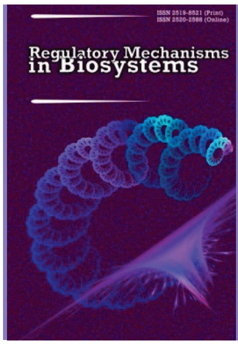

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Potential use of synthetic and natural aromatic mixtures in prevention from *Shelfordella lateralis* cockroaches

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Attractive and repellent properties of many household chemicals may be used to combat synantrophic insects, such as cockroaches. In the natural environment, *Shelfordella lateralis* (Walker, 1868) (Blattodea, Blattidae) lives in the area spanning Central Asia to North Africa. Furthermore, in many tropical and subtropical countries, it is common in human accomodations. In the laboratory conditions, we determined reaction of cockroaches to aromatic mixtures and medicinal plants often used in households. Attractiveness coefficient was the lowest for cosmetic mixtrures Tutti-fruti and Verbena and Bamboo; other cosmetic aromatizers did not repell this insect (Lilac, Mango) or repelled it poorly (Grapefruit, Amaretto, Pine). Food additives that significantly repelled *Sh. lateralis* are Apricot, Barberry and Kiwi and lower effects were produced by Biscuit, whereas Vanilla flavouring had no repellent effect. Mixtures for vaping Strawberry pie, Pear, Frozen forest, Irish Cream and Blue Magic exerted strong repellent effects on cockroaches. Low repellent effect on *Sh. lateralis* were exerted by vaping mixtures Pancakes with Honey, Turkish Tobacco and Grapefruit. No significant effects on the number of cockroaches were exerted by vaping mixtures Vanilla, Club Ice Cream, Blueberry Smoke, Mojito, Chocolate, Apple, Mint and Walnut. Out of the fishing lures, the strongest repellent effects on *Sh. lateralis* were taken by Blood Worm, Onion and Honey, and weaker effects were exerted by Corn and Vanilla. Imagoes of *Sh. lateralis* were most significantly repelled by essential oils from jojoba, eucalyptus, daisy, tee tree, Cao Sao Vang balsam, and also fir essential oil. Neither luring nor repellent effects on imagoes of *Sh. lateralis* were displayed by essential oils from lemon, aloe, peppermint and mandarin. Dry medicinal plants repelled imagoes of *Sh. lateralis*: inflorescences of *Calendula officinalis*, leaves of *Artemisia absinthium*, flowers of *Jasminum officinale*, leaves of *Origanum vulgare*, inflorescences of *Matricaria chamomilla*, inflorescences of *Crataegus monogyna*, leaves of *Mentha* x *piperita*, inflorescences of *Achillea millefolium*, leaves of *Hypericum perforatum*, leaves of *Aristolochia clematitis* and inflorescences of *Tanacetum vulgare*. No repellent effects on *Sh. lateralis* were exerted by *Chelidonium majus*, inflorescences of *Tilia cordata* and inflorescences of *Helichrysum arenarium*. Thus, most (40 of 58, or 69.0%) of the tested aromatic substances and medicinal plants repelled synantrophic Turkestan cockroach, while a much smaller share (31.0%) neither significantly lured nor repelled them. No aromatic mixtures attracted *Sh. lateralis* in our experiment.

Keywords: synanthrophic insects; Blattodea; Blattidae; repellers; attractors; aromatic mixtures; vaping mixtures; combating insect pests; sense of smell in insects; repelling insects; traps for insects.

Introduction

Cockroaches are spreading in cities as a result of global urbanization (Kamran et al., 2021). This group of insects has become so acclimated to living in human habitats that it is now known as the commonest. Only 6 of the more than 3,500 known species of cockroaches reside indoors and can contribute to indoor allergies. These include the American (*Periplaneta americana* (Linnaeus, 1758)), German (*Blattella germanica* (Linnaeus, 1767)), oriental (*Blatta orientalis* (Linnaeus, 1758)), smoky brown (*Periplaneta fuliginosa* (Serville, 1839)), and brown banded (*Supella longipalpa* (Fabricius, 1798)) cockroaches (Eggleston & Arruda, 2001) and Turkestan cockroaches *Shelfordella lateralis* (Walker, 1868). Because of their tiny size, they can fit through the myriad thin cracks and crevices found in flats and homes (Davranoglou et al., 2020). Cockroaches are nocturnal animals. They search for food and water in the dark, when it is more difficult to see. During the day, they hide in cabinet gaps, kitchen appliances, and the floor. Because of their way of life and small size, the residents of the apartment, hospital ward, or residence may not detect the insects for some time. Because of this, given the speed with which cockroaches reproduce, simply a few individuals entering into the house may be a problem for the season, and even more if you do not fight them. The fundamental issue with synanthropic insects is the possibility of transmission. Cockroaches are frequently found in landfills, dumps, and sewers. There, they feed on rotting leftover food and potentially contaminated excrement. Insects transport pathogenic microorganisms from there to human environments (Kass et al., 2009). Cockroaches may carry thousands of germs without becoming ill. Some of them are dangerous to humans. Bacteria *Escherichia coli*, *Staphylococcus aureus* and *S. citreus*, *Salmonella* sp., *Bacillus subtilis* have all been discovered on the bodies of these insects. Eggs of *Trichiurus trichiura*, *Enterobius vermicularis*, *Diphyllobothrium latum*, and *Ascaris lumbricoides* have been found in the posterior part of the intestine (Kinfu & Erko, 2008; Fakoorziba et al., 2010). Cockroaches also cause allergic reactions (Nalyanya et al., 2009; Pomés & Arruda, 2014). People may be sensitive to the excrement of these insects as well as allergens on the surface of their bodies (Gore & Schal, 2007). Additionally, they can cause asthma, rhinitis, and dermatitis (Arruda et al., 2001; Zoratti & Bassirpour, 2014). Cockroach allergens cause severe sensitization in youngsters. Their impact on young children is a risk factor for asthma. Regular targeted cockroach control would reduce their population and, consequently, the number of allergens. As a result, asthma attacks and other allergic responses in people would be reduced.

Pesticides are currently routinely utilized to control synanthropic insects such as cockroaches. This method is both efficient and cost-effective (Gaire & Romero, 2020). On the other hand, pesticides pose a substantial toxicological threat to people when abused or overused (Mille & Peters, 2004; DeVries et al., 2019). The use of chemicals to kill cockroaches is permitted for operations by insecticide specialists. Insecticide compounds can become poisonous when they penetrate the human body, affecting the central and peripheral nerve systems (Bjürling-Poulsen et al., 2008; Cassereau et al., 2017; Kozak et al., 2020). Poisoning symptoms can also include disturbances in human reproductive and endocrine systems (Mnif et al., 2011). Several studies have found that certain pesticides are carcinogenic, meaning they raise the risk of cancer (Alavanja et al., 2013). Even if pesticides are used in accordance with existing standards, there is a possibility that they will affect youngsters who have been in the vicinity of the disinsection activity. After all, the guidelines for using dangerous medications are created for adult bodies, whereas the effects of these chemicals on children are yet unknown (Li et al., 2015). Pesticide residues evaporate or wash away and end up in soils and bodies of water. This allows toxic pesticides to have a negative impact on the ecosystem, resulting in a range of environmental issues (Roubos et al., 2014; Kozak & Brygadyrenko, 2018; Martynov & Brygadyrenko, 2018). Such effects of using standard insect control methods encourage scientists all around the world to look for alternative population control approaches (Birch et al., 2011; Martynov & Brygadyrenko, 2017). Therefore, development and modernization of systems such as integrated pest management (IPM), etc. are underway (Kass et al., 2009; Ameya et al., 2021).

Many insects can interact with the environment mainly by chemical signals rather than vision or hearing. The broad range of chemical interactions between insects and the environment is constantly studied, and a relatively full data base on pheromones of insects is available on the internet (www.pherobase.com). Our studies indicate that agriculturally significant insects can react to chemical compounds and their mixture in fooder (Brygadyrenko & Nazimov 2015; Martynov et al., 2019a, 2019b), as well as chemically synthesized substances introduced to their environment (Titov & Brygadyrenko, 2021). Influence of household chemicals to which insects inside or near households are daily subjected has been studied fragmentarilly (Nehrii & Brygadyrenko, 2022), and such studies have not been conducted on Turkestan cockroach until now. Effects of the studied substances and their mixtures on insects can be direct and indirect, for example through parasitic organisms (Boyko & Brygadyrenko, 2017, 2019). In our study, we looked at two approaches: using repellents to scare cockroaches away from human property, and using attractants in combination with small dosages of traditional pesticides to improve their effectiveness and reduce toxicological effects on humans and the environment. As a result, alternative methods of cockroach control must be developed. One approach is to use non-toxic or low-toxic mixes that are safe for people and to which insects will respond. These aromatic chemicals can operate as repellents as well as components of trap mixes (attractant + pesticide). Attractive combinations can also be used to make pheromone traps, which are used to check for pests in the region.

The goal of this research was finding low-cost alternatives to repellents in 24 natural and 34 synthetic flavourings to control synanthrophic cockroaches.

Materials and methods

We purchased 160 imago Turkestan cockroaches *Shelfordella lateralis* (Walker, 1868) (Blattodea, Blattidae), which were then divided into groups of 20 individuals in each, with one serving as a reserve. Glass jars with crumpled paper inside served as incubators. Paper feeders were used to feed the insects, which were given mainly cereals soaked in warm water. Wet sponges were used to deliver water. The insects were kept at the same temperature as they would be in their natural environment (25–27 °C). A polypropylene transparent pipe with a length of 100 cm and an inner diameter of 25 mm was used as an experimental stand, and it was attached to the wooden bar with plumbing clamps (Fig. 1). The upper half of the plastic bottle connected to the middle of the pipe served as a funnel for insects to enter the pipe at the start of each experiment. To release cockroaches at the end of the experiment, plastic bottle caps were fastened to both ends of the pipe. The pipe was marked every 10 centimeters on the outside. This allowed us to count the number of cockroaches at specific intervals in relation to the aromatic substance (Fig. 2).

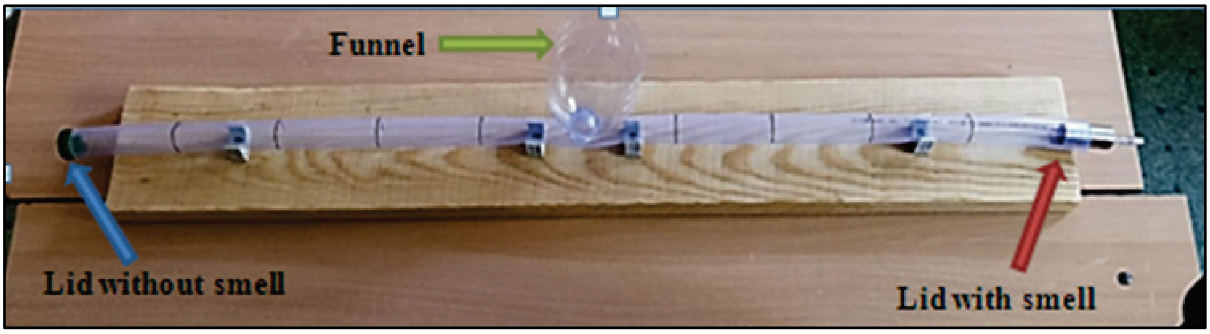

Fig. 1. The experimental stand

Fig. 2. Aromatic substances in the study: *a* – natural aromatic substances; *b* – synthetic aromatic substances

At one end of the pipe, we placed a piece of cotton wool saturated with one drop of mixture. The cockroaches were then transported to the pipe via the funnel, and video recording started. Each experiment took 120 seconds to complete. For reliability, each aromatic compound was tested five times. Every 30 seconds of footage, data on the location of cockroaches in relation to the aromatic chemical was introduced into tables. Thus, for each substance, 5-fold repetition multiplied by 4 time periods gives 20 lines of data on number of cockroaches on each of 10 10-cm sections of 1 meter experimental stand. Since for the analysis we took three 10 cm sections, the repetition of the experiment for comparison with the data in Table 1 equaled 60.

The number of cockroaches in each interval was then converted to percentage (the ratio of the number of insects at certain intervals to the total number of cockroaches in the tube at the time of the experiment). The attraction and repellency coefficients, which are described as inverse values, were determined. This is the ratio of the number of insects in each of the pipe's three extreme parts (0–30 and 70–100 cm).

Statistica 8.0 software (StatSoft Inc., USA) was used to perform statistical analysis of the data. Using one-way analysis of variance, the reliability of the results and the relationship between cockroach motor activity and the aromatic substance was determined, and $P < 0.05$ was considered significant.

Results

Attractiveness coefficient (Table 1) was the lowest for cosmetic mixtures Tutti-fruti (the attractiveness equaled 0.204), Verbena (0.275) and Bamboo (0.489); five other cosmetic aroma substances either did not repell Turkestan cockroaches (Lilac – 0.825, Mango – 0.868), or repelled them poorly (Grapefruit – 0.720, Amaretto – 0.670, Pine – 0.730).

Table 1
Ratio of number of *Sh. lateralis* at maximum and minimum distance from the aroma source ($x \pm SE$, $n = 60$)

Name of aromatic mixture	Number of insects (%) on 10 cm section near (0–30 cm) the aroma source	Number of insects (%) on 10 cm section at maximum distance (70–100 cm) from the aroma source	Coefficient of attractiveness (A) – ratio of number of insects on nearest 30 cm to the aroma source and the farthest 30 cm section of the experimental stand	P	F, $F_{0.05} = 3.93$
Cosmetic fragrances					
Tutti-fruti	1.92 ± 0.49	9.39 ± 1.17	0.204	$3.8 * 10^{-8}$	34.63
Verbena	3.52 ± 0.62	12.81 ± 1.40	0.275	$1.7 * 10^{-8}$	36.69
Bamboo	7.40 ± 0.79	15.15 ± 1.60	0.489	$3.1 * 10^{-5}$	18.79
Grapefruit	8.77 ± 0.84	12.19 ± 0.94	0.720	$7.6 * 10^{-3}$	7.37
Amaretto	7.97 ± 0.98	11.91 ± 1.37	0.670	0.021	5.49
Pine	12.17 ± 1.15	16.68 ± 1.36	0.730	0.013	6.40
Lilac	11.42 ± 1.00	13.83 ± 1.02	0.825	0.094	2.84
Mango	12.52 ± 1.07	14.42 ± 1.10	0.868	0.219	1.52
Flavorings					
Apricot	6.32 ± 0.95	18.61 ± 2.29	0.340	$2.5 * 10^{-6}$	24.46
Barberry	7.92 ± 0.99	18.33 ± 2.23	0.432	$4.0 * 10^{-5}$	18.21
Kiwi	7.59 ± 0.83	15.59 ± 1.52	0.481	$7.6 * 10^{-6}$	21.92
Biscuit	11.94 ± 1.04	17.63 ± 1.76	0.677	$6.2 * 10^{-3}$	7.75
Vanilla	6.63 ± 0.75	9.13 ± 1.37	0.726	0.112	2.57
Mixtures for vaping					
Strawberry Pie	4.67 ± 0.58	13.67 ± 1.05	0.342	$1.5 * 10^{-11}$	55.83
Pear	3.41 ± 0.59	8.42 ± 0.96	0.406	$2.1 * 10^{-5}$	19.67
Frozen forest	5.33 ± 0.90	11.14 ± 1.14	0.478	$1.1 * 10^{-4}$	15.94
Irish Cream	4.57 ± 0.68	9.45 ± 1.01	0.483	$1.1 * 10^{-4}$	15.94
Blue Magic	4.08 ± 0.68	7.50 ± 0.98	0.544	$4.8 * 10^{-3}$	8.27
Pancakes with honey	7.70 ± 1.00	12.06 ± 1.20	0.638	$6.1 * 10^{-3}$	7.79
Turkish Tabaco	9.71 ± 1.37	14.51 ± 1.26	0.669	0.011	6.68
Grapefruit	9.62 ± 1.07	13.74 ± 1.16	0.700	0.010	6.83
Vanilla	5.17 ± 0.73	7.00 ± 1.32	0.738	0.227	1.47
Ice Cream Club	7.00 ± 0.91	9.16 ± 0.88	0.764	0.091	2.91
Blueberry Jam	5.42 ± 0.82	6.92 ± 1.01	0.783	0.250	1.33
Mojito	5.58 ± 0.66	6.92 ± 0.82	0.807	0.210	1.59
Chocolate	6.18 ± 0.84	7.55 ± 0.88	0.819	0.264	1.26
Apple	7.75 ± 0.96	9.25 ± 0.98	0.838	0.277	1.20
Mint	8.67 ± 0.91	9.08 ± 1.15	0.954	0.777	0.08
Walnut	9.41 ± 1.18	7.66 ± 1.14	1.227	0.287	1.14
Fishing baits					
Blood Worm	2.73 ± 0.43	14.76 ± 1.43	0.185	$1.1 * 10^{-12}$	63.70
Onion	6.12 ± 0.68	15.22 ± 1.62	0.402	$9.8 * 10^{-7}$	26.69
Honey	6.45 ± 0.73	12.71 ± 0.98	0.507	$1.1 * 10^{-6}$	26.43
Corn	8.39 ± 1.33	14.25 ± 1.40	0.589	$2.9 * 10^{-3}$	9.26
Vanila	8.16 ± 0.84	13.79 ± 1.41	0.592	$8.5 * 10^{-4}$	11.71
Essential oils from plants					
Jojoba essential oil (*Simmondsia chinensis* (Link) C. K.)	5.67 ± 0.72	15.21 ± 1.75	0.373	$1.9 * 10^{-5}$	20.25
Eucalyptus essential oil (*Eucalyptus globosus* Labill.)	6.80 ± 0.72	17.32 ± 2.20	0.393	$1.0 * 10^{-4}$	16.50
Daisy essential oil (*Matricaria chamomilla* L.)	6.69 ± 0.87	16.01 ± 2.03	0.418	$2.8 * 10^{-4}$	14.22
Tea tree essential oil (*Malaleuca alternifolia* (Maiden & Betche) Cheel)	5.39 ± 0.97	13.82 ± 1.51	0.420	$3.6 * 10^{-4}$	13.69
Golden Star Balm – Cao Sao Vang	6.04 ± 0.74	13.99 ± 1.54	0.432	$7.2 * 10^{-5}$	17.24
Fir essential oil (*Abies balsamea* (L.) Mill.)	8.13 ± 1.01	13.75 ± 1.72	0.591	0.014	6.34

Name of aromatic mixture	Number of insects (%) on 10 cm section near (0–30 cm) the aroma source	Number of insects (%) on 10 cm section at maximum distance (70–100 cm) from the aroma source	Coefficient of attractiveness (A) – ratio of number of insects on nearest 30 cm to the aroma source and the farthest 30 cm section of the experimental stand	P	F, $F_{0.05} = 3.93$
Lemon essential oil (*Citrus limon* (L.) Osbeck)	8.63 ± 1.30	12.09 ± 1.61	0.714	0.139	2.23
Aloe essential oil (*Aloe vera* (L.) Burm.f.)	8.52 ± 1.24	11.40 ± 1.45	0.747	0.180	1.83
Peppermint essential oil (*Mentha* x *piperita* L.)	14.38 ± 1.44	13.27 ± 1.76	1.084	0.664	0.19
Mandarin essential oil (*Citrus reticulate* Blanco)	13.23 ± 1.19	10.31 ± 1.03	1.283	0.102	2.72
Dry Plants					
Calendula officinalis L. (inflorescences)	4.07 ± 0.80	9.97 ± 1.17	0.408	$3.3 * 10^{-4}$	13.89
Artemisia absinthium L. (leaves)	6.39 ± 0.79	14.62 ± 1.38	0.437	$1.1 * 10^{-5}$	21.53
Jasminum officinale L. (flowers)	5.59 ± 0.66	11.84 ± 1.41	0.472	$5.1 * 10^{-4}$	12.94
Origanum vulgare L. (leaves)	4.25 ± 0.76	8.05 ± 1.13	0.527	0.014	6.30
Matricaria chamomilla L. (inflorescences)	5.51 ± 0.66	9.93 ± 1.42	0.555	0.013	6.40
Crataegus monogyna Jacq. (inflorescences)	6.65 ± 1.03	11.59 ± 0.98	0.573	$2.4 * 10^{-3}$	9.74
Mentha x *piperita* L. (leaves)	7.12 ± 1.07	12.64 ± 1.56	0.583	0.010	6.85
Achillea millefolium L. (inflorescences)	6.95 ± 0.81	10.99 ± 1.28	0.632	0.019	5.69
Hypericum perforatum L. (leaves)	8.19 ± 0.89	12.08 ± 1.32	0.678	0.031	4.79
Aristolochia clematitis L. (leaves)	10.80 ± 1.43	15.72 ± 1.38	0.687	0.029	4.89
Tanacetum vulgare L. (inflorescences)	7.94 ± 0.96	11.13 ± 1.07	0.714	0.049	3.96
Chelidonium majus L. (leaves)	8.28 ± 1.24	10.40 ± 0.96	0.796	0.230	1.45
Tilia cordata Mill. (inflorescences)	7.84 ± 1.23	9.43 ± 0.90	0.831	0.353	0.87
Helichrysum arenarium (L.) Moench (inflorescences)	9.98 ± 1.04	11.46 ± 1.27	0.871	0.424	0.64

Strong repellent actions toward *Sh. lateralis* were displayed by food additives Apricot (0.340), Barberry (0.432) and Kiwi (0.481). Lower repellent effect on cockroaches was exerted by Biscuit (0.677). Neither repellent nor luring effects on cockroaches were produced by Vanilla flavouring (0.726).

Vaping mixtures Strawberry Pie (0.342), Pear (0.406), Frozen forest (0.478), Irish Cream (0.483) and Blue Magic (0544) displayed strong repellent actions toward cockroaches. Lower effects on *Sh. lateralis* were exerted by vaping mixtures Pancackes with Honey (0.638), Turkish Tobacco (0.669) and Grapefruit (0.700). No significant effects on the number of cockroaches on various sections of the experimental stand were exerted by vaping mixtures Vanilla (0.738), Ice Cream Club (0.764), Blueberry Jam (0.783), Mojito (0.807), Chocolate (0.819), Apple (0.838), Mint (0.954) and Walnut (1.227).

Out of fishing baits, the strongest repellent effects on *Sh. lateralis* were caused by Blood Worm (0.185), Onion (0.402) and Honey (0.507), and much lower effects by Corn (0.589) and Vanilla (0.592). Nonetheless, five out of five fishing baits we tested produced significant repellent effects on imagoes of Turkestan cockroach, while the fishing bait Blood Worm exerted the lowest attractiveness coefficient out of all the mixtures we tested (Table 1).

Imagoes of Turkestan cockroaches were significantly repelled by essential oils from jojoba (0.373), eucalyptus (0.393), daisy (0.418), tea tree (0.420), mixture of volatiles (methol – 0.455 g, camphor – 0.910 g, eucalyptus oil – 0.140 mL, carnation oil – 0.228 mL, cinnamon oil – 0.053 mL), included in Golden Star Balm balsam – Cao Sao Vang (0.432), and also fir essential oil (0.591). No significant luring or repellent effects on imagoes of *Sh. lateralis* were exerted by essential oils of lemon (0.714), aloe (0.747), peppermint (1.084) and mandarin (1.283).

A large number of the dry medicinal plants we tested (Table 1) repelled imagoes of Turkestan cockroach: inflorescences of *Calendula officinalis* (0.408), leaves of *Artemisia absinthium* (0.407), flowers of *Jasminum officinale* (0.472), leaves of *Origanum vulgare* (0.527), inflorescences of *Matricaria chamomilla* (0.555), inflorescences of *Crataegus monogyna* (0.573), leaves of *Mentha* x *piperita* (0.583), inflorescences of *Achillea millefolium* (0.632), leaves of *Hypericum perforatum* (0.678), leaves of *Aristolochia clematitis* (0.687) and inflorescences of *Tanacetum vulgare* (0.714). No repellent effects on *Sh. lateralis* were exerted by leaves of *Chelidonium majus* (0.796), inflorescences of *Tilia cordata* (0.831) and inflorescences of *Helichrysum arenarium* (0.871).

Discussion

Turkestan cockroach is broadly spread around the world – from Central Asia to West Europe and North America: India (Kashmir), Pakistan, Afghanistan, Iran, Iraq, Yemen, United Arab Emirates, Saudi Arabia, Azerbaijan, Caucasus Mountains, Jordan, Israel, Palestine, Cyprus, Turkey, Northeastern Africa (Egypt, Sudan, Libya), Canary Islands, USA (adventive) (Artiukhina & Sukhova, 1972; Bohn & Van Harten, 2006; Davranoglou et al., 2020). The global climate change undoubtfully promotes spread of its range north. This species was observed to have high physiological flexibility (for example, resistance to insecticides (Kapanadze, 1970)), but also significant morphological variability of the structure of the wings (Ross, 2012).

Turkestan cockroach has become a significant invasive species in the southwest and southern United States (Arizona: Maricopa, Pima; California: San Joaquin; Texas: El Paso). It is quickly displacing oriental cockroach *Blatta orientalis* (L.) in urban districts in southwest USA as the most significant synanthrophic species. Usually, *Sh. lateralis* lives in underground containers, such as water meters, irrigation and electric boxes, concrete ridges, fractures and gaps, and also walls of silicate blocks. Sometimes, they infest accommodations. At 26.7 °C, males and females develop into adults on average in 222 and 224 days, respectively (Kim & Rust, 2013). Males and females have five nymph ages. Adult females lay up to 25 oothecas (Kapanadze, 1971; Kim & Rust, 2013). An ootheca comprises 16.8 eggs on average, hatching coefficient is 82.7%. Adult cockroaches live no less than 612 days (Kim & Rust, 2013). Turkestan cockroach – compared with *Blatta orientalis* – is more successful due to short period of nymph development and the much larger amounts of oothecas. Therefore, Turkestan cockroaches are displacing oriental cockroaches in open air in the southwest USA (Kim & Rust, 2013).

This species of cockroach poses an epidemiologic threat not only to humans but also domestic animals: for example, for female dogs, *Sh. lateralis* are more attractive by aroma than for male dogs (Kierończyk et al., 2018). Turkestan cockroach broadly spreads parasitic organisms that live in it, for example *Herpomyces* ectoparasitic fungi (Ascomycota, Laboulbeniales) (Pfliegler et al., 2018).

Shelfordella lateralis is one of few insects that is practically significant for the epidemiological situation (Abbasi et al., 2019) in landfills and polluted territories, where this species often competes with one of the most dangerous species of cockroaches – *Periplaneta americana* Linnaeus (Blattodea, Blattidae). In the city of Quetta (Pakistan) *Sh. lateralis* is the most abundant species of the five common cockroaches (Kamran et al., 2021). It was found in 37.1% of the total residences surveyed: at landscape scale, the most common was *Sh. lateralis*, presenting a clustered distribution in two sampled zones, also heavily urbanized. At indoor scale, *Sh. lateralis* was most frequently found in kitchens. Kamran et al. (2021) suggests that *Sh. lateralis* have the potential to displace the main cosmopolitan pests and, most concerning, also carry antibiotic-resistant pathogenic bacteria. Considering that this Asian-native pest is now present in Europe and America, it may be considered a relevant urban pest deserving further international public health attention.

Studies by Schmidt et al. (2019) revealed that *Sh. lateralis* has a higher – compared with other insects – concentration of vitamin B_{12} – 13.2 µg/100 g dry weight. Therefore, this species is a promising source of not only proteins and fats, but vitamins as well. The high concentration of nutrients makes dry cockroaches of this species a promising fodder for domestic birds and mammals (Józefiak et al., 2018). Furthermore, *Sh. lateralis* is a significant object of physiological experiments (Oonincx & Dierenfeld, 2012; Renelies-Hamilton et al., 2020; Matsuda et al., 2021) and studies of microbiome of the intestine (Schauer et al., 2012, 2014; Mikaelyan et al., 2016; Tegtmeier et al., 2016), because this species is not demanding in terms of environmental conditions and can be easily kept in captivity.

According to the results of our experiments, inflorescences of *Calendula officinalis* had the strongest repellent effect on cockroaches. It repelled 75% of *Sh. lateralis* individuals at the distance of up to 30–40 cm. The essential oil of eucalyptus had a lower repellent effect compared with the repellent herbs. *Mentha piperita* essential oil contains 2.11% germacrene D (Lang & Buchbauer, 2012). This substance attracted imagoes of *Periplaneta japonica* (Karny, 1908) and *P. americana* (Linnaeus, 1758) in the amount of several mg, which is comparable to its concentration in our experiments (Kitamura et al., 1976). Our studies confirm the attractant effect of germacrene D on cockroaches *Sh. lateralis*. In control experiments (without aromatic compounds), it was confirmed that insects tended to move at both ends of the experimental stand, because they instinctively go to the nooks and crannies, so this should be taken into account for substances that have an attractive effect.

Verbena cosmetic fragrance and food flavouring Barberry are regarded as some of the most promising repellent compounds for the use in households. The flavor Verbena contains a chemical known as neral (citral b) (Sourki et al., 2019). This chemical has a repelling effect on imagoes of *P. americana* (Vartak et al., 1994). The findings of the study clearly corroborate the neral repellent properties against imagoes of *Sh. lateralis*.

Two approaches are considered in our research as options for solving problems related to toxic insecticides which have a destructive impact: using repellents against cockroaches in households, or using attractants in combination with small doses of traditional pesticides to improve their efficiency and reduce toxicological impact on people and the environment. The usefulness of attractant compounds is limited not just to their use in pesticide traps. The use of harmless fragrant compounds to track the location of cockroaches indoors is also part of integrated pest management. Although repellent compounds had a stronger effect on motor activity in studies, the employment of both repellent and attractant mixes is a viable approach to reduce the volume of hazardous insecticides used.

Conclusion

Attractiveness coefficient (ratio of number of cockroaches in the nearest 30 cm to the aroma source to those in 30 cm section of the experimental stand which was farthest from the aroma source) was minimum for cosmetic mixtures Tutti-fruti (0.204), Verbena (0.275) and Bamboo (0.489); other cosmetic aromatizers did not repell imagoes of Turkestan cockroach (Lilac – 0.825, Mango – 0.868) or repelled poorly (Grapefruit – 0.720, Amaretto – 0.670, Pine – 0.730).

Strong repellent action toward *Sh. lateralis* was caused by food additives Apricot (0.340), Barberry (0.432) and Kiwi (0.481), lower – by Biscuit (0.677) and no effect was taken by aromatizer Vanilla (0.726). Vaping mixtures Strawberry Pie (0.342), Pear (0.406), Frozen forest (0.478), Irish Cream (0.483) and Blue Magic (0544) significantly repelled cockroaches. Lowest repellent effects on *Sh. lateralis* cockroaches was exerted by vaping mixtures Pancakes with Honey (0.638), Turkish Tobacco (0.669) and Grapefruit (0.700). No significant effect on the number of cockroaches were exerted by vaping mixtures Vanilla (0.738), Ice Cream Club (0.764), Blueberry Jam (0.783), Mojito (0.807), Chocolate (0.819), Apple (0.838), Mint (0.954) and Walnut (1.227).

Of fishing baits, strong repellent effects on *Sh. lateralis* were produced by Blood Worm (0.185), Onion (0.402) and Honey (0.507), and the lowest by Corn (0.589) and Vanilla (0.592).

Imagoes of *Sh. lateralis* were repelled by essential oils from jojoba (0.373), eucalyptus (0.393), daisy (0.418), tea tree (0.420), Cao Sao Vang balsam (0.432), and also fir essential oil (0.591). Neither attractive nor repellent effects on *Sh. lateralis* imagoes were produced by essential oils from lemon (0.714), aloe (0.747), peppermint (1.084) and mandarin (1.283).

Dry medicinal plants repelled imagoes of *Sh. lateralis*: inflorescences of *Calendula officinalis* (0.408), leaves of *Artemisia absinthium* (0.407), flowers of *Jasminum officinale* (0.472), leaves of *Origanum vulgare* (0.527), inflorescences of *Matricaria chamomilla* (0.555), inflorescences of *Crataegus monogyna* (0.573), leaves of *Mentha* x *piperita* (0.583), inflorescences of *Achillea millefolium* (0.632), leaves of *Hypericum perforatum* (0.678), leaves of *Aristolochia clematitis* (0.687) and inflorescences of *Tanacetum vulgare* (0.714). No repellent effects on *Sh. lateralis* were exerted by leaves of *Chelidonium majus* (0.796), inflorescences of *Tilia cordata* (0.831) and inflorescences of *Helichrysum arenarium* (0.871).

Thus, most (40 out of 58, or 69.0%) the tested aroma mixtures and medicinal plants repelled synanthrophic Turkestan cockroaches and a small amount (31.0%) neither significantly attracted nor repelled them. No aromatic mixtures in our experiment attracted *Sh. lateralis*.

The study's findings can be used to eliminate and prevent the spread of cockroaches in residential and public buildings. Use of insecticides may be reduced by placing a fleece soaked in one drop of attractant mixed with poison or two drops of repellent next to the bug shelter. This will lessen their harmful impact on many people's health. Flavourings applied topically in conjunction with integrated pest management (IPM) could be a safer alternative to harmful insecticides. This method has a lower risk of harming human health and the environment.

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