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Thermal Effects on the Body mass, Transpiration rate, Feeding and Food Conversion of the Pillbug *Armadillo officinalis* (Isopoda, Oniscidea) Fed on the Dry Leaf of *Punica Granatum*

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التأثيرات الحرارية على كتلة الجسم و معدل النتح والتغذية و التحول الغذائي للبقة المدرعة (*Armadillo officinalis*) المتغذية على أوراق الرمان الجافة (*Punica granatum*)

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خلاصة : ملاحظات الدراسة اشتملت على كتلة الجسم معدل النتح , كفاية التمثيل الغذائي , الكفايـة الإنتاجيـة الإجمالية و الصافية معدلات كل من : التغذية , التمثيل الغذائي , التحول الغذائي و الايضى للبقة المدرعة (*Pillbug Armadillo officinalis*) والتى أقلمت على درجتي حرارة 14° C و 21° C و لمدة 15 يوم و غذيت علي أوراق الرمان(*Punica granatum*) الجافة .التأقلم الحراري لم يعطي أي قيمة معتبـرة عنـد اختلاف الزيادة الوزنية للبقة المدرعة ($P>0.05$, $t=1.09$) علي أي حال درجتي الحرارة المنوه عنهمـا وضحتا اختلافات معتبرة في معـدل النـتح ($p<0.01$, $t=9.53$) و الرطوبـة ($p<0.01$, $t=9.01$) كفاية التمثيل الغذائي ($p<0.05$, $t=5.16$) معدل التغذيـة ($p<0.05$, $t=3.76$) و معـدل التحـول الغـذائي ($p<0.05$, $t=2.58$) بين البق المدرع . الحيوانات لوحظ عليها أنها تتغذي تغذية جيدة علي أوراق الرمان في درجة حرارة 21°C لكن كفاية التمثيل الغذائي هي أفضل عند درجة حرارة 14° C . نسبة التمثيل الغذائي (Assimilated food) و المتحول إلى أنسجة جديدة كان % 3.21 عند درجة حـرارة 14° C و % 6.30 عند درجة 21°C فقط , الاستهلاك الغذائي للبقة المدرعة عند درجتي الحرارة 14° C و 21°C كان 2.05% و % 3.79 من وزن الجسم يوميا علي التوالي. الدراسة زودت بنبذة مختصرة للتركيبة الكيميائيـة لأوراق الرمان و ناقشت أيضا التأثير الحراري علي نشاط ال*A.officinalis* في البرية.

ABSTRACT: Observations were made on the body mass; transpiration rate; assimilation efficiency; gross and net production efficiencies; feeding, assimilation, conversion and metabolic rates of the pillbug *Armadillo officinalis* Dumeril acclimatized at 14º and 21 °C for 15 days and fed on the dry leaf of *Punica granatum* (Pomegranate).

A brief description is given on the chemical composition of *P. granatum* leaf. The difference in body mass increments of *A. officinalis* between the acclimatized temperatures was not significant ($t = 1.09$; $p>0.05$). However, significant differences were discernible on the transpiration rate ($t = 9.53$; $p<0.01$), moisture ($t = 9.01$; $p<0.01$), assimilation efficiency ($t = 5.16$; $p<0.01$), feeding ($t = 3.76$; $p<0.05$) and conversion ($t = 2.58$; $p<0.05$) rates between the woodlice acclimatized at 14º and 21 °C. Better feeding of *P. granatum* leaf by these animals was observed at 21° C, but better assimilation efficiency at 14 °C. Only 3.21% assimilated food at 14° C and 6.30% at 21 °C were converted into the production of new tissues. The food consumption of *A. officinalis* at 14º and 21° C was 2.05% and 3.79% body mass/day respectively. The effect of temperature on the activity of *A. officinalis* in the field is discussed.

KEYWORDS: *Armadillo officinalis*; *Punica granatum*; transpiration; body mass; feeding and assimilation.

1. Introduction

The coastal region of Benghazi (20º 10' N, 20º 06' E), Libya, like other Mediterranean coasts (Kheirallah, 1980; Warburg *et al*. 1984) is colonized by the pillbug, *Armadillo officinalis* Dumeril. Casual collections showed that these woodlice occurred in large numbers in shady places where the soil moisture was moderate. Detailed studies were conducted by us before in Benghazi on the transpiration, behavior, growth and feeding habits (Nair *et al*. 1989), conversion of leaf litter (Nair and Fadiel, 1991), relation of body dimensions and the soil factors influencing the abundance (Nair and Al-Jetlawi, 1993), breeding and population biology (Al-Jetlawi and Nair, 1994), thermobiology (Nair *et al.* 2001) and food preference and litter breakdown (Nair *et al*. 2002) of this woodlouse. The present study investigates the impact of temperature acclimatization (14º C and 21º C) on the transpiration rate, increment in body mass, moisture, feeding and food conversion of *A. officinalis* fed on the dry leaves of *Punica granatum* (Pomegranate) for 15 days. Pomegranate trees are common in Benghazi and *A. officinalis* forms the major component of the decomposer fauna of the fallen litter from these trees.

2. Materials and Methods

A. officinalis having body mass ranging from 65 to 72 mg were selected for the study. 10 pillbugs (5 males and 5 non-gravid females) each, after starving them for eight hours to evacuate their gut contents, were maintained at 14º C and 21º C in a Gallenkamp incubator. Each animal, after taking its initial body mass near to 0.01 mg in a Sartorius balance, was kept in a glass petridish (5 cm diameter, 2.5 cm height) containing a layer of wet filter paper (62 ± 2 % R.H.) at the bottom. 300 mg of the dry leaf of *Punica granatum* macerated with water for 12 hours to make it soft, was provided as food. The experiment lasted for 15 days, after which the body mass of the animal was determined. The remaining leaf and the fecal matter ejected by the pillbug were collected, dried and weighed. After measuring the transpiration rates, they were kept at 60º C for four days, dried and weighed to determine the moisture content. The experiment was repeated again and there was not much variations in the values between the replications, so the data were combined and the mean values of 20 pillbugs at each temperature were taken.

To study the transpiration rates, the pillbugs were weighed individually to 0.01 mg and exposed separately for one hour over calcium chloride at the same temperature (14º or 21º C) in which they were maintained previously for 15 days, before re-weighing. The results are expressed as water-loss in mg/cm^2 /h. The surface area of the animal was calculated from the formula $S = kW^{2/3}$, where S = surface area, W = initial weight of the animal, k = constant. A value of k = 12 was adopted as it has been used by Cloudsley-Thompson (1969) and Nair *et al*. (1989) for African woodlice, and Nair and Nair (1985) for Indian species. This value is also the mean calculated by Edney (1951) for British species.

Consumption of food (C) of *A. officinalis* exposed to 14º and 21º C was estimated in terms of mg dry food consumed by it for 15 days, assimilation (A) was calculated by subtracting the amount of dry fecal matter (Fe) ejected from the total food consumed (C). The production rate (P) (due entirely to the increase in live body mass) was determined as the difference between the body mass of the animal at the beginning and at the end of the experimental period. Metabolism (R) represents the difference between A and P. Assimilation efficiency (Ae) was calculated by expressing A as a percentage of C. Gross (Ge) and net (Ne) production efficiencies were estimated expressing P as a percentage of C and A separately. Rates of feeding (Fr), assimilation (Ar), conversion (Cr) and metabolism (Mr) were determined by dividing C, A, P and R by half the sum of initial and final weights of the animal and then by the duration of the exposure period and expressed in terms of mg/g live wt/day.
t-tests (Grimm, 1993) were done to find out the significance or otherwise of the data.

3. Results and Discussion

Duke (1992) reported that the leaf of *P. granatum* contains betulic acid, ursolic acid, corelagin, strictinin, tannin, granatins, casuariin, D-mannitol, 2-0-galloylpunicalin, 2-(2-propenyl)-delta-piperideine, 1,2,3,4,6-penta-0-galloyl-beta-D-glucose and 1.2.4.6-tetra-0-galloyl-beta-D-glucose. Our observations in the field revealed that the leaf of *P, granatum* is a preferred food for *A. officinalis* in the field, which was later confirmed through the laboratory studies on the food preference shown by them. Also, higher breakdown of the dry leaf of *P. granatum* by these animals was observed in the field when compared with the breakdown of the dry leaf of *Citrus limonia* (lemon) (Nair *et al*. 2002).

Table 1. Temperature acclimatization (14^{o}C and 21^{o}C) for 15 days on the increment in body mass, transpiration rate, moisture, feeding and food conversion (Mean ± SE) of *A officinalis* fed on *Punica granatum* dry leaf as food, t-values and their levels of significance. Total number of woodlice kept at each temperature: 20

SI.No	Factors	Animals exposed to the temperatures of		t	p
		14^{o}C	21^{o}C		
1	Increment in body mass (mg)	0.97± 0.33	1.39± 0.21	1.09	1. >0.05
2	Transpiration rate (mg/cm^2/h)	0.71± 0.01	1.01 ± 0.03	9.53	2. <0.01
3	Moisture (%)	52.20± 0.18	49.71 ±0.14	9.01	3. <0.01
4	Assimilation efficiency (%)	81.16 ± 3.21	62.51 ± 1.67	5.16	4. <0.05
5	Gross production efficiency (%)	3.06 ±1.13	3.87 ± 0.54	0.65	5. >0.05
6	Net production efficiency (%)	3.94 ±1.34	6.11 ± 0.82	1.38	6. >0.05
7	Feeding rate (mg/g live wt/day)	23.57 ± 2.02	38.22± 3.33	3.76	7. <0.05
8	Assimilation rate (mg/g live wt/day)	19.29 ±1.97	23.66 ± 1.83	1.63	8. >0.05
9	Conversion rate (mg/g live wt/day)	0.62 ±0.20	1.49 ± 0.27	2.58	9. <0.05
10	Metabolic rate (mg/g live wt/day)	18.67±2.06	22.17 ± 1.65	1.33	10. >0.05

Table 1 shows the increment in body mass; transpiration rate; moisture; assimilation efficiency; gross and net production efficiencies; feeding, assimilation, conversion and metabolic rates of *A. officinalis* at 14º and 21º C for 15 days fed on the dry leaf of *P. granatum*, the t-values and their levels of significance. There was an average increase of 0.97 mg in body mass of *A. officinalis* at 14º C which increased further to 1.39 mg in those at 21º C, even though the difference in increment in body mass between acclimatized temperatures was insignificant ($t = 1.09$; $p>0.05$).

The transpiration rate of 14º C acclimatized *A. officinalis* was 0.71 mg/cm^2/h, which increased significantly ($t = 9.53$; $p<0.01$) to 1.01 mg/cm^2/h in those at 21º C. The cuticle of land isopod is more permeable than that of insect (Wallwork, 1970) and it was previously believed that an oriented layer of lipid molecule, which functions as a water-proofing mechanism is lacking from isopods (Beament, 1961). Later, however, Warburg (1965) and Edney (1968) suggested that some type of water-proofing mechanism may be present in some species. Measurement of transpiration rates of several species of woodlice at various temperatures demonstrated a sharp increase at higher temperatures suggesting that the ability of water-proofing barrier is reduced at high temperatures (Cloudsley-Thompson, 1977; Nair and Nair, 1985). This phenomenon might not have taken place in the present study since the higher temperature of 21º C was well within their tolerance limits and temperature acclimatization might be the sole criterion for their differences in transpiration rates. Our previous studies (Nair *et al*., 1989, 2001) on *A. officinalis* revealed that the exponential regression models fitted on transpiration in relation to temperatures were good and acclimatization of these pillbugs to different temperatures for a week had marked effects on their transpiration and behavior, when later exposed to rising temperatures.

A significant difference ($t = 9.01$; $p<0.01$) in moisture content was discernible in *A. officinalis* acclimatized between 14º C (52.20%) and 21º C (49.71%). Significantly higher assimilation efficiency ($t = 5.16$; $p<0.01$) was recorded in those acclimatized at 14º C (81.16%) than those at 21º C (62.51%). The values of gross and net production efficiencies, and also of feeding, assimilation, conversion and metabolic rates were higher in *A. officinalis* exposed at 21º C when compared with the values recorded at 14º C. However, significant differences existed only between their feeding ($t = 3.76$; $p < 0.05$) and conversion ($t = 2.58$; $p< 0.05$) rates.

Warburg (1987) opined that isopods in general seem to be efficient digesters but somewhat inefficient assimilators and that food consumption varies with species. In the present study an inverse relationship was observed in *A. officinalis* on its feeding rate and efficiency of assimilation of the leaves of *P. granatum*. Better feeding was discernible in those kept at 21º C, but better assimilation efficiency was observed in those at 14º C. Only a small percentage of the assimilated food (3.21% at 14º C and 6.30% at 21º C) was converted into the production of new tissues. The food consumption of *A. officinalis* fed on *P. granatum* was 2.05% body mass/day at 14º C and 3.79% body mass/day at 21º C. These values were lower than those reported for *Porcellio scaber* (2.59% body mass/day at 14º C; 4.19% body mass/day at 21º C), another woodlouse which co-exists with *A. officinalis* in the field and were given *P. granatum* as food for 15 days (unpublished data).

In conclusion, temperature acclimatization has a significant impact on the transpiration rate, moisture, assimilation efficiency, feeding and conversion rates of *A. officinalis* fed on *P. granatum*, but not so on their increment in body mass, gross and net production efficiencies, assimilation and metabolic rates. The effects of temperature on the activity of these pillbugs were confirmed in the field where they were found in large numbers crawling over the soil surface and actively feeding on the leaf litter when the surface temperature ranged between 18 and 29º C, even though activities were restricted to shady places. It was evident that a restricted grade of temperature gradient was essential for normal activity and feeding. Except for short summer months of August/September, the temperature range of the habitats of these animals was well within their tolerance limits.

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