Conclusion of the Formas financed project about insects as food:

Äta insekter – en smaklig lösning på dagens globala problem? (Diarienr: 2016-00361)

The aim of this project was to develop a new protein- and mineral-rich Swedish food based on the house cricket. The project involved the whole value chain, i.e. a feed production system encompassing ecosystem services, cricket rearing and creation of safe, tasty Swedish dishes. This unique holistic project thus started with biological diversity in Swedish nature and ended at the dinner table.

Effects on biological diversity

One of our main hypotheses was that flowering plants, especially red clover, can be used as an ingredient in feed for crickets. It has been suggested that red clover as a crop can support biological diversity, particularly in terms of pollinators, when grown in arable fields. However, there has been little research to date on the effects of flowering crops on bumblebee abundances and diversity during and after crop bloom. In field work during the project, we observed that bumblebee worker abundances were higher in red clover than in flower-rich borders in the same landscape. Red clover had positive effects on bumblebee species richness and diversity after crop bloom and was also positively correlated with the abundance of a certain less common bumblebee species. These findings led us to conclude that cultivation of red clover has the potential to benefit less common bumblebee species in Swedish agroecosystems.

Effects of diets including flowering plants

Other results from the project showed that red clover can be safely included in the diet of house crickets, but cannot be used as the sole ingredient. We observed no difference in weight or survival between crickets fed early- or late-cut red clover, which indicates that the crop could be harvested for feed purposes after bloom, allowing it also to support wild pollinators. Forage conservation method had no effect on weight and survival, or on how efficiently the forage was used by the crickets (weight gain per unit of feed consumed). In free choice tests, we found that crickets with access to red clover (in addition to a cereal-based control feed) matured earlier than crickets with access to the control feed only. Thus red clover supplementation seemed to promote cricket maturation, which could be an advantage in commercial rearing. Altogether, inclusion of red clover in the diet of commercially-reared crickets appears interesting from a production perspective and also from an ecological perspective, since the flowering crop will provide feed for bumblebees and other pollinators.

Other flowering plants that showed some potential as feed for house crickets were lucerne and white nettle. Crickets fed white nettle showed good growth during the early stages of development. This plant attracts pollinators but it is not commercially grown as a field crop, making it a suitable subject for future cultivation studies.

In our studies, drinking water consumption by the crickets was around half that reported for pigs and poultry. However, crickets require a certain humidity (and temperature) for optimal growth and survival (>50% relative humidity and around 30°C), which means that the rearing system may need more water than just drinking water during dry conditions.

There were some differences in nutrient content of the crickets depending on the diet they were fed. Compared with crickets fed the cereal-based control diet, crickets fed diets including red clover and lucerne had lower total fat content, lower monounsaturated fatty acid content and higher polyunsaturated fatty acid content. This pattern is similar to that observed in meat from cattle offered forage or pasture instead of cereals. Copper content in the crickets was highest with the red clover diet and magnesium

and manganese content were lowest with the lucerne diet, but there were no differences in zinc and iron content between the diets. There were also no differences in total cricket amino acid content between the diets. Compared with values reported for eggs, beef and green peas (Swedish Food Agency, Livsmedelsverket), the lysine content in crickets was three-fold higher than in green peas, similar to eggs and about half that in beef. For methionine, the content was two- to three-fold higher than in green peas, slightly lower than in eggs and half that in beef. For iron, the content was higher than in eggs and green peas and similar or slightly lower than that in beef. These results confirm that crickets contain important nutrients and that the diet offered can have some importance for fat and trace mineral content in the crickets.

We also studied the effect of diet on cricket behaviour, using three diets with 0, 10 or 20 % forage replacing a similar proportion of cereals (wheat meal). Diet seems to affect cricket behaviour and inclusion of forage may potentially reduce behaviours related to anxiety and high energy expenditure. Use of forage instead of cereals in the diet of house crickets would also support biological diversity in the landscape.

Overall, our results indicate that forage use in feed could be beneficial for production and for insect welfare, but further studies are needed to verify these observations.

Food safety

We established a risk profile and identified knowledge gaps based on a review of previous publications. The review indicated that crickets as food may contain higher microbial loads than other food products, e.g. raw crickets appear to contain higher microbial loads than foods from poultry, swine or cattle. *Salmonella spp.* and *Escherichia coli* have been detected occasionally in edible insects, possibly because the whole insect is consumed, including gut contents. Therefore specific hygiene and safety criteria need to be applied before human consumption. Thermal treatments, such as blanching, boiling or frying, can decrease the microbial load. A mandatory thermal treatment process for crickets or cricket-derived products should be implemented before such products are placed on the market. Boiling before consumption can also be recommended, to ensure microbial loads that comply with hygiene and food safety standards. However, such treatments may not be sufficient to kill spores from some bacteria (*Bacillus* spp. and *Clostridium* spp.) and therefore new processes (e.g. high pressure processing) and preservation treatments, such as addition of nitrifying salts, drying or acidification, should be considered to ensure longer shelf-life.

Heavy metals are putative chemical hazards when crickets are exposed to these during rearing, with cadmium accumulation in particular having been identified as a concern. Cadmium can enter the rearing system through feeds, although this risk is likely to be lower in Sweden than in other countries since cadmium contamination of fertilisers is prohibited under Swedish law. Crickets can also trigger allergic reactions in consumers sensitive to prawns, crabs and lobsters. For safety reasons, crickets and cricket-derived food products should be labelled to raise awareness of this risk among susceptible consumers.

In conclusion, our risk profiling identified several considerable concerns (high risk) in production of cricket-based food: (1) High total aerobic bacterial counts; (2) survival of spore-forming bacteria following thermal processing; (3) allergenicity; and (4) bioaccumulation of heavy metals (e.g. cadmium). Other hazards, like parasites, fungi, viruses, prions, antimicrobial resistance and toxins, were ranked as low risk.

Based on the literature review, we identified several knowledge and data gaps in terms of food safety, e.g. regarding fungal and mycotoxin production and chemical compounds such as heavy metals or dioxins. The data gaps identified fell into four major categories: (1) Rearing conditions for the insects; (2) the actual impact of thermal processing prior to consumption; (3) fungal communities and mycotoxin-producing fungi in reared crickets; and (4) heavy metals not fully assessed and other chemical hazards produced during processing. In addition, we found very little information on the

traceability of marketed insects, especially with respect to the rearing environment, veterinary medicine products used, transport and storage conditions.

Bacterial and viral microbiota in rearing systems

We investigated microbial communities (bacteria, moulds, yeasts) in house crickets fed different diets in a controlled environment. We observed high counts of aerobic bacteria, but all batches studied tested negative for *Salmonella*, *Listeria monocytogenes*, *Bacillus cereus* and *Clostridium perfringens*. Moulds were detected and *Aspergillus flavus*, a fungus capable of producing mycotoxins, was detected in crickets fed one of the red clover diets. The high microbial loads detected in the crickets indicated a high risk of rapid spoilage, but the diet used did not seem to have a major impact on total amounts of aerobic bacteria. Considering the high microbial loads in the crickets, in order to prevent any possible food safety issues we recommend that crickets be thermally treated at harvest, immediately after the rearing phase is finished, to extend shelf-life. Overall, our results suggest a need for monitoring of rearing conditions, including any fungi present on feeds, to prevent growth of mould and mycotoxin production in edible crickets. More work is also needed to establish possible bacterial quality reference values. This will be an important step in developing parameters to ensure consumer safety.

We also investigated viruses in crickets fed different diets. The results indicated presence of only a limited number of viruses, irrespective of diet. This could be because the crickets had not been exposed to a rich viral environment, which is a good sign from a food safety perspective. Further analyses of the viral flora in industrial cricket rearing conditions need to be performed.

Dishes and sensory traits of crickets

Chef Paul Svensson and his team created three food dishes, pasta with pesto and two desserts, using house crickets fed the cereal-based control diet (see blog). Another team of chefs were asked to evaluate the taste of crickets fed different diets. In this evaluation, the chefs perceived a difference in taste between crickets fed different diets. These differences were observed for flavours like ‘roasted’, ‘dairy’ and ‘buttery’. These observations show that it can be important to evaluate sensory traits before new feed sources are introduced into cricket diets in the future.

House cricket densovirus

Another important aspect of our project was to investigate the incidence of house cricket densovirus in commercial and wild house crickets in Sweden. This virus has been found on commercial farms in Europe and the USA and causes high mortality, with devastating effects on production. If Swedish crickets were found to be free of the virus, there could be commercial value in creating a virus-free stock for food production. During 2017-2018, we collected samples from commercial retailers (selling to pet owners) and from wild populations in Sweden. No individuals from the wild populations carried cricket densovirus, but insects obtained from the retailers carried this virus. Using wild individuals found to be free of the virus, we created a virus-free breeding stock for studies at the university. In another part of the study, we showed that cricket faecal material is a suitable substrate for analysis when assessing whether a cricket population is infected with densovirus. We also developed a method for detecting the virus that is more sensitive than previously published protocols. This method is now commercially available, as are virus-free breeding crickets.

Conclusion

Overall positive conclusions from this project are that reared crickets are a protein- and mineral-rich food and that the cricket production chain can provide ecosystem services by inclusion of flowering plants in the diet. There may be a high risk of rapid spoilage of cricket-based food, but measures can be taken to prevent this. Cricket farmers should be made aware that the lethal densovirus is present in Swedish commercial stocks and that a test for detecting this virus is available.

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11. And a few more in manuscript…