Academia Journal of Agricultural Research 4(6): 000-000, June 2016
DOI: 10.15413/ajar.2016.0600
ISSN: 2315-7739
©2016 Academia Publishing

Research Paper

Potential Use of Irradiation on Edible Insects

Accepted 4th May, 2016

Nelida L. del Mastro

Instituto de Pesquisas Energéticas e Nucleares IPEN-CNEN/SP, Sao Paulo, Brazil.

*Corresponding author e-mail:

ABSTRACT

Edible insects attracted a great deal of Western interest in recent years due to their nutritional and environmental advantages, such as low levels of greenhouse gases emission. Insects have high food-to-biomass conversion efficiency, quick growth rate, enormous variety and worldwide distribution, although, until now, there is a limited amount of data on the perception and consumption of insects. By means of irradiation, different kinds of food products are exposed to certain types of radiation (electron beams, gamma and or x-rays) mainly to kill germs without harming the substance under disinfection or making it radioactive. The aim of the present article is to review important aspects of this innovative type of food highlighting that, although insects are unlikely to be consumed raw, edible insects may benefit from the use of irradiation as a measure for food safety.

Key words: Edible insects, ionizing radiation, protein food, innovative food product, food safety.

INTRODUCTION

Several insects can be produced for food and for feed (Oonincx et al., 2015). The rearing of insects has been practiced for at least 7,000 years, for sericulture, the production of shellac and, later, apiculture (Rumpold and Schluter, 2013). At least 2 billion people eat insects (over 1900 edible species) globally, though; others regard this habit as negative.

Insects constitute quality food and feed and may, partially, replace them increasing protein ingredients of compound feeds in the livestock, poultry and aquaculture industries. Grains now used as livestock feed, which often comprise half the cost of meat production, could be used for human consumption. There are more than a million species of the class of insects like the crustaceans (shrimps, lobster and krill), to the arthropods (Carpinera, 2015). Not all insects are safe to eat, some are not edible and cause allergic reactions in some individuals, even after heat processing, just as it happens with plants or any animal food (Van Broekhoven et al., 2016; Srinroch et al., 2015).

Edible insects collected in the wild may contain pesticides when they feed in pesticide-treated areas. Risks can be prevented by the consumption of common edible species reared in pollutant-free feed. For all insects, either harvested in the wild or on farms, proper processing, handling and storage is required in order to prevent contamination and spoilage, besides ensuring food and feed safety.

In contrast to countries such as China, in Western societies, the consumption of insects is not rooted in traditional diet. Nevertheless, several species of insects are prized delicacies in advanced countries, such as Japan, Australia and Europe. Hence, insects are not restricted to being 'subsistence food' of grossly impoverished people as one might imagine, though a lot of species do help the world's poor to survive. Tabassum et al. (2016) considered the fact that human beings evolved as entomophagous species and some of the special proteins and other constituents present in the insects, might have helped the human brain to develop as rapidly as it did and enable its

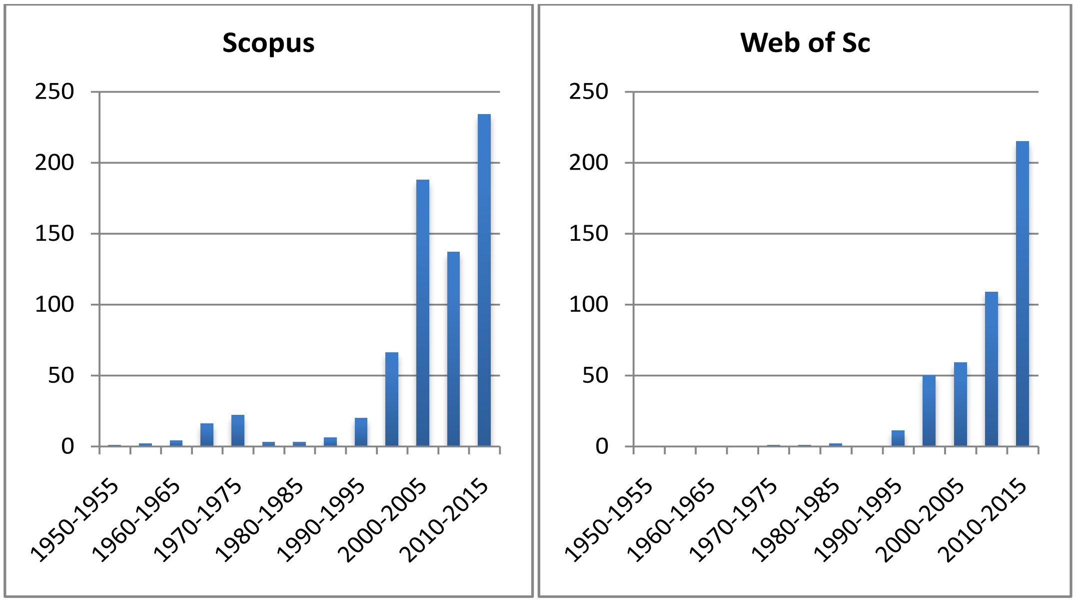

Figure 1. Surveys of the number of articles published from 1950 to 2015, using *edible insects* as tag on Scopus (left) and Web of Science (right).

evolution into Home sapiens.

Like most animals, edible insects are rich in protein and fat, but, poor in carbohydrates, containing a variety of micronutrients and they are, therefore, seen as potential contributors to food security. Development rate and chemical composition of edible insects depend on the diet they are reared. All insects undergo metamorphosis with different development stages and may be consumed in all those phases, although most data on edible insects are compiled for adult and larval stages. Examples of a wide variation of the pupal stages are described, and this occurrence may be an adaptation to annual climatic fluctuations, such as years without rain or late rainfall. The larvae present the highest mortality rate, followed by the pupae and, then, the eggs (Egan et al., 2015).

The presence of microbial pathogens on human foods is a serious global problem. Even in highly industrialized and developed countries like the United States of America, pathogen-contaminated foods and the resulting health and economic impacts are significant (Smith and Pillai, 2004).

Prevention of contamination is the most efficient way to ensure food safety. This is, however, not always possible. The application of ionizing radiation to food is a technology that improves the safety and extends the shelf life of foods, by reducing or eliminating microorganisms that cause spoilage and foodborne illnesses, such as *Salmonella* sp. and *Escherichia coli*, making food safer for the consumer (WHO, 1994; Farkas, 2007; Kume et al., 2009; Department of Health and Human Services, 2014).

The aim of the present paper is to present the potential role that irradiation may have by offering an extra guarantee by making edible insects safer. On the other side, the purpose of this article is also to highlight important benefits resulting from the introduction of this innovative type of food in our diet or as an ingredient for the food industry (Mariod and Fadul, 2015).

Scientific interest in edible insects

The interest in edible insects in the global community has increased in recent years. As a FAO (Food and Agriculture Organization of the United Nations) document (Van Huis et al., 2013) emphasized that insects offer a significant opportunity to merge traditional knowledge and modern science improving human food security worldwide that is possible to perceive analyzing data collected from two different databases on scientific papers using edible insects as tag. Figure 1 presents the results of two surveys of the number of scientific articles on edible insects published since 1950 until 2015, according to SCOPUS and Web of Science. Although, some discrepancies are evident, data from both databases showed a sharp increase on published articles on edible insects about the turn of the century, going up afterward.

Cultural aspects, consumer acceptability and regulations of insects as food

Consumer acceptance of innovative food technologies and products is a function of public trust in societal institutions to effectively manage a technology and the perception of benefits and risk (Sapp and Downing-Mati, 2009; Siegrist, 2008).

Particularly, the acceptance and rejection factors of unfamiliar food items depend on cultural identity and individual experience. Barennes et al. (2015) described that, although entomophagy is general and well accepted in Laos, it is limited to a minority of frequent consumers and income through insect sales benefits, mostly, women. They realized that consumption of edible insects varies according to ethnicity, residence and season and, also, that the development of insect farming is still at an early stage. Recently, Megido et al. (2016) reported that they made a cheap and residential small-scale production of edible crickets with local by-products in Cambodia.

Das et al. (2015) surveyed the use of edible insects by the Rabha people in Goalpara district of Assam. A total of 13 species belonging to 12 families and 13 genera were reported to be consumed by the Rabha people of the district. Both Hymenoptera and Lepidoptera order shared with a maximum number of 3 species, followed by Orthoptera and Hemiptera, by 2 species each and other orders sharing single species. April to June was the best period for most of the edible insects' collection. Apart from nutrition, edible insects also provide earning to the tribal people. The pupa and larva of *Antheraeaas samensis*, *Philoson ziaricini*, *Bombyxn zori* and the adult *Lethocercus* sp. are sold in the village markets. *Philoso miaricini* and *A. samensis* are reared for production of silk, while *Apisindica* is the Hymenopteran from where honey and different important by-products are found. Those authors considered that scientific investigation on the nutrient capabilities of these edible insects is urgent, in order to recognize them for common use and marketing.

In Western countries, until now, the majority of the population seems to reject the idea of adopting insects as food, predominantly, because people are not used to it. According to Van Huis (2013) in the Western world, consumer acceptability relates to pricing, perceived environmental benefits and the development of tasty insect-derived protein products. Positive sensory experience plays a necessary role in the process of learning to accept any food, but it can be inadequate when unusual and culturally inappropriate foods are involved. As curious tasting does not imply acceptance to introduce unusual novel foods, like insects, efforts must be made to understand consumer expectations regarding their consumption (2015).

Tan et al. (2016) analyzed cultural exposure and individual experience as determinants for the acceptance of insects as food. They performed an experiment with eight focus groups, across two cultures in Thailand - where insects are part of the local food culture - and four in the Netherlands, where insects are generally not recognized as food. Within these cultures, two groups consisted of individuals who have experience in eating insects and two groups consisted of individuals with little or no experience in insects as food. Cultural exposure created expectations of which species were more appropriate to eat and how they should be prepared, whereas individual experiences determined whether judgments were made based on memories of past eating experiences or based on the visual properties and item associations.

In a study performed by Hartmann et al. (2015), data were collected from adults in Germany (n = 502) and China (n = 443) and the influence of food neophobia on consumers' willingness to eat insects was examined in a cross-cultural comparison based on consumers' willingness to eat different insect-based, processed (for example, cookies based on cricket flour) and unprocessed (for example, crickets) food. The Chinese rated all insect-based food more favorably with regard to taste, nutritional value, familiarity and social acceptance as compared with the Germans. The Chinese indicated greater willingness to eat the tested food products and no differences were observed between their ratings of processed and unprocessed food. Germans reported higher willingness to eat the processed insect-based foods compared with the unprocessed foods. Further results revealed that low scores for food neophobia, positive taste expectations, high scores for social acceptance and experience with eating insects in the past were significant predictors of consumers' willingness to eat insects in both countries.

In another study, Sogari (2015) established that curiosity and environmental benefits are the most important factors to motivate the consumption of insects in the future, although he considers that other negative opinions might represent a significant barrier to introduce edible insects in the Western diet. Shelomi (2015) and Hamerman (2016) suggest that to overcome strong disgust sensitivity or passive rejection of insect as food, it will be necessary to market insects appropriately or use them as livestock feed to facilitate their acceptance.

Verbeke et al. (2015) studied the attitudes towards and willingness-to-accept insect-based animal feed and foods from a sample of 415 farmers, agriculture sector stakeholders and citizens in Flanders, Belgium. Attitudes towards the idea of using insects in animal feed were generally favorable, most notably for fish and poultry feed. Two thirds of the study participants were willing-to-accept the use of insects in animal feed. The food obtained from animals fed with insect-based feed was widely accepted. Insect-based feed was perceived to be more sustainable to have better nutritive value, but lower microbiological safety as compared to conventional feed, although benefit perception was stronger and outweighed risk perception as a determinant for accepting the use of insects in animal feed. Then, from our point of view, irradiation may contribute as extra guarantee for food safety.

Baker et al. (2016) made an exploration and investigation of edible insect consumption. Their results found that, in retail settings, the vision was the most significant in reducing perception of risk, while in the restaurant setting, menu description was more important. In addition, vague descriptions were more preferable when giving description to minimize the possibility of risk by the public and increase purchase intention.

There are few examples of national regulations that govern insects for human consumption. Where entomophagy is not common, the current regulatory discourse focuses primarily on food safety and consumer protection. In countries where insects contribute to local diets, nature conservation is often an issue of high importance. The variation in the ways entomophagy and its related activities are currently regulated was investigated in Thailand, Switzerland, Kenya and Canada. Insects have not been incorporated into a policy of documents yet and they have been largely omitted from regulatory frameworks. Moreover, even in nations where there is a tradition of consuming a variety of insect species, they do not appear explicitly in dietary guidelines. Although, food safety is a major concern, it is also an important nature conservation, traditional food culture, food security and potential economic development of edible insects. The development of future legislation should take into consideration the multi-dimensional nature of this subject (2015).

Insect as source of food and feed

In response to the promotion of insects as food and feed by the FAO (Van Huis et al., 2013) insect farming is now a growing industry across the world. In 2014, edible insects have been introduced, officially, into the European Union market in Belgium and the Netherlands as foodstuffs, presenting national regulations in order to ensure food safety. Entomophagy is also, practiced on a small scale in other EU countries, for example, Germany. Consumers and public health staffs are interested in knowing more about this type of food and identification of edible insects is one of the information fields that require attention (Grabowski et al., 2016).

Insects can be considered food with satisfactory energy and protein content, good amino acid and fatty acid profiles and high contents of a variety of micronutrients, such as minerals, namely, copper, iron, magnesium, manganese, phosphorous, selenium, and zinc; the following vitamins: riboflavin, pantothenic acid, biotin and in some cases, folic acid (Legner and Pelsue, 1980; Rumpold and Schluter, 2013). The content of protein, fat, carbohydrates, ash, fiber, minerals, amino acids and fatty acids in adult cricket (*Gryllodessi gillatus*), larvae of mealworm (*Tenebrio molitor*) and adult locust (*Schistocerca gregaria*) were analyzed (Zielinska et al., 2015). The protein content ranged from 52.35 to 76%. The fat percentage was in the range of 12.97 to 24.7%. Energy contribution varied from 1821 to 1896 kJ/100 g. The amino acid profile was comparable with the WHO/FAO/UNU Pattern (WHO, 2007). The highest degree of hydrolysis (DH) was noted in baked *G. gillatus* (37.76%). All species showed to be very rich in magnesium, copper, iron and zinc and the mineral content was compared to the recommended daily intakes (mg/day).

FAO/INFOODS collected and published analytical data from primary sources with sufficient quality in the Food Composition Database for Biodiversity (BioFood Comp), for 456 food entries on insects in different developmental stages. Data analysis of *T. molitor* confirms its nutritive quality, which can help to combat malnutrition. This collection of data will assist compilers to incorporate more insects into tables and databases and to further improve nutrient intake estimations (Nowak et al., 2015). Payne et al. (2016) called attention to discrepant information regarding the nutritional composition of commercially available insect species and within-species variation, as to the proportion of both macro-and micronutrients. They pointed out the need for greater adherence to international guidelines, such as INFOODS/EuroFIR recommendations. They also highlighted the importance of external factors, such as feed and ecology to determine the nutrient composition.

Toxicological evaluations of edible insects are scarce in the literature. Noh et al. (2015) administered orally freeze-dried powder of *A. dichotoma* larvae to rats, at 3 dose levels, for 28 days. The powder exhibited no mutagenic or clastogenic effects. They concluded that the NOAEL (No Observed Adverse Effect Level) of the freeze-dried powder from *A. dichotoma* larvae was 2500 mg/kg/day, or more in both sexes of rats.

Microbiological aspects

Food quality and safety concerns are of extreme importance when edible insects are promoted as an environmentally friendly source of food. As a rule, bacterial flora as well as, mycotoxins found in edible insects may vary in accordance with how they are handled during extraction, collection and transport, as established by different authors. Musundire et al. (2016) detected mycotoxin (aflatoxin B-1) at low levels in edible *Encosternum delegorguei* stink bugs, which are widely consumed in southern Africa, but, only when stored in traditionally woven wooden dung smeared baskets and gunny bags, previously used to store cereals. Those bugs were absent in insects stored in clean zip lock bags.

Hernandez-Flores et al. (2015) studied the external and internal cultivable bacterial community present in the larvae of an edible insect, *Comadiared tenbacheri Hammerschmidt*. Characterization of the isolates determining the existence of 18 morphotypes and phylogenetic analysis of the 16S rRNA gene revealed the existence of *Paenibacillus* sp., *Bacillus safensis*, *Pseudomonas* sp., *Bacillus pseudomycoides*, Coryne bacterium variabile, Enterococcus sp., Gordonia sp., *Acinetobacter calcoaceticus*, *Arthrobacter* sp., *Micrococcus* sp. and *Bacillus cereus*. Greater diversity of bacteria was found in larvae obtained from vendors than in those directly taken from Agave plants in nature. Many of the larvae obtained from vendors presented signs of potential disease and, after the analysis, results showed a greater bacterial community as compared with the larvae with a healthy appearance. This indicates that bacterial flora may vary in accordance with how the larvae were handled.

Klunder et al. (2012) made a study with mealworm larvae (*Tenebrio molitor*) from an insect farm in The Netherlands, live house smallcricket (*Acheta domesticus*) purchased from a locally produced field in Vientiane and large cricket (*Brachytrupus* sp), traditionally collected on a tobacco field in Nam Lo, both in Lao PDR, and analyzed the microbiological content of the whole edible insects, when fresh, processed and stored. They studied total viable counts, Enterobacteriaceae and bacterial spores and found that the overall levels of colony forming units (CFU)/g of total viable counts, Enterobacteraceae and spore forming bacteria, were at typical levels for fresh food harvested from soil or having been in contact with soil materials. Crushing of the mealworm resulted in higher counts of viable bacteria as a result of the release of microbiota from the insect's intestines. Enterobacteriaceae were killed during boiling of all insect species, but, not during roasting. Blanching the insects in boiling water for few minutes, previously to the roasting eliminated most of the present Enterobacteriaceae.

Stoops et al. (2016) assessed the microbial community of mealworm larvae (*T. molitor*) and grasshoppers (*Locusta migratoria migratorioides*) sold for human consumption. High microbial counts were obtained for both insect species, but, with different bacterial community composition. Different insect batches resulted in quite similar microbial numbers, except for bacterial endospores. The most abundant operational taxonomic unit in mealworm larvae was *Propioni bacterium*. Also, members of the Haemophilus, Staphylococcus and Clostridium genera were found. Grasshoppers were mainly dominated by Weissella, Lactococcus and Yersinia/Rahnella. Overall, a variety of potential spoilage bacteria and food pathogens were characterized. Even if the edible insects were usually eaten cooked instead of raw, the results of that study suggest that a processing step with a microbiocidal effect is required to avoid or minimize risks involved with the consumption of edible insects. Irradiation may fulfill such a role.

Suitability and environmental benefits of rearing insects

A large part of the environmental impact of animal production systems is due to the production of feed. Insects convert feed to body mass efficiently and might, therefore, form a more sustainable food and/or feed source, having obvious potential as a much more sustainable source of animal protein than conventional livestock, as livestock production is among the most ecologically harmful of all anthropogenic activities (Srinroch et al., 2015).

Conventional ways of animal protein production through livestock (chicken, goat, pork and beef) are highly eco-degrading; in terms of availability of pasture lands and productivity of edible zoo mass and the upper limits of animal protein production have already been reached.

An experiment was conducted by Oonincx et al. (2010) to quantify the production of carbon dioxide (CO_2) and average daily gain (ADG), as a measure of feed conversion efficiency and to quantify the production of the greenhouse gases methane (CH_4) and nitrous oxide (N_2O), as well as, NH_3 by five insect species of which the first three are considered edible: *T. molitor*, *Acheta domesticus*, *Locusta migratoria*, *Pachnoda marginata*, and *Blaptic adubia*. Large differences were found among the species regarding the production of CO_2 and GHGs. The insects in that study had a higher relative growth rate and emitted comparable or lower amounts of GHG than those described in the literature for pigs and much lower amounts of GHG than cattle. The same was true for CO_2 production per kg of metabolic weight and per kg of mass gain. Furthermore, the production of NH_3 by insects was lower than that for conventional livestock, indicating that insects could serve as a more environmentally friendly alternative for the production of animal protein regarding GHG and NH_3 emissions.

Oonincx et al. (2010) analyzed the feed conversion, survival, development and composition of four insect species (newly hatched Argentinean cockroaches, black soldier flies, yellow mealworms and house crickets) on diets composed of food by-products. The Argentinean cockroaches and the black soldier flies converted into feed more efficiently than yellow mealworms and house crickets. The first two were also more efficient than conventional production animals. On three of the four diets, yellow mealworms and house crickets had feed conversion efficiency similar to pigs. Furthermore, on the most suitable diet, they were converted into feed as efficiently as poultry when corrected for edible portion. All four species had a higher nitrogen-efficiency than conventional production animals when corrected for edible portion. Diet affected survival in all species except black soldier flies and development time was strongly influenced in all four species. The chemical composition of Argentinean cockroaches was highly variable among the diets, for black soldier flies it remained similar. Those authors concluded that the investigated species are efficient production animals when suitable diets are provided.

Miglietta et al. (2015) evaluated the water footprint (WF) as a reliable indicator to calculate the volume of water required for the production of two species of edible insects (*T. molitor* and *Zophobas morio* mealworms) already commercially produced in Western countries and compared with other animal protein sources. They demonstrated that from a freshwater resource perspective, it is more efficient to obtain protein through mealworms rather than other traditional farmed animals.

If insects were to be used massively, traditional methods of harvesting insects are not sustainable methods of production. Most are harvested in the wild and there is a need to develop harvesting and habitat management protocols to ensure sustainability. Detailed scientific information on most species is lacking. Then, it is necessary to develop appropriate methods of mass-producing insects and management plans to conserve selected species: traditional knowledge is an important and valuable foundation in order to preserve at the same time, natural ecosystems as Moon and Lee (2015) and Yen (2015) recommended.

Conclusion

The acceptance of new food productsdepends on the consumer's perception of benefits and risks: impact of the technology on taste, convenience, nutritional value, the perceived safety, and the effect of the technology on the environment.The introduction of insects as a food source in Western societies seems more likely to succeed when insects were incorporated into familiar food items, which will reduce neophobic reactions and negative attitudes towards insect-based foods.As traditional methods of harvesting insects are not sustainable, appropriate methods of mass-production of insect, without putting a strain on the natural ecosystem, are required.Although insect feed or food is a sustainable and nutritious option,it carries the risk perception of low microbiological safety.Then, food irradiation can certainly act as a supplemental tool for managingpossible presence of pathogens. As no deep study has been developed so far, applying radiation treatment to edible insects, experimental work is needed to establish proper irradiation conditions. Irradiated products are increasingly meeting consumers' expectations, in terms of safety and qualityand, thus, the application of radiation processing to any innovative food item would be suitable.

REFERENCES

Baker MA, Shin JT, Kim YW (2016). An Exploration and Investigation of Edible Insect Consumption: The Impacts of Image and Descriptionon Risk Perceptions and Purchase Intent. Psychol. Mark. 33(2): 94-112.

Barennes H, Phimmasane M, Rajaonarivo C (2015). Insect Consumption to Address Under-nutrition, a National Survey on the Prevalence of Insect Consumption among Adults and Vendors in Laos. PloS One. 10(8): e0136458.

Carpinera JL (2015). Encyclopedia of Entomology. 1-4.

Das J, Kalita S, Talukdar K, Das S (2015). Ethno-entomological practices of Rabha tribe with special reference to edible Insects in Goalpara District of Assam. Environ. Ecol. 33(4A): 1662-1666.

Department of Health and Human Services (US) (2014). Food and Drug Administration. Irradiation in the production, processing, and handling of food: final rule. https://www.federalregister.gov/articles/2014/04/14/2014-07926/irradiation-in-the- production-processing-and-handling-of-food.

Egan BA, Addo-Bediako A, Toms R, Minter L, Olivier PAS (2015). Fecundity and survival of the edible insect, Hemijanavariegata Rothschild 1917 (Lepidoptera: Eupterotidae) underambientlaboratoryconditions. Afr. Entomol. 23(2): 286-293.

Farkas J (2007). Physical methods of food preservation. in: Foyle MP, Beuchat LR, editors. Foodmicrobiology: fundamentalsandfrontiers. Washington: ASM Press. pp. 685-712.

Grabowski NT, Grootaert P, Ahlfeld B, Klein G (2016). Practical key to identify entire edible insects sold as food stuff or feed stuff in central Europe. J. Food Safety Food Qual. 67(1): 4-11.

Hamerman EJ (2016). Cooking and disgust sensitivity influence preference for attending insect-based food events. Appetite. 96: 319-326.

Hartmann C, Shi J, Giusto A, Siegrist M (2015). The psychologyofeatinginsects: A cross-cultural comparison between Germany and China. Food Qual. Prefer. 44: 148-156.

Hernandez-Flores L, Llanderal-Cazares C, Guzman-Franco AW, Aranda-Ocampo S (2015). Bacteria Present in Comadiaredtenbacheri Larvae (Lepidoptera: Cossidae). J. Med. Entomol. 52(5): 1150-1158.

Klunder HC, Wolkers-Rooijackers J, Korpela JM, Nout MJR (2012). Microbiological aspects of processing and storage of edible insects. Food Control. 26: 628-631.

Kume T, Furuta M, Todoroki S, Uenoyama N, Kobayashi Y (2009). Status offoodirradiation in the world. Radiat. Phys. Chem. 78(3): 222-226.

Legner EF, Pelsue FW (1980). Bioconversion – Tilapia fish turn insects and weeds into edible protein. California Agriculture 34(11-1): 13-14.

Mariod AA, Fadul H (2015). Extraction and characterization of gelatin from two edible Sudanese insects and its applications in ice cream making. Food Sci. Technol. Int. 21(5): 380-391.

Megido RC, Alabi T, Nieus C, Blecker C, Danthine S, Bogaert J, Haubruge E, Francis F (2016). Optimisation of a cheap and residential small-scale production of edible crickets with local by-products as analternative protein-rich human food source in Ratanakiri Province, Cambodia. J. Sci. Food Agric. 96(2): 627-632.

Miglietta PP, De Leo F, Ruberti M, Massari S (2015). Mealworms for Food: A Water Footprint Perspective. Water. 7(11): 6190-6203.

Moon SJ, Lee JW (2015). Current views on insect feed and its future. Entomol. Res. 45(6): 283-285.

Musundire R, Osuga IM, Cheseto X, Irungu J, Torto B (2016). Aflatoxin Contamination Detected in NutrientandAnti-Oxidant Rich Edible Stink Bug Stored in Recycled Grain Containers. Plos One. 11(1): e0145914.

Noh JH, Yun EY, Kim JY, Lee BS, Hwang JS, Jeong EJ, Moon KS (2015). Toxicological evaluation of genotoxicity and 28-day oral toxicity study on freeze-dried powder of *Allomyrina dichotoma larvae*. J. Asia-Pacific Entomol. 18(4): 807-813.

Nowak V, Persijn D, Rittenschober D, Charrondiere UR (2015). Review of food composition data for edible insects. Food Chem. 193: 39-46.

Oonincx DGAB, van Broekhoven S, van Huis A, van Loon JJA (2015). Feed Conversion, Survival and Development, and Composition of Four Insect Specieson Diets Composed of Food By-Products. PloS One. 10(12): e0144601.

Oonincx DGAB, van Itterbeeck J, Heetkamp MJW, van den Brand H, van Loon JJA, van Huis A (2010). An Exploration on Green house Gas and Ammonia Production by Insect Species Suitable for Animal or Human Consumption. PLoS One. 5(12): e14445.

Payne CLR, 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 Food Sci. Technol. 47: 69-77.

Rumpold BA, Schluter OK (2013). Nutritional composition and safety aspects of edible insects. Mol. Nutr. Food Res. 57(5): 802-823.

Rumpold BA, Schluter OK (2013). Potential and challenges of insects as an innovative source for food and feed production. Innov. Food Sci. Emerg. Technol. 17: 1-11.

Sapp SG, Downing-Mati T (2009). Consumer acceptance of food

irradiation: a test of the recreancy theorem. Int. J. Consumer Stud. 33(4): 417-424.
Shelomi M (2015). Why we still don't eat insects: Assessing entomophagy promotion through a diffusion of innovations framework. Trends Food Sci. Technol. 45(2): 311-318.
Siegrist M (2008). Factors influencing public acceptance of innovative food technologies and products. Trends Food Sci. Technol. 19(11): 603–608.
Smith JS and Pillai S (2004). Irradiation and Food Safety. Food Technol. 58(11): 48-55.
Sogari G (2015). Entomophagy and Italian consumers: an exploratory analysis. Progress in Nutr. 17(4): 311-316.
Srinroch C, Srisomsap C, Chokchaichamnankit D, Punyarit P, Phiriyangkul P (2015). Identification of novel allergen in edible insect, Gryllusbimaculatus and its cross-reactivity with Macrobrachium spp. allergens. Food Chem. 188: 673-673.
Stoops J, Crauwels S, Waud M, Claes J, Lievens B, Van Campenhout L (2016). Microbial community assessment of meal worm larvae (*Tenebrio molitor*) and grasshoppers (*Locusta migratoria migratorioides*) sold for human consumption. Food Microbiol. 53: 122-127.
Tabassum A, Abbasi T, Abbasi SA (2016). Reducing the global environmental impact of livestock production: the mini livestock option. Journal of Cleaner Production. 112: 1754-1766.
Tan HSG, Fischer ARH, van Trijp HCM, Stieger M (2016). Tasty but nasty? Exploring the role of sensory-liking and food appropriateness in the willingness to eat unusual novel foods like insects. Food Qual. Prefer. 48: 293-302.
Van Broekhoven S, Bastiaan-Net S, de Jong NW, Wichers HJ (2016). Influence of processing and in vitro digestion on the allergic cross-reactivity of three meal worm species. Food Chem. 196: 1075-1083.
Van Huis A, Van Itterbeeck J, Klunder H, Mertens, Halloran A, Muir G, Vantomme P (2013). Edible insects: Future prospects for food and feed security. FAO Forestry, paper 171. Food and Agriculture Organization of the United Nations, Rome, ISSN 0258-6150. pp. 187. http://www.fao.org/docrep/018/i3253e/i3253e.pdf.
Van Huis A (2013). Potential of Insects as Food and Feed in Assuring Food Security. Annu. Rev. Entomol. 58: 563-583.
Verbeke W, Spranghers T, De Clercq P, De Smet S, Sas B, Eeckhout M (2015). Insects in animal feed: Acceptance and its determinants among farmers, agriculture sector stakeholders and citizens. Anim. Feed Sci. Technol. 204: 72-87.
WHO (1994). Safety and nutritional adequacy of irradiated food. World Health Organization, Geneva, Switzerland.
Yen AL (2015). Conservation of Lepidopteraused as human food and medicine. Curr. Opin. Insect Sci. 12: 102-108.
Zielinska E, Baraniak B, Karas M, Rybczynska K, Jakubczyk A (2015). Selected species of edible insects as a source of nutrient composition. Food Res. Int. 77: 460-466.

View publication stats