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Research Article

Feeding deterrency of two medicinal plant extracts on *Tribolium castaneum* (Coleoptera: Tenebrionidae)

Roya Taghizadeh* **and Nayer Mohammadkhani**

Shahid Bakeri High Education Center of Miandoab, Urmia University, Urmia, Iran.

Abstract: The aqueous and hydroalcoholic extracts from aerial parts of *Berberis thunbergii* L. and *Alhagi maurorum* Fisch. were tested against the red flour beetle, *Tribolium castaneum* (Herbst), for antifeedant activity, which was measured by nutritional indices parameters such as relative growth rate (RGR), relative consumption rate (RCR), efficiency of conversion of ingested food (ECI) and feeding deterrence index (FDI). Treatments were evaluated by the method of flour disc bioassay in the dark, at 27 ± 1 °C and 60 ± 5% RH. Aliquots of 10 µl of several concentrations from each extract (0.25-2.0%) and controls (solvents) were spread evenly on the flour discs. After evaporation of the solvent, 10 adult insects were introduced into each treatment. After 72 h, nutritional indices were calculated. Results indicated that nutritional indices varied significantly as extract concentrations increased. The difference between extracts and treatments was significant ($P < 0.05$). In this study, *A. maurorum* decreased RGR, RCR and ECI significantly more than those of *B. thunbergii* extract. In addition, hydroalcoholic extracts decreased RGR, RCR and ECI significantly more than those of aqueous extracts. Both plant extracts increased FDI as the extract concentrations were increased, showing high feeding deterrence activity against *T. castaneum*. Generally, antifeedant activity of *A. maurorum* was greater than that of *B. thunbergii* and hydroalcoholic extract was more effective than aqueous extract.

Keywords: *Berberis thunbergii*, *Alhagi maurorum*, medicinal plant extracts, nutritional indices

Introduction

The red flour beetle, *Tribolium castaneum* (Herbst), is one of the most serious secondary pests that feeds on the wide range of durable stored products including cereals, cereal products and other high value products such as cocoa, beans and dried fruits (Adarkwah *et al*., 2010). A commonly used method of controlling pests in stored products is the application of synthetic contact insecticides and fumigants (Chaube, 2008). The development of pesticide resistance by the pest, toxic residues in food and consequent health hazards, destruction of beneficial organisms, rapid resurgence of target pest populations and undesirable environmental pollution are critical problems that have arisen (Park *et al*., 2003). So, research has been concentrated on the plant kingdom for solutions leading to the production of a myriad of secondary compounds that can have toxic, growth reducing, and antifeedant properties against insects (Berenbaum and Zangerl, 1996). Botanical insecticides are an

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* **Corresponding author**, e-mail: r.taghizadeh@urmia.ac.ir
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environmentally friendly alternative to hazardous chemicals as they are plant-derived insecticides which occur either naturally or are extracts of such plants (Gupta *et al*., 2005). Moreover, botanical insecticides contain mixtures of biologically active substances, no resistance is developed in pests and pathogens. Therefore, the use of plant insecticides has been recommended ever more as a suitable alternative of plant protection with minimum negative risks (Isman, 2006; Pavella, 2007).

Berberis thunbergii L. (Berberidaceae) is used as ornamental plant. The main constituents of plant secondary metabolites include alkaloids, phenolics and triterpenoids (Sadeghifar *et al*., 1996). Such plants could use alkaloids to protect themselves against herbivores. Alkaloid producing plants could use these metabolites as a chemical defense against all their enemies. They could also be used as a natural source of insecticides and fungicides. Data showed that leaves and stems of *B. vulgaris* contained phenolics (Achakzai *et al*., 2009). Mosch *et al*. (1989) reported that leaf extracts from *B. vulgaris* exhibited some degree of antibacterial activity against *Erwinia amylovora* (Burrill) Winslow *et al. in vitro*. The extracts from the aerial parts of *B. iliensis* L. had an acaricidal activity (20-50%) against adults of *Tetranychus urticae* (Chermenskaya *et al*., 2010).

Alhagi maurorum Fisch (Fabaceae) is used as a medicinal plant in Iran. Phytochemical research on this plant indicated that it contains saturated sterols, triterpens, tannins, carbohydrates, flavonoids (Atta and Mounein, 2004) and flavanon glycosides (Singh *et al*., 1999) such as Alhagidin, Alhagitin and proantocyanidin (Khushbaktova *et al*., 1992).

Several studies have assessed the ability of plant extracts and essential oils as antifeedants and insecticides against *Tribolium* spp. Alcoholic extracts obtained from leaf and flowers of *Nerium oleander*, leaf of *Lavandula officinalis* and gum of *Ferula assafoetida* have antifeedant activity and repellent effect on *T. castaneum* adults (Moharramipour *et al*., 2003; Moharramipour and Nazemi Rafih, 2008). *Trachyspermum ammi*, *Anethum graveolens* and *Nigella sativa* essential oils have insecticidal activity on stored product beetle *T. castaneum* (Chaubey, 2007). *Carum copticum* C. B. Clarke and *Vitex pseudo-negundo* (Hausskn.) Hand.-Mzt. essential oils have an antifeedant activity against *T. castaneum* (Sahaf and Moharramipour, 2009). *Carum copticum* L. and *Cuminum cyminum* L. essential oils have antifeedant activities and are topically toxic to *T. confusum* (Khodadoust *et al*., 2012; Ziaee, 2014). Gamma radiation and *Perovskia atriplicifolia* essential oil in combination have shown antifeedant activities on larvae and adults of *T. castaneum* (Ahmadi *et al*., 2015).

In addition, other studies have been conducted to investigate the antifeedant effect of plants secondary metabolites on other stored product pests. *Mentha piperata* L., *Cinnamomum zelanicum* Bl., *Salvia multicaulis* Vahl., *Melissa officinalis* L., *Achillea millefolium* L. and *Carum carvi* L. essential oils have antifeedant activity against *Plodia interpunctella* Hubner larvae (Rafiei-Karahroodi *et al*., 2010). The asafoetida, geranium and walnut leaves essential oils have antifeedant activity on *Rhyzopertha dominica* adults (Bahrami *et al*., 2016). However, there are no reports concerning the deterrency and antifeedant activity of aqueous and hydroalcoholic extracts from these plant against *T. castaneum*. Therefore, the present study was designed to compare the deterrency and antifeedant activity of six different concentrations of extracts from aerial parts of *B. thunbergii* and *A. maurorum* against adults of *T. castaneum* under laboratory conditions.

Materials and Methods

Insect

T. castaneum was reared on wheat flour mixed with yeast (10: 1 w/w). The cultures were maintained in the dark at 27 ± 1 °C and 60 ± 5% RH. All adults used in the experiments were 1-7 days old.

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Plant materials

Aerial parts of *B. thunbergii* and *A. maurorum* were collected from Miandoab university campus, Northwest Iran. The collected plant materials were dried on laboratory benches at room temperature (23-24 °C). Then they were stored at 4 °C until they were needed.

Extraction procedures

The air-dried ground (80 mesh) plant material (20 g for each sample) was extracted with each of the solvents – aqueous and hydroalcoholic (70 ethanol: 30 water) (200 ml) for 6 hours at room temperature in an orbital shaker. The extracts were separated from the residues by filtering through Whatman filter paper. The residues were extracted twice with the same fresh solvent and all the extracts were combined. Plant extracts was stored in a refrigerator at 4°C (Sultana *et al*., 2009).

Nutritional indices assay

Flour discs were prepared according to the method of Huang *et al*. (2000), in brief 10 g of flour was mixed with 50 ml of distilled water. Using a micropipette, 200 µl of the prepared suspension was poured on a nylon sheet to convert the suspension to circular discs. The weights of flour discs were between 40-45 mg and 18% relative humidity. The discs were placed in normal room conditions for 4 h and then transferred to sterile petri dishes with the help of fine forceps. The flour discs were stored for 12 h inside the hood to dry completely. Flour discs treated with 10 µl of different concentrations of the extracts (0.25, 0.5, 0.75, 1.0, 1.5 and 2.0%) prepared with ethanol and distilled water. Discs to which only the solvent was applied were used as the control. The solvent was allowed to evaporate for 10 min at room temperature. *T. castaneum* adults were starved for 48 h before the experiment. In each container 2 discs covered by the same dose of the extracts and 10 starved insect adults were placed. Each experiment was replicated four times, set in the dark at 27 ± 1°C and 60 ± 5 % RH. The weight of the flour discs, insects and plastic containers (130 ml) were accurately measured and recorded at the beginning and after 3 days. The nutritional indices were calculated according to Huang *et al*. (2000) formula:

Relative Growth Rate (RGR):

$RGR = (A - B) / (B \times day)$

Where: A is the weight of live insects after experiment (mg), B is the weight of insects before experiment (mg).

Relative Consumption Rate (RCR):

$RCR = D / (B \times day)$.

Where: D is the dried weight of food consumed by insect (mg).

Efficacy of Conversion of Ingested Food (ECI):

$ECI = RGR / RCR \times 100\%$

Feeding Deterrence Index (FDI):

$FDI = [(C – T) / C] \times 100\%$

Where: C is the food consumed in control (mg), T is food consumed in treatment (mg).

Statistical analysis

Statistical analysis was done using SPSS 19.0 software. Normality of the data was tested by Kolmogorov-Smirnov (Kolmogorov, 1933; Smirnov, 1933) method. One-way analysis of variance and general linear model (GLM) with Duncan's multiple range tests ($P < 0.05$) were used to determine differences between means. Also correlations between measured factors were calculated. Comparison between plant extracts were analyzed by independent t-student test.

Results

Antifeedant activity of plant extracts was assessed based on nutritional indices. The antifeedant activity varied significantly for the two extraction solvents. The RGR in treated adults decreased significantly ($P < 0.05$) with increasing *B. thunbergii* and *A. maurorum* extract concentrations. The difference between aqueous and hydroalcoholic extracts was significant ($P < 0.05$) and hydroalcoholic extracts were more effective than aqueous extracts. Treated adults with *A. maurorum* extracts showed different total mean of RGR

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(0.25 and 0.09 mg/mg/day for aqueous and hydroalcoholic extracts, respectively). These values were 0.32 and 0.22 mg/mg/day for aqueous and hydroalcoholic extracts of *B. thunbergii*. Hydroalcoholic extract of *A. maurorum* decreased RGR more than 70% at concentrations higher than 0.5% compared to control (Tables 1, 2). The reduction rate gradually increased with increasing extract concentration. Aqueous extract of *A. maurorum* decreased RGR more than 45% at concentrations higher than 0.5% compared to control. Hydroalcoholic and aqueous extracts of *B. thunbergii* decreased RGR more than 49 and 45% at concentrations higher than 0.75% compared to control, respectively. The results also indicated that the RCR in treated adults decreased significantly ($P < 0.05$) with increasing plant extract concentrations (Tables 3, 4). Hydroalcoholic extracts of *B. thunbergii* and *A. maurorum* decreased RCR more than 66% at higher concentrations (> 1.0%) compared to control, whereas aqueous extracts decreased RCR 69% and 53%, respectively.

In addition, the ECI in treated adults decreased significantly ($P < 0.05$) with increasing plant extracts concentration (Tables 5, 6). In contrast, the FDI values increased significantly ($P < 0.05$) with increasing plant extract concentrations (Tables 7, 8). Hydroalcoholic extracts of *B. thunbergii* and *A. maurorum* increased FDI from 0 to 89% and 74%, but aqueous extracts increased FDI to 82% and 47%, respectively. According to our findings, with increase of concentration of hydroalcoholic extracts, the feeding deterrent index increased at the same rate, also the efficiency of conversion of ingested food was decreased. These results showed that the hydroalcoholic extracts, in addition to the feeding deterrence, affect considerably in post-ingestive toxicity. While, with increasing the concentration of aqueous extracts of *B. thunbergii* and *A. maurorum*, the FDI increased at the same rate, but the ECI was not decreased. Although at concentration 2% feeding deterrency was 74% and 47%, but ECI was decreased compared with the control by 35% and 26%, respectively. The results indicated that the feeding deterrency effect of aqueous extracts was more than its post-ingestive toxicity. However, comparing the hydroalcoholic extracts of studied plants indicated that *A. maurorum* extracts have feeding deterrency effect and post-ingestive toxicity, while *B. thunbergii* extracts mainly have feeding deterrency effect. Consequently, antifeedant activity of hydroalcoholic extract of *A. maurorum* was more effective than *B. thunbergii* (Tables 1-8). GLM analysis showed that the difference of nutritional indices between plants was significant ($P < 0.05$), also the effects of extracts, treatments and extract × treatment were significant.

Table 1 The effects of aqueous extracts of *Berberis thunbergii* and *Alhagi maurorum* on relative growth rate (RGR) of *Tribolium castaneum* adults.

Concentration (%) (v/v)	RGR (mg/mg/day) (Mean ± SE)		t-student	p-value
	B. thunbergii	*A. maurorum*		
Control	0.5568 ± 0.0133[a]	0.5417 ± 0.0138[a]	-0.779	0.471
0.25	0.4732 ± 0.0130[b]	0.3423 ± 0.0192[b]	-5.084	0.004
0.50	0.3088 ± 0.0148[c]	0.2943 ± 0.0068[c]	-0.844	0.437
0.75	0.3035 ± 0.0198[c]	0.2298 ± 0.0069[d]	-4.353	0.007
1.00	0.2898 ± 0.0059[c]	0.1513 ± 0.0101[e]	-10.714	0.000
1.50	0.1913 ± 0.0155[d]	0.1336 ± 0.0031[e]	-3.617	0.061
2.00	0.1005 ± 0.0033[e]	0.0785 ± 0.0053[f]	-3.601	0.016
mean	0.3176 ± 0.0324	0.2531 ± 0.0283	-1.500	0.140

Different letters in a column indicate significant differences ($P < 0.05$) between treatments according to Duncan's test.

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Table 2 The effects of hydroalcoholic extracts of *Berberis thunbergii* and *Alhagi maurorum* on relative growth rate (RGR) of *Tribolium castaneum* adults.

Concentration (%) (v/v)	RGR (mg/mg/day) (Mean ± SE)		t-student	p-value
	B. thunbergii	*A. maurorum*		
Control	0.5313 ± 0.0192[a]	0.4213 ± 0.0296[a]	-2.876	0.035
0.25	0.4468 ± 0.0016[b]	0.2451 ± 0.0217[b]	-7.798	0.001
0.50	0.3063 ± 0.0160[c]	0.1264 ± 0.0127[c]	-9.325	0.000
0.75	0.2703 ± 0.0065[d]	0.0195 ± 0.0011[d]	-34.975	0.000
1.00	0.1741 ± 0.0028[e]	-0.0250 ± 0.0064[e]	-27.264	0.000
1.50	0.0936 ± 0.0042[f]	-0.0396 ± 0.0030[e]	-29.948	0.000
2.00	-0.1466 ± 0.0079[g]	-0.1055 ± 0.0047[f]	4.309	0.005
mean	0.2243 ± 0.0462	0.0917 ± 0.0336	-2.374	0.022

Different letters in a column indicate significant differences ($P < 0.05$) between treatments according to Duncan's test.

Table 3 The effects of aqueous extracts of *Berberis thunbergii* and *Alhagi maurorum* on relative consumption rate (RCR) of *Tribolium castaneum* adults.

Concentration (%) (v/v)	RCR (mg/mg/day) (Mean ± SE)		t-student	p-value
	B. thunbergii	*A. maurorum*		
Control	0.8835 ± 0.0077[a]	0.9351 ± 0.0515[a]	0.840	0.439
0.25	0.7805 ± 0.0036[b]	0.8294 ± 0.0325[b]	1.487	0.231
0.50	0.6480 ± 0.0029[c]	0.7714 ± 0.0092[b]	10.948	0.000
0.75	0.5833 ± 0.0072[d]	0.5567 ± 0.0159[c]	-1.344	0.237
1.00	0.2988 ± 0.0023[e]	0.4389 ± 0.0123[d]	9.533	0.000
1.50	0.2993 ± 0.0035[e]	0.3775 ± 0.0139[d]	5.423	0.009
2.00	0.1956 ± 0.0030[f]	0.2978 ± 0.0105[e]	8.062	0.000
mean	0.5271 ± 0.0550	0.6010 ± 0.0446	1.054	0.297

Different letters in a column indicate significant differences ($P < 0.05$) between treatments according to Duncan's test.

Table 4 The effects of hydroalcoholic extracts of *Berberis thunbergii* and *Alhagi maurorum* on relative consumption rate (RCR) of *Tribolium castaneum* adults.

Concentration (%) (v/v)	RCR (mg/mg/day) (Mean ± SE)		t-student	p-value
	B. thunbergii	*A. maurorum*		
Control	0.8204 ± 0.0107[a]	0.9120 ± 0.0324[a]	2.329	0.067
0.25	0.7417 ± 0.0027[b]	0.7829 ± 0.0213[b]	1.631	0.164
0.5	0.5854 ± 0.0021[c]	0.7388 ± 0.0346[b]	3.736	0.013
0.75	0.3882 ± 0.0044[d]	0.6121 ± 0.0149[c]	14.373	0.000
1.0	0.2780 ± 0.0041[e]	0.2776 ± 0.0109[d]	-0.026	0.980
1.5	0.2146 ± 0.0012[f]	0.1369 ± 0.0149[e]	-5.167	0.013
2.0	0.1309 ± 0.0013[g]	0.0785 ± 0.0022[e]	-20.511	0.000
mean	0.4347 ± 0.0525	0.5056 ± 0.0603	0.887	0.379

Different letters in a column indicate significant differences ($P < 0.05$) between treatments according to Duncan's test.

Table 5 The effects of aqueous extracts of *Berberis thunbergii* and *Alhagi maurorum* on Efficacy of conversion of ingested food (ECI) of *Tribolium castaneum* adults.

Concentration (%) (v/v)	ECI (%) (Mean ± SE)		t-student	p-value
	B. thunbergii	*A. maurorum*		
Control	60.90 ± 2.94[a]	58.26 ± 2.31[a]	-0.719	0.505
0.25	57.18 ± 2.28[a]	41.21 ± 1.12[b]	-6.850	0.001
0.50	48.57 ± 1.67[b]	38.16 ± 0.89[b]	-5.919	0.002
0.75	46.71 ± 2.66[b]	41.33 ± 1.41[bc]	-1.933	0.111
1.00	47.55 ± 1.28[b]	34.65 ± 2.97[c]	-3.508	0.017
1.50	35.36 ± 2.46[c]	35.46 ± 0.85[bc]	0.045	0.966
2.00	35.35 ± 1.09[c]	26.53 ± 2.32[d]	-3.063	0.029
mean	47.38 ± 2.13	39.37 ± 1.84	-2.842	0.007

Different letters in a column indicate significant differences ($P < 0.05$) between treatments according to Duncan's test.

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Table 6 The effects of hydroalcoholic extracts of *Berberis thunbergii* and *Alhagi maurorum* on efficacy of conversion of ingested food (ECI) of *Tribolium castaneum* adults.

Concentration (%) (v/v)	ECI (%) (Mean ± SE)		t-student	p-value
	B. thunbergii	*A. maurorum*		
Control	73.67 ± 0.69[a]	46.44 ± 3.92[a]	-5.815	0.002
0.25	56.33 ± 0.88[b]	31.34 ± 2.85[b]	-7.218	0.001
0.50	53.58 ± 1.78[b]	17.25 ± 2.11[c]	-12.456	0.000
0.75	47.91 ± 2.11[c]	3.200 ± 0.22[d]	-21.019	0.000
1.00	25.74 ± 1.64[d]	-4.77 ± 1.19[e]	-15.521	0.000
1.50	13.51 ± 0.87[e]	-22.42 ± 1.53[f]	-18.426	0.000
2.00	-30.58 ± 0.74[f]	-52.14 ± 1.24[g]	-14.942	0.000
mean	32.08 ± 7.21	2.70 ± 5.97	-3.166	0.003

Different letters in a column indicate significant differences ($P < 0.05$) between treatments according to Duncan's test.

Table 7 The effects of aqueous extracts of *Berberis thunbergii* and *Alhagi maurorum* on feeding deterrence index (FDI) of *Tribolium castaneum* adults.

Concentration (%) (v/v)	FDI (%) (Mean ± SE)		t-student	p-value
	B. thunbergii	*A. maurorum*		
Control	0[f]	0[e]	-	-
0.25	15.95 ± 1.60[e]	5.75 ± 0.62[d]	-6.649	0.001
0.50	36.63 ± 0.77[d]	6.75 ± 0.46[d]	-35.094	0.000
0.75	46.98 ± 2.13[c]	18.27 ± 0.98[c]	-13.461	0.000
1.00	54.23 ± 1.14[b]	41.57 ± 0.78[b]	-9.480	0.000
1.50	69.88 ± 1.27[a]	44.04 ± 1.16[b]	-14.807	0.000
2.00	74.21 ± 2.16[a]	47.24 ± 2.16[a]	-8.594	0.000
mean	42.56 ± 5.66	23.38 ± 3.65	-2.970	0.005

Different letters in a column indicate significant differences ($P < 0.05$) between treatments according to Duncan's test.

Table 8 The effects of hydroalcoholic extracts of *Berberis thunbergii* and *Alhagi maurorum* on feeding deterrence index (FDI) of *Tribolium castaneum* adults.

Concentration (%) (v/v)	FDI (%) (Mean ± SE)		t-student	p-value
	B. thunbergii	*A. maurorum*		
Control	0.000[g]	0.000[g]	-	-
0.25	25.56 ± 1.47[f]	13.17 ± 0.71[f]	-8.274	0.000
0.50	33.73 ± 1.96[e]	41.34 ± 1.33[e]	3.334	0.021
0.75	41.23 ± 2.64[d]	48.91 ± 1.76[d]	2.420	0.052
1.00	55.05 ± 0.05[c]	53.69 ± 1.76[c]	-0.652	0.543
1.50	69.43 ± 1.46[b]	77.77 ± 2.42[b]	2.666	0.045
2.00	89.30 ± 2.35[a]	82.37 ± 1.56[a]	-2.452	0.050
mean	46.67 ± 5.92	45.33 ± 5.47	-0.167	0.868

Different letters in a column indicate significant differences ($P < 0.05$) between treatments according to Duncan's test.

Discussion

This study demonstrates that aqueous and hydroalcoholic extracts of *B. thunbergii* and *A. maurorum* had toxic and significant effect on the nutritional indices of the adults of *T. castaneum* at different concentrations. These plants are used as folk medicinal herbs in Iran; *Alhagi* sp. extracts have anti-ulcer activity (Gharibnaseri and Mard, 2007), *Berberis* sp. is used for antimicrobial and antifungal activity (Freile *et al*., 2003; Iauk *et al*., 2007), antioxidant and anticancer effect (Majd *et al*., 2008), as well as hepatoprotective and therapeutic effects on liver disease (Shariatzadeh *et al*., 2013; Rafiee *et al*., 2013; Ashraf *et al*., 2014), and anti-inflammatory activities (Kiasalari *et al*., 2011) were reported for it. Also studies showed that these two medicinal plants have an antibacterial activity (Ghasemi Pirbalouti *et al*., 2010), so the use of extracts of these plants can be safe for humans and environment.

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As the nutritional indices showed, the amount of food consumed by insect determined growth rate. Also the efficiency of food consumed is different according to the food quality. If it is not favorable, the insect avoid eating. It means that this food had deterrent effect on insect. If it is consumed, the insect will not be able to ingest and absorb in the alimentary system. This food causes ingestive toxicity and is deterrent of weight gain, even weight loss of insect will occur. In this experiment with increases of concentrations of aqueous and hydroalcoholic extracts of the two medicinal plants, RGR, RCR, and ECI of *T. castaneum* decreased. In fact, with the tendency of insect to consume food, growth rate and food consumption decreased. Also, with increase of concentrations of all extracts FDI increased.

In present study there were positive significant correlations ($P < 0.01$, $r^2 > 0.9$) between RGR and RCR or ECI in treated adults with aqueous extracts of *A. maurorum*, and $r^2 > 0.8$ was estimated for hydroalcoholic extracts. In treated adults with extracts of *B. thunbergii* $r^2 > 0.9$ for both extracts, it means that aqueous and hydroalcohlic extracts showed no significant difference in correlation values.

Effects of plant extracts on nutritional indices have been studied by several researchers (Han *et al*., 2006; Silva *et al*., 2007; Pavela, 2009). Extracts (Talukder and Howse, 1995; Kumar and Gupta, 2013) and essential oils (Negahban and Moharramipour, 2007; Shakarami, 2013; Ahmadi *et al*., 2015) of various medicinal plants have been demonstrated as effective feeding deterrent against *T. castaneum*. However, before the current study, there were no reports on the feeding deterrency effects of *B. thunbergii* and *A. maurorum* extracts against *T. castaneum.* The reduction in growth rate of *T. castaneum* by *Evodia rutaecarpa* Hook f. *et* Thomas essential oil was mainly due to a feeding deterrent action rather than to post-ingestive toxicity of the oil (Liu and Ho, 1999). Also, the extracts of *Nerium oleander* L. and *Lavandula officinalis* L. do not have the post-ingestive toxicity, while *Ferula assafoetida* L. extract had the most effect on FDI (Moharramipour and Nazemi Rafieh, 2003). Sahaf and Moharramipour (2009) reported that antifeedant activity of *Carum copticum* C. B. Clarke was more effective than *Vitex pseudo-negund* (Hausskn.) Hand.-Mzt. essential oil. Kumar and Gupta (2013) reported that both petroleum ether and chloroform extract of *Azadirachta indica* A. Juss. showed maximum antifeedant activity against *T. castaneum*. According to Ali *et al*. (2014) the minimum flour consumption by *T. castaneum* adults was 11% at the 20% concentration of *Allium sativum* L. extract and maximum consumption was 29.66% in control treatment. The minimum flour consumption was 12% at the 15% concentration of *Curcuma longa* L. seed extract and maximum consumption was 31% in control treatment. Consequently, *C. longa* seed extract performed well by showing maximum inhibition even at 15% concentration as compared to the *A. sativum*. Kumar *et al*. (2008) studied insecticidal activity *Aegle marmelos* (L.) Correa essential oil against some stored grain insect pests; the results showed that there is no antifeedant activity for *T. castaneum* (FDI% = -6.18 ± 0.27). Jbilou and Sayah (2008) evaluated effects of methanol extract of *Peganum harmala* L. seeds on the major metabolites of *T. castaneum* by incorporating it into the diet at 2.5, 5 and 10% concentrations. Protein and lipid contents in last instar larvae determined eight days after feeding contaminated diet showed decreasing values at concentrations more than 2.5%. A botanical feeding deterrent operates in two ways either by blocking chemo receptors or inducing mid gut toxicity, so this cannot be explained in our study, additional studies are needed to evaluate the electrophysiological reason of antifeedant effects of studied plant extracts.

It is concluded that the hydroalcoholic extracts of the two studied plants were more effective than aqueous extracts. Both extracts have antifeedant effect against *T. castaneum*, although the hydroalcoholic extract of *A. maurorum* was more effective than that of *B. thunbergii*. Moreover, the RGR, RCR and ECI decreased strongly with the hydroalcoholic extract of *A. maurorum* and the FDI increased.

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In fact, the feeding deterrent agents contained in plant extract caused the reduction in growth rate of the insect pest. On the basis of these results it can be found that the hydroalcoholic extracts of these two medicinal plants play a role in pest control due to their antifeedant and post-ingestive toxicity. Using hydroalcoholic extracts of these medicinal plants as part of stored products pest control program would be effective in management of this pest.

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بازدارندگی عصاره‌های دو گیاه دارویی روی شپشه آرد، *Tribolium castaneum* (Coleoptera: Tenebrionidae)

رویا تقی‌زاده* و نیر محمدخانی

مرکز آموزش عالی شهید باکری میاندوآب، دانشگاه ارومیه، ارومیه، ایران.
* پست الکترونیکی نویسنده مسئول مکاتبه: r.taghizadeh@urmia.ac.ir
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چکیده: در این بررسی عصاره‌های آبی و هیدروالکلی اندام‌های هوایی گیاهان زرشک، *Berberis thunbergii* و خارشتر،*Alhagi maurorum* جهت تعیین اثرات ضدتغذیه‌ای شپشه آرد، *Tribolium castaneum* (Herbst.) مورد بررسی قرار گرفت، که با اندازه‌گیری شاخص‌های تغذیه‌ای نظیر نرخ رشد نسبی، نرخ مصرف نسبی، کارایی تبدیل غذای خورده شده و شاخص بازدارندگی تغذیه برای ارزیابی اثر ضدتغذیه‌ای عصاره‌های گیاهی استفاده شد. تیمارها به‌روش دیسک آردی در دمای ۱ ± ۲۷درجه سلسیوس و رطوبت نسبی ۵ ± ۶۰ درصد و تاریکی ارزیابی شدند. در این آزمایش ۱۰ میکرولیتر از غلظت های (٪۲-۰/۲۵) عصاره هر دو گیاه به‌همراه شاهد به‌طور یکنواخت روی دیسک‌های آردی پخش شدند. پس از تبخیر حلال در هر تکرار ۱۰ حشره کامل شپشه آرد قرار داده شد. پس از گذشت ۷۲ ساعت از شروع آزمایش، شاخص‌های تغذیه محاسبه شدند. نتایج نشان داد که افزایش غلظت عصاره دو گیاه روی شاخص‌های تغذیه شپشه آرد به‌طور معنی‌داری مؤثر بوده است. هم‌چنین تفاوت بین عصاره‌ها و تیمارها معنی‌دار ($P < 0.05$) بود. در این پژوهش، عصاره خارشتر نرخ رشد نسبی، نرخ مصرف نسبی و کارایی تبدیل غذای خورده شده توسط شپشه آرد را به‌طور معنی‌دار بیش از عصاره زرشک کاهش داده است. به‌علاوه، عصاره‌های هیدروالکلی نرخ رشد نسبی، نرخ مصرف نسبی و کارایی تبدیل غذای خورده شده را به‌طور معنی‌دار بیش از عصاره‌های آبی کاهش داده است. با افزایش غلظت، شاخص بازدارندگی تغذیه هر دو گیاه به‌نحو چشم‌گیری افزایش یافت، که نشان‌دهنده اثر بازدارندگی تغذیه‌ای بالا روی شپشه آرد است. به‌طور کلی نتایج نشان داد که خاصیت ضدتغذیه‌ای عصاره خارشتر بسیار مؤثرتر از زرشک و عصاره هیدروالکلی بسیار مؤثرتر ازعصاره آبی است.

واژگان کلیدی: زرشک، خارشتر، عصاره گیاهان دارویی، شاخص‌های تغذیه‌ای

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