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Review paper

Entomophagy — a novel option in animal and human nutrition

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ABSTRACT

Entomophagy is not a new phenomenon in the world. Moreover, it is a traditional diet in a large part of the planet. However, in the European framework it belongs to the category of novel food and although the topic is often debated, it represents a growing choice in human and animal nutrition. Edible insects have the potential to serve as a healthy, sustainable alternative to animal protein sources due to their valuable nutritional composition. They may have superior health benefits based on high levels of essential amino acids, omega-3 and omega-6 fatty acids, vitamin B12, iron, zinc, fibre and antioxidants. They could offer a myriad of environmental benefits, including overall reductions in greenhouse gas emissions and reduced use of agricultural land and water. Future research should aim to understand the beneficial effects of whole insects or insect isolates compared to traditional foods of animal and plant origin. Although insects have the potential to be used as meat substitutes or dietary supplements, leading to benefits for human health and the environment, this paper does not aim to ultimately propagate their use, but to point out their advantages and qualities, as well as potential dangers and risks, and finally to present ways of placing insects on the European market.

1. Introduction

Entomophagy, or the eating of insects, has been of great importance throughout history. There are numerous indications about the consumption of insects through various historical sources and literature and in many religious documents belonging to Christianity, Islam and Judaism. Despite the fact that entomophagy persisted in some parts of the world, in modern Western societies, through the centuries that followed, it lost its importance and presence. It is assumed that the most probable reason is the development of agriculture and livestock production. Recently, this topic has attracted the attention of the public all over the world. Due to the food security issues, new scientific research has begun on the contribution that insects make to ecosystems, nutrition, food security and livelihoods (*Nesic*, 2022).

Considering a growing world population on one side and climate change and other aggravating factors on the other, new food chain strategies are aimed at sustainable food systems that are secure, safe and environmentally friendly. Insects, which represent a new choice in the European nutrition, contribute to this concept and are favourable candidates for supplementing traditional protein sources. Insect farming is expanding in Europe and consumers are becoming increasingly receptive to this idea. To ensure future development of the insect market, it is very important to provide safe insect products.

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Although insects as a possible choice in human and animal nutrition is a great economic and ecological opportunity, consumers must first of all be fully informed and protected (*Delgado et al.*, 2022).

2. Advantages of entomophagy

Food and Agriculture Organization of the United Nations (*FAO*, 2013; 2021) published its reports to raise awareness of the many valuable roles that insects play in sustaining nature and human life, and to document the contribution that insects already make to diversifying diets and improving food security. The *EFSA* (2015) list of insects reported to have the highest potential for use as food and feed in the EU includes the following species: *Musca domestica*, *Hermetia illucens*, *Tenebrio molitor*, *Zophobas atratus (morio)*, *Alphitobus diaperinus*, *Galleria mellonella, Achroia grisella, Bombyx mori, Acheta domesticus, Gryllodes sigillatus, Locusta migratora migratorioides, Schistocerca Americana*.

Interest in entomophagy is growing primarily due to the good nutritional composition of insects. They are a source of biologically valuable proteins (they contain over 60%) with high levels of essential amino acids (e.g. lysine, tryptophan), omega-3 and omega-6 fatty acids, vitamin B12, iron, zinc, fibre and antioxidants. A recent study comparing the nutritional characteristics of a range of insects showed that the amino acid profile of dipterous insects was superior to soybean meal and more similar to fish meal (*Barroso et al.*, 2014). The profile of unsaturated fatty acids is similar to that of poultry and white fish, but contains more polyunsaturated fatty acids (PUFA) than poultry or red meat (*Rumpold and Schluter*, 2013), while it largely depends on the species and developmental stage, but also on their diet.

The price of other protein feedstuffs also contributes to the popularization of this novel food, as animal feed makes about 70% of livestock production costs. Therefore, insects that are characterized by a favourable content of nutrients, low impact on the environment, smaller requirements for living space, and which are already part of the natural diet of pigs, poultry and fish, are an ideal alternative for feeding animals (*Rumpold and Schluter*, 2013). Feed conversion ratios in insects are good, like crickets for example, which need only 2 kg of feed for every kilogram of body mass (*Collavo et al.*, 2005). In addition to the protein precedence, insect fat as a byproduct of protein production is being considered for biodiesel refineries (*Wang et al.*, 2017).

There are several environmental benefits associated with insect farming (*FAO*, 2021). Their cultivation requires less water than domestic animal farming and also has a high land use efficiency compared to traditional protein sources (*Alexander et al.*, 2017). Greenhouse gas emissions from insects are far lower than from conventional animal husbandry (*Oonincx et al.*, 2010). The production of one kg of edible protein from insects requires less energy than a kg of beef, and is comparable to the production of pork, while a kg of chicken requires slightly more energy. Insects are considered a sustainable source of protein due to the facts that they can be grown throughout the year, that most of their body is edible, that they have a high fertility and growth rate, and that they efficiently convert the growing substrate into their own body mass (*FAO,* 2021).

Insects participate in the natural recycling of nutrients. Their contribution in maximizing the efficiency of waste management by using waste nutrients for growth is also known. About one third of the food produced for human consumption worldwide is thrown away as waste. Current waste management practices are not only expensive, but also have a negative impact on the environment. Therefore, experimental evidence, such as that provided by *Yandi et al.* (2023) on the successful bioconversion of organic waste by *Hermetia illucens* larvae, is of great importance for the creation of high-value insect-derived products with the simultaneous valorization of waste. The recycling of food waste generated in urban and suburban environments using insects such as *Hermetia illucens* to create protein sources for animal feed was also discussed by *Law and Wein* (2018). One of the potential benefits of insect farming is that the excrement they produce can be used as fertilizer to improve soil fertility. However, since the nutritional composition as well as the microbiological and toxicological profiles of insects depend on the composition of the substrate on which they are produced (*Harsányi et al.*, 2020; *Parry et al.,* 2020), more research is needed to demonstrate all safety aspects of using insects for food and even for fertilizer, after cultivation on different substrates.

There are data in the literature on the degradation of materials such as Styrofoam and other forms of polystyrene, as well as polyethylene, by worms (*Brandon et al.*, 2018; *Koh et al.*, 2020; *Nukmal et al.*, 2018). Insects can also serve in the production of biofuels, as well as chitin and lipids used in food, textiles, cosmetics, pharmaceutical products and as surfactants (*Gortari and Hours*, 2013; *Houben et al.*, 2020; *Verheyen et al.*, 2020). Another use mentioned in the literature is entomoremediation, where insects are used to perform *in situ* remediation of various environmental pollutants from soil (*Ewuim*, 2013).

3. Risks of entomophagy

The use of insects in food and feed in Europe is a relatively new practice on a commercial scale and many questions are yet to be definitively answered. First of all, there are concerns about the risk of introducing pathogens and other safety threats into the production system. Further limitations are based on the lack of complete information on the bioavailability of all nutrients found in insects, the effect of different processing methods on nutrient composition, and the lack of evidence that insects are an acceptable substitute for meat in the quantities necessary to be nutritionally beneficial (*Payne et al.*, 2016). The problem of consumer acceptability of insects is one of the biggest obstacles to mass use. It is also necessary to adopt appropriate regulations, address welfare issues and establish adequate laboratory control of food and feed.

Regarding the presence in insects of bacteria, species of the genera *Staphylococcus*, *Streptococcus*, *Bacillus, Pseudomonas, Micrococcus, Lactobacillus, Erwinia, Clostridium* and *Acinetobacter* are mentioned, as well as members of the *Enterobacteriaceae* family (*EFSA*, 2015; *Garofalo et al.*, 2019; *Murefu et al.*, 2019). Some of these species are not only pathogenic and opportunistic bacteria, but can also be responsible for reducing the shelf life of edible insects. To reduce the transmission of pathogens to humans through the consumption of insects, it is important that insect farms have strong biosecurity measures and prevent contact with other animals. Growing materials may also present a potential microbiological risk to consider. For example, if materials such as paper egg cartons are used for rearing insects, there is a risk of contamination with S*almonella* and *Campylobacter*. The risks are higher if the cartons have been in contact with poultry droppings (*Walia et al.*, 2018). Research shows that treating insects in the same way as other food of animal origin (washing and thorough heating) greatly reduces the risk of foodborne bacterial diseases (*Grabowski & Klein*, 2017). The occurrence of transmissible antimicrobial resistance (AMR) genes has also been investigated, and potential sources of AMR bacteria are linked to contamination of the substrate, water and/or insect breeding environment (*Milanović et al*., 2016).

So far, the risks associated with food-borne viruses, such as hepatitis A, hepatitis E and norovirus, which could have their source in the consumption of insects, are considered to be quite negligible, but care must still be taken to ensure that the viruses are not introduced into insect production units via substrate (*Vandeweyer et al.*, 2020). Insects can potentially serve as replicative vectors for viruses that infect vertebrates. Additional studies are needed to investigate the possibility of arboviruses transmitted by edible insects, which are transmitted by arthropods and can cause a number of diseases in humans, such as West Nile disease, Rift Valley fever and haemorrhagic fever (*EFSA*, 2015).

Some mycotoxicological risk has also been identified, given that several mycotoxins have been detected in edible insects, but not at levels of public health concern (*De Paepe et al.*, 2019). The publication by *FAO* (2021) also mentions certain types of moulds and yeasts (*Aspergillus, Penicillium* and *Fusarium*), but more research is needed to better identify the metabolic pathways, metabolites and their potential toxicological effects.

Regarding the presence of parasites, *Belluco et al.* (2013) report the finding of metacercariae in some species of edible insects in Asia, and consequently the development of intestinal fluke (trematode) infections in humans. Infection of mammals and humans with nematodes for which insects are the transitional host, as well as oral trypanosomiasis, have also been recorded. Myiasis, parasitic infestation of the body of live animals and humans with fly larvae is also possible. *Gałęcki and Sokól* (2019) warn that insect farms supplying edible insects can pose both direct and indirect parasitic risks for humans and animals, so therefore, have to be regularly monitored for parasites to guarantee the safety of food and feed sources. In the *EFSA* (2021) scientific opinion on *Tenebrio molitor* as novel food, it is stated that the applicant of this request confirms application of measures to monitor the presence of the developmental forms of tapeworms (class: *cestodes*), *Hymenolepis diminuta* and *Hymenolepis nana*, which can cause zoonotic symptoms in humans.

Studies on the level of contamination with organic and metal contaminants in both whole edible insects and insect-based food products indicate that contaminant levels are generally lower than those reported in other common animal products (*Poma et al.,* 2017). The *EFSA* (2021) opinion states that levels of heavy metals, pesticide residues, polychlorinated biphenyls and dioxins need to be monitored in feed for *Tenebrio molitor* larvae, as they can bioaccumulate such chemical agents. *Truzzi et al.* (2020) suggested that since the content of heavy metals in *Hermetia illucens* pupae depends on the growth substrate, in addition to the list of insect species that can be used for the production of processed animal proteins, a specific list of tested growth substrates that are used safely for the production of edible insects should be formed.

Insects could contain some anti-nutritive factors (*Nishimune et al.*, 2000, *Shantibala et al.*, 2014). Considerations of allergic threats related to insects and their consumption are also ongoing. *EFSA* (2021) states that people allergic to mites are also potentially sensitive to some edible insects; allergens from feed consumed by larvae can have a prolonged allergenic effect. Edible insect allergens appear to be resistant to heat treatments and enzyme digestion (unless very specific conditions are applied), similar to the behaviour of crustacean allergens (*Ribeiro et al.*, 2021). Therefore, for safety reasons, it is necessary for food products made from insects to be clearly labelled and adequately declared in order to draw attention and warn susceptible consumers (*Nešić et al.,* 2020).

4. Placement of insects on food and feed market

In mid-2017, the European Commission adopted the amendment EU Regulation No. 2017/893 (*European Union*, 2017), allowing seven species to be reared and used in feeding aquaculture. This closed list of authorised insects includes: black soldier fly (*Hermetia illucens*), common housefly (*Musca domestica*), yellow mealworm (*Tenebrio molitor*), lesser mealworm (*Alphitobius diaperinus*), house cricket (*Acheta domesticus*), banded cricket (*Gryllodes sigillatus*) and field cricket (*Gryllus assimilis*). The conditions for the production of insect processed animal protein (PAP) are strictly regulated. Insects must be fed only with category 3 material (which in principle would still be appropriate for human consumption), not allowing, for example, manure or heavy metal contaminated debris as a feed source. Furthermore, insect PAP has to be treated at least according to method no. 7, following Regulation (EU) No. 142/2011 (*European Union*, 2011), which means that bacterial contamination must be reduced in order to make a safe product. By the EU Regulation 2021/1372 (*European Union*, 2021), entered into force on September 7th 2021, insects are, besides for aquaculture animals and pets, for the first time officially approved for use in pig and poultry nutrition.

For the approval of novel food in Europe, Regulation 2015/2283 has been in force from 2018 (*European Union*, 2015). This regulation determines conditions that allow food business operators to introduce new food items to the EU market, while ensuring a high level of food safety for European consumers. Insects are explicitly mentioned, for which traditional use in the European Union is not evident. It is necessary for companies placing insects on the EU market to submit an application for review and approval to EFSA. However, in certain cases, a simplified procedure is possible for traditional food originating from third countries, if it can be proven that it has been part of the human diet for at least 25 years without any safety concerns. Considering that, it is expected that some insects or their products will enter the European market in this way.

The last authorisation of the European Commission was granted for frozen, paste, dried and powder forms of *Alphitobius diaperinus* (lesser mealworm) in January 2023. In addition to this insect, three more species were previously approved: *Acheta domesticus* (house cricket), *Tenebrio molitor* (yellow mealworm) and *Locusta migratoria*. Currently, there are eight applications for insects intended to be marketed in different forms, which are subject to a safety evaluation by EFSA (*European Commission*, 2023).

5. Conclusion

It is generally considered that insects as an ingredient in food and feed can be consumed without additional risks compared to conventional animal products. It is necessary to establish safety and quality standards from primary production to consumption, appropriate regulations and control methods for their implementation. The upcoming goal is also to help establish the profile of insects as a source of food and animal feed as recognized by national and international food agencies and to attract the attention of farmers, the media, the general public and decision makers in governments, donor agencies, investment firms, the large number of research centres and the food and feed industries. After all, consumer acceptance is crucial.

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References

Alexander, P., Brown, C., Arneth, A., Dias, C., Finnigan, J., Moran, D. & Rounsevell, M. D. A. (2017). Could consumption of insects, cultured meat or imitation meat reduce global agricultural land use? *Global Food Security*, 15, 22–32, https://doi.org/10.1016/j.gfs.2017.04.001

Barroso, F. G., de Haro, C., Sánchez-Muros, M-J., Venegas, E., Martínez-Sánchez, A. & Pérez-Bañón, C. (2014). The potential of various insect species for use as food for fish. *Aquaculture*, 422–423, 193–201, https://doi.org/10.1016/j.aquaculture.2013.12.024

Belluco, S., Losasso, C., Maggioletti, M., Alonzi, C. C., Paoletti, M. G. & Ricci, A. (2013). Edible insects in a food safety and nutritional perspective: A critical review. Comprehensive *Reviews in Food Science and Food Safety*, 12, 296–313, https://doi.org/10.1111/1541-4337.12014

Brandon, A. M., Gao, S. H., Tian, R. & Criddle, C. S. (2018). Biodegradation of polyethylene and plastic mixtures in mealworms (larvae of *Tenebrio molitor*) and effects on the gut microbiome. *Environmental Science and Technology*, 52, 6526–6533, https://doi.org/10.1021/acs.est.8b02301

Collavo, A., Glew, R. H., Huang, Y. S., Chuang, L. T., Bosse, R. & Paoletti, M. G. (2005). House cricket small-scale farming. In: Paoletti, M.G. Ecological implications of Minilivestock: Potential of insects, Rodents, Frogs and Snails. Science publisher, New Hampshire, USA.

De Paepe, E., Wauters, J., Van Der Borght, M., Claes, J., Huysman, S., Croubels, S. & Vanhaecke, L. (2019). Ultra-high-performance liquid chromatography coupled to quadrupole orbitrap high-resolution mass spectrometry for multi-residue screening of pesticides, (veterinary) drugs and mycotoxins in edible insects. *Food Chemistry*, 293, 187–196, https://doi.org/10.1016/j.foodchem.2019.04.082

Delgado, L., Garino, C., Moreno, F. J., Zagon, J. & Broll, H. (2022). Sustainable Food Systems: EU Regulatory Framework and Contribution of Insects to the Farm-To-Fork Strategy. *Food Reviews International*, http://dx.doi.org/10.1080/87559129.2022.2130354

EFSA (2015). Risk profile related to production and consumption of insects as food and feed. *EFSA Journal*, 13(10), 4257, https://doi.org/10.2903/j.efsa.2015.4257

EFSA (2021). Safety of dried yellow mealworm (*Tenebrio molitor* larva) as a novel food pursuant to Regulation (EU) 2015/22 83, Scientific Opinion. *EFSA Journal*, 19(1), 6343, https://doi.org/10.2903/j.efsa.2021.6343

European Commission. (2023). Approval of fourth insect as a Novel Food. Retrieved from https://food.ec.europa.eu/safety/novel-food/authorisations/approval-insect-novel-food_en. Accessed April 5, 2023.

European Union (2011). European Commission. Commission regulation (EU) No 142/2011 of 25 February 2011 implementing Regulation (EC) No 1069/2009 of the European Parliament and of the Council laying down health rules as regards animal by-products and derived products not intended for human consumption and implementing Council Directive 97/78/EC as regards certain samples and items exempt from veterinary checks at the border under that Directive. *Official Journal of the European Union*, L54, 1–25, http://data.europa.eu/eli/reg/2011/142/oj

European Union (2015). Regulation (EU) No 2015/2283 of 25 November 2015 on novel foods, amending Regulation (Eu) No 1169/2011 and repealing Regulation (EC) No 258/97 and Commission Regulation (EC) No 1852/2001. Official Journal of the European Union, L327, 1–22, http://data.europa.eu/eli/reg/2015/2283/oj

European Union (2017). Regulation (EU) No 2017/893 of 24 May 2017 amending annexes I and IV to regulation (EC) No 999/2001 of the European Parliament and of the Council and annexes X, XIV and XV to commission regulation (EU) No 142/2011 as regards the provisions on processed animal protein. *Official Journal of the European Union*, L138, 92–116, http://data.europa.eu/eli/reg/2017/893/oj

European Union (2021). Commission Regulation (EU) 2021/1372 of 17 August 2021 amending Annex IV to Regulation (EC) No 999/2001 of the European Parliament and of the Council as regards the prohibition to feed non-ruminant farmed animals, other than fur animals, with protein derived from animals. *Official Journal of the European Union*, L295, p. 1–17, http://data.europa.eu/eli/reg/2021/1372/oj

Ewuim, S. C. (2013). Entomoremediation — A novel in-situ bioremediation approach. *Animal Research International*, 10, 1681–1684.

FAO (2013). Edible insects: future prospects for food and feed security, FAO, UN, https://www.fao.org/3/i3253e/i3253e.pdf

FAO (2021). Looking at edible insects from a food safety perspective. Challenges and opportunities for the sector. Rome, https://doi.org/10.4060/cb4094en

Gałęcki, R. & Sokół, R. (2019). A parasitological evaluation of edible insects and their role in the transmission of parasitic diseases to humans and animals. *PLoS ONE*, 14, e0219303, https://doi.org/10.1371/journal.pone.0219303

Garofalo, C., Milanović , V., Cardinali, F., Aquilanti, L., Clementi, F. & Osimani, A. (2019). Current knowledge on the microbiota of edible insects intended for human consumption: A state-of-the-art review. *Food Research International*, 125, 108527, https://doi.org/10.1016/j.foodres.2019.108527

Gortari, M. C. & Hours, R. A. (2013). Biotechnological processes for chitin recovery out of crustacean waste: a mini review. *Electronic Journal of Biotechnology*, 16, http://dx.doi.org/10.2225/vol16-issue3-fulltext-10

Grabowski, N. T. & Klein, G. (2017). Microbiology of processed edible insect products — results of a preliminary survey. *International Journal of Food Microbiology*, 243, 103–7, https://doi.org/10.1016/j.ijfoodmicro.2016.11.005

Harsányi, E., Juhász, C., Kovács, E., Huzsval, L., Pintér, R., Fekete, G., Varga, Z. I., Aleksza, L. & Gyuricza, C. (2020). Evaluation of organic wastes as substrates for rearing *Zophobas morio*, *Tenebrio molitor*, and *Acheta domesticus* larvae as alternative feed supplements. *Insects*, 11(9), 604, https://doi.org/10.3390/insects11090604

Houben, D., Daoulas, G., Faucon, M.-P. & Dulaurent, A.-M. (2020). Potential use of mealworm frass as a fertilizer: Impact on crop growth and soil properties. Scientific Reports, 10, https://doi.org/10.1038/s41598-020-61765-x

Koh, D.W.-S., Ang, B.Y.-X., Yeo, J.Y., Xing, Z. & Gan, S.K.-E. (2020). Plastic agriculture using worms: Augmenting polystyrene consumption and using frass for plant growth towards a zero-waste circular economy. bioRxiv (preprint server), https://doi.org/10.14324/111.444%2F000048.v2

Law, Y. & Wein, L. (2018). Reversing the nutrient drain through urban insect farming — opportunities and challenges. *AIMS Bioengineering*, 5, 226–237, https://doi.org/10.3934/bioeng.2018.4.226

Milanović, V., Osimani, A., Pasquini, M., Aquilanti, L., Garofalo, C., Taccari, M., Cardinali, F., Riolo, P. & Clementi, F. (2016). Getting insight into the prevalence of antibiotic resistance genes in specimens of marketed edible insects. *International Journal of Food Microbiology*, 227, 22–28, https://doi.org/10.1016/j.ijfoodmicro.2016.03.018

Murefu, T. R., Macheka, L., Musundire, R. & Manditsera, F. A. (2019). Safety of wild harvested and reared edible insects: A review. *Food Control*, 101, 209–224, https://doi.org/10.1016/j.foodcont.2019.03.003

Nesic, K. (2022). Insekti kao izvor proteina u hrani i hrani za životinje. Naučni institut za veterinarstvo Srbije, Beograd, Srbija.

Nesic, K. & Zagon, J. (2019). Insects — a promising feed and food protein source? *Meat Technology*, 60(1), 56–67, https://doi.org/10.18485/meattech.2019.60.1.8

Nešić, K., Tasić, A. & Pavlović I. (2020). Insekti kao održivi izvori proteina u hrani i hrani za životinje. *Ecologica*, 99, 553–559.

Nishimune, T., Watanabe, Y., Okazaki, H. & Akai H. (2000). Thiamin is decomposed due to *Anaphe spp.* entomophagy in seasonal ataxia patients in Nigeria. *The Journal of Nutrition*, 130(6), 1625–1628, https://doi.org/10.1093/jn/130.6.1625

Nukmal, N., Umar, S., Amanda, S. P. & Kanedi, M. (2018). Effect of styrofoam waste feeds on the growth, development and fecundity of mealworms (*Tenebrio molitor*). *OnLine Journal of Biological Sciences*, 18, 24–28, https://doi.org/10.3844/ojbsci.2018.24.28

Oonincx, D. G . A . B., Van Itterbeeck, J., Heetkamp, M. J. W., Van Den Brand, H., Van Loon, J. J. A. & Van Huis, A. (2010). An exploration on greenhouse gas and ammonia production by insect species suitable for animal or human consumption. *PLoS ONE*, 5, e14445, https://doi.org/10.1371/journal.pone.0014445

Parry, N. J., Pieterse, E. & Weldon, C. W. (2020). Stocking rate and organic waste type affect development of three *Chrysomya* species and *Lucilia sericata* (*Diptera: Calliphoridae*): Implications for bioconversion. *Journal of Applied Entomology*, 144, 94–108, https://doi.org/10.1111/jen.12712

Payne, C. L. R., Scarborough, P., Rayner, M. & Nonaka, K. (2016). A systematic review of nutrient composition data available for twelve commercially available edible insects and comparison with reference values. *Trends in Food Science and Technology*, 47, 69–77, https://doi.org/10.1016/j.tifs.2015.10.012

Poma, G., Cuykx, M., Amato, E., Calaprice, C., Focant, J. F. & Covaci, A. (2017). Evaluation of hazardous chemicals in edible insects and insect-based food intended for human consumption. *Food and Chemical*, 100, 70–9, https://doi.org/10.1016/j.fct.2016.12.006

Ribeiro, J. C., Sousa-Pinto, B., Fonseca, J., Caldas Fonseca, S. & Cunha, L. M. (2021). Edible insects and food safety: allergy. *Journal of Insects as Food and Feed*, 7(5), 833–847, https://doi.org/10.3920/JIFF2020.0065

Rumpold, B. A. & Schluter, O. K. (2013). Nutritional composition and safety aspects of edible insects. *Molecular Nutrition and Food Research*, 57(5), 802–823, https://doi.org/10.1002/mnfr.201200735

Shantibala, T., Lokeshwari, R. K. & Debaraj, H. (2014). Nutritional and antinutritional composition of the five species of aquatic edible insects consumed in Manipur, India. *Journal of Insect Science*, 14, https://dx.doi.org/10.1093%2Fjis%2F14.1.14

Truzzi, C., Annibaldi, A., Girolametti, F., Giovannini, L., Riolo, P., Ruschioni, S., Olivotto, I. & Illuminati, S. (2020). A Chemically Safe Way to Produce Insect Biomass for Possible Application in Feed and Food Production. *International Journal of Environmental Research and Public Health,* 17(6), 2121, https://doi.org/10.3390/ijerph17062121

Vandeweyer, D., Lievens, B. & Van Campenhout, L. (2020). Identification of bacterial endospores and targeted detection of foodborne viruses in industrially reared insects for food. *Nature Food*, 1, 511–516, https://doi.org/10.1038/s43016-020-0120-z

Verheyen, G. R., Theunis, M., Vreysen, S., Naessens, T., Noyens, I., Ooms, T., Goossens, S., Pieters, L., Foubert, K. & Van Miert, S. (2020). Glycine-acyl surfactants prepared from black soldier fly fat, coconut oil and palm kernel oil. *Current Green Chemistry*, 7, 239–248, http://dx.doi.org/10.2174/2213346107999200424084626

Walia, K., Kapoor, A. & Farber, J. M. (2018). Qualitative risk assessment of cricket powder to be used to treat undernutrition in infants and children in Cambodia. *Food Control*, 92, 169–182, https://doi.org/10.1016/j.foodcont.2018.04.047

Wang, H., Rehman, K., Xiu Liu, Yang, Q., Zheng, L., Li, W., Cai, M., Li, Q., Zhang, J. & Yu, Z. (2017). Insect biorefinery: a green approach for conversion of crop residues into biodiesel and protein. *Biotechnology for Biofuels*, 10, 304–317, https://doi.org/10.1186/s13068-017-0986-7

Yandi, I., Öztürk, R. C., M. Kocabas, M., Kurtoglu, I. Z. & Altinok, I. (2023). Nutritional composition of black soldier fly (*Hermetia illucens*) reared on chicken waste meal, fruit & vegetable waste, and their mixture. *Journal of Insects as Food and Feed* (in press), 1–12, https://doi.org/10.3920/JIFF2022.0064