The nutritionists within: Firebugs depend on gut bacteria for vitamin supply

December 1 2014

Firebugs, like the European firebug Pyrrhocoris apterus (left), which is often found under linden trees, and the African cotton stainer Dysdercus fasciatus (right), obtain their vitamin supply by using the service of symbiotic gut bacteria. Credit: Martin Kaltenpoth, MPI Chem. Ecol.

Microbial partners are important for the nutrition of many insects. They help detoxify and digest food, but also provide essential nutrients that

insects need in order to survive. The European firebug Pyrrhocoris apterus and the African cotton stainer Dysdercus fasciatus feed mainly on plant seeds that are poor sources of essential B vitamins. Scientists of the Max Planck Research Group Insect Symbiosis at the Max Planck Institute for Chemical Ecology in Jena, Germany, together with colleagues at the Friedrich Schiller University, have now found that bacterial symbionts in the insects' gut produce these vitamins and thereby ensure the host's metabolic stability and, ultimately, survival.

Interestingly, the vitamin supply provided by the symbionts directly influences the gene regulation of their host: If the bacterial associates are absent, the bugs show a characteristic vitamin deficiency response. However, the symbiosis between the bugs and their bacteria is not necessarily a harmonious one: The insects are proposed to actively harvest the vitamins from the bacteria by using specific enzymes that burst open the bacterial cell walls. (*Proceedings of the Royal Society B: Biological Sciences*, November 2014).

In their quest for a balanced meal plan, firebugs - and many other animals - depend on dietary supplements. Firebugs are a group of terrestrial insects that includes the ubiquitously found European firebug *Pyrrhocoris apterus* as well as the agricultural pest, the African cotton stainer *Dysdercus fasciatus*. As demonstrated previously, firebugs depend on their gut microbes for successful development. The symbiotic bacteria from the Coriobacteriaceae family provide essential vitamins. Microbe-free bugs suffer high mortality and produce fewer young than bugs that have their microbial partners (see "Bugs need symbiotic bacteria to exploit plant seeds").

Controlled experiments by the scientists from Jena implicate the bacterial symbionts in supplementing B vitamins to firebugs as an important feature of this association. Firebugs that lack their symbionts, but are reared on an artificial diet rich in B vitamins do perfectly fine

compared to bugs that have their microbes. It is only when B vitamins are eliminated from the artificial diet that symbiont-free bugs are observed to suffer high mortality during their juvenile stages.

What is even more striking is the effect of symbiont absence on the host's metabolism. "As a condition of nutrient limitation, firebugs that lack their symbionts were found to exhibit a different metabolic profile; one that can be restored either through the artificial supply of B-vitamins into their diet, or by reintroducing the insect to its symbionts," Hassan Salem, the first author of the study explains. Profiling the expression patterns of host genes revealed that the insect significantly increases the abundance of B vitamin transporters and activation enzymes when reared in the absence of its gut microbes. As the scientists found out, proteins that carry out the active transport of B vitamins across the gut epithelium and into cells are expressed in higher amounts when the host is lacking these important nutrients, as a means of increasing the efficiency in scraping the scarce vitamins together from the gut content. Supplementing B vitamins into the insect's diet or reestablishing the symbiotic partnership restores normal expression patterns of those genes.

An examination into the host's immune response to symbiont presence suggests that firebugs actively harvest their bacterial partners by lysing, or bursting open, the bacterial cells. This enables them to take up the free vitamins from the dead cells. The expression of genes encoding special antimicrobial peptides, specifically, lysozyme, supports this assumption. "Vitamin supplementation is probably too friendly of a word. Surrendered is somewhat more accurate, given how the host is thought to extract the vitamins from its microbes, it basically exploits the microbes to gain the benefits. Still, since only a fraction of the symbiont population is harvested, the microbes likely benefit from the association with the host by gaining nutrition in the bug's gut and a secured transmission route to the next generation," says Hassan Salem.

While strides have been made in our effort to understand the importance of the complex human microbiome, the exact functions of the majority of our gut associates remain unknown, as is their impact on our metabolism and overall physiology. As such, valuable insights can be gained from insects and their often simple and experimentally tractable microbial communities.

More information: Salem H, Bauer E, Strauss A, Vogel H, Marz M, Kaltenpoth M. (2014) Vitamin supplementation by gut symbionts ensures metabolic homeostasis in an insect host. *Proceedings of the Royal Society B*: *Biological Sciences*. 281, 2014183. dx.doi.org/10.1098/rspb.2014.1838

Provided by Max Planck Society