Available Online at ESci Journals
International Journal of Entomological Research
ISSN: 2310-3906 (Online), 2310-5119 (Print)
http://www.escijournals.net/IJER

DOES SUGAR CONSUMPTION ATTRACT BEDBUGS AND/OR INCREASE BEDBUG FERTILITY?

Nancy L. Ralph, Heidi E. Jones
CUNY School of Public Health, Hunter College, New York, USA.

A B S T R A C T

Bedbugs are attracted to carbon dioxide (CO_2) and sebum, the production of which may be affected by dietary sugar. Increased intake of sugar may produce an unknown threshold of CO_2 or sebum needed to influence prey selection. Our hypothesis was that, in a non-laboratory setting, a differential sugar intake might measurably influence bedbug human prey selection. After adjusting for socioeconomic and other confounding factors in a large representative sample of non-institutionalized New York City adults, we found an association between daily consumption of sugar-sweetened beverages (SSBs) and bedbug infestation (AOR 2.1, 95% confidence interval, 1.4, 3.0). While these findings are clearly exploratory, we feel they warrant further investigation of dietary sugars as a determinant of bedbug prey selection.

Keywords: Bedbugs, *Cimex lectularius*, prey, sugar, carbon dioxide.

INTRODUCTION

Little is known about *Cimex lectularius*, or bedbug, transmission in relation to their prey selection. Carbon dioxide (CO_2) has been shown to excite bedbugs, and is hypothesized to play a role in host detection.(Anderson, Ferrandino, McKnight, Nolen, & Miller, 2009; Weeks, Birkett, Cameron, Pickett, & Logan, 2011) Some evidence suggests that glucose consumption increases CO_2 production in humans as part of glucose oxidization.(Singal, Janghorbani, Schuette, Chisholm, & Mather, 2013; Van Aerde, Sauer, Pencharz, Smith, & Swyer, 1989) Research has found that other haemaphageous insects, such as mosquitoes are attracted by host-emitted odor.(Tauxe, MacWilliam, Boyle, Guda, & Ray, 2013) CO_2 has been hypothesized to sensitize receptors for these odors in mosquitoes.(Dekker, Geier, & Carde, 2005) Similarly, sebum has been shown to attract bedbugs, improving bedbug traps,(Weeks et al., 2011) and the increased production of nasal sebum (or 'nose grease') has also been linked to human sugar consumption. (Smith, Braue, Varigos, & Mann, 2008) Based on these findings, sugar consumption in humans could lead to differential prey detection via increased CO_2 and/or sebum production. Relevant studies on haemaphageous insects focus on those whose diet includes sugar meals in addition to blood meals, such as mosquitoes. These studies have compared blood meals and sugar meals on fertility and overall insect size, and detected complex patterns of nutrient and sugar availability in relation to mating frequency and egg viability.(Foster, 2009; Jordao, Nakano, & Janeiro, 2010; Naksathit & Scott, 1998) For insects that feed on blood meals exclusively, such as bedbugs, the potential impact of blood sugar on growth and fertility is less well known. Increased feeding among bedbugs, however, has been shown to be associated with higher fecundity.(How & Lee, 2010) Furthermore, two free sugars (glucose and trehalose) have been shown to be important exogenous energy sources for sperm motility based on assays of bedbug's seminal fluid.(Rao, 1972). The level of free sugars available to bedbugs through haemaphageous feeding has not been determined, nor has the benefit of higher availability of free sugars: whether bedbugs need to select prey with higher blood sugar to fulfill a quota of sugars in their reproductive systems, whether prey selection on this basis would be an advantage in reproduction, or

* Corresponding Author:
Email: nlralph@gmail.com

whether this apparent need for glucose and trehalose in reproduction has a threshold fulfilled by any human blood source has not yet been evaluated. The influence of any real-world levels of human expression of CO_2 and sebum on prey selection is unknown. We investigate this question by examining sugar consumption with the indirect measure of prey selection – reported infestation.

MATERIAL AND METHODS

We analyzed data from the 2009 New York City Community Health Survey, a representative survey of 9,934 non-institutionalized adults in New York City,("Community Health Survey,") to estimate prey selection with crude models and those adjusted for putative risk factors. Prey selection was measured through the proxy of reported bedbug infestation prevalence. Our outcome definition was self-reported bedbug infestation requiring an exterminator in the past year.

RESULTS

Results of models are seen in Table 1. Even after adjusting for participant's age, race, domestic or foreign birth, poverty status, neighborhood poverty in tertiles, number of units in building, household makeup by ages of children and by number of adults, and number of sexual partners (which may increase exposure to bedbugs), drinking one or more SSBs per day was associated with a 2.1 (95% confidence interval, CIs, 1.4, 3.0) increase in the odds of reporting a bedbug infestation requiring extermination in the past 12 months.

Table 1. Crude and adjusted logistic regression models of self-reported bedbug infestation, New York City Community Health Survey, 2009.

Average daily sugar-sweetened beverage	Crude*	Adjusted*
	OR (95% CIs)	aOR (95% CIs)
None	1.0	1.0
Less than one	1.8 (1.3, 2.5)	1.7 (1.2, 2.5)
One or more	2.6 (1.9, 3.5)	2.1 (1.4, 3.0)
Age in years		
18-24	3.2 (2.0, 5.2)	1.6 (0.8, 3.0)
25-44	2.3 (1.7, 3.1)	1.4 (0.9, 2.1)
45-64	1.5 (1.1, 2.1)	1.1 (0.7, 1.8)
65+	1.0	1.0
Race/ethnicity		
White, non-Hispanic	1.0	1.0
Black, non-Hispanic	2.0 (1.4, 2.9)	1.1 (0.7, 1.7)
Hispanic	3.1 (2.2, 4.3)	1.1 (0.7, 1.8)
Other	1.7 (1.0, 2.8)	1.4 (0.8, 2.5)
Nativity		
US-born	1.0	1.0
Foreign born	1.6 (1.3, 2.2)	0.9 (0.6, 1.2)
Household poverty status		
≤ 200% federal poverty level	3.6 (2.7, 4.9)	2.7 (1.9, 3.8)
> 200% federal poverty level	1.0	1.0
Neighborhood income: tertile of houses below poverty level		
Lowest tertile	3.7 (2.5, 5.5)	1.8 (1.1, 3.0)
Middle tertile	1.9 (1.3, 2.8)	1.2 (0.8, 1.9)
Highest tertile	1.0	1.0
Number of units in residential building		
1-2	0.5 (0.4, 0.8)	0.4 (0.3, 0.7)
3-9	1.6 (1.1, 2.4)	1.0 (0.6, 1.5)
10-49	1.4 (1.0, 2.1)	1.0 (0.7, 1.6)
50+	1.0	1.0

Total household size		
1	1.0	1.0
2	1.0 (0.7, 1.4)	0.9 (0.6, 1.5)
3	1.3 (0.9, 2.0)	1.2 (0.7, 2.0)
4+	2.3 (1.6, 3.4)	1.7 (1.0, 2.8)
Number of children <6 yrs in household		
0	1.0	1.0
1	1.6 (1.1, 2.3)	0.8 (0.5, 1.3)
2+	2.5 (1.6, 3.8)	1.2 (0.6, 2.1)
Number of sexual partners in last year		
0-1	1.0	1.0
2+	1.7 (1.1, 2.4)	1.6 (1.0, 2.5)

OR=odds ratio; aOR=adjusted odds ratio; CI=confidence interval

* Adjusted for complex sample and sampling weights

DISCUSSIONS

In an exploratory analysis from the New York City Community Health Survey of 2009, we found an association between self-reported daily consumption of SSBs and reporting a bedbug infestation requiring extermination in the past 12 months, even in a fully adjusted model. Daily SSB consumption increases blood sugar levels in humans on a continuous basis, so any link between blood sugars and prey selection may be independent from the timing of consumption related to exposure. While these findings could be spurious, caused by residual confounding, given biological plausibility, the possible link warrants further examination. It is also possible that bedbugs are attracted to CO_2 and sebum because of their association with sugar consumption as blood sugar levels could impact bedbug growth and fertility.

CONCLUSIONS

Clearly there are limitations to this model. Participants reported on daily SSB consumption rather than the overall sugar and carbohydrate content of their diets; the direct effect of SSB consumption on CO_2 or sebum production has not been quantified for our sample. Further, the measure of SSB consumption and infestations were based on self-reports, and both could be subject to recall bias. Additionally, residual confounding could explain these findings; people who report one or more SSBs per day may differ in important ways from people who report no such consumption in terms of other risk factors for exposure to bedbugs. Also, there may be inflammatory response to bedbugs associated with sugar consumption that could increase bedbug reporting for those who consume more SSBs. Nevertheless, our findings are intriguing and provide population-based evidence for the potential biological mechanisms by which bedbugs could be attracted to humans with higher sugar consumption.

REFERENCES

Anderson, J. F., Ferrandino, F. J., McKnight, S., Nolen, J., & Miller, J. 2009. A carbon dioxide, heat and chemical lure trap for the bedbug, Cimex lectularius. *Medical and Veterinary Entomology, 23*(2), 99-105.

Community Health Survey. 2012. Retrieved June 30, 2012, 2012, from http://www.nyc.gov/html/doh/html/survey/chs-methods.shtml

Dekker, T., Geier, M., & Carde, R. T. 2005. Carbon dioxide instantly sensitizes female yellow fever mosquitoes to human skin odours. *J Exp Biol, 208*(Pt 15), 2963-2972. doi: 10.1242/jeb.01736.

Foster, S. 2009. Sugar feeding via trehalose haemolymph concentration affects sex pheromone production in mated Heliothis virescens moths. *J Exp Biol, 212*(17), 2789-2794. doi: 10.1242/jeb.030676

How, Y. F., & Lee, C. Y. 2010. Fecundity, nymphal development and longevity of field-collected tropical bedbugs, Cimex hemipterus. *Med Vet Entomol, 24*(2), 108-116. doi: 10.1111/j.1365-2915.2010.00852.x

Jordao, A. L., Nakano, O., & Janeiro, V. 2010. Adult carbohydrate feeding affects reproduction of Phthorimaea operculella (Zeller) (Lepidoptera: Gelechiidae). *Neotrop Entomol, 39*(3), 315-318.

Naksathit, A. T., & Scott, T. W. 1998. Effect of female size on fecundity and survivorship of Aedes aegypti fed only human blood versus human blood plus sugar. *J Am Mosq Control Assoc, 14*(2), 148-152.

Rao, H. 1972. Free sugars in the reproductive system and haemolymph of the bedbug. (6), 294-302. doi: 10.1007/bf03045723

Singal, P., Janghorbani, M., Schuette, S., Chisholm, R., & Mather, K. 2013. Intra-individual variability of CO(2) breath isotope enrichment compared to blood glucose in the oral glucose tolerance test. (1557-8593 (Electronic)). doi: D - NLM: PMC3014756 EDAT- 2010/12/07 06:00 MHDA- 2011/04/09 06:00 CRDT- 2010/12/07 06:00 AID - 10.1089/dia.2010.0109 [doi] PST – ppublish.

Smith, R. N., Braue, A., Varigos, G. A., & Mann, N. 2008. The effect of a low glycemic load diet on acne vulgaris and the fatty acid composition of skin surface triglycerides. *J. Dermatol Sci, 50*(1), 41-52. doi: 10.1016/j.jdermsci.2007.11.005

Tauxe, G. M., MacWilliam, D., Boyle, S. M., Guda, T., & Ray, A. 2013. Targeting a dual detector of skin and CO2 to modify mosquito host seeking. *Cell, 155*(6), 1365-1379. doi: 10.1016/j.cell.2013.11.013

Van Aerde, J., Sauer, P., Pencharz, P., Smith, J., & Swyer, P. 1989. Effect of replacing glucose with lipid on the energy metabolism of newborn infants. (0143-5221 (Print)).

Weeks, E. N., Birkett, M. A., Cameron, M. M., Pickett, J. A., & Logan, J. G. 2011. Semiochemicals of the common bed bug, Cimex lectularius L. (Hemiptera: Cimicidae), and their potential for use in monitoring and control. *Pest Manag Sci, 67*(1), 10-20. doi: 10.1002/ps.2024.