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Bioactivities of Different Essential Oils Against The Adults of Two Stored Product Insects

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Abstract.- In this study we have tested fumigant toxicity of ten aromatic plant essential oils on red flour beetle, *Tribolium castaneum,* and bean weevil, *Acanthoscelides obtectus,* under laboratory conditions. The plant samples were collected from different sites of Turkey, air dried at room temperature and the essential oils were obtained by steam distillation, using a Clevenger-type apparatus. Laurel and myrtle essential oils showed strong fumigant activity against *A. obtectus* and *T. castaneum* adults at different concentrations. Estimated LC_{50} and LC_{99} values for *A. obtectus* adults were 45.31 and 70.75 µl/l air for myrtle, 27.36 and 43.05 µl/l air for laurel or tansy oils, respectively. The *T. casteneum* were more resistant to myrtle and laurel than *A. obtectus* and lethality values were estimated as 92.80 (LC_{50}) and 159.03 (LC_{99}) µl/l air for myrtle 56.98 and 89.73 µl/l air for laurel oils, respectively. The mean longevity of *A. obtectus* adults was significantly decreased depending on the increasing doses of savory, myrtle, marjoram, laurel, lemon, tansy and sage essential oils. While savory, myrtle, marjoram and laurel essential oils decreased the mean longevity of *T. castaneum* adults the other essential oils did not change the longevity of these insects.

Keywords: Fumigant toxicity, mortality, longevity, *Acanthoscelides obtectus*, *Tribolium castaneum*

INTRODUCTION

Tribolium castaneum (Herbst) (Coleoptera: Tenebrionidae) has had a long association with human stored food and has been found in association with a wide range of commodities including grain, flour, peas, beans, cacao, nuts, dried fruits, and spices, but milled grain products such as flour appear to be their preferred food (Good, 1936; Campbell and Runnion, 2003). This species is a cosmopolitan stored product pest with a preference for cereal grains and wheat flour. It is also a good model for animal breeding and entomological research (Orozco, 1967).

Among the insects attacking stored products, Bruchidae and especially *Acanthoscelides obtectus* (Say, Coleoptera: Bruchidae) has attracted the attention of many scientists not only because it can easily be manipulated but also because of the economic importance it has. In fact, *A. obtectus* with its physiological adaptability, is one of the most destructive pests of *Phaseolus vulgaris* L. (kidney bean), one of the most important food pulses in South America and in the Mediterranean region (Papachristos and Stamopoulos, 2002). Its oviposition and growth are continuous, the larvae feeding on the seeds, and after emergence, the adults reproducing either in the field or in the stored seeds in a continuous cycle (Labeyrie, 1962). Pest damage by this species has been estimated to cause 20–40% loss of stored seeds per annum (Regnault-Roger and Hamraoui, 1994; Pemonge *et al*., 1997).

Control of these insects relies heavily on the use of synthetic insecticides and fumigants, which has led to problems such as disturbances of the environment, increasing costs of application, pest resurgence, pest resistance to pesticides and lethal effects on non-target organisms in addition to direct toxicity to users (Jembere *et al*., 1995; Okonkwo and Okoye, 1996). The demand for organic crops, especially vegetables for the fresh market, has greatly increased worldwide. Attack by pests on vegetables cultivated in organic systems, however, hinders the expansion of organic farming because of the lack of effective methods to manage pests effectively and, at the same time, comply with the requirements of organic farming. Therefore, investigations on alternative methods such as the use of natural insecticides and their combinations are important (Michereff-Filho *et al*., 2008).

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Essential oils produced in various external and internal glands of these plants are a very complex mixture of terpenes, sesquiterpenes, their oxygenated derivatives and other aromatic compounds (Ogendo *et al.,* 2008). Many studies of the fumigant activity of such natural substances have been undertaken to establish new control practices with lower mammalian toxicity and low persistence in the environment (Hall and Oser, 1965; Miyakado *et al*., 1997; Isman, 2000; Erler, 2005; Isikber *et al*., 2006).

In the current study we evaluated the fumigant toxicity of savory *Satureja thymbra* L., Turkish oregano *Origanum onites* L., marjoram *Origanum majorana* L., laurel *Laurus nobilis* L., myrtle *Myrtus communis* L., lemon *Citrus limon* L., sticky goosefoot *Chenopodium botrys* L., thyme *Thymus sipyleus* Boiss., tansy *Tanecetum armenum* (DC.) Suchultz Bip. and sage *Salvia cryptantha* Montbret et Aucher ex Benth. against *Tribolium castaneum* and *Acanthoscelides obtectus* at laboratory conditions.

MATERIALS AND METHODS

Insects cultures

The founding insect culture of bean weevil *Acanthoscelides obtectus* was collected from Kayseri Province of Turkey as infested kidney beans (*Phaseolus vulgaris* L.). Adults oviposited on dry *P. vulgaris* beans and the larvae developed inside the beans until adult emergence. Red flour beetle, *T. castaneum* used in experiments was derived from a laboratory culture initially established from adults collected from infested wheat germs (*Triticum vulgare* L.) in Kayseri Province, central Turkey. *T. castaneum* was reared on wheat flour mixed with 5 % brewer's yeast (19:1, w/w) (Ayvaz *et al*., 2002). Throughout the experiments insect cultures were maintained at constant temperature (27±1°C), 14L: 10D photoperiod and %60±5 relative humidity (Ayvaz *et al*., 2007; 2009).

Plant material and extraction of essential oil

The data related to the aromatic plants containing essential oils summarized in Table I. Species of plants were identified by botanists from Erciyes University and Bozok University (voucher specimens were deposited in the herbarium of the Erciyes University, Kayseri/Turkey). The plant samples were air dried at room temperature and their essential oil were obtained by steam distillation, using a Clevenger-type apparatus. The distilled essential oils were stored in a refrigerator at 4°C until treatments.

Bioassays

In order to test the toxicity of vapor of essential oils on the adults of *A. obtectus* and *T. castaneum*, (<5 and 7 day age, respectively) ten adults were put into the 300 ml glass jars. Essential oils were applied on a filter paper strip measuring 3 x 3 cm which was attached to the lower side of the jar's lid. The adults of *A. obtectus* and *T. castaneum* were exposed to vapor of essential oils between 50-150 µl doses for 24 h. The number of dead and survivor adults was counted after exposure and percentage mortality determined for each essential oils. The surviving adults isolated from glass jars and were placed individually in glass tubes (1.6 x 16 cm). The mean longevity of adults at each dose was noted starting from the beginning of the test to the time of their dead. The LC_{50} and LC_{99} values were estimated for each essential oil and exposure time. Three and four replicates were set up for each dose for *A. obtectus* and *T. castaneum*, respectively.

Statistical procedures

The data were corrected for the mortalities in the controls and were subjected to probit analysis using SPSS (2001) for Windows (SPSS Inc. Chicago, IL, USA) to estimate LC_{50} and LC_{99} values (as µl/l air) of the essential oils against each pest. The mean longevity values compared with control using the same statistical program. Means were separated at the 5% significance level by least significant difference (LSD) test.

RESULTS

Insecticidal activity of essential oils

Insecticidal activity of vapor of essential oils, obtained from different plants, against *A. obtectus* adults after 24 h exposure are presented in Table II.

Table I. Collected plants and related details, from different sites of Turkey.

Plant species	Plant family	Plant parts used	Collection site	Collection period (Month)
Satureja thymbra	Lamiaceae	Leaves	Mersin	July
Origanum onites	Lamiaceae	Leaves	Çanakkale	August
Origanum majorana	Lamiaceae	Leaves	Çanakkale	July
Laurus nobilis	Lauraceae	Leaves	Mersin	July
Myrtus communis	Myrtaceae	Leaves	Mersin	July
Citrus limon	Rutaceae	Leaves	Mersin	January
Chenopodium botrys	Chenopodiaceae	Seeds	Kayseri	September
Thymus sipyleus	Lamiaceae	Leaves and flowers	Kayseri (Sarız)	June
Tanacetum armenum	Asteraceae	Leaves and flowers	Kayseri (Sarız)	June
Salvia cryptantha	Lamiaceae	flowers	Kayseri (Sarız)	June

Table II. Mortality effect of different plant essential oils on *A. obtectus* adults after 24 h exposure.

Plant	Dose dependant percentage mortality			
	Control±SE	50 µl±SE	100 µl±SE	150 µl±SE
Savory	0.00±0.00	13.33±0.18	50.00±0.32	70.00±0.37
Turkish oregano	0.00±0.00	0.00±0.00	6.67±0.11	16.67±0.21
Myrtle	0.00±0.00	66.67±0.28	100.00±0.00	100.00±0.00
Marjoram	0.00±0.00	13.34±0.23	26.67±0.31	93.34±0.13
Laurel	0.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00
Lemon	0.00±0.00	10.00±0.15	53.34±0.25	60.00±0.29
Sticky goosefoot	0.00±0.00	6.67±0.20	6.67±0.12	13.34±0.09
Tansy	0.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00
Thyme	0.00±0.00	10.00±0.37	13.34±0.27	16.67±0.35
Sage	0.00±0.00	10.00±0.33	46.67±0.74	63.34±0.60

Increasing mortality was observed on *A. obtectus* adults with increasing dosage of all essential oils. The oil obtained from Myrtle caused 66.67 and 100% mortality on *A. obtectus* adults when exposed to 50 µl and above concentrations, respectively. Laurel and tansy essential oils resulted in 100% mortality on the adults with the same application dose (Table II). However, other essential oils caused low mortal effect (approximately 10%) on the adults at 50 µl dose. Moreover essential oil obtained from Turkish oregano did not have any lethal effect on the adults at the same dose. With 150 µl application of savory and marjoram oils 70 and 93.34% mortality recorded. The lemon and sage essential oils showed approximately 60% mortal effect at highest dose (150 µl). However, Turkish oregano, sticky goosefoot and thyme oils showed lower mortal effect (15%) against *A. obtectus* adults at highest dose.

T. castaneum adults were more resistant against essential oils than *Acanthoscelides obtectus* adults. The essential oils showed very low or no mortal effect against *T. castaneum* adults at 50 µl dose. Sticky goosefoot, tansy and thyme essential oils did not show mortal effect on the adults at all doses (Table III). Turkish oregano, lemon and sage oils showed very low mortal effect on the adults at the highest dose (150 µl). On the contrary, savory and marjoram oils had 72.50 and 67.50% mortality on the *T. casteneum* adults when exposed to 150 µl dose, respectively. Myrtle essential oil caused 82.50 and 95% mortality on the adults with applied dose of 100 and 150µl, respectively. The application of the essential oils obtained from laurel showed 100% mortality on the red flour beetle adults over 50 µl doses (Table III).

The LC_{50} and LC_{99} values of essential oils against *A. obtectus* and *T. castaneum* were estimated as µl/l air for 24 h (Tables IV, V).

Table III.- Effect of different plant essential oils on *T. castaneum* adults after 24 h exposure.

Plant	Dose dependant percentage mortality			
	Control±SE	50 µl±SE	100 µl±SE	150 µl±SE
Savory	0.00±0.00	5.00±0.09	7.50±0.15	72.50±0.74
Turkish oregano	0.00±0.00	0.00±0.00	5.00±0.18	7.50±0.20
Myrtle	0.00±0.00	0.00±0.00	82.50±0.41	95.00±0.55
Marjoram	0.00±0.00	0.00±0.00	5.00±0.10	67.50±0.57
Laurel	0.00±0.00	12.50±0.20	100.00±0.00	100.00±0.00
Lemon	0.00±0.00	2.50±0.09	2.50±0.09	2.50±0.09
Sticky goosefoot	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Tansy	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Thyme	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Sage	0.00±0.00	0.00±0.00	2.50±0.09	2.50±0.09

Table IV.- The LC_{50} and LC_{99} values of essential oils after 24 h exposure against *A. obtectus.*

Plant	LC_{50} (µl/l air)	LC_{99} (µl/l air)	df	χ^2	*P*
Savory	104.99	215.41	10	3.652	0.962
Turkish oregano	209.29	360.08	10	2.538	0.990
Myrtle	45.31	70.75	10	1.199	1.000
Marjoram	108.09	208.55	10	8.979	0.534
Laurel	27.36	43.05	10	0.016	1.000
Lemon	121.23	260.72	10	6.017	0.814
Sticky goosefoot	302.08	628.90	10	4.722	0.909
Tansy	27.36	43.05	10	0.016	1.000
Thyme	272.88	607.14	10	3.068	0.980
Sage	120.27	253.34	10	6.847	0.740

Table V.- The LC_{50} and LC_{99} values of essential oils after 24 h exposure against *T. castaneum.*

Plant	LC_{50} (µl/l air)	LC_{99} (µl/l air)	df	X^2	*P*
Savory	133.85	221.21	10	20.535	0.114
Turkish oregano	270.71	479.09	10	5.662	0.974
Myrtle	92.80	159.03	10	28.305	0.008
Marjoram	192.78	300.13	10	5.401	0.979
Laurel	56.98	89.73	10	0.699	1.000
Lemon	664.87	1311.75	10	12.504	0.566
Sticky goosefoot	-	-	-	-	-
Tansy	-	-	-	-	-
Thyme	-	-	-	-	-
Sage	372.550	654.27	10	9.388	0.805

-: No detectable because of no mortality

The LC_{50} and LC_{99} values for myrtle, laurel and tansy oils were found to be lower at than other seven essential oils applied on *A. obtectus*. These values were estimated as 45.31 and 70.75, 27.36 and 43.05 µl/l air for myrtle and laurel or tansy oils, respectively. The LC_{50} and LC_{99} values showed variation between 104.99 and 628.90 µl/l air for other essential oils. The LC_{50} and LC_{99} values for myrtle and laurel were found lower than other essential oils used against *T. castaneum*. These values estimated as 92.80 and 159.03, 56.98 and 89.73 µl/l air for myrtle and laurel oils, respectively. The LC_{50} and LC_{99} values were estimated as 664.87 and 1311.75 for lemon oil. *T. castaneum* adults did not show any response against applied doses of sticky goosefoot, tansy and thyme essential oils and LC_{50} and LC_{99} values could not be calculated. The LC_{50} and LC_{99} values showed variation between

Table VI.- Longevity of *A. obtectus* adults after exposure to (24 h) essential oils.

Plant	Dose dependent mean longevity (day)			
	Control±SE	50 µl±SE	100 µl±SE	150 µl±SE
Savory	09.60±0.38a*	05.60±0.74ab	03.23±0.58b	02.03±0.27b
Turkish oregano	09.60±0.38a	09.66±0.56a	08.16±0.42a	05.12±0.34a
Myrtle	09.60±0.38a	01.50±0.17b	01.00±0.00b	01.00±0.00b
Marjoram	09.60±0.38a	05.93±0.58ab	03.33±0.60b	01.16±0.13b
Laurel	09.60±0.38a	01.00±0.00b	01.00±0.00b	01.00±0.00b
Lemon	09.60±0.38a	08.46±0.95a	03.50±0.58ab	01.73±0.03b
Sticky goosefoot	09.60±0.38a	07.40±0.58a	07.46±0.54a	05.36±0.54a
Tansy	09.60±0.38a	01.00±0.00b	01.00±0.00b	01.00±0.00b
Thyme	09.60±0.38a	09.53±0.88a	07.10±0.79a	06.30±0.54a
Sage	09.60±0.38a	05.76±0.78ab	03.26±0.54ab	01.10±0.16b

*Means followed by the same letter within a row not significantly different at P<0.05 (ANOVA followed by LSD test).

Table VII.- Longevity of *T .castaneum* adults after exposure to (24 h) essential oils.

Plant	Dose dependent mean longevity (day)			
	Control±SE	50 µl±SE	100 µl±SE	150 µl±SE
Savory	15.70±0.56a	12.67±0.55a	12.65±0.67a	01.85±0.22b
Turkish oregano	15.70±0.56a	12.97±0.42a	12.77±0.60a	10.37±0.49a
Myrtle	15.70±0.56a	11.37±0.45a	01.22±0.08b	01.05±0.03b
Marjoram	15.70±0.56a	12.32±0.35a	11.55±0.57a	02.17±0.31b
Laurel	15.70±0.56a	11.32±0.74a	01.00±0.00b	01.00±0.00b
Lemon	15.70±0.56a	11.92±0.37a	12.82±0.51a	11.67±0.47a
Sticky goosefoot	15.70±0.56a	14.87±0.53a	14.43±0.41a	10.40±0.75a
Tansy	15.70±0.56a	12.87±0.34a	12.58±0.42a	10.98±0.66a
Thyme	15.70±0.56a	15.72±0.35a	16.35±0.36a	15.85±0.45a
Sage	15.70±0.56a	11.22±0.46a	11.10±0.52a	11.07±0.50a

*Means followed by the same letter within a row not significantly different at P<0.05 (ANOVA followed by LSD test).

133.85 and 654. 27 µl/l air for savory, Turkish oregano, marjoram and sage oils.

Effect of the essential oils on adult longevity

Mean longevity of the adults of *A. obtectus* significantly decreased depending on the increasing doses of savory, myrtle, marjoram, laurel, lemon, tansy and sage essential oils (for savory, F= 4.361; df= 3, 116; P < 0.043, for myrtle, F= 43.891; df= 3, 116; P < 0.001, for marjoram, F= 4.334; df= 3, 116; P < 0.043, for laurel, F= 112.162; df= 3, 116; P < 0.001, for lemon, F= 4.208; df= 3, 116; P < 0.046, for tansy, F= 112.162; df= 3, 116; P < 0.001 and for sage, F= 4.18; df= 3, 116; P< 0.048) (Table VI). While the control adults of the *A. obtectus* lived 9.60 days the longevity for these adults decreased to 1 day after exposure to 50 µl laurel and tansy oils. When the savory, marjoram, lemon and sage essential oils were applied at 150 µl dose on *A. obtectus* adults, the mean longevity was found as 2.03 days for savory, and 1 day for marjoram, lemon and sage essential oils. Similar results were observed at 100 µl application dose of myrtle essential oil. When *A. obtectus* adults were exposed to Turkish oregano, sticky goosefoot and thyme oils, mean longevity did not significantly change compared to control (F= 0.980; df= 3, 116; P = 0.449, F= 1.130; df= 3, 116; P= 0.393 and F= 0.618; df= 3, 116; P= 0.623, respectively) (Table VI).

Longevity of *T. castaneum* adults also decreased significantly depending on the increasing doses of savory, myrtle, marjoram and laurel essential oils (for savory, F= 15.326; df= 3, 156; P < 0.001, for myrtle, F= 59.718 df= 3, 156; P < 0.0001, for marjoram, F= 12.710; df= 3, 156; P < 0.002 and for laurel F= 39,667; df= 3, 156; P < 0.0001) (Table VII). The control adults lived 15.70 days but the longevity of the adults exposed to essential oils was

1 day for myrtle and laurel and 2 days for savory or marjoram at highest concentration (150 µl), respectively. Comparing with control the other essential oils tested (Turkish oregano, lemon, sticky goosefoot, tansy, thyme and sage) did not cause significant decrease in the longevity of *T. castaneum* adults (for T. oregano, lemon, sticky goosefoot, tansy, thyme and sage, F= 1.23; df= 3, 156; P= 0.343, F= 1.012; df= 3, 156; P= 0.437, F= 1.349; df= 3, 156; P= 0.326, F= 1.162; df= 3, 156; P= 0.382, F= 0.041; df= 3, 156; P= 0.988 and F= 1.322; df= 3, 156; P= 0.333, respectively) (Table VII).

DISCUSSION

The rust-red flour beetle, *T. castaneum* and dried bean beetle, *A. obtectus* were important to occupy a place among most common target insects (Rajendran and Sriranjini, 2008). Many studies were reported on the insecticidal activity of essential oils against rust-red flour beetle and dried bean beetle (Shaaya *et al*., 1991; Regnault-Roger and Hamraoui, 1993, 1995; Pemonge *et al*., 1997; Papachristos and Stamopoulos, 2004; Mondal and Khalequzzaman, 2006; Negahban *et al*., 2007). The essential oils obtained from laurel and myrtle showed strong fumigant activity against *A. obtectus* and *T. castaneum* adults at different concentrations. The doses of 100 and 150 µl/l air caused complete (100%) mortality *A. obtectus* adults after exposed to myrtle essential oil during 24 h exposure. That the myrtle essential oil on *A. obtectus* was more effective than savory and Turkish oregano was reported by Ayvaz *et al.* (2010) However, myrtle essential oils caused 95% mortality on the *T. castaneum* adults with applied dose of 150µl/l air. Laurel was the most effective essential oils on the adults of *A. obtectus* and *T. castaneum*, and complete mortality observed at 50. µl/l air dose for *A. obtectus* and 100 µl/l air dose for *T. casteneum.* The essential oil tansy also caused 100% mortality on the *A. obtectus* adults at 50 µl/l air dose, but the same essential oil did not have any mortal effect on the *T. castaneum* adults at all applied doses. Regnault-Roger and Hamraoui (1993) reported that *Origanum marjorana* L. and *Thymus serphyllum* L. are toxic to *A. obtectus* (Say). Our results showed similar effect against *A. obtectus* for marjoram (93.34%), but *Thymus sipyleus* showed very little mortal effect (16.67%) against *A. obtectus*. Also Regnault-Roger (1997) pointed out that insects vary enormously in their responses to secondary plant products and it is well known that the sensitivity of different insect species could be quite different for the same substance**.** Our results and those reported earlier clearly indicate that the insecticidal activity of the essential oils varies regarding the stage of the insects, the species and the plant origin of the essential oil (Tunc *et al*., 2000; Chiasson *et al*., 2001; Choi *et al*., 2003; Sedy and Koschier, 2003; Negahban *et al*., 2007; Ayvaz *et al*., 2009).

When the savory oil applied on *A. obtectus* as 150 µl/l air doses during 24 h, 70% of the adults were killed. In our previous study (Ayvaz *et al*., 2010) the same essential oil caused complete mortality (100%) when exposed to 195 µl/l air dose for 144 h, and to obtain the same mortality rate with myrtle essential oil much lower dose (65 µl/l air) and exposure time (72 h) were adequate. However, savory and marjoram oils had 72.50 and 67.50% mortality on the adults of *T. castaneum*, when exposed to 150 µl/l air, respectively. The lemon and sage essential oils showed approximately 60% mortal effect at highest dose (150 µl/l air) on the *A. obtectus*, but the same essential oils showed very little (2.5%) mortal effect on the red flour beetle. Although sticky goosefoot and thyme oils showed 15% mortal effect against *A. obtectus* adults, the same essential oils did not show any mortal effect on the red flour beetle adults at the highest dose. Our result showed that *T. castaneum* adults were relatively more resistant against essential oils than that of *A. obtectus*. Several reports indicate that *T. castaneum* is relatively tolerant to different plant essential oils compared to other stored product pests (Xie *et al*., 1995; Huang *et al*., 1997; Liu and Ho, 1999; Sahaf *et al*., 2007).

The LC_{50} and LC_{99} values for myrtle, laurel and tansy oils were found lower than other seven essential oils applied to *A. obtectus*. These values were estimated as 45.31 and 70.75, 27.36 and 43.05 µl/l air for myrtle, and laurel or tansy oils, respectively. The LC_{50} and LC_{99} values for myrtle and laurel were found lower than other essential oils used against *T. castaneum*. The LC_{50} and LC_{99} values estimated as 92.80 and 159.03, 56.98 and

89.73 µl/l air for myrtle and laurel oils, respectively. Lee *et al*. (2004) reported that LC_{50} and LC_{95} values showed fluctuation between 13.7 and 20.03 µl/l air for *Eucaliptus nicholii*, *E. codonocarpa*, *Callistemon sieberi*, *Melaleuca fulgens*, *E. blakelyi* and *M. armillaris* essential oils for *T. castaneum*. The LC_{50} and LC_{95} of these essential oils against *Stophilus oryzae* adults varied between 19.0–30.6 and 43.6–56.0 ml/l air, respectively.

The mean longevity of *A. obtectus* adults was significantly decreased depending on the increasing doses of savory, myrtle, marjoram, laurel, lemon, tansy and sage essential oils. Pemonge *et al*. (1997) stated that presence of the plant material reduced longevity of *A. obtectus*. When *A. obtectus* adults were exposed to Turkish oregano, sticky goosefoot and thyme oils, mean longevity did not significantly decrease compared to control. Exposure to savory, myrtle, marjoram and laurel essential oils significantly decreased the mean longevity of *T. castaneum* adults compared to control. But Turkish oregano, lemon, sticky goosefoot, tansy, thyme and sage essential oils did not change the longevity.

Our data strongly suggest that the essential oils of especially laurel, myrtle, savory, and marjoram are toxic against the stored product pests *A. obtectus* and *T. castaneum*. Therefore these essential oils can be used as an effective protecting agent for invasion in stored products. The broadened use of essential oils by the development of their use in the control of stored product pests could be of both economic and ecological benefit. The essential oils present a widespread range of activities on insects and could be used for environmentally safer pest management and can be used as a part of integrated pest management tactics.

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