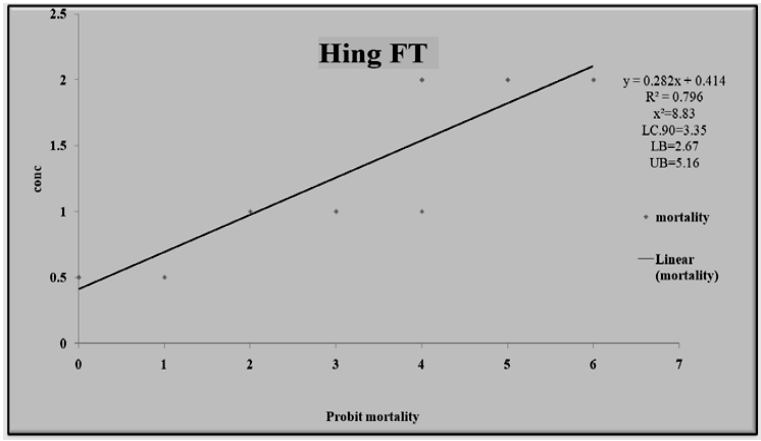


**Fig. 9.** Represent the Regression-line graph between Conc. and Probit mortality through fumigation toxicity with *Ferula asafoetida* (asafoetida/hing) essential oil against the larva of *Anthrenus verbasci* after 7 days of treatment

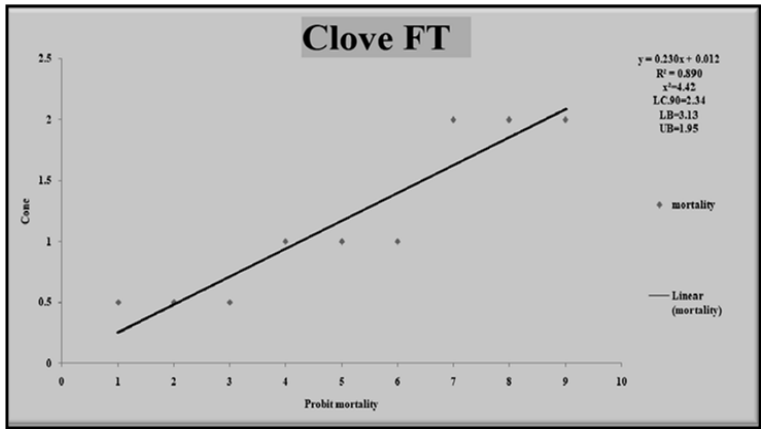


**Fig. 10.** Represent the Regression-line graph between Conc. and Probit mortality through fumigation toxicity with *Syzygium aromaticum* (clove) essential oil against the larvae of *Anthrenus verbasci* after 7 days of treatment

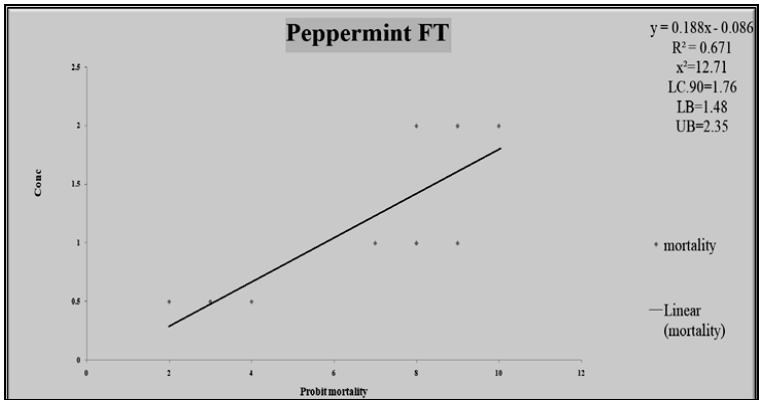


**Fig. 11.** Represent the Regression-line graph between Conc. and Probit mortality through fumigation toxicity with *Mentha x piperita* (peppermint) essential oil against the larvae of *Anthrenus verbasci* after 7 days of treatment

The other values of probit analysis were seen to be such as, $\chi 2$ is 4.42, $R^2$ is 0.890, upper and lower fiducial limits are 3.13 and 1.95, and y is 0.230x + 0.012. The inference of this study represents the relative effects of the three indigenous medicinal plant essential oils, as it is evident that *Mentha x piperita* proved to be the most toxic and effective fumigant against the larvae of *A. verbasci* followed by *S. aromaticum* and *F. asafoetida.*

## Conclusions

The aim of this study was to evaluate the toxic potency of three locally found botanicals, against the larval stage in the life cycle of *Anthrenus verbasci*, which is recognized as a major insect pest of the stored product and the skin and skin-product collections particularly found in museum, libraries and archives, under the conditions of practical usage. From above results of probit analysis, it becomes evident that the botanical fumigants were found much effective against the pests selected. The fumigation toxicity of peppermint essential oil was found to be the most efficacious against larvae of *Anthrenus verbasci* after 7 days of time exposure. The required lethal concentration dose (LC90) for killing 90% of population of insect pest was observed at 1.76mL/cm$^3$. Henceforth, it can be proposed that such information could be used to provide as reference guidelines on its application rates, exposure periods that would be required in the museum environment specifically based on fumigant mode of action with indigenous herbal and medicinal plant oils and extracts.

An additional aim of surveying conditions in a sample of museums and their collections has been also fulfilled in this study, showing that the most common and in most cases, severe damaging biodeteriogens in museums found were dermestid beetles, moths, termites, mold, silver fishes, cockroaches, rodents, birds and bats, etc. However, the list of important biodeteriogens is quite massive, but still, no proper actions are taken in museums to control or prevent the destruction they cause. According to the survey, the response received was 100% infestation was found in the skin and skin-product collections, invaded by dermestid beetles (*Dermestidae*) in museums. 100% respondents have also agreed to integrate natural chemical control methods in their museum's integrated pest management (IPM) plan on the basis of its efficacy, and availability in the future.

The futuristic aspect of this study is to identify the active molecules from promising plant sources and evaluate them for application at the commercial level to develop environmentally friendly and human safe biopesticides with high efficiency and recyclability. The effective constituents of the herbal pesticides can be separated by infra-red spectroscopy so that the high concentrated compounds can be easily extracted and used in controlling the pest problems. In addition, it is also suggested that there is a massive requirement to re-assess the

validity of traditional material and methods for insect pest control with the adaptation of nanotechnology by exploring the potential of ingenious bionanomaterials in insect pest management of museums, libraries and archives. Therefore, it is recommended that, there is an utmost need for professionals to reintroduce the indigenous methods of pest control and to integrate those traditional methods and materials into development of conservation strategies. Wherefore, it necessitates for the integration of traditional and natural methods and materials for controlling pests in the strategies of Integrated Pest Management (IPM) of museums for the safety of human being, their environment and as well as for the museum valuable collections.

**Acknowledgments**

The author is gratefully acknowledged to Prof. Abduraheem K, Chairman Department of Museology, Aligarh Muslim University, Aligarh, India for providing necessary research facilities like samples, reagents, analysis chamber instruments, glass wares etc. We are also thankful to University Grant Commission (UGC) for providing the financial assistance to complete my research work.

**References**

[1] S. Kaewklom, J. Euanorasetr, B. Intra, W. Panbangred, R. Aunpad, *Antimicrobial activities of novel peptides derived from defensin genes of Brassica hybrid CV Pule*, **International Journal of Peptide Research and Therapeutics**, **22**(1) 2016, pp. 93-100. DOI10.1007/s10989-015-9488-2.

[2] H. Wiegand, *Finney D.J.: Probit analysis. 3. Aufl. Cambridge University Press, Cambridge 1971. XV, 333 S., 41 Rechenbeispiele, 20 Diagr., 8 Tab., 231 Lit., L 5.80*. **Biometrische Zeitschrift, 14**(1), 1972, pp. 72-72. https://doi.org/10.1002/bimj.19720140111.

[3] W.S. Abbott, *Abbotts Formula - A method of computing the effectiveness of an insecticide*, **Journal of the American Mosquito Control Association, 3**(2), 1987, pp. 302-302.

[4] M.A. Ashraf, M.J. Maah, I. Yusoff, *Soil contamination, risk assessment and remediation*, **Environmental Risk Assessment of Soil Contamination**, **25**, 2014, pp. 3-56.

[5] R. Gahukar, *Evaluation of plant-derived products against pests and diseases of medicinal plants: A review*, **Crop Protection, 42**, 2012, pp. 202-209.

[6] E. Shaaya, M. Kostjukovski, J. Eilberg, C. Sukprakarn, *Plant oils as fumigants and contact insecticides for the control of stored-product insects*, **Journal of Stored Products**

[7] F. Faheem, K. Abduraheem, *Management of pests risks in museums: A review*, **International Journal of Advanced Research in Biological Sciences, 6**(9), 2019, pp. 122-136. DOI: http://dx.doi.org/10.22192/ijarbs.2019.06.09.016.

[8] H.D. Burgess, N.E. Binnie, *The development of a research approach to the scientific study of cellulosic and ligneous materials*, **Journal of the American Institute for Conservation**, **29**(2), 1990, pp. 133-152.

[9] M.T. Baker, , et al. *Laboratory investigation of the fumigant Vikane®*, **ICOM Committee for Conservation, 9th Triennial Meeting, Dresden, German Democratic Republic, 26-31 August 1990**, Preprints, 1990.

[10] O. Madden, R. Hodgkins, S. Heald**, Substituting SPME for noses in the detection and quantification of mothball vapors from textiles in the National Museum of the American Indian collection**. 2014.

[11] R.J. Koestler, E. Parreira, E.D. Santoro, P. Noble, *Visual effects of selected biocides on easel painting materials*, **Studies in Conservation, 38**(4), 1993, pp. 265-273.

[12] M.W. Ballard, R.J. Koestler, **Thirty Years of Pest Control in Museums: Policy & Practice.** 2014.

[13] M.K. Nayak, G.J. Daglish, T.W. Phillips, P.R. Ebert, *Resistance to the fumigant phosphine and its management in insect pests of stored products: a global perspective*, **Annual**

**Review of Entomology, 65,** 2020, pp. 333-350. DOI: 10.1146/annurev-ento-011019-025047.
[14] S. Rajendran, *Insect resistance to phosphine- challenges and strategies*, **International Pest Control, 43**, 2001, pp. 118-123.
[15] S. Rajendran, *Phosphine Resistance in Stored Grain Insect Pests in India,* **Proceedings of vtke 7th International Working Conference on Stored Product Protection**,14-19 octomber, 1998, Bejing, R.P. China (Editors: J. Zuxum, L. Quan, L. Yongsheng, T. Xianchang, G. Lianghua), Sichuan Publishing House of Science and Techology, Chengdu, Sicuan Province, R.P. China. 1999.
[16] * * *, MBTOC, *Assessment of Alternatives to Methyl Bromide*, **Report of the Methyl Bromide Technical Options Committee**. UNEP, Nairobi (H. Nuyten, Personal communication, Breda. Prospect 1997. Methyl Bromide Background Report), 1999.
[17] J.H. Butler, J.M. Rodriguez, *Methyl bromide in the atmosphere*. **The Methyl Bromide Issue**, Vol. I. (Editors: C.H. Bell, N.C. Price and B. Chakrabarti), John Wiley & Sons, Chichester, UK, 1996, pp. 27-90.
[18] B. Subramanyam, D.W. Hagstrum, **Alternatives to Pesticides in Stored-Product IPM,** Springer Science & Business Media, 2012.
[19] W. Thomas, *Methyl bromide: effective pest management tool and environmental threat*, **Journal of Nematology, 28**(4S), 1996, Article Number: 586.
[20] D.J. Webley, W.A. Airey, *A laboratory evaluation of the effectiveness of diflubenzuron against Dermestes maculatus De Geer and other storage insect pests*, **Pesticide Science, 13**(6) 1982, pp. 595-601.
[21] S. Rajendran, K.H. Parveen, *Insect infestation in stored animal products*, **Journal of Stored Products Research, 41**(1), 2005, pp. 1-30.
[22] M. MacQuillan, E. Shipp, *Evaluation of chlorpyrifos and chlorpyrifos-methyl for control of Dermestes maculatus Deg. (Coleoptera: Dermestidae) on sheepskins*. **Journal of Stored Products Research**, **12**(2), 1976, pp. 93-96.
[23] H. Wainman, B. Chakrabarti, M.A. Woodward, *Control of insects in baled skins by fumigation with methyl bromide and phosphine*, **International Pest Control,** 1980, pp. 28-33.
[24] I.C. Yadav, N.L. Devi, *Pesticides classification and its impact on human and environment*, **Environmental Science and Engineering, 6,** 2017, pp. 140-158.
[25] V. Salgado, **BASF Insecticide Mode of Action Technical Training Manual.** 2013.
[26] S. Hill, *Cultural methods of pest, primarily insect, control*, **Proceedings of the Annual Meeting of the Canadian Pest Management Society.** 1990.
[27] N.E. El-Wakeil, *Retracted article: botanical pesticides and their mode of action*, **Gesunde Pflanzen, 65**(4), 2013, pp. 125-149.
[28] A. McCaffery, R. Nauen, *The insecticide resistance action committee (IRAC): public responsibility and enlightened industrial self-interest*, **Outlooks on Pest Management**, **17**(1), 2006, pp. 11-14.
[29] W. Buhler, *Pesticidal Insecticidal Stewardship*, **The Fifth Annual National Pesticide Safety Education**, Month – February 2022.
[30] M.F.F. Bernardes, M. Pazin, L.C. Pereira, D. Junqueira Dorta, *Impact of pesticides on environmental and human health*, **Toxicology Studies - Cells, Drugs and Environment** (Editors: A.C. Andreazza and G. Scolao)**,** 2015, pp. 195-233. DOI: 10.5772/59710.
[31] I. Mahmood, S. Ruqia Imadi, K. Shazadi, A. Gul, K. Rehman Hakeem, **Effects of Pesticides on Environment, in Plant, Soil and Microbes,** Springer, 2016, pp. 253-269.
[32] A. Özkara, D. Akyıl, M. Konuk, **Pesticides, Environmental Pollution, and Health**, IntechOpen, 2016.
[33] V.I. Lushchak, T.M. Matviishyn, V.V. Husak, J.M. Storey, K.B. Storey, *Pesticide toxicity: a mechanistic approach*, **EXCLI Journal**, **17**, 2018, pp. 1101-1136.
[34] * * *, **Conserving Biodiversity: A Research Agenda for Development Agencies,** National Research Council, The National Academies Press, Washington, DC, 1992. https://doi.org/10.17226/1925.

[35] D. Timofte, B. Ciuntu, D. Bulgaru Iliescu, R. Hainarosie, A. Pantea Stoian, V. Mocanu, *Laparoscopic Sleeve Gastrectomy is Associated with Reduced Depressive Symptoms: One-Year Follow-Up Study*, **Revista de Cercetare si Interventie Sociala**, **61**, 2018, pp. 147-154.
[36] D. Timofte, L. Ochiuz, M. Ursaru, B. Ciuntu, L. Ionescu, V. Calu, V. Mocanu, I.C. Puia, *Biochemical Modifications Related to Calcium Deficiencies in Obesity and after Laparoscopic Sleeve Gastrectomy*, **Revista de Chimie**, **68**(10), 2017, pp. 2341-2345.
[37] D. Timofte, L. Ochiuz, M. Ursaru, B. Ciuntu, I. Hristov, I.C. Puia, V. Calu, V. Mocanu, *The Biochemical Effect of Laparoscopic Sleeve Gastrectomy on Serum Magnesium Levels*, **Revista de Chimie, 68**(9), 2017, pp. 1997-2001.
[38] S. Ungurianu, F. Dimofte, R.D. Negru, D.C. Cojocaru, F. Popa, D. Vintila, B.M. Ciuntu, *Aggressive Giant Cell Tumors. A Clinical Case*, **International Journal of Medical Dentistry, 22**(1), 2018, pp. 30-34.
[39] F.T. Bakker, A. Antonelli, J. Clarke, J.A. Cook, S.V. Edwards, P.G.P. Ericson, S. Faurby, N. Ferrand, M. Gelang, R.G. Gillespie, M. Irestedt, K. Lundin, E. Larsson, P. Matos-Maravi, J. Muller, T. von Proschwitz, G.K. Roderick, A. Schliep, N. Wahlberg, J. Wiedenhoeft, M. Kallersjo, *The Global Museum: natural history collections and the future of evolutionary science and public education*, **Peer J, 8,** 2020. Article Number: e8225. DOI10.7717/peerj.8225.
[40] F. Faheem, K. Abduraheem, *Repellent activity of Nigella sativa, Syzygium aromaticum and Azadirachta indica essential oils against the skin and skin product pest (Anthrenus verbasci) in Museums*, **Journal of Innovations in Pharmaceutical and Biological Sciences**, 6(4), 2019, pp. 57-69.
[41] M. Kite, R. Thomson, **Conservation of leather and related materials**, Routledge, 2006.
[42] F. Faheem, K. Abduraheem, *Toxic effect of myristica fragrans essential oil against the museum pest anthrenus verbasci (coleoptera: dermestidae) to control biodeterioration of animal collections*, **Journal of Bio Innovationa, 8**(5), 2019, pp. 554-571.
[43] K. Winker, *Natural history museums in a postbiodiversity era*, **BioScience, 54**(5), 2004, pp. 455-459.

*Received: April 1, 2021*
*Accepted: April 20, 2022*