FUMIGANT TOXICITY OF ESSENTIAL OILS AND THEIR COMBINATIONS TOWARDS *Sitophilus oryzae* (L.), *Tribolium confusum* (J. du Val), AND *Callosobruchus maculates* (FABR.)

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ABSTRACT

This study examined the fumigant efficacy of seven essential oils from rosemary, caraway, coriander, thyme, dill, camphor and basil against the adult of *Sitophilus oryzae* (L.), *Tribolium confusum* (J. du Val) and *Callosobruchus maculates* (Fabr.). The rosemary and caraway oil showed the highest fumigant efficacy against the rice weevil at a concentration of LC_{50} (26 µl/l air); and (38 µl/l air), respectively. Rosemary (19 µl/l air) and coriander (23 µl/l air), had potent fumigant activities against the *T. confusum*. The caraway and rosemary were the most effective against *C. maculates* at LC_{50} (19 µl/l air) and LC_{50} (25 µl/l air) respectively. In conclusion rosemary and caraway showed strong fumigant toxicity to the *S. oryzae, T. confusum* and *C. maculates*. However, thyme and coriander had a lower fumigant activity than rosemary to insects. On the other hand, camphor, dill and basil also showed promising fumigant toxicities on the insects. The toxicity of the essential oils in combination (21 combinations) was investigated. The results obtained indicate that the mixture (caraway + coriander) was the most toxic to the *S. oryzae* and *T. confusum* with synergic category 86 and 71.6, respectively. Whereas the mixture (caraway + camphor) was the most toxic to the *C. maculates* with synergic category 71.2. Therefore, rosemary and other natural volatiles could be safe fumigants to control stored-grain insect pests, and can be used in the IPM programmes.

Key words: *Sitophilus oryzae*, *Tribolium confusum*, *Callosobruchus maculates* Fumigant toxicity, Essential oils,

INTRODUCTION

Stored products of agricultural origin are attacked by more than 600 species of beetle pests, 70 species of moths and about 355 species of mites causing quantitative and qualitative losses **(Rajendran, 2002)** and insect contamination in food commodities is an important quality control problem of concern for food industries. Currently, chemical control is the most commonly used strategy against these pests. Many chemicals including, insecticides and fumigants such as phosphine, methyl bromide, carbonyl sulphide and ethane dinitrile are common used for stored-product protection world over **(Park *et al.*, 2003)**. These chemicals have a residual problem, and in addition, the resistance of S. oryzae to insecticides has increased **(Kljajic and Peric, 2006).** As well as, methyl bromide consider threat the environment and its use will be minimize gradually. Because of the increasing drawbacks in continued use of today's conventional fumigants an effort is needed for development of new compounds to replace those currently used **(Lee *et al.*, 2001)**. There are several reports on the insecticidal activities of essential oils against stored-products pests **((Regnault-Roger *et al.*, 1993; Regnault-Roger and Hamraoui, 1993; Othman, 2000a,b; Lee *et al.*, 2001; Park *et al.*, 2003; Rozman *et al* 2007; Lopez *et al.*, 2008)**.

Extracts and components from more than 75 plant species belonging to different families have been studied for fumigant toxicity to insects. Fumigant toxicity tests conducted with essential oils of plants (mainly belonging to Apiaceae, Lamiaceae, Lauraceae and Myrtaceae) and their components (cyanohydrins, monoterpenoids, sulphur compounds, thiocyanates and others) have largely focused on beetle pests such as *Tribolium castaneum, Rhyzopertha dominica, Sitophilus oryzae* and *Sitophilus zeamais* but little or no attention has been paid towards moths such as *Corcyra cephalonica* and *Sitotroga cerealella* **(Rajendran and Sriranjini, 2008)**. However some areas of research of the joint action for different essential oils or their constituents against stored-product insects are rare and need attention for the exploitation of the natural products as alternative fumigants for stored product insect control to cover the fumigant action and joint action of the essential oils mixture.

Therefore the objective of this study is to evaluate the toxicity of a commercial mixture of plant essential oils (camphor, dill, basil, coriander, thyme, rosemary and caraway oil), and their combination to three important stored products insects, *Sitophilus oryzae, Tribolium confusum* and *Callosobruchus maculates.*

MATERIALS AND METHODS

Insects

All test insects, *S. oryzae* (L.) (Coleoptera: Curculionidae), *T. confusum* (J. du Val) (Coleoptera: Tenebrionidae), *C. maculates* (Fabr.) (Coleoptera: Bruchidae) were taken from laboratory cultures reared in glass jars in an incubator maintained at 28±2 ˚C and 60±5% RH. The insects were reared to the adult stage using the techniques described by **Othman (2000a)**. The emerging adults were collected daily and stored in other clean jars with food until used for experiment. Approximately one-week-old adult were used for this experiment.

Essential oils

A total of commercial 7 essential oils were obtained from El-Captin Company (CAPPHARM), Al Obour City, Cairo, Zamzam Company, pyramids,Giza and Kato aromatic Company, Sakara road, Giza, Egypt, which are listed in Table1.

Fumigant test

The method used to determine the fumigant activity of tested oils was based on that described by **Othman (2000a, b)**. Fumigation chambers were one liter glass round-bottom, provided with air-tight screw lids. Batches of ten adults each of *S. oryzae*, *T. confusum* and *C. maculates* per replicate were placed in fumigant chamber. The tested oils were added separately on filter paper (Whatman No. 1, diameter 2.0 cm) and placed, in a small plastic cup (100 ml) separated from the fumigant chamber by a sheet of gauze, thus avoiding direct contact between the deposit and the insects. The cup was stood in the fumigant chamber **(Lopez *et al.*, 2008 and Regnault-Roger and Hamraoui, 1995)**. Four replicates were made for each tested oil and as well as for control treatment. The insects were fumigated for 24 h. at 28±2 °C and 60±5% RH. Mortality was observed after 24h.

Table 1. List of the commercial essential oils, their scientific names and their major components.

Essential oils& Scientific name	Plant family	Major components	Company
Rosemary *Rosmarinus officinalis* L.	Lamiaceae (Labiatae)	Borneol, 1,8 Cineol	El-Captin
Thyme *Thymus vulgaris* L.	Lamiaceae	Thymol, Cymene, Thymine, Carvacrol	El-Captin
Basil *Ocimum basilicum* L.	Lamiaceae	Linalool, Cineol, Eugenol	El-Captin
Caraway *Carum carvi* L.	Apiaceae (Umbelliferae)	Carvone, Limonene	El-Captin
Coriander *Coriandrum sativum* L.	Apiaceae	Linalool, cymene, Terpinine	kato
Dill *Anethum graveolens*	Apiaceae	Carvone, limonene, Phellandrene	El-Captin
Camphor *Cinnamomum camphora* L.	Lauraceae	Camphor, Borneol, Estragole	Zamzam

Binary mixtures of the tested oils

The joint action of different binary mixtures of the essential oils was assessed according to the method described by **Swelam and Sayed (2006).** The tested oils were mixed at the level of the LC_{25} with the ratio 1:1.

The joint action of the different mixtures was expressed as the co-toxicity factor, which was used to classify results into three categories. A positive factor +20 ≥ is considered potentiation, a negative factor –20 ≥ is considered antagonism and the values between -20 and +20 means additive effect.

Data analysis

The mortality percentage was recorded after 24-h exposure, corrected by the formula of **Abbott (1925)** if necessary, and data were analyzed by the log-probit method of **Finney (1971)** using the EPA probit analysis program version 1.5, Florida to calculate the LC_{25}, LC_{50}, LC_{90} and slope values

The percent mortality of each mixtur was recorded after 24h. The joint action of the different mixtures was expressed as the cotoxicity factor which was estimated according to the equation given by **Mansour *et al.* (1966).**

The standard error of mean was calculated using the Microcal origin software version 5.

RESULTS AND DISCUSSION

The experimental work presented here is based on bioassays in which the volatile activity was tested. *S. oryzae, T. confusum* and *C. maculates* were never in contact with the oils.

The data in table 1 show the major components of each essential oil. They are most representative monoterpenes, molecules constituting 90% of the essential oils. They consist of several functions: Carbures (mycene, cymene and phellandrenes), Alcohol (linalool, borneol and terpineol), Ketone (carovene and camphor), Ether (1,8-cineole) and phenol (thymol and carvacrol) while, eugenol and estagole were drived from aromatic compounds (**Bakkali *et al.*, 2008).**

Toxicity to *Sitophilus oryzae*

Data in table 2 summarize the effectiveness of the seven essential oils under investigation towards the rice weevil, *S. oryza*. Rosemary (LC_{50} 26 µl/l air) and caraway (LC_{50} 38 µl/l air) essential oils exhibited high toxicity against the rice weevil. The major components of the rosemary are Borneol and 1,8 Cineol while, caraway contains Carvone, Limonene. The insecticidal effects of these monoterpenes have been previously reported.

Lopez *et al.*, 2008 concluded that the active component was linalool, which produced average 73% dead insects of *S. oryzae*. The activities of the carvone against bacteria and fungi have been previously reported **(Isman, 2000).** The insecticidal activity of limonine was reported **(Tripathi *et al.*, 2003)** against the stored product beetles, *Rhyzopertha dominica, S. oryzae* and *T. castaneum*. They pointed out that carvone was active by direct contact to *S. oryzae* as well as by vapor. Moreover, **Yoon *et al.*, 2007** reported that the carvone and lemonine showed repellent activity against *S. oryzae*. Therefore the result of this study and previous studies suggest that rosemary and caraway essential oils might be useful for managing *S. oryzae* populations in spaces such as storage due to their fumigant and repellent activities.

From the toxicity index values it is clear that rosemary superior and camphor essential oil the lowest one. According to the relative potency and toxicity index values of the tested oils, they can be arranged in descending order as rosemary, caraway, thyme, coriander, dill, basil and camphor.

Table 2. Toxicity of seven essential oils against *Sitophilus oryzae*

Tested oils	LC_{25} µl/l air	LC_{50} µl/l air (95 % C L)	LC_{90} µl/l air	Slope	Relative potency	Toxicity index
Rosemary	15	26 (21-32)	69	3.01	2.88	100
Caraway	26	38 (30-46)	82	3.8	1.97	68.4
Thyme	37	64 (49-86)	202	2.57	1.17	40.6
Coriander	23	65 (46-109)	478	1.48	1.15	40.0
Dill	25	67 (49-102)	340	1.82	1.12	38.8
Basil	29	72 (50-117)	391	1.75	1.04	36.1
Camphor	42	75 (52-101)	24	2.54	1.00	34.7

CL: Confidence limit

Relative potency: obtained by comparing the potency of the lowest effective oil at the level of the LC_{50} to the tested oils

Toxicity index: obtained by comparing the efficiency of the tested oil at the level of LC_{50} to their most effective oil

Coats *et al.*, (1991) found that exposure of *S. oryzae* for 24 h to linalool and *d* limonene had an LC_{50} of 14 and 19 µl/l air whereas the LC_{50}'s for myrcene and α terpineol were '100 µl /l. Results of studies by **Lee *et al.*, (2001)** showed different toxicity doses of linalool (LD_{50} 39.2 µl /l air), limonene (LD_{50} 61.5 µl/l air) and α terpineol (LD_{50} 69.1 µl/l air) to the rice weevil than those found in **Coats *et al.*, (1991)** study. They mentioned previously, this difference may result from use of different strains of rice weevils.

Toxicity to *Tribolium confusum*

Toxicities of commercially available essential oils are shown in Table 3. Three essential oils, rosemary (LC_{50} 19 µl/l air), coriander (LC_{50} 23 µl/l air) and caraway (LC_{50} 25 µl/l air), had potent fumigant activities against the *T. confusum*. However the oil thyme (LC_{50} 28 µl/l air), had a lower fumigant toxicity to the *T. confusum* than the rosemary, coriander and caraway to the *T. confusum*. On the other hand, camphor (LC_{50} 53 µl/l air) and dill (LC_{50} 28 µl/l air), showed a promising fumigant toxicities on the *T. confusum*. The basil (LC_{50} 104 µl/l air) oil showed the lowest fumigant activities against the *T. confusum*.

The relationship between fumigant toxicity and structure of monoterpenes against the red flour beetles, *T. castaneum* was previously reported **(Rice and Coats, 1994)**. In general, ketones were more effective than alcohols and less toxic than aldehydes in the fumigant assays. However, result from **Lee *et al.* (2001)** did not show that terpenoid toxicity is necessarily correlated with the structure. This finding suggests that there may be different modes of action of monoterpene toxicity to *S. oryzae* from that of *T. castaneum*.

Table 3. Toxicity of seven essential oils against *Tribolium confusum*

Tested oils	LC_{25} µl/l air	LC_{50} µl/l air (95 % C L)	LC_{90} µl/l air	Slope	Relative potency	Toxicity index
Rosemary	11	19 (15-24)	56	2.76	5.47	100
Coriander	13	23 (18-29)	71	2.60	4.52	82.6
Caraway	15	25 (20-30)	71	2.79	4.16	76.0
Thyme	18	28 (23-33)	64.0	3.5	3.71	67.9
Camphor	24	53 (40-75)	251	1.9	1.96	35.8
Dill	39	73 (54-104)	249	2.41	1.42	26.0
Basil	51	104 (73-194)	391	2.22	1.00	18.3

CL: Confidence limit

Relative potency: obtained by comparing the potency of the lowest effective oil at the level of the LC_{50} to the tested oils

Toxicity index: obtained by comparing the efficiency of the tested oil at the level of LC_{50} to their most effective oil

Toxicity to *Callosobruchus maculates*

Table 4 summarizes the response of the *C. maculates* to the seven essential oils. Caraway (LC_{50} 19 µl/l air) and rosemary oils (LC_{50} 25 µl/l air) demonstrated a particularly high activity against the *C. maculates*. The Thyme oil was toxic at a LC_{50} of 37 µl/l air but coriander oil show toxicity at 77 µl/l air. However, the toxic activity was obtained from dill, camphor and basil at LC_{50} 105 µl/l air, LC_{50} 174 µl/l air and LC_{50} 194 µl/l air, respectively. In this study, caraway and rosemary oils were more toxic to the adult *C. maculates* compared with the other oils.

Table 4. Toxicity of seven essential oils against *Callosobruchus maculates.*

Tested oils	LC_{25} µl/l air	LC_{50} µl/l air (95 % C L)	LC_{90} µl/l air	Slope	Relative potency	Toxicity index
Caraway	11	19 (15-24)	52	2.95	10.2	100
Rosemary	17	25 (20-31)	56	3.7	7.76	76.0
Thyme	20	37 (30-46)	11	2.67	5.24	51.3
Coriander	30	77 (46-408)	511	1.55	2.52	24.7
Dill	55	105 (78-170)	384	2.26	1.85	18.1
Camphor	60	174 (104-575)	1220	1.51	1.12	10.9
Basil	70	194 (113-736)	1360	1.5	1.0	9.79

CL: Confidence limit

Relative potency: obtained by comparing the potency of the lowest effective oil at the level of the LC_{50} to the tested oils

Toxicity index: obtained by comparing the efficiency of the tested oil at the level of LC_{50} to their most effective oil

According to the relative potency in table 4 ,caraway is 10 times more toxic than the basil in the cowpea beetle (*C. maculates*), but in the *T. confusum*, rosemary is more than one as active as caraway, and five times more active than basil. For the rice weevil *S. oryzae* the rosemary is more than twice as active as camphor and 1.5 times more active than the caraway. The salient point is that these chemicals and other essential oil constituents can be *blended* to achieve a desired spectrum of activity and optimal efficacy against pests **(Isman, 2000).**

In general, *T. confusum* was the most susceptible insect for rosemary, thyme, coriander and camphor oils, while *S. oryzae* was susceptible to the dill and basil oils than the other two insects. In contrast, *C. maculates* was susceptible to caraway oil and highly tolerant to basil and camphor. A difference in the insect susceptibility to the plant essential oils was also noticed by

Regnault-Roger and Hamraoui (1995); Othman (2000a, b) and Lopez *et al.* (2008).

Among 22 essential oils tested as fumigants against the bean weevil *Acanthoscelides obtectus* (Bruchidae), those of *Thymus serpyllum* (rich in the phenols thymol and carvacrol) and *Origanum majorama* (rich in terpinen-4-ol) were the most toxic **(Regnault- Roger *et al.*, 1993).** In a more detailed study, **Shaaya *et al.* (1991)** evaluated the fumigant toxicity of 28 essential oils and 10 of their major constituents against four different species of stored product coleopterans. Most interestingly, there was little overlap among the insect species with respect to the most toxic oils and constituents, indicating that while these substances are generally active against a broad spectrum of pests, interspecific toxicity of individual oils and compounds is highly idiosyncratic. **Sarac and Tunc (1995)**, investigating the fumigant action of four essential oils to three species of stored product pests, reached the same conclusion.

Certain essential oil monoterpenes are competitive inhibitors of acetylcholinesterase *in vitro* **(Grundy and Still, 1985; Miyazawa *et al.*, 1997)**, but this action may not be correlated with toxicity to insects *in vivo* **(Isman, 2000).**

Based on the results, rosemary and caraway showed strong fumigant toxicity to the *S. oryzae, T. confusum* and *C. s maculates*. These results are mostly in agreement with the results of other investigators. Rosemary essential oil showed potent toxicity to the red flour beetle and the primary component of the essential oil, 1, 8-cineole, was found to be the principal active component. In addition, 1, 8-cineole showed similar fumigant toxicity to a PH_3-resistant strain relative to a PH_3-susceptible strain. This natural monoterpene could be used as an environmentally friendly fumigant to control stored-grain insect pests **(Lee *et al.*, 2002).**

Joint action of tested essential oils

The toxicity of the essential oils in combination (21 combinations) was investigated. Regarding their biological properties, it has to be kept in mind that essential oils are complex mixtures of numerous molecules, and one might wonder if their biological effects are the result of a synergism of all molecules. Thus, synergistic functions of the various molecules contained in an essential oil, in comparison to the action of one or two main components of the oil, seems questionable. However, it is possible that the activity of the main components is modulated by other minor molecules **(Franzios *et al.*, 1997 and Bakkali *et al.*, 2008).**

The combinations were prepared by mixing the oils according to their related LC_{25}. Some of the commercial essential oils were found to have a synergic effect when mixed together. The results in table 5 show that the synergic effect was observed from the mixtures (thyme + caraway), (thyme + camphor), (rosemary + caraway), (rosemary + camphor), (caraway + camphor), (caraway + coriander) and (camphor + coriander) towards the three insects. Based on the potential effects category, the order were (caraway + coriander) > (camphor + coriander)> (rosemary + camphor)> (rosemary + caraway)> (camphor + coriander)> (thyme + caraway) > (thyme + camphor). While the mixtures (thyme + coriander) and (rosemary + coriander) showed synergic effect towards the *S. oryzae* and *C. maculates*. The mixture (rosemary + basil) showed synergic effect only against *S. oryzae*.

Six combinations showed additive effects against the three insects, they were (thyme + rosemary), (thyme + basil), (rosemary + dill), (caraway + dill), (camphor + dill) and (coriander + dill). Whereas the combinations (thyme + dill), (caraway + basil), (camphor + basil) and (coriander + basil) gave additive effects against *S. oryzae* and *C. maculates*

The antagonistic effects were observed from the mixture dill and basil oils against the three insects.

It is clear also that the mixture (caraway + coriander) was the most toxic to the *S. oryzae* and *T. confusum* with synergic category 86 and 71.6, respectively. Whereas the mixture (caraway + camphor) was the most toxic to the *C. maculates* with synergic category 71.2.

The results in this study are mostly in the agreement with the results of other investigators. By comparing the fumigant activities of seven essential oils against the three insect species, 1, 8-cineole (the main compound in rosemary essential oil) was arguably the most effective, followed by camphor and linalool

Yoon *et al.* (2007) examined the repellent efficacy of six essential oils against the rice weevil, *S. oryzae*. They found that the Limonene mixed with carvone, the components of caraway oil, strongly repelled the weevils. A mixture of carvone and limonene showed higher levels of repellent activity than did carvone alone. Carvone is the main constituent (61.9%) and appears to be the main repellent component of caraway oil against the weevils. Moreover, a mixture of carvone and limonene components at a ratio of 6:4 showed higher repellent activity than did their related components alone. Therefore, carvone appears to work synergistically with limonene, which confirms the findings of **Tripathi *et al.* (2003).** In another study, **Lopez *et al.* (2008)** found that the active compound of coriander essential oil against *S. oryzae* was linolool. Mixtures of linalool, camphor and generally acetate were as active against *R. dominica* and *C. pusillus* as linalool alone. They also concluded that linalool, carvone, estragole and methyl eugenol are example of toxic fumigant compounds in the essential oils from coriander, caraway or basil that are active against the *S. oryzae, R. dominica* and *C. pusillus.* They had greater activity when applied in mixtures.

The exact mode of action of the essential oils remains unknown although from recent studies it was suggested that they impact the functioning of the octopaminergic nervous system **(Isman, 2000 and Rajendarn and Sriranjini, 2008).**

Table 5. The effect of the essential oils mixtures on the *S. oryzae*, *T. confusum* and *C. maculates*.

Combination		*S. oryzae*			*T. confusum*			*C. maculates*		
		% Observed mortality	Co-Toxicity factor	Category	% Observed mortality	Co-Toxicity factor	Category	% Observed mortality	Co-Toxicity factor	Category
Thyme	Rosemary	55 ± 0.8	10	Add.	47.6 ± 0.7	-4.8	Add.	51.0 ± 1.2	2	Add.
	Caraway	70.4 ± 0.8	40.8	Pot.	65.2 ± 0.9	30.4	Pot.	62.2 ± 0.7	24.4	Pot.
	camphor	69.2. ± 1.1	38.4	Pot.	62.8 ± 0.9	25.6	Pot.	69.0 ± 0.3	38	Pot.
	coriander	69.2 ± 1.0	38	Pot.	60 ± 1.0	20	Add.	69.0 ± 0.3	38	Pot.
	Dill	45.8 ± 0.7	-10	Add.	37.8 ± 0.6	-24.4	Antag.	40.8 ± 0.8	-18.4	Add.
	Basil	48.8 ± 0.4	-2.4	Add.	42.6 ± 1.1	-14.8	Add.	45.2 ± 1.5	-9.6	Add.
Rosemary	Caraway	77.0 ± 0.5	54	Pot.	64.8 ± 0.6	29.6	Pot.	69.6 ± 0.7	39.2	Pot.
	camphor	82 ± 0.4	64	Pot.	70.0 ± 0.4	40.4	Pot.	72.2 ± 0.7	44.4	Pot.
	coriander	71.0 ± 0.5	42	Pot.	58.8 ± 0.4	17.6	Add.	64.0 ± 1.2	28	Pot.
	Dill	52.4 ± 1.0	4.8	Add.	45.4 ± 0.5	-9.2	Add.	42.8 ± 1.3	-14.4	Add.
	Basil	61.8 ± 1.1	23.6	Pot.	55.6 ± 0.5	11.2	Add.	56.8 ± 0.6	13.6	Add.
Caraway	Camphor	89.8 ± 0.7	79.6	Pot.	83.6 ± 1.1	67.2	Pot.	85.6± 0.7	71.2	Pot.
	Coriander	93.4 ± 0.9	86	Pot.	85.8 ± 0.9	71.6	Pot.	84.4 ± 1.2	68.8	Pot.
	Dill	50.0 ± 1.1	0.0	Add.	47.8 ± 0.9	-4.4	Add.	51.2 ± 1.2	2.4	Add.
	Basil	55.6 ± 0.5	11.2	Add.	37.4 ± 0.7	-25.2	Antag.	48.8 ± 1.4	2.4	Add.
Camphor	Coriander	76.2 ± 0.9	52.4	Pot.	73.0 ± 0.7	46	Pot.	78.8 ± 0.5	57.6	Pot.
	Dill	43.8 ± 1.0	-12.4	Add.	42.4 ± 0.8	-15.2	Add.	48.2 ± 0.6	-3.6	Add.
	Basil	51.4 ± 0.9	2	Add.	39.4 ± 0.5	-21.2	Antag.	46.6 ± 0.8	-6.8	Add.
Coriander	Dill	49.2± 0.37	-1.6	Add.	46.4 ± 0.51	-7.2	Add.	47.4 ± 0.7	-5.2	Add.
	Basil	58.2 ± 0.66	16.4	Add.	35.0 ± 1.05	-30	Antag.	54.4 ± 1.5	8.8	Add.
Dill	Basil	32.0 ± 1.12	-34.8	Antag.	28.0 ± 0.77	-44	Antag.	35.2 ± 1.4	-29.6	Antag.

: Potentiation effect
.: Additive effect
Antag.: Antagonism

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التأثير السام لأبخرة الزيوت الأساسية و مخاليطها ضد كل من *Sitophilus oryzae* (L.), *Tribolium confusum* (J. du Val), و*Callosobruchus maculates* (Fabr.)

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تهدف هذه الدراسة الى إختبار فعالية سبعة من الزيوت الأساسية كمواد للتبخير وهى روزماري، كراوية، كزبرة، الزعتر، الشبت، وكافور وريحان ضد الحشرات الكاملةلكل من سوسة الارز *Sitophilus oryzae*، خنفساء الدقيق *Tribolium confusum*، وخنفساء اللوبيا *Callosobruchus maculates*.

وأكدت النتائج المتحصل عليها ان لهذة الزيوت تاثيرا إباديا كمواد تبخير، حيث أظهر كل من زيت الروزماري و الكراوية أعلى فعالية كمواد تبخير ضد سوسة الأرز حيث كانت قيم التركيز النصفى LC_{50} (٢٦ µl / لتر الهواء)) و (٣٨ µl / لتر الهواء)، على التوالي. كما أظهر كل من زيت الروزماري (١٩ µl / لتر الهواء)، والكزبرة (٢٣ µl / لتر الهواء)، تأثيرا قويا ضد الحشرات الكاملة لحشرة خنفساء الدقيق. كم وجد ان كل من زيت الكراوية والروزماري الأكثر فعالية ضد خنفساء اللوبيا حيث كانت قيم التركيز النصفى LC_{50} (١٩ µl / لتر الهواء)) و (٢٥ µl / لتر الهواء) على التوالي.

وعند إختبار مخاليط الزيوت تحت الإختبار (٢١ خلطة) كمواد تبخير، وجد ان النتائج التي حصل عليها تشير إلى أن مزيج (كراوية + كزبرة) هو أكثر سمية على كل من سوسة الأرز و خنفساء الدقيق مع معامل سمية ٨٦ و ٧١,٦ على التوالي. في حين أن مزيج (كراوية + كافور) هو أكثر سمية على خنفساء اللوبيا مع معامل سمية ٧١,٢. ولذلك فإن هذة النتائج تؤكد ان تلك الزيوت المستخدمة فى البحث يمكن ان تلعب دورا هاما فى مكافحة حشرات الحبوب المخزونة، كما يمكن استخدامها في برامج المكافحة المتكاملة للآفات.