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Using of botanical repellent extracts for protection of food packaging

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Abstract: Infestation of foodstuffs by storage insects is still an actual problem. Pests may contaminate food with body fragments or change storage microenvironment so it is suitable for developing of fungi and other microorganisms. As a consequence, for producers pest infestations pose problems in the form of complaints and thus economic damage. Thus, using of a reliable packaging is of great importance in protection of durable food from insect pests. One possibility how to improve protective properties of the packaging is using of repellents. Traditional synthetic insecticides are associated with the increasing pest resistance and the formation of undesirable chemical residues in the environment or in treated commodities. Therefore, we seek for possible use of plant essential and vegetable oils in enhancement of packaging protection against storage pest insects. One of the goals was to verify the bio-efficacy of the essential oil used on a tertiary packaging. It was found that the oil repels pests from stored food, even when used on a wooden transport pallet, and thus does not come into contact with the food. Another output was the development and testing of a glue with incorporated vegetable oil. In this case, however, the glue had rather attractive effects for pests. Nevertheless, the development of new formulations of plant insecticides and repellents can be expected in the near future.

Key words: active packaging; repellence; essential oils; edible oils; stored product protection

Introduction

Owing to ongoing development of new methods and modern types of packaging it could seem that infestation of food with harmful organisms is not a serious problem at present. But farmers, warehouse keepers and food manufacturers know how hard it is to protect stored commodities and food products from infestation by unwanted organisms. The field study by Trematerra et al. (2011) showed that arthropods and their body parts are the most common contaminants of flour and thus may become part of pastry. The main risks arising from the presence of pests are quite obvious. Arthropod pests produce substances (toxins, carcinogens, allergens) that may have negative effect on human health. Also, pests and their metabolic activity create conditions for the growth of undesirable microorganisms such as fungi (Hubert et al., 2018). Last but not least, the presence of pests also poses economic risks, as they degrade food which then often becomes the subject of complaints.

Chemical protection and synthetic insecticides have long been integral part of integrated protection in stores. However, due to the possible contamination of food and adverse effects on human health and environment (as well as the current resistance of many pest species), it is not possible to use synthetic insecticides directly on stored food. For this reason, reliable packaging protecting food from pest infestation is therefore a key element of food protection (Stejskal et al., 2017; Aulicky et al., 2019). Currently, many packaging materials with different properties

and resistance to pests are used. However, in spite of development of modern types of packaging, pests are still able to penetrate or invade the packaging. As an alternative to synthetic insecticides and repellents, substances of natural origin such as plant oils which do not have the negative properties of synthetic substances may be used. Currently widely used plant extracts are essential oils (EO) (Pierattini et al., 2019). They are secondary metabolites of plants produced by different parts of many plant species. They are compounds of secondary plant metabolites that are volatile and aromatic. Because of their aromatic properties, EOs may negatively affect organoleptic properties of food. Alternatively, vegetable oils with weaker aromatic odour can be used, however, their repellent effects are not so well studied. Essential oils have some properties that complicate their use for long-term stock protection. It is mainly their instability, caused by low persistence due to effect of light and heat (Turek and Stintzing, 2013). Another unpleasant feature of essential oils is their variable action depending on the concentration, which changes over time. Their efficacy may also significantly differ for various pest species.

Materials and methods

Efficacy of essential oil on tertiary packaging

The aim of the experiment was to verify the possibility of treating individual components of the tertiary packaging (i.e., wooden transport pallets, cardboard spacers and paper boxes) with EO. It was expected that such form of treatment would prevent the EO from coming into direct contact with the primary packaging/food while repelling pests from package invasion/penetration. For the experiment, we constructed a pallet model with a spacer and a paper box, simulating the packaging of food ready for distribution (Figure 1). The pallet dimensions were 15 × 5 × 2.5 cm. The box was made of standard paper rice packaging. It was tested treatment of i) pallets, ii) spacers, and iii) boxes with bergamot oil. A solution of oil and acetone (5 %) was pipetted as evenly as possible at 0.25 µl/cm^2 on each material. Treatment with acetone alone served as a control. After the solution/acetone treatment, the packaging parts were left for 1, 24 and 168 h in a dark room at 22 °C, and after this time, they were mounted and placed in the container. Two choice test with one treated and one untreated model in Lock & Lock box was conducted. Fifty individuals of *Sitophilus granarius* were used. Each paper box contained 150 g of wheat grains as an attractant. The boxes were stored at 24 °C. After one hour, the box was opened and the beetles inside each box were counted. Because beetles tend to hide in the cells of the cardboard spacers from which they can subsequently migrate to food (i. e., paper boxes), the beetles in the spacers were also counted. The number of replications per pest species/treatment/time was 10. For further methodical details see Vendl et al. (2021).

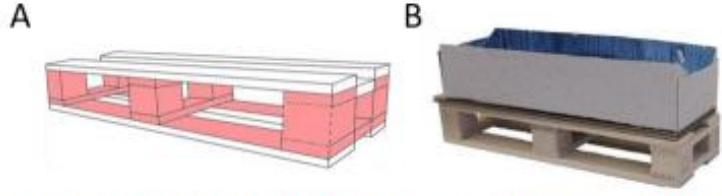

Figure 1. A. model of a pallet with highlighted parts treated with EO/acetone (pink). B. a whole model of a tertiary packaging set, containing wooden transport pallet, pallet spacer and paper box. (Adapted according to Vendl et al., 2021).

Repellency of glue with incorporated vegetable oil

Primary or secondary food packaging is often sealed with glue (especially paper or cardboard boxes). Therefore, we tested the possibility of adding vegetable oil into a glue to create a glue with repellent effects. Because essential oils are aromatic and could affect the organoleptic properties of food, non-aromatic vegetable almond oil (AO) was tested. A paper box for packing rice and the glue with which the box is glued as standard were used for the test. The boxes were glued in places that are intended for gluing – i. e., on the bottom and top of the boxes. Glue with AO in concentration of 10 % was used. The glue was heated in a ceramic beaker to a temperature of 140 °C and AO was dissolved in the glue. As a host food attractant, 200 grams of rice was placed in a glued box. Due to the fact that primary pests can penetrate the packaging in any place and therefore do not have to come into contact with the glue, only secondary pests, namely *Tribolium confusum* and *Oryzaephilus surinamensis*, were used. The experiment took the form of a two-choice test, in one Lock & Lock box – a box glued with repellent glue was placed together with a box glued with glue without oil. Thirty individuals of a particular pest species were introduced into the box, and after 48 hours the beetles in both boxes of rice were counted. The number of replications was 10.

Results

Efficacy of essential oil on tertiary packaging

The results suggest that bergamot oil treatment has the potential to reduce the infestation of packaged commodities on pallets by storage pests (Figure 2). In general, the treatment of the wooden pallet had the greatest repellent effect on the number of beetles in the box (72 % repellency was observed for *S. granarius*), but the treatment of other packaging components also had an effect. In contrast, treating the pallet did not prevent beetles invading into the pallet spacer, whereas treatment of the spacer strongly protected the spacer from beetle presence (after 1 h, 94 % repellency was observed). However, the protective effect of bergamot oil decreased over time and disappeared completely a week after the treatment.

Efficacy of essential oil on tertiary packaging

Contrary to the initial expectations, the boxes with glue with almond oil have attractive effects on *T. confusum,* as there were on average more beetles in boxes treated with AO glue than in the control boxes (t-test: 3.7; $p = 0.0015$). Conversely, in the case of *O. surinamensis*, fewer beetles infested treated boxes than control boxes, but this difference was on the edge of significance (t-test: 2.1; $p = 0.0501$) (Figure 3).

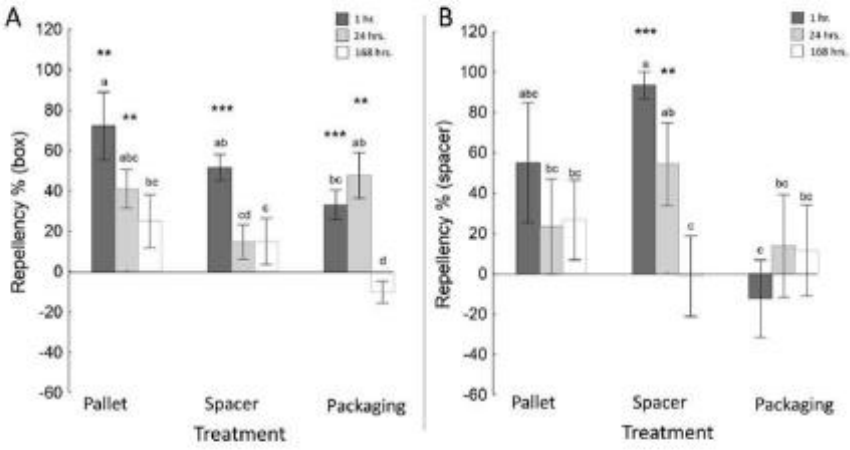

Figure 2. Repellency produced by bergamot oil on *Sitophilus granarius* when used on different parts of the storage set. A – repellent effect on beetles invading the paper box; B – repellent effect on beetles invading the pallet spacer. Each bar represents the mean repellency ± SE. Bars with the same letter do not differ significantly at $P \geq 0.05$ according to Fisher's LSD test. The asterisks above the bars indicate significant repellency according to a one sample t-test (* $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$). Adapted according to Vendl et al., 2021.

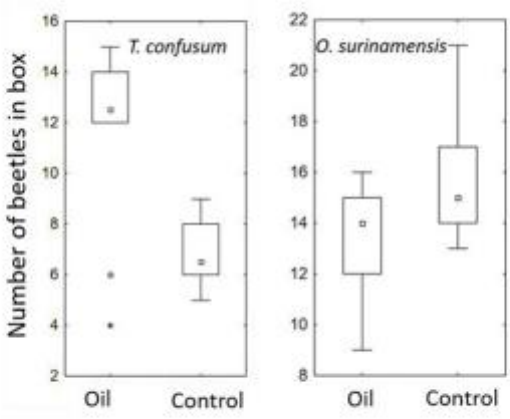

Figure 3. Number of individuals of *Tribolium confusum* and *Oryzaephilus surinamensis* infesting boxes with rice glued with glue with incorporated almond oil (Oil) compared with untreated (Control) boxes.

Discussion

The use of synthetic insecticides or repellents in the protection of commodities and foodstuffs has been progressively restricted in EU. As the reason, there is frequently claimed their potential for causing adverse effects on human health and non-target species. In addition, they may contaminate the environment and trigger resistance in a number of pest species. Natural plant oils have recently proved to be a suitable substitute for synthetic substances. However, to use them successfully in the protection of stored products, it will be necessary to overcome certain difficulties. In particular, it is the limited persistence of plant oils and the variability of their effect depending on the pest species and concentration. Within one type of oil and pest species, the oil can have insecticidal, repellent and even attractive effects over time, depending on its concentration.

In this presentation, we demonstrated one successful and one failure usage of plant oils. It indicates that the development of the efficient EO-based repellents for risk management of storage pests is promising but not way straightforward and easy. However, it is believed that, due to the increasing societal demand and governmental support for research of "green" synthetic alternatives, it can be expected the development of new formulations of plant-based insecticides and repellents in the near future.

Acknowledgements

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