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Survival and weight change among adult individuals of *Periplaneta americana* (Linnaeus, 1758) (Blattaria, Blattidae) subject to various stress conditions

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Resumo

Sobrevivência e variação de peso de adultos de *Periplaneta americana* (Linnaeus, 1758) (Blattaria, Blattidae) submetidos a diferentes condições de estresse. *Periplaneta americana* é uma espécie de grande importância para a saúde pública, já que pode atuar como vetor de diversos patógenos e atinge altas populações em ambientes urbanos. Isso provavelmente se deve à sua capacidade de resistir à fome e a dessecação. O objetivo deste estudo foi avaliar os efeitos da ausência de água e alimento sobre a sobrevivência e variação de peso entre adultos de *P. americana* e verificar se o peso inicial dos indivíduos influencia em sua sobrevivência. Quatro grupos com 20 casais de *P. americana* foram formados e submetidos a: I) estresse hídrico e alimentar; II) estresse alimentar; III) estresse hídrico; e IV) grupo controle. Os insetos foram individualizados conforme os grupos, os quais foram pesados no início e no fim das condições de estresse. Permaneceram sob essas condições até que todos os indivíduos de cada grupo de teste estivessem mortos. As condições de estresse causaram redução do tempo de sobrevivência quando comparados ao grupo controle. Adultos com massa corporal superior sobreviveram por mais tempo quando privados somente de alimento, enquanto que naqueles com ausência de água o peso não influenciou na sobrevivência. A perda total de peso foi maior nos indivíduos privados de água do que naqueles privados somente de alimento.

Palavras-chave: Barata; Desidratação; Inanição; Longevidade; Peso corporal

Abstract

Periplaneta americana is a species of great importance to public health, since it can act as a vector of many pathogens and it reaches large populations in urban environments. This is probably due to its ability to resist starvation and desiccation. This study aimed to evaluate the effects of absence of water and food on survival and weight change among adult *P. americana* individuals and check whether the initial weight of individuals influences on their survival. Four groups having twenty *P. americana* couples were formed and subject to: I) no water or food; II) no food; III) no water; and IV) control group. Insects were isolated according to the groups, which were weighed at the beginning and end of the stress conditions. They remained under these conditions until all individuals in each test group were dead. Stress conditions caused reduction in survival time when compared to the control group. Adults with higher body mass survived longer when deprived only of food, while among those lacking water, weight had no influence on survival. Total weight loss was greater among individuals deprived of water than those deprived only of food.

Key words: Body mass; Cockroach; Dehydration; Longevity; Starvation

Introduction

Periplaneta americana (Linnaeus, 1758) (Blattaria, Blattidae), also known as American cockroach, is a species of great importance to public health, because it goes through latrines, septic tanks, sewers, and animal corpses, where it comes into contact with agents that cause diseases to human beings and domestic animals (MARICONI, 1999). These insects reach larger populations in urban environments and they act as vectors of viruses (BAUMHOLTZ et al., 1997), bacteria (RIVAULT et al., 1993; PRADO et al., 2002), fungi (PRADO et al., 2002), protozoa (BAUMHOLTZ et al., 1997; PAI et al., 2003), and helminths (BAUMHOLTZ et al., 1997; THYSSEN et al., 2004), causing major problems to the health of human beings and other animals.

Although there is usually abundance of food and water in these environments, some insects develop the ability to resist the absence of these resources, such as cockroaches, which can survive for a long period due to their ability to withstand starvation or dehydration (WILLIS; LEWIS, 1957).

Stress conditions in insects may be caused by multiple biotic and abiotic factors, such as overcrowding, pathogenic/parasitic infections, extreme temperatures, metamorphosis, mechanical damages, chemical poisoning, starvation, etc. (BREY, 1994). Starvation and dehydration can have consequences for insect biology, including growth, survival, longevity, reproduction, movement, gregariousness, and they reduce the production of energy to perform these functions (PANIZZI; PARRA, 2009; CHAPMAN, 2012).

Willis and Lewis (1957) reported that under artificial conditions of low humidity and absence of water and food drastically reduces the survival time of adult *P. americana* individuals. However, there is a need to evaluate the influence of these stress conditions on other aspects of the biology of this insect, such as nutritional reserves, development time, and reproductive performance, as well as evaluate its survival time under humidity conditions similar to those found in its niches.

This study aimed to evaluate the effects of absence of water and food on survival and weight change among adult *P. americana* individuals and check whether the initial weight of individuals influences on their survival.

Material and Methods

Establishment and maintenance of *Periplaneta americana* colonies

Adult *Periplaneta americana* individuals were collected in the Campus Universitário of Universidade Federal de Pelotas (31°48'S; 52°25'W). They had been raised for more than five generations under laboratory conditions before the experiment began.

Throughout the period, *P. americana* colonies remained within a climatic chamber at 25 ± 2°C, relative humidity of 70% ± 10% and photophase of 12 hours. Stock and experimental colonies were kept according to the methodology adopted by Cárcamo et al. (2013), differing only in the diet used. In this study we used a diet consisting of meat meal and sugar, in the proportion 1:1.

Evaluation of survival among adult individuals subject to various stress conditions

Four treatment groups having twenty couples each (at most 10 days after emergence) were formed: I) no food or water; II) with water but no food; III) with food but no water; and IV) with water and food *ad libitum* (control group). In order to avoid cannibalism, each specimen was individualized in a 16 cm x 8 cm round glass flask, covered with organza fabric, and kept into a B.O.D. incubator at 25 ± 0.2ºC, relative humidity of 70% ± 10%, and photophase of 12 hours. Nutritional resources were provided in 1 cm x 2.5 cm round polyethylene recipients. To provide water, these recipients had cotton embedded in water for reducing evaporation.

As soon as they were isolated and after their death, insects were weighed on a precision scale. Every three days, flasks were checked and when there was any dead individual, it was registered. Also, if there was any ootheca, it was removed, so that they could not use it as a food and/or water source. Insects were kept under these conditions until all individuals in each test group were dead.

Statistics analysis

The survival analysis of adult *P. americana* individuals subject to stress conditions was performed by using the Kaplan-Meier method. The Logrank test ($p = 0.05$) was used to perform the statistical comparison between dependent variables. The estimated mean lethal time was determined by probit analysis.

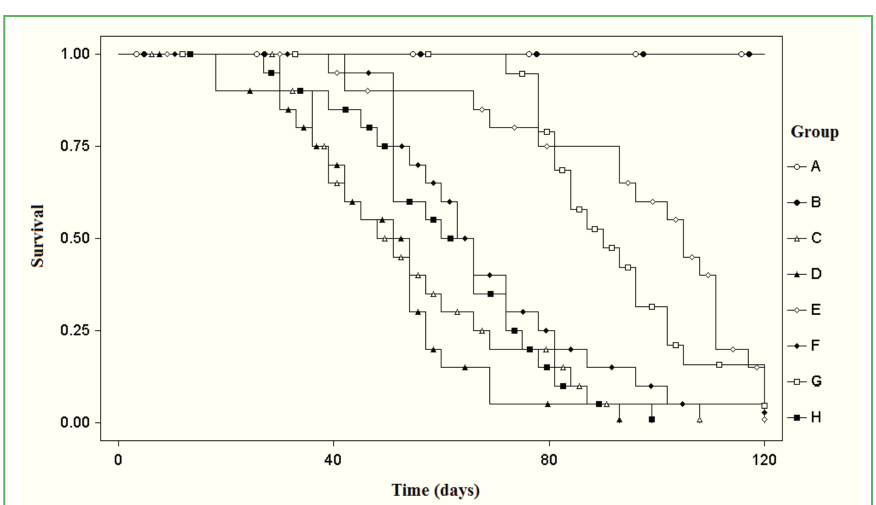
Pearson's correlation test ($p = 0.05$) was used to evaluate whether the initial weight of adult individuals influenced on their survival.

Initial weights were converted into relative weights, in this case, all individuals had an initial weight converted into 100%, undergoing increase or decrease. Weight data were evaluated by two-way analysis of variance (ANOVA), whose variables were the stress condition to which the insect was subject and the individual's sex. Tukey's test ($P = 0.05$) was used to compare treatments and sexes. Before using ANOVA, all percentages were converted by means of arcsine transformation. All statistical approaches were performed by using the software *SPSS for Windows*, version 11.0.

Results

Under all stress conditions, adult *P. americana* individuals had a significant decrease in their survival time when compared to the control group and there was also a significant difference between the groups ($\chi^2 = 145.18$; DF = 7; $p < 0.001$) (Figure 1). The shortest survival time was found among the insects (females and males) deprived of food and water, while the group showing the longest survival time was that with females deprived only of food (Figure 1).

FIGURE 1: Survival analysis of adult individuals of *Periplaneta americana* (Linnaeus, 1758) subject to various stress conditions. A-B = control group; C-D = no food or water; E-F = no food; G-H = no water. White symbols represent females and black symbols represent males.



We did not observe a significant difference in the survival time between males and females deprived of food and water ($\chi^2 = 0.6$; DF = 1; p = 0.44). However, when the insects were deprived of water ($\chi^2 = 15.27$; DF = 1; p < 0.001) or food ($\chi^2 = 8.69$; DF = 1; p < 0.001), females had a survival time significantly longer than males (Table 1).

The shortest mean lethal time was found in the group of males deprived of food and water (48.5 days), while the groups with females deprived only of food had a mean lethal time of 99.6 days (Table 1).

There was no significant correlation between the survival time and initial weight of the insects, neither when they were deprived of food and water (females: r = 0.21; p = 0.36; males: r = 0.42; p = 0.06) or when they were deprived only of water (females: r = -0.08; p = 0.74; males: r = 0.03; p = 0.89). However, when they were kept without food, both females (r = 0.62; p < 0.05) and males (r = 0.81; p < 0.05) had a significant positive correlation.

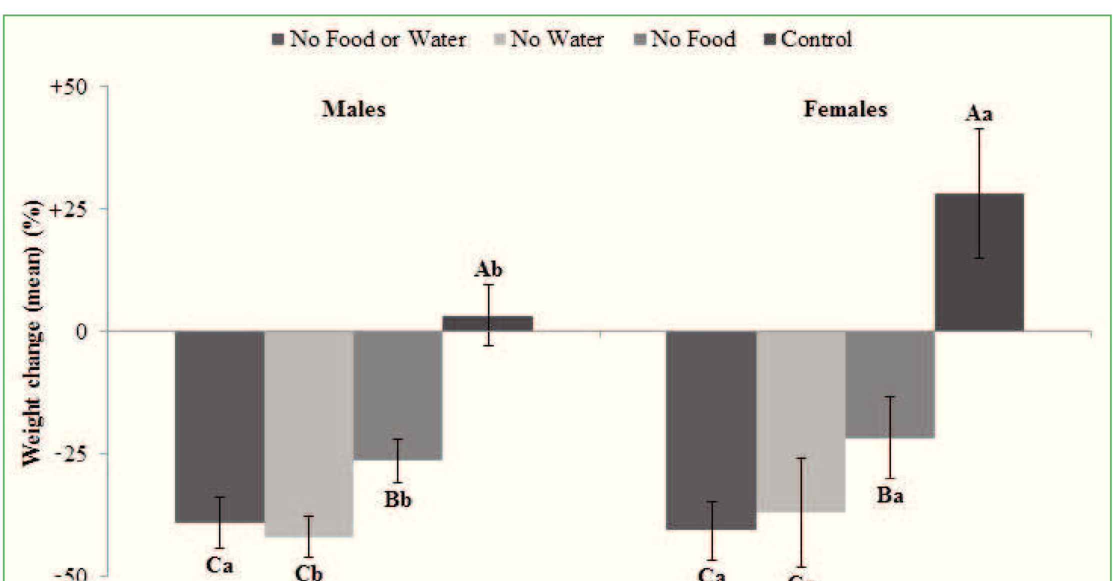
The final weight change of adult *P. americana* individuals was significantly influenced by different groups (F = 392.25; GL = 3; p < 0.001), sex of individuals (F = 34.99; GL = 1; p < 0.001), and their interaction (F = 14.10; GL = 3; p < 0.001) (Figure 2). The maximum weight loss among females and males in groups with

TABLE 1: Mean lethal time (LT50) (days) among adult individuals of *Periplaneta americana* (Linnaeus, 1758) subject to various stress conditions. Different capital letters in the same line represent significant difference in survival between sexes, while different small letters in the same column represent significant difference between groups (Logrank test p = 0.05).

Groups	Females				Males			
	N	Slope ± SE	LT_{50} (days) (95% CI)	χ^2	N	Slope ± SE	LT_{50} (days) (95% CI)	χ^2
No food or water	20	0.04 ± 0.002	55.1 (53.5 – 56.6) Ab	85.19	20	0.05 ± 0.002	48.5 (47.1 – 49.8) Ab	48.21
No water	20	0.06 ± 0.003	93.1 (91.8 – 94.5) Aa	54.09	20	0.05 ± 0.002	60.7 (59.3 – 62.2) Ba	16.72
No food	20	0.03 ± 0.001	99.6 (97.2 – 102.2) Aa	66.22	20	0.05 ± 0.002	69.0 (67.5 – 70.5) Ba	92.19
Control	20	*	*	*	20	*	*	*

* It was not possible to determine LT50, because there were no deaths throughout the period observed.

FIGURE 2: Total relative weight change (%) among adult individuals of *Periplaneta americana* (Linnaeus, 1758) in each group until the death (under stress conditions) or at the end of the experimental period (control group). Different capital letters represent significant difference between groups, while different small letters represent significant difference between sexes (Tukey p = 0.05). Bars represent the standard deviation of mean.



no water was about 40% of their initial weight, while in groups deprived only of food the maximum weight loss was about 27% of initial weight for males and 22% for females (Figure 2).

Discussion

When deprived of water and/or food, the survival time decreased in many species reported by many authors: Blattaria (WILLIS; LEWIS, 1957; PARK et al., 2013), Isoptera (HU et al., 2011), Coleoptera (DAGLISH, 2006), Lepidoptera (CHEN; GU, 2006), Diptera (SINGH; BALA, 2009), and Hymenoptera (ISHAY, 1975).

In this study, absence of water and food among female *P. americana* individuals decreased longevity in 85% when compared to Vianna et al. (2001), which reported that females can survive up to 848 days with food and water *ad libitum*, kept at 30ºC and relative humidity above 80%.

We observed longer survival time when compared to Willis and Lewis (1957) among *P. americana* individuals subject to the same stress conditions. The difference between results was probably due to the fact that these authors adopted a humidity of about 36%. It is low when compared to the humidity found at the niche of these insects, according to Joseph et al. (2012), humidity in sewers is usually above 70%, a condition similar to that found by the insects used in this study.

Female *Periplaneta americana* individuals deprived of food or water survived longer than male individuals, a fact that has already been reported regarding another cockroach species, such as *Rhyparobia maderae* (synonym: *Leucophaea maderae*) (Fabricius, 1781) (Blattaria, Blaberidae), under the same conditions (TAYLOR; FRECKLETON JR., 1969). These results suggest that survival is more related to sex than stress condition. The longer survival time among females is biologically significant since, according to Roth and Willis (1956), female *P. americana* individuals are able to reproduce by parthenogenesis, i.e. they do not require males for egg fertilization.

This longer survival time may be justified by the fact that females have more fat bodies than males. Taylor and Freckleton Jr. (1969) report that, under starvation, the nutritional reserves of fat bodies are consumed to ensure survival and the authors infer that if females were still actively producing offspring, the difference between sexes might decrease.

Besides enabling a longer survival time, the greater amount of fat bodies of female *P. americana* individuals can also make them more resistant to some types of chemical insecticides (MUNSON; GOTTLIEB, 1953). Furthermore, Arrese and Soulages (2010) report that fat bodies are responsible not only for energy reserves, but also for synthesis of proteins, production of several antimicrobial peptides, and detoxification of nitrogen metabolism.

The correlation between initial weight and survival time was only observed in groups having no food. This is probably due to the fact that heavier specimens showed a greater amount of fat, surviving longer. According to Fast (1964 apud IWAO, 1967), the survival time of insects deprived of food is directly correlated to the amount of fat stored before the beginning of starvation. In contrast, in other groups, the limiting factor seems to be absence of water, regardless of their initial weight.

We believe that weight gain among females in the control group is probably due to accumulation of nutrients for oothecae production, as according to Arrese and Soulages (2010), most of accumulated lipids in oocytes are originated from females' fat bodies. On the other hand, males in the control group maintained their weight, with no change or little change over time, perhaps because they do not need to store fat for this purpose.

When insects were deprived of water and/or food, weight loss was reported for many insect species: Orthoptera (PUNZO, 1989), Phasmatodea (NICOLSON et al., 1974), Blattaria (EDNEY, 1968; WALL, 1970; TUCKER, 1977a; 1977b), Coleoptera (LAPARIE et al., 2012), Lepidoptera (CHEN; GU, 2006), and Hymenoptera (ISHAY, 1975).

Among *P. americana* adults deprived only of food, total weight change was lower than among those under other stress conditions. It is probably due to the fact weight loss was only related to fat, since water was always available. Auerswald and Gäde (2000) reported that carbohydrate levels in haemolymph, flight muscles, and fat bodies in *Pachnoda sinuata* (Fabricius, 1775) (Coleoptera, Scarabaeidae) were quickly and fully depleted during starvation. Furthermore, according to Gunn (1932 apud WHARTON et al., 1965), *P. americana* has an amount of water ranging from 70.4 to 74.8% of its body weight, something which suggests that the insects lost fat bodies and muscles, but kept some of their water content until death.

Although there was no difference in weight loss between groups with no water, groups where food was available survived more. This is probably due to the fact that insects deprived only of water fed at the onset of the stress condition. Thus, they maintained their initial weight for a few days, but in order to avoid excessive water loss through digestion, they may have stopped feeding on the subsequent days. According to Chapman (2012), the haemolymph volume is decreased when insects feed, seemingly due to relocation of haemolymph water to the gut.

We observed weight loss varying from 22% to 40%, something which can compromise the reproductive capacity of female *P. americana* individuals, since according to Kunkel (1966), females of this species stop oviposition when they lose about 25% of their weight. Furthermore, insects with decreased weight can show changes in their locomotion activity (REYNIERSE et al., 1972; BARCAY; BENNETT, 1991) and increased susceptibility to pathogens (FURLONG; GRODEN, 2003; BANVILLE et al., 2012) and chemical insecticides (LEE; HENG, 2000). Thus, even before the insect reaches its minimum body weight threshold, weight loss can reduce the population of this species, either due to reproductive inability or because of greater exposure to biotic and abiotic mortality agents.

This study showed that when adult *Periplaneta americana* individuals are deprived of water and/or food, their survival time is decreased and they lose over 1/5 of their weight until death. Besides, the correlation between survival time among adults and their initial weight is found only when insects are deprived only of food. These data may help understanding the resistance ability of this species when subject to adversities, something which may be used in further research on this species' reaction to chemical and biological insecticides, insect immunology, and population dynamics.

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