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The chemical analysis and insecticidal activity of *Francoeuria undulata* essential oil on the German cockroach, *Blattella germanica*

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Abstract. Cockroaches are the most resistant urban and domestic pests in the world. Hence, investigations into alternative control strategies such as the use of active compounds of plants against this insect pest are important. In this study, *Francoeuria undulata* (L.) plants were collected from Isfahan province, Iran, and then the essential oil of the aerial parts of the plant was extracted by hydro-distillation. Plant essential oil was analyzed using GC/MS. The German cockroach, *Blattella germanica* L. (Blattodea: Ectobiidae), were obtained from the Tehran University of Medical Sciences. Different concentrations of *F. undulata* essential oil were prepared in acetone, and contact and repellency tests were carried out on German cockroaches. Moreover, 40 male rats were divided into 4 groups including 1 Control and 3 treated groups that received *F. undulata* oil with 5%, 15%, and 30% v/v concentrations once daily for 10 days. The blood samples were collected and biochemical parameters were assayed in serum. Also, the liver tissue was isolated for histopathological examination. The major components of the essential oil were 1,8-cineole (26.02%), α-pinene (12.51%), Camphor (8.36%), and Camphene (5.03%). The results showed that the concentrations of 5%, 15%, and 30% v/v of *F. undulata* oil in 60 min of exposure had 100% insecticidal activity against the German cockroach. The repellency percentage of *F. undulata* oil at 5% concentration was not significant compared to the control, while the concentrations of 15% and 30% of essential oil showed a significant repellent effect on the German cockroach. Furthermore, the essential oil, at 5% concentration, was non-toxic to the livers of rats. The changes in the activities of aspartate aminotransferase, alanine aminotransferase, and alkaline phosphatase were also detected in the treated rats. This finding revealed that the *F. undulata* essential oil has effective insecticidal activity against the German cockroach, making it a candidate for being considered in the management programmas of this pest.

Keywords: Essential oil, Francoeuria undulata, Insecticidal, Liver, Pest control, Botanical pesticide

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Introduction

The use of herbal medicines in Asia demonstrates a long history of human interactions with the environment (Diallo *et al.*, 1999). Many attempts have been made to discover new effective compounds from different sources such as micro-organisms, plants, and animals (Karimi e*t al.*, 2016) so that botanicals are appropriate alternatives to the conventional synthetic toxic pesticides against urban pests (Kafle & Chinkangsadarn, 2022). The genus *Francoeuria* is represented by one perennial species, *F. undulata* (L.) Lack in Iran, which is synonymous with *F. crispa* (Forssk), *Pulicaria undulata* (L.) C.A., and *P. crispa* (Forssk), and is an aromatic herb of the Asteraceae family (tribe: Inuleae) that thrives in Iran's deserts and sandy environments (Mozaffarian, 1996). Flowers are bright yellow, in terminal cymes forming capitulum from March to June (Mahmoud, 2010). *Francoeuria undulata* is locally called "Kak goriz". Studies have shown the anticancer, antiviral, and antibacterial properties of this plant (Bakkali *et al.*,

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2008; Firoozian *et al.*, 2017). Phytochemical studies have demonstrated that the essential oil of *F. undulata*, growing wild in the south of Iran (Hormozgan province), contained: α-bisabolol (17.5%), chrysanthenone (12.5%), 1,8-cineol (10.7%), trans-thujone (9.7%), and linalool (6.6%) (Bastan & Sadeghi, 2015). A previous study revealed that the essential oil of *F. undulata*, obtained from Fars province in the south of Iran, contained five main components, including 1,8-cineole (21%), alloaromadendrene epoxide (17%), α-terpineol (8%), α-pinene (5%), and terpinene-4-ol (5%) (Bastan & Sadeghi, 2015). These studies show the role of different ecological conditions on the effective compounds of plants.

The German cockroach, *Blattella germanica* (L.) is found throughout the world. It is not only a source of allergic diseases but also spreads several intestinal diseases including diarrhea, dysentery, and cholera (Wirtz, 1984; Schal & Hamilton, 1990). The widespread use of chemical insecticides has resulted in the development of resistance in German cockroaches, as well as environmental and human health problems (Chang, 2010; Mansour *et al.*, 2015; Fazeli-Dinan *et al.* 2022).

This study aimed to detect the effective compounds in the essential oil by Gas Chromatography-Mass Spectrometry (GC-MS). Also, to assess the insecticidal and repellent activities of *F. undulata* essential oil against adults of *B. germanica* and test whether these oils would affect the liver of rats as the most important organ in detoxification activity.

Materials and methods

Ethical considerations

The study procedures were carried out by the institution's scientific procedures for animals; thus, all tests were conducted under Council Directive 86/609/EEC of November 24, 1986 on the approximation of laws, regulations, and administrative provisions of the Member States regarding the protection of animals used for experimental and other scientific purposes (Louhimies, 2002), and by the Research and Ethics Committee of Islamic Azad University, Falavarjan Branch, Isfahan, Iran with the ethical code of (IR.IAU.FALA.REC.1396.012).

Plant material

The aerial parts of *F. undulata* were collected in September 2015 from Ardestan, Isfahan province, Iran. Plant ID: Mohammadtaghi Feizi from the herbarium of the Research Institute for Forests and Rangelands identified it with specimen number 1032 from the herbarium, which is kept in the library.

Preparation of the essential oil

The aerial parts of *F. undulata* were dried in shade and powdered using an electric blender. Then, the essential oil was extracted from 50 g of each powder by hydro-distillation with a Clevenger-type apparatus for 3 h. The oil was stored at 5 °C in dark, sealed, glass vials until the next experiments (Amjad *et al.*, 2014).

Gas chromatography-mass spectrometry (GC-MS)

The chemical composition of *F. undulata* essential oil was analyzed using GC-MS. The GC/MS analysis was carried out with Agilent company (model 5975C-7890, United States) GC-MSD system in the research laboratory of Islamic Azad University, Isfahan Branch, Isfahan, Iran. HP-5MS column (30m × 0.25mm. 0.25µm film thickness) was used with helium as the carrier gas (1.2 ml/min). GC oven temperature was kept at 50 °C for 3 min and programmed to 280 °C at a rate of 5 °C/min, and increased to 290°C and kept constant at 290 °C for 3 min, at splitless mode. The injector temperature was 290 °C. Transfer line temperature was 280 °C. MS was taken at 70 20 eV. Mass ranger was from 35 to 450 m/z. Headspace (150 g, 290 °C, 3 min) GC-MS was used in this study (Amjad *et al.*, 2016).

Insects

German cockroaches (*B. germanica*) were obtained from the School of Public Health, Tehran University of Medical Sciences, and were identified by Dr. Mansoureh Shayeghi (Professor of Medical Entomology and Vector Control, School of Public Health, Tehran University of Medical Sciences). Cockroaches were reared in glass boxes (10×15 cm) and were supplied with water from a glass flask fitted with a cotton stopper, and fed with dried mouse food. They were maintained at 25±1 °C, 60% relative humidity (RH), and a photoperiod of 12:12h light: dark (Yeom *et al.*, 2015).

The bioassays

Contact toxicity test

Different concentrations (5%, 10%, and 30% v/v) of *F. undulata* essential oil were prepared in acetone as a semi-polar solvent for dissolving monoterpene and sesquiterpene compounds. German cockroaches were put into different beakers. For the control insects, the beaker's surface was smeared with acetone only (2.5 ml), so that it was possible to evaporate through the opening of the glass. Treated insects (n=10) received 2.5 ml of various concentrations of the essential oils, including 5%, 10%, and 30% (v/v). Mortality in these groups was determined 5, 15, 30, 45, and 60 min after treatment. Each assay was replicated five times (Appel *et al.*, 2001).

Repellency test

A wooden box (50×50×15 cm) was utilized in this test. All four walls of the box were smeared with Vaseline® to prevent the escape of cockroaches, and a piece of filter paper (Whatman No.1) was used to divide it into two equal parts (control and treated areas) from the bottom of the box. For a repellent test, 2.5 ml of each concentration of *F. undulata* essential oil (5%, 10%, and 30% v/v) was applied by placing drops from a pipette on the treated area to cover the filter paper, while the control area was treated with acetone. Cockroaches were able to move freely between the treated and untreated areas. These areas were surrounded by aluminum foil to keep a dark environment (Thavara *et al.*, 2007). The cockroaches (n=10) located in the treated and control areas were carefully observed and counted 24 h after treatment. Repellency against the German cockroaches was calculated according to the following equation (Thavara *et al.*, 2007):

Repellency (%) = 100 – [T × 100]/N; where T is the number of cockroaches located in the treated area, and N is the total number of cockroaches.

Animals

Adult male Wistar rats (*Rattus norvegicus* (Berkenhout, 1769) (200-250g) were obtained from the Pasteur Institute of Iran. They were maintained under controlled temperature (22±1°C) and 12 h light/12 h dark exposure for 1 week for adaptation to laboratory conditions before starting the experiments.

Liver enzymes assay and tissue sampling

The animals were randomly divided into 4 groups (n=10 per group) and received the treatments by intraperitoneal injection. The groups included the control group that received normal saline and essential oil, and 3 treated groups that received *F. undulata* essential oil with 5%, 15%, and 30% v/v concentrations once daily for 10 days (Kelishadi *et al.*, 2017). The animals were anesthetized with ketamine injections (0.07 ml/100kg body weight), and blood samples were taken directly from the heart one day after the last injection of essential oil. The biochemical parameters including aspartate aminotransferase (AST), alanine transaminase (ALT), and alkaline phosphatase (ALP) enzymes were assayed using an autoanalyzer (902 Hitachi Automatic Analyzer, Roche, India). For histological studies, the animals were dissected after bleeding, and their livers were rapidly removed. After that, the samples were fixed in 10% formalin, dehydrated in ethanol 70%, cleared in xylene, and embedded in paraffin, respectively. Sections were prepared from the fixed tissue and then stained with Hematoxylin-Eosin (H&E) for the observation of liver tissue transformations.

Statistical analysis

According to the Kolmogorov Smirnov test (P>0.05), the data were normal. Data were analyzed in three replicates by using a completely randomized design with a one-way analysis of variance (ANOVA) by SPSS statistics software version 18. The statistical differences among means were compared using the Duncan test at a 0.05 significance level (SPSS, 2018). Also, to compare the percentage of insect mortality at different times for each concentration, Repeated Measures ANOVA was used.

Results & Discussion

Francoeuria undulata essential oil analysis

According to the results, the oil was 100 µl of *F. undulata* essential oil yielded from 50 g of dried aerial parts and the essential oil contained 49 components. The major compounds which were found in the essential oil included 1,8-cineole (26.02%), α-pinene (12.51%), camphor (8.36%), camphene (5.03%), caryophyllene (2.61%), and isopinocarveol (2.06%) that constituted a total of 56.59%. Thus, 1,8-cineole, α-pinene, and camphor were the major components of the essential oil (Table 1). Previous studies showed a variation in the compounds of *F. undulata* essential oil in different geographical areas, but there was little difference in the components and amounts of essential oil compounds in similar geographical conditions (Javadinamin & Asgarpanah, 2014; Bastan & Sadeghi, 2015; Kasraei *et al.*, 2020). The difference could be attributed to production conditions such as storage time and harvesting date, as well as edaphic factors or climatic (Yeom *et al.*, 2015).

The bioassays

Contact toxicity test

The contact toxicity of *F. undulata* essential oil varied according to concentration and duration of exposure. German cockroaches at essential oil concentrations of 15% v/v and 30% v/v after 15, 30, 45, and 60 min of exposure showed 100% insecticidal activity.

Table 1. Chemical composition of *Francoeuria undulata* essential oil

No.	Compound	Rt[a]	Aerial parts (%)	Rep.KI	Cal.KI
1	Cyclotrisiloxane	5.63	0.47	884	887
2	Butanoic acid	6.03	0.35	896	899
3	ɣ-Terpinene	7.67	0.69	953	950
4	α.-Pinene	8.01	12.51	962	960
5	Camphene	8.44	5.03	976	973
6	Butanamide	8.76	0.17	980	982
7	β.-Pinene	9.34	1.31	997	999
8	Butane	9.88	0.33	1018	1015
9	Trimethylbenzene	10.12	0.19	1021	1022
10	Benzene	11.49	1.11	1065	1061
11	1,8-Cineole	11.74	26.02	1067	1069
12	3,6,8Nonatrienoic acid	13.25	0.30	1113	1112
13	3,3-Dichloro camphor	13.44	0.48	1119	1117
14	Butanal	13.91	0.40	1133	1130
15	1-Methy-2-aminomethylimidazole	13.92	0.48	1135	1131
16	α-Methyl acrylic amide	14.42	0.24	1141	1144
17	Linalool	15.13	1.62	1166	1164
18	β-Linalool	15.30	0.22	1169	1169
19	Salicylic acid	15.88	0.39	1188	1185
20	Iso-pinocarveol	16.32	2.06	1196	1197
21	Camphor	16.47	8.36	1205	1201
22	Tetradecanamine	16.88	0.33	1216	1213
23	Pinocarvone	17.08	1.08	1219	1219
24	Borneol	17.21	1.57	1222	1222
25	Pentanamide	18.53	0.36	1263	1260
26	Heptadecanamine	20.37	0.15	1315	1312
27	Formamide	21.29	0.47	1335	1338
28	Caryophyllene	23.23	2.61	1398	1395
29	Pentasiloxane	24.70	0.74	1443	1440
30	Camphene	24.91	0.29	1449	1447
31	Octadecanoic acid	26.27	1.17	1487	1489
32	n-Heptadecylamine	27.46	0.30	1526	1528
33	Pyrrolidine carboxylic acid	27.48	0.48	1527	1529
34	Cyclooctasiloxane	27.56	0.87	1533	1531
35	Benenamine	27.94	0.91	1547	1544
36	Bisabolol oxide A	28.94	1.63	1579	1577
37	Cyclononasiloxane	30.03	0.65	1617	1615
38	Benzenepropanoic acid	31.01	0.27	1653	1650
39	Tetradacamethyl hexasiloxane	31.81	1.51	1681	1679
40	H-isoindole	32.59	0.78	1706	1708
41	Benzeneacetic acid	32.67	1.61	1714	1711
42	Tetracosamethylcyclododecasiloxane	33.24	1.34	1737	1734
43	Propiophenone	33.74	0.73	1756	1753
44	Silikonfett	34.24	0.37	1776	1773
45	Phthalic acid	34.32	6.46	1779	1776
46	Cyclotrisiloxane	34.82	0.24	1799	1796
47	Tetrasiloxane	36.69	1.66	1878	1875
48	Methyldibenzazepine	37.17	0.19	1899	1896
49	Cyclotrisiloxane	37.32	0.23	1908	1903
	Oxygenated monoterpenes		41.71		
	Hydrocarbon monotrpenes		19.53		
	Sesquiterpenes		2.60		
	Non-terpene hydrocarbons		17.84		
	Oxygenated non-terpenes		11.94		
	Non-oxygenated constituents		2.29		
	Total identified constituents		95.94		
	[a] Rt (Retention time)		41.71		
	Cal. KI (Calculated kovats index)		19.53		
	Rep. KI (Reported kovats index)		2.60		

Whereas the insecticidal activity of *F. undulata* essential oil with a concentration of 5% after 60 min was 100%. Moreover, only 30% v/v essential oil showed a significant insecticidal effect (37%) after 5 min (P<0.01) (Table 2). Also, the percentage of mortality in each concentration increased significantly with time. In the control group, there was no mortality in the treatment period.

The essential oil of *F. undulata* with a concentration of 30% indicated excellent repellency against German cockroaches in the laboratory.The percentage repellency of *F. undulata* essential oil at 5% v/v concentration was not significant compared to the control, but the concentrations of 15% v/v and 30% v/v of essential oil showed a significant *repellent* effect on German cockroaches (40 and 70%, respectively; P < 0.01, P <0.001) (Figure 1), The percentage repellency of *F. undulata* essential oil at 5% v/v concentration was significant compared to the 15% v/v and 30% concentration and thus, the concentration of 15% essential oil was significant compared to the 30% concentration (P<0.001).

Table 2. Contact toxicity of *Francoeuria undulata* essential oil against the German cockroach

Concentration of essential oil (%)	Mortality (%) (Mean± SD) 5 min after treatment	15 min after treatment	30 min after treatment	45 min after treatment	60 min after treatment	
5	0±0.00	0±0.00	23±7.07	51±14.14	100±0.00	*P*<0.001
15	0±0.00	***100±0.00	***100±0.00	***100±0.00	100±0.00	*P*<0.001
30	**37±7.07	***100±0.00	***100±0.00	***100±0.00	100±0.00	*P*<0.001
	P < 0.01	*P* < 0.001	*P* < 0.001	*P* < 0.001	*P* > 0. 05	

**Significant difference at *P*<0.01 level
***Significant difference at *P*<0.001 level

The essential oil of *F. undulata* with a concentration of 30% indicated excellent repellency against German cockroaches in the laboratory.The percentage repellency of *F. undulata* essential oil at 5% v/v concentration was not significant compared to the control, but the concentrations of 15% v/v and 30% v/v of essential oil showed a significant *repellent* effect on German cockroaches (40 and 70%, respectively; *P* < 0.01, *P* <0.001) (Figure 1), The percentage repellency of *F. undulata* essential oil at 5% v/v concentration was significant compared to the 15% v/v and 30% concentration and thus, the concentration of 15% essential oil was significant compared to the 30% concentration (*P*<0.001).

Several plant essential oils have been reported to exhibit contact toxicity against German cockroaches. For example, a mixture of estragole, linalool, and limonene in the blending ratio of 7:2:7 displays the same insecticidal activity as the binary mixture of basil and mandarin oils (Kim *et al.,* 2021). Yeom *et al.,* 2012 reported that 11 species of Apiaceae plant essential oils have insecticidal effects on *Blattella germanica.* Among the compounds: carvone, 1,8-cineole, p-cymene, and γ-terpinene demonstrated strong fumigant toxicity against *Blattella germanica.*Yeom *et al.*, 2015 showed contact toxicities of 16 species of Asteraceae plant essential oils against *Blattella germanica.* Among the compounds identified from essential oils, estragole illustrated potent fumigant and contact toxicity against German cockroaches. Those effects have mainly been attributed to compounds such as 1,8-cineole, α-pinene, ρ-cymene, limonene, α-terpinene, and γ–terpinene (Yeom *et al.,* 2012). Appel *et al.* (2001) revealed that compounds of essential oils such as thymol, linalool, α- and β- pinene, citronellol, limonene, and carvacrol have been responsible for mortality effects on the adult and larva of different insect pests including cockroaches.

Our results confirmed the findings of other researchers who showed that 1,8-cineole and α-pinene have strong insecticidal activity against the adult German cockroaches. Enan (2001) demonstrated that the insecticidal activity of monoterpenoids (belonging to terpenoids) depends on various factors including insect species, concentration, time of influence, method of application, and contact surface. The findings of other researchers explored that monoterpenoids might be more quickly degraded in the environment compared to synthetic compounds; therefore, they are relatively safer for the environment than common insecticides such as carbamates and organophosphorus (Pilmmer, 1993).

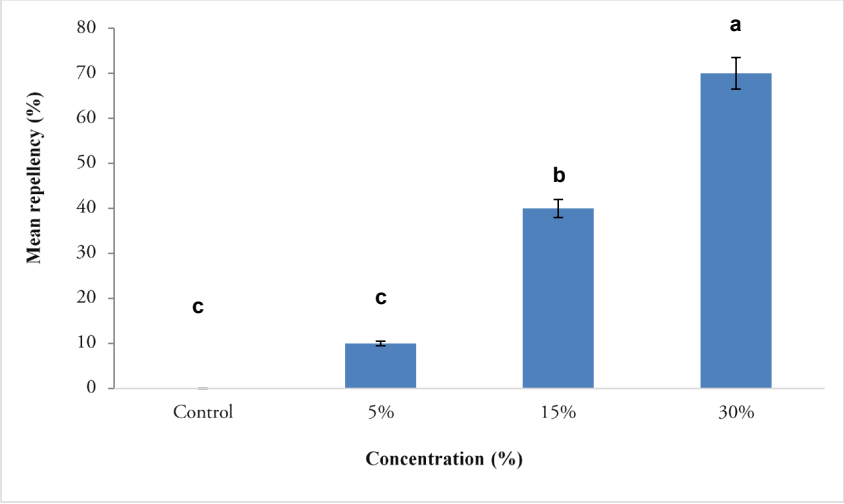

Fig. 1. The percentage repellency of *Francoeuria undulata* essential oil on the German cockroach. Non-similar letters on top of the columns indicate a significant difference at *P* <0.001 (Dunkan test)

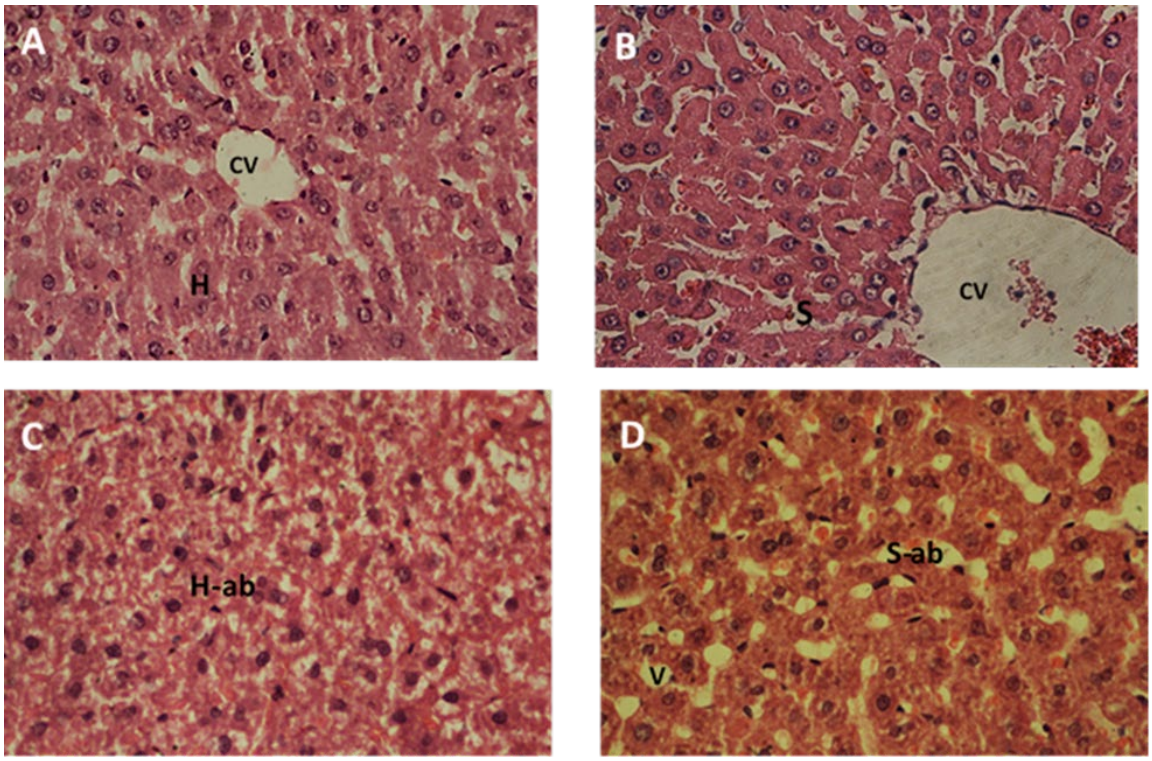

Fig. 2 Histological sections of rat liver by staining hematoxylin-eosin (× 400). A: control group, the morphological structure of hepatocytes (H), sinusoids (S) and central vein (cv) were normal. B: 5% essential oil treated. C: 15% essential oil treated, the degeneration of hepatocytes and irregular sinusoids (H-ab) is seen. D: 30% essential oil treated, the sinusoidal dilatation (S-ab) and vacuolated hepatocytes (V) is seen.

Table 3. The activity of liver enzymes following *Francoeuria undulata* essential oil injection

Essential oil percentage	AST (U/L)	ALT (U/L)	ALP (U/L)
0 (control)	231.75±29.45b	121.32±10.33b	406.20±25.66b
5	253.41±28.65b	132.45±16.87b	392.65±45.27b
15	345.27±51.23[a]	145.35±28.96[a]	498.58±71.69[a]
30	376.56±65.48[a]	148.78±31.12[a]	512.28±68.49[a]

[a] Significant increase in enzyme activity ($P < 0.05$)

Effect of the essential oil on animal

Intraperitoneal injection (10 times) of the essential oil of *F. undulata* in 15% v/v and 30% v/v concentrations caused remarkable disturbances in the structure of the liver tissue. Some of these abnormalities include hepatocyte lysis, disorder, and dilation of sinusoids, degenerating of hepatocytes cytoplasm which led to the formation of empty cavities (vacuolation); while 5% v/v concentration of essential oil did not cause significant changes in the liver tissue (Figure 2). The results showed that intraperitoneal injection of 15% v/v and 30% v/v essential oils of *F. undulata* after 10 days significantly increased the level of liver enzyme activity ($P < 0.05$). While no significant difference was observed in the 5% concentration. (Table 3).

The results of our studies showed that the concentration of 5% *F. undulata* essential oil was not significant compared to the control, but the 15% v/v and 30% v/v concentrations of essential oil showed a significant effect on liver enzyme activity compared to the control ($P<0.05$), thus liver enzyme changes in concentration of 15% v/v compared to the 30% v/v concentration of essential oil were not significant ($P>0.05$).

The findings revealed that *F. undulata* essential oil is non-toxic at a 5% concentration. Treatment with this concentration was well tolerated by rats and there were no toxic symptoms in liver tissue and function. Treatments with 15% and 30% of *F. undulata* essential oil led to liver toxicity including hepatocyte degeneration and a significant increase in enzyme activity that is possible because of generating free radicals. In this state, the cells

have different defense processes including non-enzymatic and enzymatic antioxidant mechanisms to protect themselves against the harmful effects of oxidative stress (Yusufoglu *et al*., 2018). It seems that the application of *F. undulata* essential oil (5%) created strong insecticidal effects on German cockroaches after 60 min, but did not have toxic effects on rats.

Conclusion

Urban pests live near, or sometimes in, human habitats; therefore, pest control strategies should be susceptible. To control urban pests, environmental, human, and non-targeted animal-friendly control methods are always in high demand instead of synthetic toxic chemicals. The present study investigated the potential for *F. undulata* essential oil to be used as a natural insecticide against the cockroach *Blattella germanica*. These results indicated that *F. undulata* essential oil might be developed as an aerosol for direct spray onto German cockroaches. More research is needed to make a controlled formulation from this insecticide that could be used in different places.

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تجزیه و تحلیل شیمیایی و فعالیت حشره کشی اسانس *Francoeuria undulata* روی سوسری آلمانی (*Blattella germanica*)

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چکیده

سوسری ها مقاوم ترین آفات شهری و خانگی در جهان هستند. از این رو، بررسی راهبردهای کنترل جایگزین مانند استفاده از ترکیبات فعال گیاهان در برابر این آفت حائز اهمیت است. در این تحقیق، گیاهان *Francoeuria undulata* (L.) از استان اصفهان جمع‌آوری و اسانس اندام‌های هوایی گیاه به روش تقطیر با آب استخراج شد. اسانس گیاهی با استفاده از دستگاه GC/MS آنالیز شد. سوسری آلمانی *Blattella germanica* L. (Blattodea: Ectobiidae)، از دانشگاه علوم پزشکی تهران تهیه شد. غلظت‌های مختلف اسانس *F. undulata* در استون تهیه شد و آزمایش‌های تماسی و دورکنندگی بر روی سوسک‌های آلمانی انجام شد. همچنین ۴۰ سر موش صحرایی نر به ۴ گروه شامل ۱ گروه کنترل و ۳ گروه تیمار شده تقسیم شدند، که اسانس گیاه را با غلظت های ۵، ۱۵ و ۳۰ درصد حجمی روزانه به مدت ۱۰ روز دریافت کردند. نمونه خون جمع آوری شد و پارامترهای بیوشیمیایی در سرم مورد سنجش قرار گرفت. همچنین بافت کبد برای بررسی هیستوپاتولوژیک جدا شد. اجزای اصلی اسانس ۱،۸-سینئول (۲۶/۰۲ ٪)، آلفا-پینن (۱۲/۵۱ ٪)، کامفور (۸/۳۶ ٪) و کامفن (۵/۰۳ ٪) بودند. نتایج نشان داد که غلظت‌های ۵٪، ۱۵٪ و ۳۰٪ حجمی اسانس *F. undulata* در ۶۰ دقیقه در معرض قرار گرفتن، ۱۰۰٪ فعالیت حشره‌کشی روی سوسری آلمانی داشت. درصد دور کنندگی اسانس *F. undulata* در غلظت ۵ درصد نسبت به شاهد معنی دار نبود، در حالی که غلظت های ۱۵ و ۳۰ درصد اسانس اثر دور کنندگی معنی داری را روی سوسری آلمانی نشان داد. همچنین اسانس در غلظت ۵ درصد برای کبد موش غیر سمی بود. تغییرات در فعالیت‌های آسپارتات آمینوترانسفراز، آلانین آمینوترانسفراز و آلکالین فسفاتاز نیز در موش‌های تحت درمان مشاهده شد. یافته‌های این پژوهش نشان داد که اسانس *F. undulata* دارای فعالیت حشره‌کشی مؤثری روی سوسری آلمانی است که این اسانس را به عنوان عاملی با پتانسیل جهت استفاده در برنامه های کنترل این آفت تبدیل می‌کند.

کلمات کلیدی: اسانس، *Francoeuria undulata*، حشره کشی، مدیریت آفات، کبد، حشره‌کش گیاهی

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