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Effectiveness of Peppermint (*Menta piperita*) and Nutmeg (*Myristica fragrans*) Essential Oil on Mortality of Storage Pest *Tribolium castaneum*

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ABSTRACT

Tribolium castaneum commonly known as the red flour beetle, stands as a significant stored insect pest, inflicting crucial damage upon stored commodities. The infestations by *T. castaneum* result in substantial losses both in terms of quality and quantity of the stored products. The use of essential oils presents itself as an alternative pest control strategy, functioning as fumigants that can effectively thwart reinfestations of these pests during storage periods. This research was conducted to ascertain the efficacy of peppermint (*Mentha piperita*) and nutmeg (*Myristica fragrans*) essential oils in the management of the stored insect pest *T. castaneum*. The essential oil assessment was carried out utilizing the fumigation technique within Petri dishes, employing various concentrations of 1%, 2%, 2%, 4%, and 5%. Observations on *T. castaneum* mortality were conducted after 72 hours post-treatment (HAT). The results obtained at the 72 HAT juncture exhibited the highest mortality rate of *T. castaneum* within the treatment using a 5% concentration of peppermint essential oil, yielding a mortality rate of 90%. In contrast, the highest mortality rate for the nutmeg essential oil treatment was recorded at 48% within the 5% concentration. Thus, it can be concluded that the application of a 5% concentration of peppermint essential oils proves to be effective in controlling the *T. castaneum* infestation.

Keywords: Tribolium castaneum, essential oils, fumigation, peppermint, nutmeg, pest management, stored-insect pests

Introduction

Post-harvest storage is a critical phase in the agricultural supply chain as it directly influences the quality and quantity of stored commodities. However, this stage is frequently plagued by the menace of pest infestations. Storage pests, insects known for their destructive tendencies, target stored products within warehouses, often evading detection due to their ability to take refuge within storage facilities (Lumi et al., 2021). These pests exploit favorable storage conditions that support their growth and development, as well as the availability of sustenance. Consequently, storage pest infestations not only lead to qualitative degradation, reducing the quality of stored commodities but also result in quantitative losses, commonly referred to as shrinkage (Nuraini et al., 2022). One notable intruder among these storage pests is *Tribolium castaneum*.

Also known as the flour beetle, *T. castaneum* is a significant storage pest species, wreaking havoc on various commodities during both its larval and adult stages. Its destructive habits extend to staples such as rice, maize, coffee, cocoa, and processed goods like wheat flour. *T. castaneum* is an important pest due to its wide host range and ability to find and infest commodities and rapidly increase

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commodity populations (Campbell et al., 2022). The severity of infestations becomes evident through the presence of benzoquinone, an excretion of *T. castaneum*, contaminating foodstuffs and rendering them unfit for consumption (Hendrival et al., 2016). In combating such relentless storage pest infestations, fumigation has emerged as a common practice. This chemical method involves the application of fumigants within an enclosed storage environment to eliminate pests. While fumigation has exhibited effectiveness, it comes with its share of drawbacks. Chemical fumigants can pose risks to human health, contaminate the environment, and develop pest resistance over time. The excessive and improper use of fumigants, contrary to established usage standards, can yield adverse effects on commodities subjected to fumigation treatments (Harman, 2017). Furthermore, their usage raises concerns about food safety and sustainability, highlighting the pressing need for alternative, eco-friendly pest management strategies.

Addressing the limitations of conventional fumigation, the exploration of essential oils as botanical pesticides offers a promising avenue for the development of safer, environmentally friendly alternatives (Campos et al., 2018). Essential oils, derived from diverse plant sources, comprise intricate blends of compounds that exhibit low toxicity to mammals and minimal environmental impact (Chaubey, 2019). These oils possess an array of potential applications, serving as repellents, attractants, contact and respiratory poisons, antifeedants, oviposition deterrents, growth inhibitors, hormonal disruptors, fertility reducers, and even anti-insect vectors (Hasyim et al., 2014). Among the prolific essential oil sources are peppermint (*Mentha piperita*) and nutmeg (*Myristica fragrans*). Peppermint essential oil, enriched with menthol, has demonstrated fumigant properties capable of inducing mortality in *T. castaneum* (Lashgari et al., 2014). Equally compelling, nutmeg essential oil exhibited significant insecticidal potential, resulting in a mortality rate of up to 96% in *Oryzaephilus mercator* insects at a concentration of 0.2 ml/L (Prasetiani, 2016).

This study endeavors to assess the efficacy of peppermint and nutmeg essential oils in curbing the mortality of the storage pest *T. castaneum*. The findings derived from this research could potentially provide an alternative approach to pest control, offering insights into strategies to prevent reinfestation within stored commodities.

Material and Methods

Material

The tools used include a 9 cm diameter petri dish, 1 ml and 2 ml volumetric pipettes, scissors, filter paper, measuring cup, paper glue, gauze, labels, stationery, and a cellphone camera with a resolution 48 MP, f/1.8. While the materials needed in this study are peppermint and nutmeg essential oils, acetone, plasticine, and *T. castaneum* test insects obtained from the SEAMEO BIOTROP Entomology Laboratory collection.

Methods

The research was conducted at the Entomology Laboratory of SEAMEO BIOTROP, Bogor, West Java. The research was conducted on November 16-19th, 2021. The assessment of the efficacy of peppermint and nutmeg essential oils against the postharvest pest *T. castaneum* was carried out through the fumigation technique in petri dishes, following the documented protocol by Syam et al. (2017). Each essential oil was treated with concentrations of 1%, 2%, 3%, 4%, and 5%, each replicated five times and dissolved in acetone solvent. Subsequently, solutions containing varied concentrations of peppermint and nutmeg essential oils were applied onto filter paper by gradually dripping 0.5 ml of the solution in a spiral manner. As a comparative measure, the control group received treatment solely with acetone. The treated filter paper was left to air-dry for 2 minutes. For each experimental trial, a total of 20 *T. castaneum* adult specimens were introduced into each petri dish. The dish was then covered with gauze, securing its upper surface. To prevent potential evaporation of essential oil from

the petri dish, any gaps between the lid and the base were sealed using plasticine. Proper labeling corresponding to the concentration treatment was applied to each petri dish.

Figure 1. Testing the Effectiveness of Essential Oil by Fumigation Method

The subsequent observation period occurred at the 72-hour post-treatment (HAT). During this observation, the mortality rate of the subjected insects was ascertained through calculation. This methodology allowed for the comprehensive evaluation of the impact of peppermint and nutmeg essential oils on *T. castaneum*, specifically focusing on their mortality rates. The mortality percentage was calculated using the following formula (Azwana et al., 2019):

$$P = \frac{A}{B} \text{ X } 100\% \quad (1)$$

Information:
P = Mortality percentage of *T. castaneum*
A = Number of dead *T. castaneum* imago
B = Total number of *T. castaneum* imago

Results and Discussion

The results of the testing of the effects of fumigation using essential oils of peppermint and nutmeg revealed a noticeable trend in which the mortality percentage of *T. castaneum* adults increased in tandem with escalating concentrations of the essential oils. Mortality percentages obtained from the peppermint essential oil after 72 hours of exposure were 2%, 5%, 53%, 82%, and 90% for concentrations of 1%, 2%, 3%, 4%, and 5%, respectively. Similarly, the nutmeg essential oil showed mortalities of 1%, 2%, 10%, 48%, and 48% for the corresponding concentrations (Table 1). The efficacy of the essential oils increased with higher concentrations, a perspective supported by Sari and Desita (2020), suggesting that higher doses correlate with greater total mortality, thereby reducing the surviving insect population.

Table 1. Percentage Mortality of *T. castaneum* Imago by Treatment with Peppermint and Nutmeg Essential Oils

Treatment	Concentration (%)	Mortality on 72 HAT (%)
Control	0	0
Peppermint	1	2
	2	5
	3	53
	4	82
	5	90
Nutmeg	1	1
	2	2
	3	10
	4	48
	5	48

Peppermint essential oil exhibited higher mortality percentages in comparison to nutmeg essential oil. The highest mortality rate in the peppermint essential oil treatment was observed at the 5% concentration, resulting in a mortality rate of 90%. The use of peppermint essential oil as a botanical insecticide was effective in controlling infestations of *T. castaneum* warehouse pests. The main constituents of peppermint essential oil, menthol, and menthone, played a pivotal role in its fumigation effect on the *T. castaneum* insects. Menthol possesses volatile properties, allowing it to evaporate into the air. When applied as fumigation, menthol vaporizes and disperses within the environment. This gaseous menthol can enter the insects' respiratory system and disrupt their breathing process. This obstruction hinders the exchange of oxygen and carbon dioxide, leading to asphyxia and the eventual demise of the insects (Taherpour et al., 2017; Rajkumar et al., 2019).

Figure 2. *T. castaneum* imago after essential oil application

The active compounds in peppermint essential oil not only induced mortality in the test insects but also impeded the development of surviving insects. This is consistent with the findings of Syam et al. (2017), indicating that the fumigation effects of compounds found in the n-hexane fraction of *M. piperita*, in addition to causing mortality, also hindered the development of *T. castaneum* at sublethal concentrations. The application of essential oil concentrations of 4% and 5% were deemed effective in *T. castaneum* control, as they demonstrated high mortality rates exceeding 80%. In alignment with Dadang and Prijono's (2008) assertion, botanical pesticides are considered effective when they induce mortality in the test insects exceeding 80%.

The mortality rates of *T. castaneum* in the nutmeg essential oil testing did not reach the heights observed in peppermint essential oil tests, with the highest mortality percentage reaching only 48% at the 5% concentration. The application of 5% nutmeg essential oil concentration proved less effective for control, suggesting a need for fumigation testing at concentrations exceeding 5% to ascertain the optimal concentration for *T. castaneum* control. This notion is based on the research conducted by Cristiana (2019), which established that preliminary mortality tests of nutmeg essential oil on *Oryzaephilus surinamensis* yielded effective fumigation at a dose of 0.06 ml/L, resulting in an 85% mortality rate. Additionally, another study by Shintohapsari (2018) found that nutmeg essential oil caused 85% mortality in *O. surinamensis* adults at a fumigation dose of 0.075 mg/L.

Nutmeg essential oil holds potential as an insecticide, fungicide, antibacterial agent, and larvicide. The vapor phase of monoterpenoid compounds and eugenol is toxic to insects (Iffah et al., 2008). Moreover, the myristicin compound in nutmeg possesses toxic properties and an intensely strong odor (Seneme et al., 2021). Nutmeg essential oil can also function as a fungicide due to its flavonoid content. Flavonoids act against fungal growth by disrupting substance movement across the fungal cell membrane. This leads to alterations in organic elements and nutrient transport processes within the fungal cells, ultimately resulting in toxic effects on the fungus (Pashapoor et al., 2020).

Conclusion

Peppermint and nutmeg essential oils showed fumigant effects against adult *T. castaneum*, with peppermint essential oil showing higher efficacy. The volatile compound menthol in peppermint oil disrupts the insect's respiratory system, causing death through asphyxiation. Concentrations of 4% and 5% of peppermint essential oil could be one of the potential essential oils as a botanical alternative to control *T. castaneum* infestation. Further research is needed to explore higher concentrations for nutmeg essential oil fumigation.

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