FOOD AND SOCIETY
PROCEEDINGS

CARDIFF 27 - 28TH JUNE 2019

11th International Conference on Culinary Arts and Sciences

EDITED BY
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Insects as food - a review of sustainability, nutrition and consumer attitudes

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Keywords: Insects, Food, Sustainability, Nutrition, Consumer

Introduction

Interest in the use of insects as food is increasing, not least because they are both nutritious and sustainable! Despite these factors, the vast majority of people, mostly in Western cultures, are reluctant to put insects into their mouths. In some European countries the use of insects as food is prohibited by law[1]. From an international perspective, there is nothing strange about eating insects. There are more people in the world who include insects in their diet than those who do not. Insects are a large group of animals that fall under the group of arthropods: phylum arthropoda. It is common to consume insects as food in about 120 countries around the world, and it is estimated that more than 2000 insect species are edible[2]. Historically, it was most common to eat insects that were harvested in the wild and this is still true today. In order to ensure stable access to edible insects, the International Center of Insect Physiology and Ecology (ICIPE) in Kenya is studying different ways of rearing insects[3]. More and more cookbooks are appearing that aim to increase interest in the use of insects as food, for example the University of Columbia has published a cookbook with recipes for how to cook different insects[4]. Three "gateway" insects are being referred to as being those that will pave the way for increased insect consumption in Western cultures; these are meal worms, crickets and locusts. Some of the arguments for eating insects are that they are nutritious, sustainable and tasty! In a newly published report, the Dutch Council of Affairs describes an increased interest in consuming insects and proposes large-scale production in Europe[5]. The aim of this review is to give an overall insight into insects as food from the perspectives of sustainability, nutrition, consumer attitudes and European legislation.

Methods

A literature search was performed using the Web of Science and Diva databases; personal communications with persons engaged in Insektsföretagen (the Swedish insects organisation) provided guidance regarding useful websites. The search terms used were: insects, food, sustainability, nutrition, consumer attitudes and European legislation. The search identified a small number of key references which give an overall insight into the area of insects as food.

Key References

The key references identified included 44 items in total, of which 25 were research articles, 3 books, 4 reports, 4 master's/bachelor's theses, 4 websites and 4 others. The references were divided into the sub-themes: sustainability, nutrition, consumer attitudes and legislation.

Results

Sustainability

The world's population is increasing and is expected to reach around 11 billion people in 2050[6]. This increases the pressure on the earth's resources. It is therefore necessary to

review our eating habits and consumption patterns in order to ensure the food supply for the world's population[7]. Based on population growth, FAO estimates that food production must increase by 70 percent by 2050[6]. We face major challenges, and new methods and new strategies are necessary in all areas of the food chain. Both nationally and internationally, the consumption of meat and fish is increasing, leading to higher use of both resources and energy[8]. Although the increase in meat consumption is both well known and not sustainable, there are few signs that global consumption is decreasing. With a growing global population and a consumer demand for high-quality food including meat, it is necessary to find and use new sources of production of important nutrients and to inform consumers about alternatives to meat and fish, i.e. alternative proteins[9]. One such alternative could be to increase the use of plant protein, such as in peas and legumes, another would be to use insect protein.

Insects do not contribute to greenhouse gases to a large extent, and the rearing of insects requires fewer resources than livestock farming. The production of insects as food exerts less ecological pressure than that of conventional livestock, such as cattle, pigs, poultry, by requiring less feed, soil and water[4,10,11,12,13,14,15]. Dobermann et al[16] argue that the economic value of insect production may be higher than conventional meat production. Insects convert the feed they eat effectively and can therefore be seen as efficient protein producers. For example, about 10 kilograms of feed are required to produce one kilogram of beef protein, while only 2 kilograms of feed are required to produce one kilogram of insect protein. In addition, insects can be fed on various residuals and by-products, such as bran from wheat and rye kernels. Another advantage is that insects tend to live close to each other, thereby requiring a smaller production area and reducing the burden on the environment[4]. However, there are studies indicating that the environmental impact is very different between different insect species[17] and there is some debate as to whether the pressure on the environment can be eased by an increased production of insects[16].

Nutrition

Nutritionally, insects contain proteins, fats, vitamins and minerals. The nutritional content of insects varies between species, stage of growth and breeding factors such as feed, temperature, water and location. The reported nutritional content of insects may also differ between different research references, which may be due to the above-mentioned variations and differences in analytical methods, and if analyses have been carried out on fresh or dried raw materials[18,19,20,21]. Table 1 shows the nutritional values for the three gateway insects: cricket, meal worm and locust.

Table 1. Nutrient composition of cricket, meal worm and locust per 100 gram dry matter[20]

	Cricket (Gryllodes sigillatu) per 100 gram dry matter	Mealworm (Tenebrio molitor) per 100 gram dry matter	Locust (Schistocerca gregaria) per 100 gram dry matter
Macronutrient			
Protein (g)	70	52	76
Fat (g)	18	25	13
Fiber (g)	3,6	2,0	2,5
Ash(g)	4,7	3,6	3,3
Energy (kcal)	1900	1860	1820

Energy (kJ)	452	444	432
Mineraler			
Calcium (mg)	130	41	70
Iron (mg)	4,2	3,3	8,4
Potassium (mg)	1190	840	750
Magnesium (mg)	100	300	80
Sodium (mg)	330	57	173
Zinc (mg)	13	11	19
Fatty acid composition (% fat)			
SFA	34	25	35
MUFA	35	43	38
PUFA	32	31	26

The protein in insects generally contains a high proportion of essential amino acids, and the fats in insects include a high amount of polyunsaturated fatty acids[4,19,22]. The protein content in edible insects is generally high and varies between 20 and 70 percent (dry matter basis). Protein quality is determined by both the content of amino acids and its digestibility. Virtually all amino acids can be found in insect protein, although tryptophan and lysine are only found in limited amounts, and digestibility is very high[23,24]. Insect protein has been shown to be of higher quality than soy protein[25]. The fat content of different insect species varies greatly, but they all contain a high percentage of polyunsaturated fatty acids, see Table 1. It is noted that the level of n-6 (omega-6) is high compared to n-3 (omega-3)[20,24,26]. As far as the content of minerals and vitamins is concerned, this varies widely between species, but is also dependent on the environment in which the insects are present, their feed etc. For example, it is noted that the iron content may differ largely between species. Furthermore, insects can be a source of vitamin B12[20,27]. It can also be noted that vitamin D content may vary depending on the insects' exposure to the sun or UVB irradiation[28]. In conclusion, it can be said that insects are good sources of energy, protein, fat, minerals and vitamins. They are usually fully comparable to other protein sources, such as meat, fish and soybeans, although there is a large variation between and within different insect species. A number of research articles indicate that insects have the potential to play an important role in covering the future need for protein and other nutrients. However, whether they can reduce malnutrition globally is a matter currently being debated[16,26,29].

Consumer Attitudes

The inclusion of insects in our food would mean benefits from a nutritional and sustainability perspective[7]. Another important criterion for accepting insects as food is that they taste good. The three so-called gateway insects - meal worms, crickets and locusts - are all described as tasty due to their mild flavours. The flavour of meal worm is described as nutty with a taste of umami and cereals, cricket resembles popcorn with a hint of chicken and umami, while locust has the flavour of shrimp, nuts and vegetables[30,31,32]. Insects may be eaten raw or cooked in a variety of ways[4]. Despite all the possible benefits, the acceptance of insects is very low, at least in Western societies. Only a few studies have mentioned positive culinary aspects and consumer attitudes about food based on insects[33]. Several studies indicate that it is easier to accept insect products

with neutral and less visible or minced insect ingredients than dishes including whole insects [34,35].

The underlying causes of the low acceptance of insects as food can, to a great extent, be attributed to aversion and negative attitudes towards insects, which may be perceived as things that are creeping and crawling. Aversion can be the result of various sensory signals, such as ugliness or bad odour, and is often associated with feelings of anxiety. It is a human reaction which is considered to be part of the so-called behavioural immune system since it triggers actions designed to avoid health risks[36]. A negative attitude towards invertebrates, both generally but especially as food, is deeply rooted in Western culture[37]. One way to measure aversion to food is to use the so-called Food Disgust Scale (FDS)[38]. This has been used to measure the level of aversion to various types of food in different populations. What is classified as food that can be eaten, however, differs between cultures and the same is true for what evokes disgust. The disgust factor is seen as a serious threat to the introduction of insects into the daily diet in cultures where insects are not normally eaten[39]. However, in countries where eating insects is the norm, they are seen as a valuable protein source and knowledge about which species are edible is considered important[16].

In an effort to answer the question about what can be done to reduce the aversion to insects in Western culture there are, according to Looy, et al.[37], a few key aspects to consider in order to achieve a lasting change in attitudes towards insects. In such work, there must be an awareness of the psychological and cultural barriers to a positive attitude towards insects as well as an understanding of the processes through which these barriers have arisen. Furthermore, clear communication of the fact that insects are required as a valuable food resource is necessary. It has been demonstrated that the acceptance of insects as food increases when consumers are given the opportunity to familiarise themselves with this new raw material, for example by having a taste of insect products and perhaps even preparing their own insect dishes in which, for example, meal worms or locusts are included[40]. In the Netherlands, entomophagy has been successfully promoted for almost 30 years and, according to Dickie et al.[41], the key to success has been technological congruence of the research community, the private sector, universities, state and local governments, foundations, and non-profit organisations.

Legislation

Legislation regarding using insects as food varies between countries[1]. In Europe, insects are considered as novel foods according to Regulation (EU) 2015/2283 of the European Parliament and of the Council, since they had not been significantly consumed in the EU before May 15, 1997. This means that the production of insects for food purposes is not allowed, furthermore it is forbidden to sell insects for human consumption unless the specific insect species has been assessed as safe after examination by the European Food Safety Authority, and approved by the European Commission. Since January 1, 2018, Novel Foods have been governed by Regulation (EU) No. 2015/2283, based on the same principles as the previous Regulation (EC) No 258/97. Although the legislation is common in the EU, the regulation is applied differently in different countries. Some countries, such as Belgium, the Netherlands and Denmark, have interpreted the regulation less strictly than others, such as Sweden and Great Britain. In the less strict countries, the rules have been interpreted such that whole animals cannot be counted as novel foods. Therefore, all insects can be sold without special approval. As of January 1, 2018, the

regulations state that whole animals are new foods. Therefore, Sweden and other EU countries follow the interpretation that insects must be examined and approved before being sold for human consumption. Special rules apply to "traditional food from third countries", that is, food that has been proven to be consumed in non-EU countries. These rules can simplify the process of specific insect species being consumed without harm to people and being sold within the EU; this is according to EU 2015/2283 Regulation. To ensure that this type of food is not harmful to health, any company who wishes to sell the food is required to provide proof that it has been eaten as food

- in at least one third country
- for at least 25 years
- by a large proportion of the population
- as part of the usual diet, without harming the population [1]

Discussion

Insects are common foods in many countries, their nutritional values are good, they are mild in flavour, and are a sustainable source of protein and other nutrients. The environmental and nutritional aspects of edible insects appear to be highly convincing arguments for their consumption[42]. Although there seem to be several rational reasons for eating insects, most people in Western societies regard insects in the diet as something strange and even disgusting. With an ambition to promote insects as a part of the diet and as part of sustainable development, it is necessary to consider how aversions and negative attitudes can be addressed and overcome. A better understanding of what might evoke disgust in food would be helpful to bring clarity here. Information and education are important to give objective insight into sustainability and nutrition. These factors might appeal to moral issues such as a person's value orientation, moral obligation and environmental concerns regarding food choices[43]. However, sensory and visual aspects of food are important criteria for consumers when deciding on the overall acceptability of a dish[42] and have to be taken into account when forming messages about using insects as food. Moreover, factors such as neophobia and disgust are very strong, but may vary in individuals over the course of a lifetime[44].

Conclusion

The aim of this review was to give an insight into the use of insects as food from the perspectives of sustainability, nutrition, consumer attitudes, and European legislation. It can be concluded that insects have the potential to be part of a sustainable, nutritious and flavourful diet.

Acknowledgement

This study was financially supported by KK-stiftelsen (The Knowledge-foundation), Sweden.

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