Why should we feed pigs and poultry with insect protein?

April 2021

This policy paper was written as a response to a European Commission public consultation on feed. The consultation addresses the possible authorisation to feed poultry and pig with insects protein.

Here is the link to the consultation:
https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/11640-Authorisation-to-feed-poultry-with-processed-animal-protein-derived-from-farmed-insects-or-domestic-porcine-animals

Table of contents

1. Introduction

In order to continue feeding the world population, it is necessary to optimise our food-producing sectors. This will be a major challenge since models predict an increase in world population the following decades, which means also a rising demand for animal proteins. This does not only imply an increase in human food production, but an increase in animal feed production as well. Currently, the leading resources of feed protein are oilseed meals, fish/animal proteins and biofuel coproducts[1]. The production of oilseeds, such as soy beans, contributes to deforestation significantly[2]. Furthermore, fisheries for the production of fishmeal exceed the maximum capacity to maintain a sustainable system[3]. Nevertheless, the need for protein will proceed to grow. Therefore, research is conducted on the potential of alternative protein resources, such as insects for feed and food.

2. Nutritional value

Research has shown that insects are mainly composed of protein and fat[4], with the remaining being carbohydrates, fibres, vitamins and minerals. Insect protein contents can go up to 82%[5], although commercially reared insect species like mealworms, black soldier fly larvae, desert locusts and house crickets have protein contents of respectively 53, 42, 57 and 63%[6], which is still significant. Insect proteins, like those present in black soldier fly larvae have favourable amino acid profiles, which are comparable to amino acid profiles in fishmeal[7]. These proteins therefore are an interesting alternative protein source.

Insects can also contain high fat contents. The fatty acid profile varies among different species, but is also dependent on the substrates on which the insects are grown. As an example, it is possible to grow black soldier fly larvae that contain high amounts of omega-3 and omega-6 fatty acids by using feed substrates rich in these fatty acids[8].

Moreover, insects' edible fraction is higher than that of conventional farm animals. 80 to 100% of an insect is edible, while poultry and pork have on average an edible fraction of 55%. For ruminants, this edible fraction is even lower[9].

Insects are well accepted by farmed animals as feed. For many fish, poultry and pig species, insects are part of their natural food source. Many fish species have adapted their physiology to hunt insects and the diet of some wild Salmonidae species contain up to 70% of insects[10]. Feed trials conducted with poultry species indicated that diets containing insects are preferred over diets that lack insects[11]. In the wild, pig species forage and dig to find and eat insects[11]. Trials were conducted for pigs, with dietary replacement of fishmeal by black soldier fly larvae meal. Research showed a full replacement of fishmeal by full-fat larvae meal was possible and did not adversely affect growth and blood characteristics[12]. For poultry, black soldier fly larvae (BSFL) have a good level of acceptance as well[13]. A study with a 10% inclusion of BSFL in poultry feed highlighted the possibility of using them as ingredients[14]. Moreover, feeding live BSFL to broilers and laying hens improves animal welfare[15,16].

3. Immunological advantages in feed

Insects are not only an interesting protein source, but also have immunological advantages. The most important advantageous characteristics are the presence of chitin, the favourable fatty acid profile and their beneficial effects on the gut microbiota of the animal they are fed to[17]. Chitin and its derivatives are beneficial for the digestive system. Research suggests it promotes the antioxidant status, immune response and intestinal development of poultry[18,19]. Furthermore, chitin and chitosan have antimicrobial traits: it impedes bacterial metabolism and RNA transcription[20–22]. Chitin, combined with the fatty acid profile of insects such as the black soldier fly, has an advantageous effect on the gut microbiota of poultry. Poultry cannot fully digest chitin. Once the remaining chitin reaches the ceca, the gut microbiota can use it as prebiotics to enhance the production of short-chain fatty acids (SCFAs), such as acetate and propionate[23]. These are indispensable for the animal's metabolism and gut physiology[23]. Furthermore, they inhibit virulence factors of pathogenic bacteria[24]. Research has indicated that the black soldier fly in feed caused changes in the cecal microbiota of poultry due to diversification of microbiota. There is a strong correlation between microbial diversity and SCFAs content[23].

In insects such as black soldier fly larvae, dodecanoic acid makes up between 29 and 50% of the total fatty acid profile. Dodecanoic acid has an antimicrobial effect on gram-positive bacteria[25,26]. Furthermore, lauric acid can transform into monolaurin, which could dismantle the lipid membrane of bacteria[27]. Both in vitro tests and tests with piglets have used lauric acid to combat gram-positive bacteria such as *D streptococci* (2 log fold reduction in vitro). Gram-negative bacteria such as coliforms were almost unaffected[25]. In poultry, it significantly lowered the amount of *Bifidobacterium* and *Lactobacillus*, which could be attributed to the antimicrobial effects of chitin and saturated fatty acids such as lauric acid[28].

4. Environmental benefits

Insects seem to be a promising agent in food and feed since they are highly efficient in converting organic matter into biomass. They have the ability to accumulate protein very efficiently. Under optimised diets, poultry can convert 33% of dietary protein into edible biomass, while black soldier fly larvae are able to convert 43-55% into edible biomass[29]. When it comes to feed conversion ratio, they surpass other farm animals, such as ruminants and pigs[29]. This means that a higher proportion of ingested feed is converted into biomass. One explanation for this is insects being cold-blooded, thus not having to spend energy on the regulation of their body temperature[9]. In order to reach a high efficiency, it is important to gain knowledge about their nutritional requirements and pay attention to genetic selection to establish more efficient strains[10].

The biggest environmental impact of most commonly-used protein sources like milk, eggs and meat is associated with agricultural field activities used to grow and harvest crops, required to feed the animals[30]. Therefore insects are extremely interesting because they can be reared on a wide range of substrates, such as agricultural side streams and supermarket food waste[31]. Since insects can be reared on unused or underused organic streams, they can possibly be the missing link towards increased circularity in the agriculture and food industry. Thus, both waste reduction and biomass production can be addressed simultaneously. Waste reduction is an important topic, since 27% of the world's annual agricultural produce (worth US$750 billion) goes to waste[10,32].

With regards to land-use efficiency, insects are an efficient protein source. It is possible to stack boxes in which insects are grown, a method known as 'vertical farming'. This is possible since larvae of multiple insect species, such as those of black soldier flies, do not require much space and any source of light for their development[33].

Since they grow and breed quickly, it is possible to have multiple cycles of insects farmed every year. Their land use efficiency can be up to 70 times higher than commonly used materials of vegetal origin[5].

Insects, such as house crickets, desert locusts, mealworms also produce a low greenhouse gas equivalent when compared to traditional farm animals. They produce merely 1% of the greenhouse gasses compared to ruminants. Additionally, the ammonia emissions for these insect species is lower than conventional farm animals[34].

5. Safety aspects

In order to evaluate the safety risks of insects in food and feed, it is important to evaluate chemical, microbiological and allergenic hazards, as well as the presence of prions.

Feed substrates on which insects are grown are the main exposure route of insects to chemical hazards. Research has shown that essential heavy metals do not accumulate in insects[35–37], although precaution should be taken with high levels of cadmium and arsenic in feed substrates as cadmium may accumulate in the black soldier fly[38] and arsenic in yellow mealworm larvae[39]. The accumulation of certain EU-regulated mycotoxins has already been investigated: those that were tested did not accumulate in black soldier fly larvae, but were metabolized instead[40,41].

It should be noted that no indications are present that currently reared insect species for the use for food and feed produce reactive, irritating or toxic substances in the life stages during which they are used for consumption[42]. The microbiological hazards in insects used for food and feed are affected by both the intrinsic microbial community linked to the insect as the microbial community introduced during the rearing and processing[42]. The substrate used for insect rearing influences the insects' microbial load. Therefore the hygienic conditions of both the substrates and farming environment are important[43]. Heat treatment may eliminate most microbiological hazards[44]. However, in order to eliminate bacterial spores, sterilisation at high temperature under high pressure will be necessary[44,45] .

There are allergens present in insects which one should be aware of. Certain proteins may trigger allergic reactions or play a role in cross-reactivity with crustaceans or dust mites[46,47]. For example, mealworms contain the pan-allergin, which is also commonly found in prawn and shrimp[47]. Chitin, found in the insects' exoskeleton can play a role in allergenicity, but so far the mechanisms are poorly understood[10,42,43].

No specific prionic diseases have been found in insects due to the lack of a PrP-encoding gene[43]. Nevertheless, they might be able to act as mechanical vectors of prions. Thus, risk substrates of ruminant origin should not be used as feed substrates for insects[48].

6. Conclusion

Actions need to be taken in order to supply sufficient proteins to keep feeding the world population. Therefore, it is necessary to find alternative and more sustainable protein sources. Insects as food and feed show a great potential, since they can successfully convert low-value organic by-products into high-value protein. Proteins produced by insects have environmental benefits compared to farmed animals, such as lower greenhouse gas emissions, lower land use and favourable conversion ratios. Insects in feed have immunological advantages for the animals they are fed to. Insects are safe to be used as feed, if one pays attention to allergic factors, their feed substrates, keeping a hygienic environment and proper processing techniques. Since they are accepted as a feed source by numerous farmed animals, they can be a potent source of renewable protein in the feed industry.

7. References

1. Kim, S. W. *et al.* Meeting Global Feed Protein Demand: Challenge, Opportunity, and Strategy. *Annu. Rev. Anim. Biosci.* **7**, 221–243 (2019).
2. Chancellor, C. *The trouble with soy: the threats to small-scale producers across Europe eco ruralis*. (2018).
3. FAO. The State of Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. *Rome. Licence CC BY-NC-SA 3.0 IGo* (2018).
4. Rumpold, B. A. & Schlüter, O. K. Nutritional composition and safety aspects of edible insects. *Molecular Nutrition and Food Research* vol. 57 802–823 (2013).
5. ipiff. The nutritional benefits of insects in animal feed. https://ipiff.org/factsheets/ (2020).
6. Makkar, H. P. S., Tran, G., Heuzé, V. & Ankers, P. State-of-the-art on use of insects as animal feed. *Animal Feed Science and Technology* vol. 197 1–33 (2014).
7. Nogales-Mérida, S. *et al.* Insect meals in fish nutrition. *Rev. Aquac.* **11**, 1080–1103 (2019).
8. St-Hilaire, S. *et al.* Fish offal recycling by the black soldier fly produces a foodstuff high in omega-3 fatty acids. *J. World Aquac. Soc.* **38**, 309–313 (2007).
9. van Huis, A. *et al.* Edible Insects - Future prospects for food and feed security. *Food aAgriculture Organ. Unated Nations* (2013).
10. van Huis, A. & Oonincx, D. G. A. B. The environmental sustainability of insects as food and feed. A review. *Agronomy for Sustainable Development* vol. 37 1–14 (2017).
11. Star, L. *et al.* Gradual Provision of Live Black Soldier Fly (Hermetia illucens) Larvae to Older Laying Hens: Effect on Production Performance, Egg Quality, Feather Condition and Behavior. *Animals* **10**, 216 (2020).
12. Chia, S. Y. *et al.* Effect of dietary replacement of fishmeal by insect meal on growth performance, blood profiles and economics of growing pigs in Kenya. *Animals* **9**, (2019).

13. Ruhnke, I. *et al.* Impact of on-range choice feeding with black soldier fly larvae (Hermetia illucens) on flock performance, egg quality, and range use of free-range laying hens. *Anim. Nutr.* **4**, 452–460 (2018).

14. Kawasaki, K. *et al.* Evaluation of black soldier fly (Hermetia illucens) larvae and pre-pupae raised on household organic waste, as potential ingredients for poultry feed. *Animals* **9**, 98 (2019).

15. Ipema, A., Gerrits, W. J. J., Bokkers, E., Kemp, B. & Bolhuis, J. E. Provisioning of live black soldier fly larvae (Hermetia illucens) benefits broiler activity and leg health in a frequency and dose-dependent manner. 33–33 (2020).

16. Star, L. *et al.* Gradual Provision of Live Black Soldier Fly (Hermetia illucens) Larvae to Older Laying Hens: Effect on Production Performance, Egg Quality, Feather Condition and Behavior. *Animals* **10**, 216 (2020).

17. Abd El-Hack, M. E. *et al.* Black soldier fly (Hermetia illucens) meal as a promising feed ingredient for poultry: A comprehensive review. *Agriculture (Switzerland)* vol. 10 1–31 (2020).

18. Swiatkiewicz, S., Swiatkiewicz, M., Arczewska-Wlosek, A. & Jozefiak, D. Chitosan and its oligosaccharide derivatives (chito-oligosaccharides) as feed supplements in poultry and swine nutrition. *Journal of Animal Physiology and Animal Nutrition* vol. 99 1–12 (2015).

19. Khambualai, O., Yamauchi, K., Tangtaweewipat, S. & Cheva-Isarakul, B. Growth performance and intestinal histology in broiler chickens fed with dietary chitosan. *Br. Poult. Sci.* **50**, 592–597 (2009).

20. Chung, Y. C. *et al.* Relationship between antibacterial activity of chitosan and surface characteristics of cell wall. *Acta Pharmacol. Sin.* **25**, 932–936 (2004).

21. Je, J. Y. & Kim, S. K. Chitosan derivatives killed bacteria by disrupting the outer and inner membrane. *J. Agric. Food Chem.* **54**, 6629–6633 (2006).

22. Benhabiles, M. S. *et al.* Antibacterial activity of chitin, chitosan and its oligomers prepared from shrimp shell waste. *Food Hydrocoll.* **29**, 48–56 (2012).

23. Borrelli, L. *et al.* Insect-based diet, a promising nutritional source, modulates gut microbiota composition and SCFAs production in laying hens. *Sci. Rep.* **7**, 1–11 (2017).

24. Li, D. F. *et al.* Effect of fat sources and combinations on starter pig performance, nutrient digestibility and intestinal morphology. *J. Anim. Sci.* **68**, 3694–3704 (1990).

25. Spranghers, T. *et al.* Gut antimicrobial effects and nutritional value of black soldier fly (Hermetia illucens L.) prepupae for weaned piglets. *Anim. Feed Sci. Technol.* **235**, 33–42 (2018).

26. Skrivanova, E., Marounek, M., Dlouha, G. & Kanka, J. Susceptibility of Clostridium perfringens to C2-C18 fatty acids. *Lett. Appl. Microbiol.* **41**, 77–81 (2005).

27. Srivastava, Y., Semwal, A. D. & Sharma, G. K. Virgin Coconut Oil as Functional Oil. in *Therapeutic, Probiotic, and Unconventional Foods* 291–301 (Elsevier, 2018). doi:10.1016/B978-0-12-814625-5.00015-7.

28. Kawasaki, K. *et al.* Evaluation of Black Soldier Fly (Hermetia illucens) Larvae and Pre-Pupae Raised on Household Organic Waste, as Potential Ingredients for Poultry Feed. *Animals* **9**, 98 (2019).

29. Oonincx, D. G. A. B., Van Broekhoven, S., Van Huis, A. & Van Loon, J. J. A. Feed conversion, survival and development, and composition of four insect species on diets composed of food by-products. *PLoS One* **10**, (2015).

30. Smetana, S., Palanisamy, M., Mathys, A. & Heinz, V. Sustainability of insect use for feed and food: Life Cycle Assessment perspective. *J. Clean. Prod.* **137**, 741–751 (2016).

31. Liu, C., Wang, C. & Yao, H. Comprehensive resource utilization of waste using the black soldier fly (*Hermetia illucens* (L.)) (*diptera: Stratiomyidae*). *Animals* vol. 9 (2019).

32. Economist. Food loss and its intersection with food security. Global food security index 2014 Special report of the intelligence unit of The Economist. http://foodsecurityindex.eiu.com/Home/DownloadResource?fileName=EIU_GFSI 2014_Special report_Food loss.pdf. (2014).

33. Fisher, H. & Romano, N. Black soldier fly larval production in a stacked production system : Global Aquaculture Advocate. https://www.aquaculturealliance.org/advocate/black-soldier-fly-larval-production-in-a-stacked-production-system/ (2020).

34. Oonincx, D. G. A. B. *et al.* An Exploration on Greenhouse Gas and Ammonia Production by Insect Species Suitable for Animal or Human Consumption. *PLoS One* **5**, e14445 (2010).

35. Crawford, L. A., Lepp, N. W. & Hodkinson, I. D. Accumulation and egestion of dietary copper and cadmium by the grasshopper Locusta Migratoria R & F (orthoptera: Acrididae). *Environ. Pollut.* **92**, 241–246 (1996).

36. Maryański, M., Kramarz, P., Laskowski, R. & Niklińska, M. Decreased energetic reserves, morphological changes and accumulation of metals in carabid beetles (Poecilus cupreus L.) exposed to Zinc- or Cadmium-contaminated food. *Ecotoxicology* **11**, 127–139 (2002).

37. Vijver, M., Jager, T., Posthuma, L. & Peijnenburg, W. Metal uptake from soils and soil-sediment mixtures by larvae of Tenebrio molitor (L.) (Coleoptera). *Ecotoxicol. Environ. Saf.* **54**, 277–289 (2003).

38. Diener, S., Zurbrügg, C. & Tockner, K. Bioaccumulation of heavy metals in the black soldier fly, Hermetia illucens and effects on its life cycle. *J. Insects as Food Feed* **1**, 261–270 (2015).

39. van der Fels-Klerx, H. J., Camenzuli, L., van der Lee, M. K. & Oonincx, D. G. A. B. Uptake of Cadmium, Lead and Arsenic by Tenebrio molitor and Hermetia illucens from Contaminated Substrates. *PLoS One* **11**, e0166186 (2016).

40. Bosch, G., Van Der Fels-Klerx, H. J., De Rijk, T. C. & Oonincx, D. G. A. B. Aflatoxin B1 tolerance and accumulation in black soldier fly larvae (hermetia illucens) and yellow mealworms (tenebrio molitor). *Toxins (Basel).* **9**, (2017).

41. Camenzuli, L. *et al.* Tolerance and excretion of the mycotoxins aflatoxin B1, zearalenone, deoxynivalenol, and ochratoxin A by alphitobius diaperinus and hermetia illucens from contaminated substrates. *Toxins (Basel).* **10**, (2018).

42. FASFC. *Food safety aspects of insects intended for human consumption. Common advice of the Belgian Scientific Committee of the Federal Agency for the Safety of the Food Chain (FASFC) and of the Superior Health Council (SHC)*. (2014).

43. van der Fels-Klerx, H. J., Camenzuli, L., Belluco, S., Meijer, N. & Ricci, A. Food Safety Issues Related to Uses of Insects for Feeds and Foods. *Compr. Rev. Food Sci. Food Saf.* **17**, 1172–1183 (2018).

44. Stoops, J. *et al.* Minced meat-like products from mealworm larvae (Tenebrio molitor and Alphitobius diaperinus): microbial dynamics during production and storage. *Innov. Food Sci. Emerg. Technol.* **41**, 1–9 (2017).

45. Huesca-Espitia, L. C. *et al.* Effects of steam autoclave treatment on Geobacillus stearothermophilus spores. (2016) doi:10.1111/jam.13257.

46. Verhoeckx, K. C. M. *et al.* House dust mite (Der p 10) and crustacean allergic patients may react to food containing Yellow mealworm proteins. *Food Chem. Toxicol.* **65**, 364–373 (2014).

47. Van Broekhoven, S., Bastiaan-Net, S., De Jong, N. W. & Wichers, H. J. Influence of processing and in vitro digestion on the allergic cross-reactivity of three mealworm species. *Food Chem.* **196**, 1075–1083 (2016).

48. EFSA. Risk profile related to production and consumption of insects as food and feed. *EFSA J.* **13**, (2015).

What is ValuSect?

ValuSect is a project funded by Interreg North-West Europe. The ValuSect consortium will improve the sustainable production and processing techniques of insect-based products and transfer developed knowledge to agri-food businesses in North-West Europe.

Since March 2021, the project extended its focus to the insect feed sector.

Associated partners

Full partners