

Chapter 4:

Insects' Oil as an Alternative Lipid Source: Extraction, Composition, and Potential Applications

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Insects offer a promising solution as a source of food due to their fascinating life cycles. Their rapid turnover is a marvel of efficiency. Insects have the ability to adapt and thrive across different environmental conditions. Many types of insects are found to have high oil contents and efficient conversion of organic matter into valuable nutrients. However, the utilization of insect as an oil source raises questions regarding its compliance with Halal and Kosher dietary laws, which are significant considerations for Muslim and Jewish communities, respectively. In this review we are trying to discuss the potential uses of insect farming and processing technologies aimed at addressing concerns related to insects as an alternative source for vegetable oils, considering their implications for adhering to religious dietary requirements. Also, it is important to address the issue of insect-derived oil and the potential challenges and opportunities in market acceptance. It is mainly due to religious guidelines governing permissible foods; especially regarding the key factors influencing the Halal and Kosher status of insect-derived products. Overall, this review provides valuable insights into the intersection of insect oil production by addressing religious concerns and promoting transparency in production processes. Moreover, the integration of insect-derived oils into mainstream markets can be facilitated, offering sustainable solutions to the growing demand for edible oils & fats, respecting diverse cultures, religions and values.

1 Introduction

Insects are almost innumerable and found in tropical regions, which have high levels of biodiversity, signifying that environmental factors are related to the abundance (Lesnik, 2017). A crucial aspect is that insects give a good nutritional value with a high food conversion efficiency because of their shorter growth period (lifecycle) which can be influenced by the substrate used for nurturing other foods. Insects such as black soldier fly larvae (*Hermetia illucens*), mealworm larvae (*Tenebrio molitor*) and adult house crickets (*Acheta domesticus*) are currently used in pet food. These insects are widely fed to exotic pets, mainly in whole, live or dehydrated forms (Valdés, 2022).

Regardless of halal or non-halal issues, insects are part of the human diet in many parts of the world. Some species of insects have been indicated as suitable and alternative sources of nutrients for both humans and animal diets. Whole insects including their parts were included in the EU novel food regulation update starting from 2018 (reg. EU 2015/2283; EC, 2015). This new regulation provides a strong agenda and certainty to the insect industry as a food or feed source in the EU (Izompa-Sosa and Fogliano, 2017). About 470 edible insect species in Africa are collected from nature such as caterpillars, grasshoppers, beetles and termites. Van Huis (2020), discussed the nutritional value of three of these species: the mopane caterpillar, bush cricket and Shea caterpillar, and their contribution to food security in Africa.

Most edible insects are harvested from the wild, although semi-domestication and indoor farming have increased the insect availability (Melgar-Lalanne et al., 2019). Among the traditional cultures, insects are processed in a number of ways including steaming, roasting, smoking, frying, stewing, and curing, among others to improve their sensory and nutritional qualities. In order to increase consumer interest, various technologies such as freeze-, oven- or microwave-drying have been developed in the West. This is mainly aimed at using insects as ingredients in the form of powders or flour. Given the fact that protein



fats & oils and other ingredients are more in insect's species such as crickets, palm weevils, and mealworms were investigated as sustainable resources of protein and oil (Zhou et al., 2022).

Focusing on fats & oils, the extraction of edible oil from insects is still a new and emerging field. Hence, there is limited information regarding research advancement and commercial level production. Insect oils were extracted from yellow mealworm (*Tenebrio molitor*), lesser mealworm (*Alphitobius diaperinus*), house cricket (*Acheta domesticus*) and Dubia cockroach (*Blattella germanica*) by aqueous-based oil extraction method (Tzompa-Sosa et al., 2019). The extracted insect oil showed melting peaks ranging from -30.7 to 22.7° C, which makes them liquid at an ambient temperature. In fact, the colour of the oil was bright yellow-reddish. The oil from insects can be rich in nutrients, including healthy fatty acids, and can be used as a cooking oil, baking ingredient, or biofuel source. Most insect oils had compounds related to pleasant aromas. Despite this, there is no widespread insect oil consumption as a food source (Jinadasa et al., 2022).

2 Yellow mealworm (*Tenebrio molitor*) larvae

This oil is extracted from yellow mealworm (*Tenebrio molitor*) (Coleoptera: Tenebrionidae) larvae that have been nurtured on diets enriched with edible oils (Rossi et al., 2022). It is noteworthy that the fatty acid (FA) composition of *Tenebrio molitor* larvae changes with different rearing substrates. A total of 15 FA was identified and quantified; the most abundant FAs were palmitic, oleic and linoleic acids. The contents of palmitoleic, oleic, alpha-linolenic and eicosapentaenoic acids were tended to correlate with their corresponding amounts in the rearing diets, indicating strict dependence on the diet mainly for PUFA n-3. The n-6/n-3 ratio was influenced by the substrate as well, showing a similar trend between insects and diets but with less variability in larvae (Bordiean et al., 2020). The studies highlighted the importance of the diet in determining the final fatty acid profile of mealworm larvae, although fatty acid enrichment could be dampened by the physiological processes of the insects.



Figure 4.1: Yellow mealworm (*Tenebrio molitor*)

3 Lesser mealworms (*Alphitobius diaperinus*)

The Lesser mealworm (*Alphitobius diaperinus*) is a type of beetle that can be used as a feeder insect for various pets like reptiles, birds, amphibians, and some other mammalian species. Since they are small, easy to raise and store, and high in protein, they have become popular food source for many pet owners (Lourenço et al., 2022). However, it is important to note that not all pets can tolerate mealworms and some may even have an allergic reaction to them. It is also important to consider the nutritional content of the mealworms, since they may not provide all the necessary nutrients that your pet requires (Valdés, 2022). Before introducing them as a diet, it is best to consult with a veterinarian or a specialist in reptile nutrition to ensure that they are a safe food source for your pet. McAllister et al., (1995) isolated the infectious bursal disease virus (IBDV) from adult lesser mealworms, *Alphitobius diaperinus* (Panzer), up to 14 d after exposure, but the isolation of the virus was erratic over this period of time as it was undetected after 24 h in beetle larvae. The virus (IBDV) tends to reoccur causing disease in successive broiler flocks in spite of good sanitary measures (Snedeker et al., 1966). Shedding of IBDV occurs in chick faeces and is highly contagious.



Figure 4.2: Lesser mealworm (*Alphitobius diaperinus*)

4 Watermelon Bug (*Aspongopus viduatus*) as a Source of Edible Oil

Insects were used as a source of edible oil, protein, and gelatin. The amino acids, fatty acids, and nutritional quality of the watermelon bug (*Aspongopus viduatus*) showed it to be a good and safe source of edible oil and protein. According to proximate analysis, adult insects were found to contain about 8.3% moisture & volatile matter, 27.0% crude protein, 54.2% fat, and 3.5% ash. Among the fatty acids of the oil, oleic, palmitic, linoleic, and linolenic acids were the most dominant. The oil that was extracted was found to be suitable for cooking, bio-lubricants and biodiesel production (Mariod, 2020).



Figure 4.3: Watermelon Bug (*Aspongopus viduatus*)

5 Dubia cockroach (*Blaptica dubia*)

Lam et al., (2018) reported that the nutrient composition of the edible Dubia cockroach *Blaptica dubia* (Order: Blattodea) as an alternative insect's source of protein. Based on the findings of this study, the cockroach *Blaptica dubia* is a good and cheap source of protein & fats (profat) that is used to feed reptiles and amphibians. The nutritional value based on proximate analysis showed that the *B. dubia* contained 59 - 63% moisture, 2.47- 4.17% ash, 48 - 54% crude protein and 35.5 -44.0% fat based on the dry weight (Lam et al., 2018).



Figure 4.4: Dubia cockroach (*Blaptica dubia*)

According to another study by Mariod et al., (2017), medium-sized species of cockroach (*Blaptica dubia*) (4.0 - 4.5 cm) were found to contain 35.49%–44.22% fat on a dry weight basis with high amounts of unsaturated fatty acids (76.31%) relative to saturated fatty acids (23.30%). The most abundant unsaturated fatty acids in *B. dubia* lipid extracts were C18:1 cis9 and C18:2 cis9,12 while the most abundant saturated fatty acids were C16:0. The other parameters of the analysis were 59.06%–62.70% moisture, 2.47%–4.17% ash, 47.50%–54.32% protein and 3.83%–5.58% chitin. The oil content reaching up to 44% on a dry basis of the insect tells us that cockroach *B. dubia* could be a potential source of lipids.

6 House cricket (*Acheta domesticus*)

The house cricket (*Acheta domesticus*) is an insect, which is typically grey or brownish in colour. It grows up to 16–21 mm in length, having long hind wings when they became adults. The range of protein content of adult house cricket is 64.4%–70.8%, the lipid content is 18.6%–22.8%, and the crude fibre content is ranged from 16.4% to 19.1% (Mariod *et al.*, 2017). *Acheta domesticus* is considered as one of the most promising reared insects due to its attractive nutritional profile and low feed conversion ratio. However, putative health hazards associated with the consumption of this insect have previously not been investigated. The study by Fernandez-Cassi *et al.* (2019) assessed the risks of *A. domesticus* reared in closed systems controlled by the implementation of hazard analysis and critical control points (HACCP) and good farming practices. The present risk profile identified as main hazards of high counts of aerobic bacteria, spore-forming bacteria, accumulation of cadmium and other heavy metals and a possible increase of allergenic reactions. Although other hazardous chemicals were not studied, most studies explored the food safety risks associated with the consumption of *A. domesticus*.



Figure 4.5: House cricket (*Acheta domesticus*)

In the oil extracted from the adult cricket (*A. domesticus*), the major fatty acids were linoleic (30%–40%), oleic (23%–27%), palmitic (24%–30%), and stearic acids (7%–11%). Despite these, smaller amounts of palmitoleic (3%–4%), myristic (~1%), and linolenic acids (<1%) were also detected. The vitamin analysis of the house cricket showed that the adult insect contains a high amount of vitamin A (24.3 µg), vitamin E (63–81 IU/kg), vitamin C (9.74 mg), and vitamin B complex (85 mg). The total essential amino acids of the adult house cricket were 396.8 mg/g protein, while the nonessential amino acids were 412.8 mg/g. The percentage of sulfur-containing amino acids (Met + Cys, isoleucine, leucine, lysine) in house cricket was 228.9 mg/g crude protein. *A. domesticus* adults are eaten as a deep-fried snack and are also sold as a protein powder or protein extract. House crickets can recycle poultry manure into a protein-rich feedstuff for poultry on an economically competitive basis. (Mariod *et al.*, 2017; Valdés, 2022).

7 Greenfly, Blackfly (*Aphids spp*)

The aphids are soft and small insects (< 7 mm) and feed by sucking plant sap. They usually live in colonies on the undersides of leaves or tender terminal shoots. Aphids excrete considerable amounts of sugary liquid, honeydew, on which sooty mould usually turns them black. The aphids are unique on account of their peculiar mode of reproduction, development and polymorphism (Singh & Singh, 2021). They damage crops directly by sucking their nutrients, making galls and hampering photosynthesis and respiration by the growth of sooty moulds on the honeydew deposited thereon. Aphids also damage the crop indirectly by transmitting hundreds of plant viruses. Because of their economic importance, their population must be controlled to save the crops. One of the solutions could be to collect them and use them for poultry feeding. (Jarzembowski, 1989).



Figure 4.6: greenfly, blackfly (Aphids spp)

8 Sorghum Bug (*Agonoscelis pubescens*) as a Source of Edible Oil

The amino acid, fatty acid and mineral composition of the sorghum bug *Agonoscelis pubescens* were investigated by Mariod *et al.* (2011). The approximate analyses of *A. pubescens* adults showed 7.6% moisture, 28.2% crude protein, 57.3% fat and 2.5% ash on a dry-matter basis. The amino acid analysis showed that the bug protein contained 16 amino acids, including all of the essential ones. When making a comparison with the amino acid profile recommended by FAO/WHO, the protein was of medium quality. The most predominant fatty acids present in sorghum bugs were oleic, palmitic, linoleic and linolenic acids, viz 41.15, 11.41, 35.28 and 1.28%, respectively. However, in a previous study sorghum bug oil content was 60% with 40.9, 34.5 and 12.1% of oleic, linoleic and palmitic acids, respectively. The oil also contains 34 mg/100 g tocopherols (Mariod *et al.*, 2004). The mineral analysis indicated the presence of high P and K contents. The chemical composition, amino acids, and fatty acids of the sorghum bug indicated its good nutritional value. The quality of its protein showed the sorghum bug to be a good and suitable source of edible protein. Analysis of dried adults showed high levels of crude protein and fat. The bug protein contained 16 known amino acids, including all essential ones (Mariod *et al.*, 2011). Oleic, palmitic, linoleic, and linolenic acids were the predominant fatty acids in the oil from the sorghum bug. The extracted insect oil was suitable for frying and biodiesel production.



Figure 4.7: Sorghum Bug (*Agonoscelis pubescens*)

9 Halal Issue

The concept of halal (permissible) food in Islam pertains to various aspects, including the source of the food, the method of preparation, and the ingredients used. Most food items are considered halal unless there is specific evidence or reason to deem them non-halal or haram. When it comes to insects' oil, the permissibility would depend on several factors (Mohd Hatta *et al.*, 2023). Regarding insect oil, there is a difference of opinion among Islamic scholars. Some scholars consider insects to be haram based on specific narrations that mention the prohibition of insects as food. Others argue that since insects are not explicitly mentioned in the Quran as forbidden, they should be considered permissible unless they are harmful or toxic (Butrym *et al.*, 2018).

When it comes to extracting oil from insects, the process itself is not a determining factor for its permissibility. The main concern would be the source of the insects used to produce the oil. If the insects

are permissible for consumption according to Islamic dietary guidelines, then the oil derived from them would also be considered halal (Bawa & Anilakumar, 2013).

However, it is important to note that there may be regional or cultural variations in the interpretation of halal guidelines. Some Muslim-majority countries or communities may have specific regulations or fatwas (religious rulings) regarding insect oil (Kurth & Glasbergen, 2017). Therefore, it is advisable to consult with a knowledgeable Islamic scholar or a recognized halal certification authority to obtain a definitive answer based on your specific context or region.

In fact, the manufacture of animal feed from by-products of the livestock such as internal organs and bones consists of less amount of nutrients that might not be sufficient to support the diet of the rearing animals. Besides, the halal issues on animal feed are also being questioned regarding the sources of raw materials. Thus, it could be an alternative way to get other protein sources to replace the livestock meat or by-products in animal feed. Insects have been becoming more and more economically important in other countries as they are more profitable when compared with imported feed or raw materials that built up the higher cost of production (Lam et al., 2018). However, the halal issue is still taking place when it comes to the source of the food or feed product.

10 Conclusion

In conclusion, the issue of using insect oil from a halal and *toyyiban* (wholesome) perspective is a subject of ongoing debate among Islamic scholars. While there is no explicit prohibition in the Quran regarding insects as food, some scholars consider them haram based on specific narrations. However, others argue that insects should be considered permissible unless they are harmful or toxic. When it comes to extracting oil from insects, the process itself does not determine the permissibility of the oil. The key factor is the source of the insects used in the production. If the insects are halal and permissible for consumption according to Islamic dietary guidelines, then the derived oil would also be considered halal. It is essential to recognize that interpretations of halal guidelines may vary across different regions and communities. Therefore, seeking guidance from knowledgeable Islamic scholars or recognized halal certification authorities is recommended to obtain a definitive answer based on the specific context or region.

Further research and discussions are needed to address this topic comprehensively, considering scientific advancements, the well-being of consumers, and the principles of Islamic law. The evolving understanding of halal and *toyyiban* principles in light of emerging technologies and novel food sources can contribute to informed discussions and informed decision-making in this field.

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