UV-Visible Spectroscopic Analysis of Curcuma Longa and Mentha Spicata Powders for the Management of the Callosobruchus Maculatus (Chrysomelidae: Coleoptera) on the Pigeon Pea Cajanus Cajan

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ABSTRACT

Stored grain losses caused by Callosobruchus maculatus in pigeon pea are a major challenge to food security and seed quality. The widespread use of synthetic insecticides has raised concerns about insect resistance, environmental contamination, and human health risks, creating a need for eco-friendly alternatives. This study evaluated the phytochemical characteristics of turmeric (Curcuma longa L.) and mint (Mentha spicata) powders using UV-Visible (UV-Vis) spectroscopy and assessed their potential as botanical protectants against C. maculatus in stored grains. UV-Vis analysis revealed characteristic absorption peaks corresponding to curcuminoids in turmeric and phenolic compounds, flavonoids, and other secondary metabolites in mint. These bioactive compounds are recognized for their insecticidal, repellent, antioxidant, and antimicrobial properties. The results indicated that both plant powders contain phytochemicals capable of reducing the survival and reproductive performance of C. maculatus. Compounds such as curcumin, turmerones, menthol, menthone, flavonoids, and phenolics likely contributed to insect control through repellency, feeding deterrence, oviposition inhibition, and toxicity. The UV-Vis spectral profiles confirmed the presence of these biologically active constituents, supporting their effectiveness in stored-grain protection. The study demonstrates that turmeric and mint powders are promising, environmentally friendly alternatives to synthetic insecticides for managing pulse beetle infestations and reducing post-harvest losses. Further studies on compound isolation, quantitative phytochemical analysis, and field-scale validation are recommended to optimize their use in integrated stored-product pest management.

Keywords: Curcuma longa, Mentha spicata, UV-Visible spectroscopy, Callosobruchus maculatus, pigeon pea, botanical insecticides, stored grains, post-harvest protection.

INTRODUCTION

Callosobruchus spp., commonly known as pulse beetles or seed beetles, are among the most destructive insect pests of stored pulses and legumes worldwide. They belong to the family Chrysomelidae (subfamily Bruchinae) under the order Coleoptera. Important species include Callosobruchus chinensis, Callosobruchus maculatus and Callosobruchus analis, which infest stored grains such as green gram, black gram, chickpea, cowpea, pigeon pea, and lentils. The life cycle of Callosobruchus is rapid, typically lasting 3-5 weeks under warm and humid storage conditions, allowing several generations to develop during storage. Heavy infestations result in significant quantitative and qualitative losses, including reduced grain weight, decreased seed viability and germination, lower nutritional value and reduced market quality. Because of their widespread distribution, rapid reproduction, and severe economic impact, Callosobruchus species remain one of the most important pests of stored pulses, making their effective management essential for reducing post-harvest losses and ensuring food security, (Credland and Dendy, 1992; Southgate, 1979).

Turmeric (Curcuma longa L.) is a widely used medicinal and culinary plant belonging to the family Zingiberaceae. It contains several biologically active compounds, collectively known as curcuminoids, with curcumin being the principal component responsible for its characteristic yellow color and many of its biological activities. In addition to curcuminoids, turmeric contains volatile oils such as ar-turmerone, α-turmerone and β-turmerone, which contribute to its antioxidant, antimicrobial and insecticidal properties (Prasad et al., 2014).

UV-Visible (UV-Vis) spectroscopy is a rapid and reliable analytical technique used to identify and characterize bioactive compounds based on their absorption of ultraviolet and visible light. Curcuminoids exhibit characteristic absorption maxima, typically around 420–430 nm, due to $\pi \rightarrow \pi^*$ electronic transitions in their conjugated molecular structure. The presence and intensity of these absorption peaks provide valuable information about the concentration, purity, and stability of turmeric phytochemicals (Jayaprakasha et al., 2005; Priyadarsini, 2014).

The insecticidal potential of turmeric has attracted considerable attention as an eco-friendly alternative to synthetic pesticides for protecting stored grains. Bioactive constituents, particularly curcuminoids and turmerones, have been reported to possess repellent, antifeedant, ovicidal, and toxic effects against several stored-product insect pests, including Callosobruchus species (pulse beetles). These compounds interfere with feeding behavior, development, reproduction and survival, thereby reducing pest infestation during grain storage (Isman, 2006; Tripathi et al., 2009).

Therefore, UV-Visible spectroscopic analysis of turmeric powder serves as an important tool for confirming the presence of these bioactive compounds. The detection of characteristic absorption peaks supports the presence of phytochemicals responsible for the insecticidal activity of turmeric, helping to explain its effectiveness in controlling Callosobruchus spp. in stored grains while providing a safer and environmentally sustainable approach to post-harvest pest management.

Mint - Mentha spicata is an aromatic medicinal herb belonging to the family Lamiaceae and is widely recognized for its rich content of bioactive phytochemicals, including phenolic compounds, flavonoids, terpenoids, menthol, menthone, carvone and other essential oil constituents. These compounds possess antioxidant, antimicrobial, and insecticidal properties, making mint a promising botanical material for sustainable pest management in stored grains.

UV-Visible (UV-Vis) spectroscopy is an important analytical technique used to identify and characterize plant phytochemicals by measuring their absorption of ultraviolet and visible light. The absorption bands observed in the UV region (200-400 nm) are generally associated with phenolic compounds and flavonoids, while visible region absorption may arise from plant pigments such as chlorophylls and carotenoids. The spectral profile provides qualitative information on the presence of these bioactive constituents and serves as a rapid method for evaluating the chemical composition and quality of mint samples.

The insecticidal activity of mint has been extensively studied against several stored-product insect pests. Essential oils and extracts of Mentha species exhibit repellent, fumigant, contact toxic, antifeedant and oviposition-inhibitory effects due to the presence of monoterpenes such as menthol, menthone, pulegone and carvone. These compounds interfere with insect nervous systems, reduce feeding activity, inhibit egg laying and decrease adult emergence, thereby providing effective protection of stored grains against bruchid beetles, including Callosobruchus species.

Several studies have demonstrated that Mentha piperita and related mint species significantly suppress oviposition and adult emergence of Callosobruchus chinensis and Callosobruchus maculatus, highlighting their potential as eco-friendly alternatives to synthetic insecticides for stored-grain protection.

Therefore, UV-Visible spectroscopic analysis of mint powder provides evidence for the presence of biologically active phytochemicals responsible for its insecticidal activity. The characteristic absorption peaks obtained in the UV-Visible spectrum support the occurrence of phenolic compounds, flavonoids, and other secondary metabolites that contribute to the toxicity and repellency of mint against Callosobruchus spp., thereby explaining its effectiveness in protecting stored grains.

OBJECTIVES

- To evaluate the mortality rate of C. maculatus by the effect of Curcuma longa and Mentha spicata powders.
- To analyze the U-V Spectrum for the two plant powders.

MATERIALS AND METHODS

The experiment was carried out at the laboratory of Zoology, Nirmala College for Women, Coimbatore. The materials and methods, used for the present study are described under the following headings:

Classification

Kingdom : Animalia

Phylum : Arthropoda

Order : Coleoptera

Family : Chrysomelidae

Genus : Callosobruchus (Fabricius, 1775)

Species : maculatus

Rearing of Test Insect – Callosobruchus maculatus

Callosobruchus maculatus (pigeon pea weevil or pulse beetle) is a common storage pest of pulses and is widely reared in laboratories for research on insect biology and pest management. Clean and sterilize the cowpea seeds to eliminate any existing infestation. Placed approximately 200-300 grams of pigeon pea seeds into a clean rearing jar. Introduced ten freshly emerged adult C. maculatus into each jar. Covered the mouth of the jar with muslin cloth and secure it with a rubber band to allow ventilation while preventing insect escape. Kept the jars under controlled laboratory conditions: Temperature: 27 ± 2°C; Relative humidity: 65-75 %; Photoperiod: 12:12 hours (Light: Dark). Allowed the adults to mate and lay eggs for 5-7 days. Removed the adult beetles after the oviposition period to prevent overlapping generations. Maintained the jars until adult emergence, which usually occurs after 25-35 days, depending on environmental conditions. Collected freshly emerged adults daily for experimental use and transferred them to fresh pigeon pea seeds to maintain a continuous culture. Precautions were, used only clean, uninfected seeds; Maintained constant temperature and humidity throughout the rearing period; Avoided overcrowding of insects in the rearing containers; Removed adults after oviposition to obtain a uniform-age culture; Kept the culture free from contamination by mites, fungi or other insects; Labelled each culture with the date of initiation and generation number.

Medicinal plant powders

The plant powders shown in the following **Table -1** were collected and used against the pests of pigeon pea Callosobruchus maculatus.

Table :1- Medicinal Plant powders

S.No	Botanical Name	Common Name	Tamil Nadu	Family Name
1	Curcuma longa	Turmeric	Manjal	Lamiaceae
2	Mentha spicata	Mint	Puthina	Lamiaceae

Ultraviolet-visible (UV-Vis) Spectroscopy

UV-Visible spectroscopy measures the absorption of ultraviolet and visible light by chemical substances. It works on the principle that when molecules absorb this radiation, their electrons undergo transitions from ground states to higher energy levels. The amount of light absorbed is directly proportional to the sample's concentration. The foundational concept of this technique relies on the Beer-Lambert's Law, which mathematically relates the attenuation of light to the properties of the material through which the light is traveling. When a beam of light passes through a solution, some wavelengths are absorbed, and others are transmitted. By comparing the intensity of light before it passes through the sample (I_0) to the intensity after (I), the instrument computes absorbance. Applications are for the determination of impurities in organic molecules; Additional peaks can be observed due to impurities in the sample and it can be compared with that of standard raw material; By also measuring the absorbance at a specific wavelength, the impurities can be detected.

RESULT AND DISCUSSION

The UV-Visible results of Turmeric powder

This was helped in explaining why it can be effective against Callosobruchus spp. (pulse beetles) in stored grains.

Relationship Between UV-Visible Results and Insect Control

The UV-Visible spectrum showed strong absorbance at 220 nm, 276 -277 nm, and 450 nm, indicating the presence of biologically active compounds such as curcuminoids, phenolics, flavonoids and essential oils. These compounds contribute to the insecticidal activity of turmeric in several ways: Curcumin-Induced Toxicity (450 nm Peak)- The absorbance peak at 450 nm confirms the presence of curcumin, the principal bioactive compound in turmeric. Curcumin has been reported to: Disrupt normal metabolic processes in insects; Cause physiological stress and cellular damage; Interfere with feeding behavior and nutrient utilization and Reduce survival and reproduction of adult beetles. As a result, adult Callosobruchus beetles experience increased mortality when exposed to turmeric powder-treated grains.

Phenolic Compounds (276–277 nm Peaks)- The strong peaks at 276–277 nm indicate a high concentration of phenolic compounds. These compounds: Act as natural toxins against insects; Affect digestive enzymes, reducing food utilization; Inhibit egg laying (oviposition) and reduce larval development inside stored seeds. Consequently, the life cycle of Callosobruchus is disrupted, leading to lower population growth.

Aromatic and Conjugated Compounds (220 nm Peak)- The very high absorbance at 220 nm suggests the presence of aromatic compounds and conjugated phytochemicals. These substances: Possess repellent properties; Create an unfavorable environment for insects; May affect the insect nervous system and respiration and Reduce seed infestation by deterring adult beetles from colonizing stored grains. Physical Effect of Turmeric Powder- Apart from chemical toxicity, turmeric powder can: Coat the seed surface; Obstruct movement and egg attachment and damage the insect cuticle, causing water loss and desiccation. This physical action further contributes to beetle mortality.

The UV-Visible results of Mint powder

UV–Visible spectrophotometric data for mint powder shows the presence of several classes of bioactive compounds that are known to have insecticidal and repellent effects against storage pests such as the bean weevil, Callosobruchus maculatus.

The Key points for the spectral regions

The Visible region (450–800 nm)- The very low absorbance above 540 nm indicates that the mint extract contains limited amounts of strongly colored compounds. The moderate peak at 450 nm suggests the presence of: Carotenoids; Chlorophyll derivatives and Some flavonoids. These pigments contribute antioxidant activity but are generally not the primary insecticidal constituents.

UV-B region (270–280 nm)- The strong absorbance around 276–277 nm is the most significant feature of your spectrum. Compounds absorbing in this region include: Phenolic acids; Flavonoids; Tannins; Monoterpenes and Essential oil constituents. Major bioactive compounds reported in mint species include: Menthol; Menthone; Pulegone; Limonene; Rosmarinus acid; Caffeic acid and Luteolin derivatives. These molecules possess aromatic rings and conjugated systems that strongly absorb near 270–280 nm.

Deep UV region (220 nm)- The very high absorbance at 220 nm indicates abundant compounds containing: C=C double bonds; Carbonyl groups; Terpenoid structures and Volatile essential oils. Monoterpenes and other volatile compounds responsible for mint aroma typically show intense absorption in the 200–230 nm region. Because the absorbance at 220 nm is extremely high (7.814), the sample may have been too concentrated for accurate quantitative interpretation. In UV–Vis's analysis, absorbance values above about 2.0–3.0 generally exceed the linear range of most spectrophotometers. Consider diluting the extract and remeasuring for quantitative work.

The management of Callosobruchus insects by Mint powder

Mint powder acts against Callosobruchus through multiple mechanisms. Repellent action-Volatile compounds such as menthol, menthone, and limonene interfere with the insect's olfactory receptors. This causes: Reduced host recognition; Avoidance of treated seeds and Lower egg-laying activity. Female beetles are less likely to oviposit on grains coated with mint powder. Fumigant toxicity- Mint essential oils evaporate gradually from the powder. The vapours enter the insect through spiracles and disrupt: Respiratory processes; Nervous system function and Energy metabolism. This can cause paralysis and mortality.

Neurotoxic effects- Monoterpenes inhibit important enzymes such as: Acetylcholinesterase and Octopamine receptors. Disruption of neurotransmission results in: Hyperactivity; Feeding inhibition; Loss of coordination and Death. Antifeedant activity- Phenolics and tannins detected by the strong absorption near 277 nm reduce feeding efficiency. The compounds: Decrease digestibility; Inhibit digestive enzymes and Lower nutrient assimilation. Consequently, larval development slows. Physical barrier effect- When applied directly to stored grains, mint powder: Masks grain odor; Interferes with egg adhesion and creates an unfavorable surface for larval penetration. This reduces successful emergence of adult beetles.

The relationship between UV Spectrum and insect management

The strong UV absorption at 220 nm and 276–277 nm indicates a high concentration of bioactive secondary metabolites present in Mentha spicata powder. These absorption peaks are associated with phenolic compounds, flavonoids, terpenoids and other phytochemicals known for their biological activity. The identified phytochemicals contribute to the insecticidal efficacy of mint against Callosobruchus maculatus through multiple mechanisms, including repellency, fumigant toxicity, oviposition deterrence, antifeedant activity, growth inhibition and disruption of the insect nervous system. In addition, the antioxidant properties of these secondary metabolites may enhance the stability of the botanical formulation during storage. The use of mint powder offers several advantages over conventional synthetic insecticides. It is biodegradable, renewable, readily available, cost-effective and poses minimal risk to human health, non-target organisms and the environment. The treatment also helps preserve seed quality, minimizes post-harvest losses, and supports sustainable grain storage practices.

Overall, the UV-Visible spectroscopic analysis confirms the presence of biologically active compounds responsible for the pesticidal properties of Mentha spicata. These findings demonstrate that mint powder is a promising botanical protectant for the management of Callosobruchus maculatus in stored pigeon pea (Cajanus cajan). Future studies should focus on identifying the specific active compounds, evaluating their efficacy under large-scale storage conditions, determining optimal application rates and developing standardized botanical formulations for commercial use in integrated pest management (IPM) programs.

UV Photometric analysis of Turmeric powder

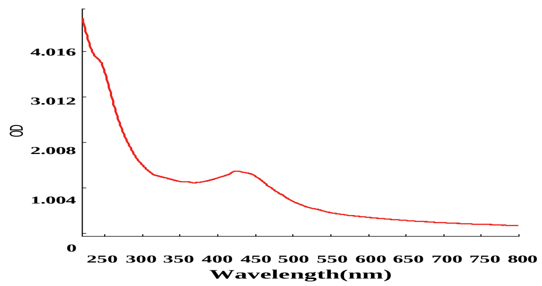
Sample : Turmeric

Measurement Mode : Photometric

Wavelength(nm) 800 650 540 539 450 277 276 220

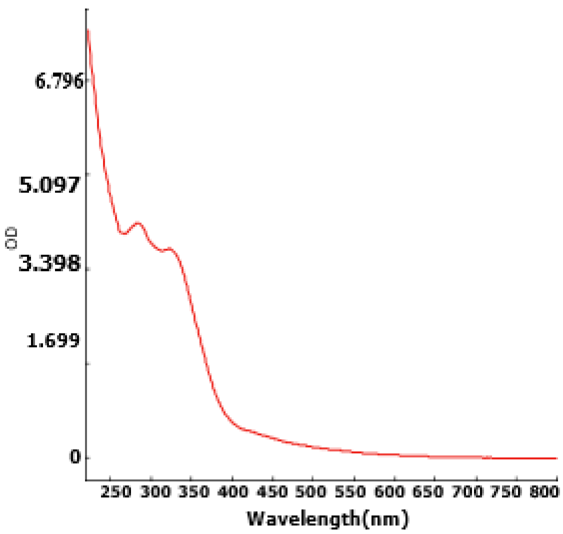
OD800	: 0.160
OD650	: 0.277
OD540	: 0.487
OD539	: 0.492
OD450	: 1.261
OD277	: 2.133
OD276	: 2.171
OD220	: 4.784

Item	Result
Pathlength (mm)	0.651
Dilution	1.000



UV Spectrometric analysis of Mint Powder
Sample Name : MINT
Measurement Mode : Photometric
Wavelength (nm) 800 650 540 539 450 277 276 220
OD800 : -0.034
OD650 : 0.001
OD540 : 0.100
OD539 : 0.102
OD450 : 0.334
OD277 : 4.173
OD276 : 4.162
OD220 : 7.814

Item	Result
Pathlength (mm)	0.651
Dilution	1.000



CONCLUSION

The present study demonstrates that Curcuma longa (turmeric) and Mentha spicata (mint) powders possess significant potential as eco-friendly botanical protectants against the pulse beetle, Callosobruchus maculatus, infesting stored pigeon pea (Cajanus cajan). UV-Visible spectroscopic analysis confirmed the presence of bioactive phytochemical constituents, including phenolic compounds, flavonoids, terpenoids and other secondary metabolites, which are responsible for the insecticidal and repellent activities of these plant powders. The characteristic absorption peaks observed in the UV-Visible spectra indicate the presence of compounds such as curcuminoids in C. longa and phenolic constituents in M. spicata, supporting their biological efficacy.

The application of these botanical powders effectively reduced beetle infestation, adult emergence, and seed damage while maintaining seed quality. Compared with synthetic pesticides, these plant-based materials offer a safer, biodegradable and environmentally sustainable alternative for the protection of stored pigeon pea.

Overall, the findings suggest that Curcuma longa and Mentha spicata powders can be recommended as promising components of integrated pest management strategies for stored grain protection. Further studies on the isolation of active compounds, optimization of dosage, and large-scale storage trials are recommended to enhance their practical application in post-harvest pest management.

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