



## Influence of medicinal plants on *Blaberus craniifer* cockroaches and their parasites, gregarines and nematodes

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**Parhomenko, O. V., Ostapchuk, V. V., Komlyk, V. O., & Brygadyrenko, V. V. (2024). Influence of medicinal plants on *Blaberus craniifer* cockroaches and their parasites, gregarines and nematodes. *Biosystems Diversity*, 32(3), 398–405. doi:10.15421/012443**

Cockroaches, especially those living in forest litter and feeding on foliage, have been consuming plants for millions of years. Can secondary metabolites of plants affect the parasite-host system and successfully treat the cockroaches' parasites – gregarines and nematodes? In our experiment, 204 *Blaberus craniifer* (Blattodea, Blaberidae) cockroaches consumed the standard diet supplemented with medicinal plants in a dose of 10% of the general fodder mass, particularly, plants of the families Acoraceae (*Acorus calamus*), Papaveraceae (*Chelidonium majus*), Rosaceae (*Potentilla erecta*), Juglandaceae (*Juglans regia*), Fagaceae (*Quercus robur*), Brassicaceae (*Capsella bursa-pastoris*), Hypericaceae (*Hypericum perforatum*), Gentianaceae (*Centaurium erythraea*), Lamiaceae (*Origanum vulgare*, *Salvia officinalis*, *Thymus pallasianus*), and Asteraceae (*Achillea millefolium*, *Arctium lappa*, *Artemisia absinthium*, *Matricaria chamomilla*, and *Tanacetum vulgare*). With age (i.e. gaining body mass), the intensity of infestation of cockroaches with female and male nematodes *Cranifera cranifera* significantly increased. The multifactor dispersion analysis found no significant effect of the number of parasites (two gregarines, *Blabericola cubensis* and *Protomagalhaensia granulosa*, and one nematode, *Cranifera cranifera*) on the rates of changes in body mass of the cockroaches during the experiment. Also, there was observed no effect of the number of parasites on the rates of cockroaches' food consumption. The rates of body-mass gain during the experiment were closely associated with the initial body mass of the cockroaches: the larger the cockroach was in the beginning of the experiment, the greater the increase in its body mass later in the experiment. None of the three species of *B. craniifer* parasites that we studied significantly changed their numbers when subject to 10% dry medicinal plants in the hosts' fodder, compared to the control group of cockroaches that did not consume the medicinal raw material. Intake of none of the 16 species of medicinal plants we tested led to significant changes in the rates of body-mass gain in the cockroaches. Compared to the control group, the experimental groups of cockroaches had no significant changes in the fodder consumption rates. Our experiment demonstrated that the cockroaches, together with their parasites, are substantially adapted to the influences of secondary metabolites of the 16 medicinal plants that we studied, although, in their natural range they had most likely never encountered any of those plants. Therefore, on the one hand, the considered parasite-host system was observed to be very balanced, the host being minimally harmed, and on the other hand, secondary metabolites of the plants had no significant effect either on the parasites (two species of gregarines and one species of nematodes) or on their hosts even in the highest tested concentrations (10% of the fodder mass).

**Keywords:** Blattodea; Thelastomatidae; Eugregarinorida; gregarines; medicinal plants; parasites of insects.

### Introduction

The history of using plants to treat various diseases dates back to the old days. Over millions of years of evolving together, animals have been instinctively finding necessary plants for treatment. Humans, having noticed those behaviors of animals, became aware of medicinal properties of plants and started using them against various diseases caused by diverse pathogens (bacterial or parasitic). Today, the practice of utilizing medicinal plants to treat animals and humans is gaining popularity. For instance, as of now, there are around 20,000 species of higher plants used in medicine (Sofowora et al., 2013; Ozkan et al., 2016; Jamil et al., 2022). Many plants have antibacterial, antifungal, anti-inflammatory, and anthelmintic properties due to the presence of biologically active compounds – flavonoids, alkaloids, saponins, and others (Table 1). Also, there is ongoing research on other simple compounds to use against parasitic diseases in animals (Boyko & Brygadyrenko, 2017, 2019, 2022).

To study the effects of medicinal plants on insects and their parasites, we chose the cockroaches *Blaberus craniifer* Burmeister, 1838 (Blattodea, Blaberidae), a species of South American cockroaches, which in nature

feed on foliage. They can be easily kept in laboratory conditions, as they can consume various plants (leaves, fruits) and even dry fodder for cats and dogs. Vegetal food provides them with all the necessary vital compounds. This cockroach is parasitized by several species of nematodes and gregarines (Smith & Cook, 2008; Clopton, 2012b; Parhomenko et al., 2023). Due to the fact that the diet of cockroaches is predominantly vegetal they are a good object for studying various biologically active compounds from plants on the metabolism of insects and their parasitogenesis.

The objective of this study was to evaluate the effects of medicinal plants on the metabolism of cockroach larvae (the rates of body-mass gain) and the number of their intestinal parasites (gregarines and nematodes).

### Materials and methods

The experiment was performed on 204 larvae of *Blaberus craniifer* (Blattodea, Blaberidae) of various ages, which were held in one container for 6 months (Fig. 1). Those insects are easy to maintain in containers

where they can actively breed and many researchers use them for various experiments (Goudey-Perrière et al., 2007; Anacarso et al., 2016; Kulma et al., 2020). During the experiment (Table 1), we used medicinal raw materials of plants of the families Acoraceae (*Acorus calamus*), Papaveraceae (*Chelidonium majus*), Rosaceae (*Potentilla erecta*), Juglandaceae (*Juglans regia*), Fagaceae (*Quercus robur*), Brassicaceae (*Capsella bursa-pastoris*), Hypericaceae (*Hypericum perforatum*), Gentianaceae (*Centaurium erythraea*), Lamiaceae (*Origanum vulgare*, *Salvia officinalis*, *Thymus pallasianus*), and Asteraceae (*Achillea millefolium*, *Arctium lappa*, *Artemisia absinthium*, *Matricaria chamomilla*, and *Tanacetum vulgare*), which in dry condition were added to the diet of the cockroaches (10% of the fodder mass). As fodder for the larvae, we used meat-bone flour, which contained 50% protein, up to 9% fats, 20% ash, 6% lysine, 0.7% tryptophan, as well as calcium, phosphorus, vitamins, and microelements.

The experiment lasted for seven days. The intestinal parasites (gregarines and nematodes) were studied using the generally accepted methods. For this purpose, the intestines were removed from the larvae and made into temporary micropreparations of the frontal, middle, and posterior sections. Those micropreparations were analyzed under a microscope to count gregarines and nematodes. The parasites were identified according to the works of Adamson & Van Waerebeke (1992), Clopton & Hays

(2006), Clopton (2011, 2012a, 2012b), and Camino & Quelas (2008). The materials for the statistical analyses were processed using the standard methods of variance statistics, regression and correlation analyses, and also cluster analysis in the software pack Statistica 8.0 (StatSoft Inc., USA). We estimated the mean value and standard error ( $\bar{x} \pm SE$ ). To compare the samplings, we used single-factor and multifactor dispersion analyses. To compare several samplings, we used the Tukey Test. The differences were considered significant at  $P < 0.05$ .



Fig. 1. Larvae of *Blaberus crantifer* at various stages

**Table 1**  
Brief characteristics of the plant raw materials used in the experiment

Plant, family, part of plant	The main active compounds	Physiological effects on mammals	Sources
<i>Acorus calamus</i> L., Acoraceae, rhizome	The roots contain up to 5% of essential oil, bitter glycoside named acorine, ascorbic acid, palmitic acid, tannins, natural gums, resin, phytoncides, starch, and others.	The roots exert tonic, anti-inflammatory, pain-mitigating, cholagogue, antibacterial, and disinfecting actions.	Khomenko & Khomenko (1994), Bilenko (2004), Cahlikova et al. (2010), Li et al. (2011), Park et al. (2011)
<i>Chelidonium majus</i> L., Papaveraceae, leaf	The plant contains alkaloids, chelidonine, homochelidonine, sanguinarine, chelerythrine, protopine, and others; the herbs contain alkaloids (up to 1.87%), essential oil (up to 1.71 g/kg), vitamin C, carotene, chelidonic acid, malic acid, citric acid, flavonoids, and saponines.	The greater celandine displays antispasmodic, cholagogue, and anti-inflammatory actions. Chelidonine acts calmly upon the central nervous system, reduces the rhythm of heart contractions. Homochelidonine, by contrast, stimulates the central nervous system and has a local anesthetic effect. Protopine increases the tone of the smooth muscles, and also has a broad range of antimicrobial activity.	Bilenko (2004), Khomenko & Khomenko (1994), Cahlikova et al. (2010), Li et al. (2011), Park et al. (2011)
<i>Potentilla erecta</i> (L.) Rausch., Rosaceae, rhizome	The roots of the plants contain 14–31% of tannins with predominance of condensed tannins, ellagic acid, the tormentillin glycoside, the tormentiol ether, resins, natural gum, starch, and other compounds.	The roots of common tormentil exhibit astringent and hemostatic properties, which are due to the high content of tannins. Furthermore, it demonstrates insignificant antimicrobial action. When orally administered, the drugs mitigate the secretory function of the digestive glands; they are effective as astringent agents during inflammatory diseases of the gastrointestinal tract, and hemostatic for controlling hemorrhages in the stomach, intestines, and womb.	Khomenko & Khomenko (1994), Bilenko (2004), Shushunov et al. (2009)
<i>Juglans regia</i> L., Juglandaceae, leaf	The leaves of the Persian walnut contain chinones, flavonoids, vitamin C (up to 5%), vitamins of group B, tannins, ellagic acid, gallic acid, and caffeic acid, carotenoids (including beta-carotene), essential oil, flavoxanthin, violaxanthin	The main effects of the Persian walnut's leaves are as follows: wound-healing, antimicrobial, antiviral, anti-inflammatory. They increase blood coagulability, and decrease the sugar level.	Khomenko & Khomenko (1994), Bilenko (2004), Ozkan & Koyuncu (2005)
<i>Quercus robur</i> L., Fagaceae, bark	The bark contains 10–20% of tannins, gallic and ellagic acids, up to 6% of pectin compounds, 13–14% of pentosans, flavonoid quercetin, starch, mucilage, and other compounds.	The presence of large amounts of tannins, pectin, and quercetin mediates the anti-inflammatory and astringent actions of oak bark; the plant's astringent action is based on the ability of tannins to improve the stability of cellular membranes.	Khomenko & Khomenko (1994), Bilenko (2004)
<i>Capsella bursa-pastoris</i> (L.) Medik., Brassicaceae, herb	The herbs contain flavonoids (rutin, luteolin-7-rutinoside, luteolin-7-glycoside), tannins, amines (choline, acetylcholine, tyramine, and others), saponins, organic acids (fumaric, citric, malic, and tartaric acids), and essential oil	Drugs made from the plant produce hemostatic action, especially in cases of insufficient formation of fibrin. At the same time, they stimulate the contraction function of the uterus, reduce the arterial pressure, enlarge the venous vessels, and display cholagogue and anti-inflammatory actions, enhance the motor activity of the intestines and stomach. The leaves exert high phytoncide activity.	Kuroda et al. (1976), Khomenko & Khomenko (1994), Bilenko (2004)
<i>Hypericum perforatum</i> L., Hypericaceae, leaf	The plant herbs contain tannins of the pyrocatechol group (up to 12%), derivatives of anthracene – hypericin and pseudohypericin (up to 0.5%), flavonoids, saponins, resin compounds, vitamin C, carotene, and essential oil (0.2–0.3%)	Drugs made of St John's wort have astringent, anti-inflammatory, and antimicrobial properties, promote fast regeneration of damaged tissues. Moreover, the plant's anthelmintic, hemostatic, disinfecting, and cholagogue effects have been determined.	Khomenko & Khomenko (1994), Bilenko (2004), Crockett & Robson (2011)
<i>Centaurium erythraea</i> Rafn., Gentianaceae, herb	The plant was found to have glycosides erythrocentaurin, erythramine, alkaloids gentianine (around 1%) and erythrycin, oleanolic and ascorbic acids, resins, tannins, and salts of organic acids	Drugs made from common centaury usually stimulate the secretion of glands of the digestive tract, exert anesthetic and antipyretic properties, and increase biliary excretion.	Khomenko & Khomenko (1994), Kumarasamy et al. (2003), Bilenko (2004)

Plant, family, part of plant	The main active compounds	Physiological effects on mammals	Sources
<i>Origanum vulgare</i> L., Lamiaceae, herb	It contains tannins, ascorbic acid and essential oil (up to 1.2%), which includes the phenols carvacrol and thymol, bicyclic sesquiterpenes, and other aroma compounds, and flavonoids.	The plant acts calmingly upon the central nervous system, increases the secretion of sweat, gastric, and bronchial glands, and peristalsis of the intestines.	Khomenko & Khomenko (1994), Bilenko (2004), Teixeira et al. (2013)
<i>Savia officinalis</i> L., Lamiaceae, leaf	The leaves contain essential oil (up to 2.5%), condensed tannins (4.0%), triterpene acids (ursolic and oleanolic), diterpenes, resinous (5.5%) and bitter compounds, flavonoids, aesculetin coumarin, and other compounds.	Sage-based drugs produce astringent, anti-inflammatory, disinfecting, expectorant, estrogenic, and hypoglycemic effects, decrease perspiration, provoke secretion of gastric juice, and have insignificant antiseptic and hemostatic actions.	Khomenko & Khomenko (1994), Bilenko (2004), Miroddi et al. (2014), Lopresti (2017)
<i>Thymus pallasianus</i> Heind. Braun, Lamiaceae, herb	The herbs contain 0.8–1.2% of essential oil, which includes phenols (thymol, carvacrol, terpenes, and others), and also tannins and bitter compounds, flavonoids, organic acids, and other compounds.	The herbs exert expectorant and stimulating effects on the motility in the epithelium of the upper respiratory ways, increase the amount of secretion, promote sputum liquefaction, and enhance its release. Thymol present in the plant acts as an antiseptic and disinfectant, especially in cases of inflammatory processes, complicated by pathogenic antibiotic-resistant microflora. Thymol and carvacrol exert anthelmintic properties.	Khomenko & Khomenko (1994), Bilenko (2004), De Baggio & Tucker (2009)
<i>Achillea millefolium</i> L., Asteraceae, inflorescences	Inflorescences contain essential oil (which includes azulenes, compound ethers, camphor, and others), phytoncides, organic acids, astringent compounds, carotene, wormwood, vitamin C, mineral salts, and other compounds,	Inflorescences produce anti-inflammatory, bactericidal, hemostatic, spasmolytic, and wound-healing actions.	Khomenko & Khomenko (1994), Bilenko (2004), Farasati Far et al. (2023)
<i>Arctium lappa</i> L., Asteraceae, leaf	The plant roots contain up to 45% polysaccharide, inulin, essential oil, tannins and bitter compounds (caffeic, citric, malic), arctiin glycoside, which during hydrolysis breaks down into artigenin lactone and glucose. The leaves were found to have tannins, flavonoids, anthocyanins, organic compounds, essential oil, tannins, mucus, and ascorbic acid.	Greater burdock displays cholagogue and sudorific (antipyretic) activities, is used against kidney and bladder stones, gastritis, and ulcers in the stomach and duodenum.	Khomenko & Khomenko (1994), Bilenko (2004), Matsumoto et al. (2006)
<i>Artemisia absinthium</i> L., Asteraceae, leaf	The herbs contain 0.5–2.0% essential oil, which includes thujyl alcohol and number of carbohydrates; sesquiterpene lactones, particularly monocyclic ketolactones and sesquiterpene guaianolides (artabsin, absinthin, and its isomer anabsinthin). Furthermore, a flavonoid artemetin, tannins, organic acids, carotene, and ascorbic acid were isolated from the herbs.	The bitter taste of the plant is due to absinthin and anabsinthin. Wormwood exerts anti-inflammatory and antimicrobial effects. The bitter taste of the plant can stimulate appetite and enhance the activity of the digestive organs (stomach, liver, and pancreas). At the same time, it boosts the activity of digestive glands, secretion of bile and pancreatic juice.	Khomenko & Khomenko (1994), Bilenko (2004)
<i>Matricaria chamomilla</i> L., Asteraceae, inflorescences	The inflorescences contain up to 0.8% of bluish essential oil, which contains chamazulene, the sesquiterpene carbohydrates farnesene and cadinene, the sesquiterpene alcohol bisabolol, aliphatic terpene, myrcene, caprylic, nonanoic, isovalerianic and other acids. Furthermore, essential oil from the daisy flowers contain apigenin-glycoside (6–7%), coumarine compounds (umbelliferone and its methyl ether hemiarin), sitosterol, choline, vitamin C, carotene, organic acids, polysaccharides, mineral salts (12%), and others.	Daisy displays disinfecting, sudorific, cholagogue, anti-inflammatory, and anesthetic effects, and also inhibits the gas formation processes in the intestines. Glycosides of daisy block the cholinergic innervation, relax the smooth musculature, and relieve spasms.	Khomenko & Khomenko (1994), Bilenko (2004), Singh et al. (2011), El Mihiyaoui et al. (2022)
<i>Tanacetum vulgare</i> L., Asteraceae, inflorescences	The inflorescences contain up to 0.3% essential oil, which includes camphor, borneol, pinene, b- and a-thujone, thujol; the inflorescences were found to contain flavonoids, tannins, and bitter compounds	The plant exerted cholagogue, antimicrobial, anthelmintic, phytoncidal, astringent, and anti-inflammatory effects.	Khomenko & Khomenko (1994), Bilenko (2004), Judzentiene & Mockute (2005), Pålsson et al. (2008)

Note: this brief analysis of the physiological activity of most of the medicinal plants we studied is to various degrees based on the data on the generally available website [www.wikipedia.org](http://www.wikipedia.org).

## Results

The results of multifactor regression analysis show (Table 1) that the body mass of the cockroaches was significantly affected by the number of female and male *Cranifera cranifera* nematodes and interaction of all four independent variables in Table 2. A more correct interpretation of those data is as follows: with age (i.e. increase in body mass) the infestation of the cockroaches with female and male *C. cranifera* nematodes significantly increased.

The multifactor regression analysis (Table 3) found no significant effect of the number of parasites (two gregarines and one species of nematodes) on the rates of changes in the body mass of the cockroaches during the experiment. Similar statistical studies (Table 4) revealed the absence of influence of the number of parasites on the rates of food consumption during the experiment. The rates of increase in body mass during the experiment were significantly affected by the initial body mass of the cockroaches (the larger the cockroach was at the beginning of the experiment, the

greater its body-mass gain later on), and also the interactions among all the analyzed factors (Table 5).

The cockroaches with higher body mass at the beginning of the experiment demonstrated an upward tendency in the rates of body-mass gain (Fig. 2). The larger cockroaches also consumed more fodder, also at level of tendency (Fig. 3).

The results of the analysis of the main objective of the study (evaluating the influence of intake of the commonest medicinal plants on the cockroaches' infestation with parasitic gregarines and nematodes) are presented in Table 5. None of the cockroach parasites had significantly decreased or increased in number while the hosts were consuming the medicinal plants, as compared to the control group, which did not consume the plant raw material (Table 6). The cockroaches' body mass (Fig. 4) in the control variant of the experiment (without addition of the medicinal plants) remained almost unaltered. We observed no significant differences ( $P < 0.05$ ) in the rates of body-mass changes during the exposure to all the 16 tested species of medicinal plants.

Compared with the control group of cockroaches that did not consume medicinal plants (Fig. 5), the other groups had no significant changes in the rates of food consumption. However, while provided with dry leaves of *Origanum vulgare* at a dose of 10% of fodder mass, the cockroaches

consumed reliably less per day of the experiment than in the variants with the roots of *Acorus calamus*, leaves of *Capsella bursa-pastoris*, inflorescences of *Achillea millefolium*, *Matricaria chamomilla*, and *Tanacetum vulgare*.

**Table 2**  
Influence of the parasites on the body mass of the *Blaberus craniifer* cockroaches

Independent variable	Beta	SE	B	SE	t(198)	P-level
Intercept	–	–	701.0910*	38.8997*	18.0230*	<0.0001*
<i>Blabericola cubensis</i>	0.0049	0.0677	0.1881	2.5862	0.0727	0.9421
<i>Protomagalhaensia granulosa</i>	–0.0597	0.0695	–1.7557	2.0429	–0.8594	0.3912
<i>Cranifera craniifera</i> female	0.1911*	0.0722*	17.1640*	6.4806*	2.6485*	0.0087*
<i>Cranifera craniifera</i> male	0.1937*	0.0752*	39.2193*	15.2191*	2.5770*	0.0107*
<i>Cranifera craniifera</i> larvae	0.0124	0.0723	1.9946	11.6069	0.1719	0.8637

Note: N = 204, R = 0.3089, R<sup>2</sup> = 0.0955, Adjusted R<sup>2</sup> = 0.0726, F(5,198) = 4.1800, P = 0.0012, SE = 286.65; significant differences (P < 0.05) are indicated with the symbol “\*”.

**Table 3**  
Influence of the parasites on body mass of the *Blaberus craniifera* cockroaches (N = 204)

Independent variable	Beta	SE	B	SE	t(198)	P-level
Intercept	–	–	2.5034	2.2899	1.0933	0.2756
<i>Blabericola cubensis</i>	0.0165	0.0704	0.0356	0.1522	0.2337	0.8154
<i>Protomagalhaensia granulosa</i>	0.0114	0.0722	0.0189	0.1203	0.1576	0.8749
<i>Cranifera craniifera</i> female	–0.0785	0.0750	–0.3988	0.3815	–1.0455	0.2971
<i>Cranifera craniifera</i> male	–0.0622	0.0782	–0.7125	0.8959	–0.7953	0.4274
<i>Cranifera craniifera</i> larvae	–0.0743	0.0752	–0.6745	0.6832	–0.9871	0.3248

Note: N = 204, R = 0.1474, R<sup>2</sup> = 0.0217, F(5,198) = 0.8791, P = 0.4961, SE = 16.87; significant values (P < 0.05) in Table 2 are absent.

**Table 4**  
Influence of the parasites on the rates of food consumption by the *Blaberus craniifera* cockroaches

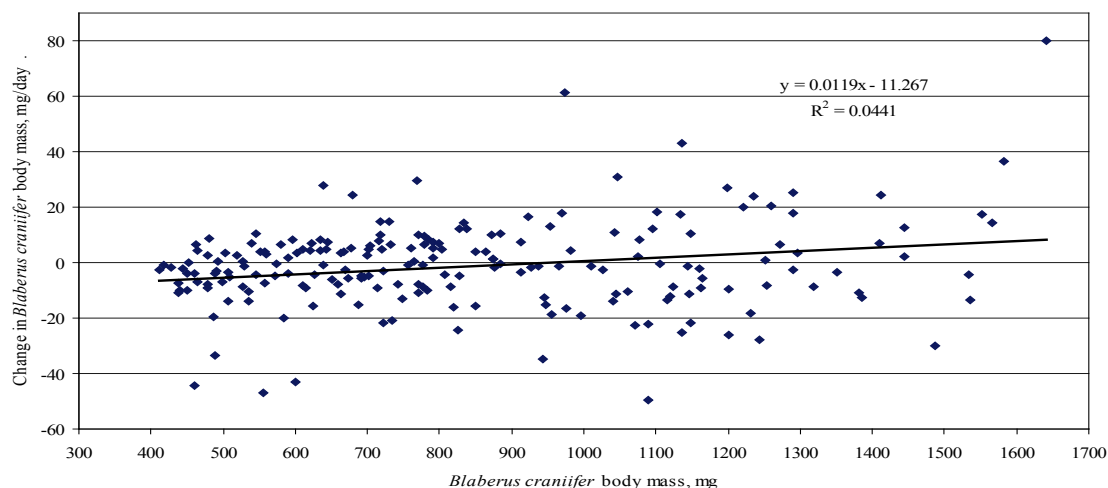
Independent variable	Beta	SE	B	SE	t(198)	P-level
Intercept	–	–	17.0977*	2.1662*	7.8920*	<0.0001*
<i>Blabericola cubensis</i>	0.0039	0.0708	0.0081	0.1440	0.0561	0.9553
<i>Protomagalhaensia granulosa</i>	–0.0512	0.0726	–0.0803	0.1138	–0.7059	0.4811
<i>Cranifera craniifera</i> female	0.0122	0.0754	0.0582	0.3609	0.1613	0.8720
<i>Cranifera craniifera</i> male	0.0154	0.0786	0.1659	0.8475	0.1957	0.8450
<i>Cranifera craniifera</i> larvae	0.0849	0.0756	0.7256	0.6463	1.1226	0.2629

Note: N = 204, R = 0.1082, R<sup>2</sup> = 0.0117, F(5,198) = 0.4694, P = 0.7988, SE = 15.96; significant values (P < 0.05) are indicated with the symbol “\*”.

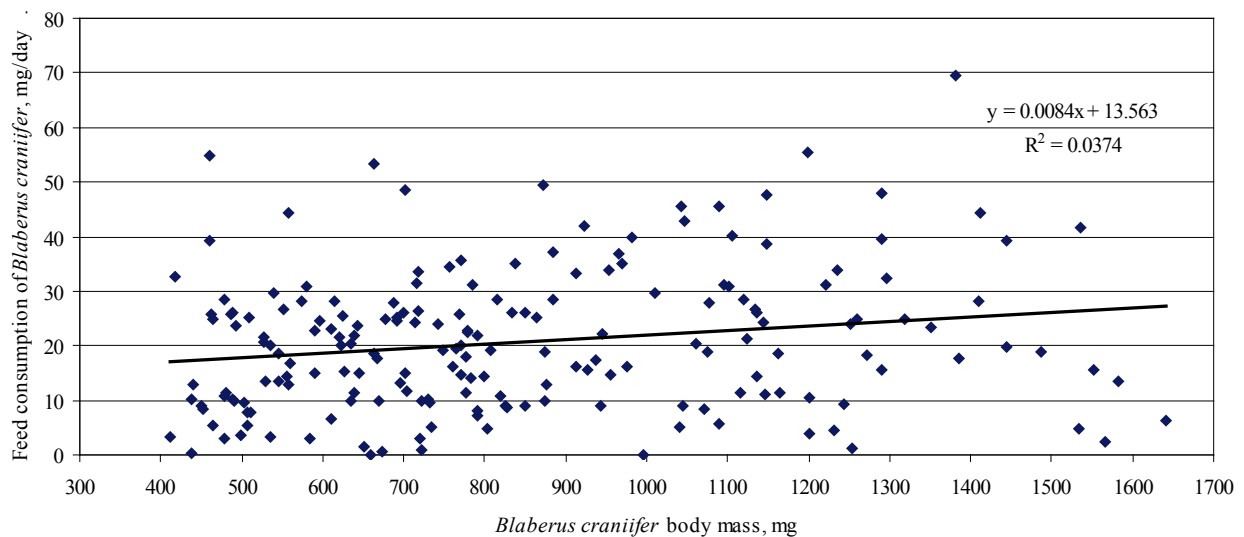
**Table 5**  
Influence of the initial body mass, fodder consumption, and parasites on the body-mass gains in the *Blaberus craniifera* cockroaches

Independent variable	Beta	SE	B	SE	t(196)
Intercept	–	–	–9.5101*	3.6336*	–2.6173*
<i>Blaberus craniifera</i> body mass, mg	0.2497*	0.0729*	0.0141*	0.0041*	3.4235*
Feed consumption of <i>Blaberus craniifera</i> , mg/day	0.1158	0.0698	0.1230	0.0741	1.6588
<i>Blabericola cubensis</i>	0.0148	0.0678	0.0319	0.1465	0.2180
<i>Protomagalhaensia granulosa</i>	0.0322	0.0697	0.0537	0.1160	0.4625
<i>Cranifera craniifera</i> female	–0.1276	0.0735	–0.6486	0.3737	–1.7359
<i>Cranifera craniifera</i> male	–0.1123	0.0765	–1.2873	0.8766	–1.4685
<i>Cranifera craniifera</i> larvae	–0.0872	0.0726	–0.7919	0.6595	–1.2008

Note: N = 204, R = 0.3218, R<sup>2</sup> = 0.1036, Adjusted R<sup>2</sup> = 0.0716, F(7,196) = 3.2353, P = 0.0029, SE = 16.24; significant values (P < 0.05) are indicated by the symbol “\*”.



**Fig. 2.** Relationship between changes in the body mass during the experiment in *B. craniifera* (mg/day, the ordinate axis) and the initial body mass of the cockroaches (mg, the abscissa axis)



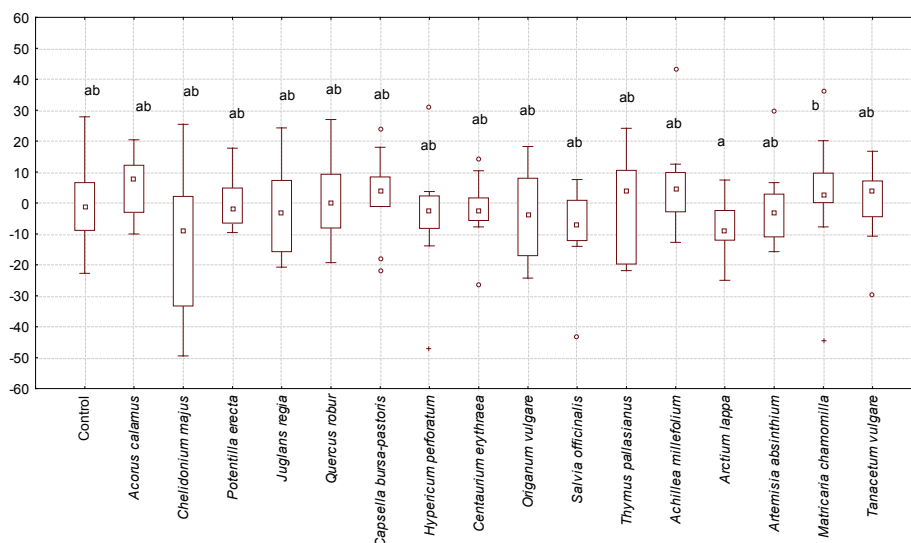
**Fig. 3.** Relationship between food consumption by the *B. craniifer* cockroaches during the experiment and their initial body mass (mg, the abscissa axis)

**Table 6**

Relationship between consumption of diet containing various medicinal plants and the intensity of infestation ( $x \pm SE$ , specimens) of the *B. craniifer* cockroaches with two gregarines and one nematode

Groups	<i>Blabercola cubensis</i>	<i>Protomagalhaensia granulosa</i>	<i>Cranifera craniifera</i> female	<i>Cranifera craniifera</i> male	<i>Cranifera craniifera</i> larvae
Control	7.07 ± 5.07	0.20 ± 0.16	3.73 ± 1.15	2.07 ± 0.37 <sup>ab</sup>	1.07 ± 0.30
<i>Acorus calamus</i>	1.08 ± 0.60	0.75 ± 0.75	4.33 ± 1.32	2.17 ± 0.47 <sup>ab</sup>	1.75 ± 0.51
<i>Chelidonium majus</i>	0.00 ± 0.00	3.80 ± 2.71	5.20 ± 1.01	3.00 ± 0.54 <sup>a</sup>	2.20 ± 0.45
<i>Potentilla erecta</i>	1.00 ± 0.62	3.42 ± 1.92	4.42 ± 0.56	1.17 ± 0.32 <sup>b</sup>	1.67 ± 0.31
<i>Juglans regia</i>	0.75 ± 0.30	5.33 ± 2.80	3.75 ± 0.82	2.33 ± 0.50 <sup>ab</sup>	1.50 ± 0.47
<i>Quercus robur</i>	2.17 ± 1.35	0.00 ± 0.00	4.33 ± 1.18	2.33 ± 0.53 <sup>ab</sup>	1.50 ± 0.53
<i>Capsella bursa-pastoris</i>	1.64 ± 0.96	0.36 ± 0.27	3.64 ± 1.62	1.55 ± 0.45 <sup>ab</sup>	0.91 ± 0.27
<i>Hypericum perforatum</i>	3.75 ± 3.57	1.92 ± 1.16	3.33 ± 0.47	1.33 ± 0.31 <sup>ab</sup>	1.75 ± 0.37
<i>Centaurium erythraea</i>	0.25 ± 0.13	11.33 ± 10.45	5.08 ± 1.19	0.83 ± 0.30 <sup>b</sup>	0.67 ± 0.22
<i>Origanum vulgare</i>	4.17 ± 3.90	0.08 ± 0.08	2.85 ± 0.78	1.33 ± 0.38 <sup>ab</sup>	1.33 ± 0.31
<i>Salvia officinalis</i>	2.08 ± 1.20	0.33 ± 0.33	3.67 ± 0.43	2.00 ± 0.39 <sup>ab</sup>	3.00 ± 0.78
<i>Thymus pallasianus</i>	1.82 ± 1.28	0.82 ± 0.53	3.64 ± 0.91	1.36 ± 0.37 <sup>ab</sup>	2.55 ± 1.32
<i>Achillea millefolium</i>	4.00 ± 3.38	1.64 ± 1.57	3.18 ± 0.68	1.09 ± 0.27 <sup>b</sup>	1.27 ± 0.34
<i>Arctium lappa</i>	0.92 ± 0.52	0.69 ± 0.57	3.54 ± 0.93	2.00 ± 0.41 <sup>ab</sup>	2.85 ± 0.63
<i>Artemisia absinthium</i>	0.08 ± 0.08	3.25 ± 3.16	3.58 ± 0.67	1.08 ± 0.23 <sup>b</sup>	1.25 ± 0.37
<i>Matricaria chamomilla</i>	3.83 ± 2.98	0.58 ± 0.58	3.67 ± 1.12	1.33 ± 0.41 <sup>ab</sup>	2.00 ± 0.35
<i>Tanacetum vulgare</i>	1.77 ± 1.06	2.69 ± 1.90	4.62 ± 0.96	2.62 ± 0.48 <sup>ab</sup>	1.77 ± 0.43
<i>F</i> , $F_{0.05} = 1.70$	0.738	0.936	0.434	2.268	1.547
<i>P</i>	0.753	0.530	0.972	0.0048	0.088

Note: the results of the ANOVA revealed that the male nematodes *Cranifera craniifera* significantly changed their numbers in different variants of the experiment, and therefore those samplings were compared with one another using the Tukey Test, the results of which are indicated with the upper indices a, ab, b; the different letters mark the samplings that are significantly ( $P < 0.05$ ) different one from another within one column; no significant differences were found for the cells of the columns and the control variant of the experiment (without consumption of the medicinal plants in the diet).

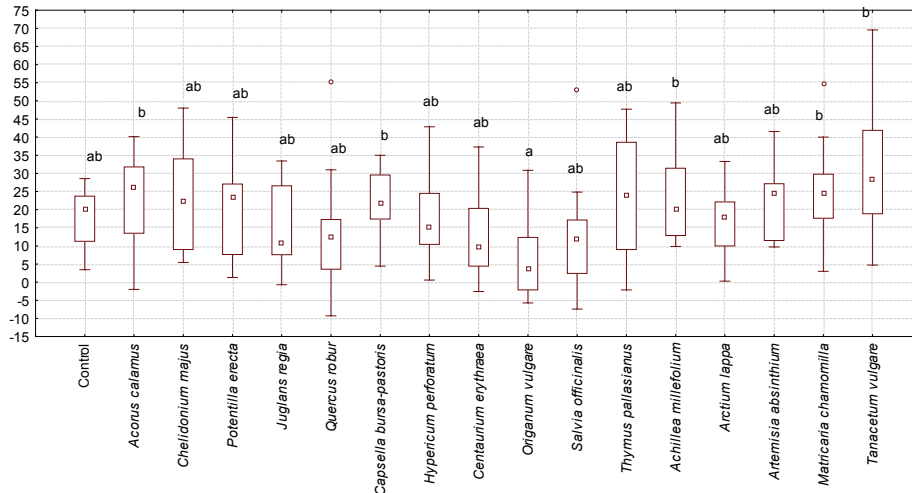


**Fig. 4.** Changes in the body mass of the *B. craniifer* cockroaches (mg/day) depending on addition of the medicinal plants to their diet (10%): different letters in the figure indicate samplings that are significantly different from another according to the Tukey Test

Thus, the herbs of *O. vulgare* insignificantly inhibited the trophic activity of the cockroaches, while the roots of *A. calamus*, leaves of *C. bursa-pastoris* and inflorescences of *A. millefolium*, *M. chamomilla* and *T. vulgare* insignificantly increased the rates of food consumption.

## Discussion

Using plant raw materials for medicinal purposes is gaining popularity every year due to the fact that such drugs are much cheaper and in many aspects more effective than synthetic ones. Such practice reduces



**Fig. 5.** Changes in food consumption by *Blaberus craniifer* cockroaches (mg/day) depending on addition of medicinal plants to their diet (10%): different letters in the figure indicate samplings that are significantly ( $P < 0.05$ ) different one from another according to the Tukey Test

The results of our study demonstrated that in most larvae, the increases in body mass and rates of food consumption were not related to the presence of medicinal plants in food. Nonetheless, while consuming dry leaves of *Origanum vulgare* in the amount of 10% of fodder mass, the cockroaches ate reliably less per day of the experiment than in the other variants, suggesting insignificant decline in the trophic activity. At the same time, the rates of food consumption insignificantly increased during contact with the roots of *Acorus calamus*, leaves of *Capsella bursa-pastoris*, inflorescences of *Achillea millefolium*, *Matricaria chamomilla*, and *Tanacetum vulgare*. Similarly to the control group, the larvae of *Blaberus craniifer* gained body mass with age, as well as when consuming various medicinal plants. At the same time, the presence of two species of gregarines and one species of nematodes had no effect on the consumption rates.

The efficacy of using the plant raw materials or drugs based on them to treat helminthiasis and protozoic diseases of mammals and birds has been confirmed by many studies (Qadir et al., 2010; Bauri et al., 2015; Štrbac et al., 2022). Numerous researchers have investigated the influence of plants and their biologically active compounds on the pathogens of parasitic and infectious diseases of birds (Khalaji et al., 2011; Lee et al., 2012; Angel et al., 2018; Khater et al., 2020; Jamil et al., 2022), confirming their effectiveness.

In our experiment, in which *B. craniifer* consumed dry medicinal plants in the fodder in the amount of 10%, as compared with the control group of cockroaches that consumed no medicinal raw material, none of the three tested species of parasites of *B. craniifer* significantly changed its numbers. Our experiment demonstrated that the cockroaches, together with their parasites, are sufficiently adapted to the action of secondary metabolites of the 16 species of medicinal plants we studied. Therefore, on the one hand, the analyzed parasite-host system is very balanced, imposing minimum harm on the host, and on the other hand, secondary metabolites of the plants caused no significant effects either on the parasites (two gregarines and one nematode) or their hosts even in the highest tested concentrations.

## Conclusion

Many species of cockroaches live in the litter, feed on foliage, and have been consuming medicinal plants for millions of years. Over centu-

costs in animal husbandry, and also has a considerable ecological effect, since such drugs cause no harm to the environment. Many authors continue the search for new plants that could be used to treat various diseases in animals (Sanhokwe et al., 2016; KJaviņa et al., 2021; Degla et al., 2022; Štrbac et al., 2022, 2023). Some compounds, when added to food, were observed to influence the rates of food consumption and body-mass gain in insects (Martynov & Brygadyrenko, 2017) or exert repellent properties (Parhomenko et al., 2022). Also, there are known insecticidal properties of plants and they are used to deter pests or protect food products (Padin et al., 2013; Senthil-Nathan, 2013).

ries of evolution, cockroaches – together with their parasites – have adapted to many secondary metabolites of plants – alkaloids, phenolic compounds, saturated and non-saturated carbohydrates, alcohols, aldehydes, and acids.

Our experiment demonstrated that, on the one hand, the parasite-host system can be balanced, causing minimal harm to the host, and, on the other hand, that the secondary metabolites of medicinal plants had no significant effect on either the parasites (two gregarines and one nematode) or the hosts. Our expectation that some of the medicinal plant species tested in our experiment would successfully treat cockroach parasites was unmet. The nematode and gregarines have successfully passed the test with high-intensity “treatment”, i.e. 10% of fodder mass comprising fragmented dried leaves, inflorescences, and roots of various species of medicinal plants.

If dried medicinal plants are added to the human diet in an amount of 10% of the food mass, we will most likely be unable to consume such bitter food over a long period. Cockroaches, on the other hand, can. Perhaps, the taste receptors of mammals and insects react to various chemical stimuli differently: what we consider to be of pleasant taste (for example, herbs of *O. vulgare*, which is added to tea in many countries), reduces the food consumption in cockroaches; what we find very bitter (for example, inflorescences of common tansy *T. vulgare* or common yarrow *A. millefolium*), does not provoke “rejection” in cockroaches, and vice-versa, enhances food consumption, compared with the variant of the experiment where *B. craniifer* was provided with the leaves of *O. vulgare*.

The results of our experiments were unexpected to us and raised many new questions.

(1) Are there any plant components in the cockroaches’ diet that do actually effectively decrease their infestation with parasites (gregarines and nematodes)? Perhaps, treatment of cockroaches and other species of insects against nematodes and gregarines will be useful in novel biotechnological methods of processing food wastes, recycling household wastes, etc.

(2) Are there plant components of cockroaches’ diet that could increase or reduce the intensity of food consumption? Such knowledge may be useful for optimization of the diet of cockroaches that soon will be extensively grown as food for broilers, swine, and other domestic animals on specialized farms.

(3) Are there plants, the consumption of which would regulate obesity or weight loss in cockroaches? Normalization of body mass of humans and domestic animals is one of the most significant modern directions of studies in human healthcare and veterinary medicine. Perhaps, this direction should be also developed in physiology of insects and many invertebrates.

These are only the most simple and comprehensible questions that we dealt with in our experiment. Moreover, further research is needed for understanding of the general biological patterns, on the one hand, and for optimization of technologies of maintenance of cockroaches, on the other hand. This is crucial because soon cockroaches may become one of the most important sources of protein for agricultural animals and people.

The authors declare they have no conflict of interests.

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