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Review article

Nutritional and sensory quality of edible insects

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ABSTRACT

Insects are for many nations and ethnic groups an indispensable part of the diet. From a nutritional point of view, insects have significant protein content. It varies from 20 to 76% of dry matter depending on the type and development stage of the insect. Fat content variability is large (2–50% of dry matter) and depends on many factors. Total polyunsaturated fatty acids' content may be up to 70% of total fatty acids. Carbohydrates are represented mainly by chitin, whose content ranges between 2.7 mg and 49.8 mg per kg of fresh matter. Some species of edible insects contain a reasonable amount of minerals (K, Na, Ca, Cu, Fe, Zn, Mn and P) as well as vitamins such as B group vitamins, vitamins A, D, E, K, and C. However their content is seasonal and dependent on the feed. From the hygienic point of view it should be pointed out that some insects may produce or contain toxic bioactive compounds. They may also contain residues of pesticides and heavy metals from the ecosystem. Adverse human allergic reactions to edible insects could be also a possible hazard.

Contents

1. Introduction

The term "entomophagy" (from the Greek words ἔντομον *éntomon*, "insect" and φᾰγεῖν *phagein*, "to eat") refers to the use of insects as food: human insectivory [1]. The eggs, larvae, pupae and adults of insects were used in prehistoric times as food ingredients in humans, and this trend has continued into modern times. Man was omnivorous in early development and ate insects quite extensively. Before people had tools for hunting or farming, insect constituted an important component of the human diet. Moreover, people lived mainly in warm regions, where different kinds of insects were available throughout the year. Insects were often a welcome source of protein in the absence of meat from vertebrates [2].

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Evidence of eating insects in human history has been found from analysis of fossils from caves in the USA and Mexico. For example, coprolites from caves in Mexico included ants, beetle larvae, lice, ticks and mites [3]. The evidence of entomophagy was confirmed using analytical techniques. Analysis of stable carbon isotopes showed that *Australopithecus* bones and enamel were significantly enriched in the isotope ^{13}C. This suggests that the diet of these people was mostly animals feeding on grasses, including insects [2]. Another evidence is from paintings in the Artamila caves in northern Spain (9000–3000 BC.) [3]. According to Lesnik [4] termites were included into the Plio-Pleistocene hominin diet.

Nowadays human insect-eating is traditionally practised in 113 countries around the world. Over 2000 insect species are known to be edible. Globally, the most frequently consumed species are beetles, caterpillars, bees, wasps and ants. They are followed by grasshoppers, locusts and crickets, cicadas, leafhoppers and bugs, termites, dragonflies, flies and other species [5]. The largest consumption of insects is in Africa, Asia and Latin America [5]. In most European countries, the human consumption of insects is very low and often culturally inappropriate or even taboo. The nutritional value of insects is comparable to commonly eaten meats. Considering the growing population in the world and the increasing demand for production of traditional beef, pork and chicken meat, edible insects should be seriously considered as a source of animal protein [6].

In terms of farming conditions the following insect species could be bred and consumed in Europe: house cricket (*Acheta domestica*), Jamaican field cricket (*Gryllus assimilis*), African migratory locust (*Locusta migratoria*), desert locust (*Schistocerca gregaria*), yellow mealworm beetle (*Tenebrio molitor*), superworm (*Zophobas morio*), lesser mealworm (*Alphitobius diaperinus*) western honey bee (*Apis mellifera*) and wax moth (*Galleria mellonella*) [7].

2. Why eat insects?

Increasing population growth in the world increases demand for protein sources but the amount of available farmland is limited. In 2050 the world population is estimated at more than 9 billion people, resulting in an additional need for food of half the current needs. Conventional protein sources may be insufficient and we will have to focus on alternative sources [8], which may be edible insects [9]. In Africa, Southeast Asia and the northern part of Latin America, this large group of animals is a popular delicacy and an interesting assortment of food enrichment. For example in Mexico, chapulines (grasshoppers of the genus *Sphenarium*) are a frequent national dish together with beef and beans [10].

Compared with livestock, breeding insects seems to be more environmentally friendly because of lower greenhouse gas emissions, water pollution and land use [11]. Insects show higher feed conversion efficiency (i.e. a measure of the animal's efficiency in converting feed mass into body mass) in comparison with mammalian livestock. Van Huis et al. [11] even stated the feed conversion of house cricket (*A. domestica*) to be twice that of chickens, 4 times higher than in pigs and more than 12 times higher than in cattle.

An interesting positive aspect of entomophagy is its help in reducing pesticide use. Collection of edible insects considered as pests can contribute to reduced use of insecticides. Furthermore, the economic benefits of collecting insects as compared with the cultivation of plants should also be taken into account. In Mexico, collecting insects for human consumption resulted in a reduction in the quantity of pesticides in agricultural crop production and a decreased financial burden on farmers [10,12].

3. Nutritional value of edible insect

The nutritional value of edible insects is very diverse mainly because of the large number and variability of species. Nutritional values can vary considerably even within a group of insects depending on the stage of metamorphosis, origin of the insect and its diet [13]. Similarly the nutritional value changes according to the preparation and processing before consumption (drying, cooking, frying etc.) [11]. According to Payne et al. [14] insect nutritional composition showed high diversity between species. The Nutrient Value Score of crickets, palm weevil larvae and mealworm was significantly healthier than in the case of beef and chicken and none of six tested insects were statistically less healthy than meat. Most edible insects provide sufficient energy and proteins intake in the human diet, as well as meeting the amino acid requirements. Insects also have a high content of mono- and polyunsaturated fatty acids; they are rich in trace elements such as copper, iron, magnesium, manganese, phosphorus, selenium and zinc, as well as vitamins like riboflavin, pantothenic acid, biotin, and folic acid in some cases [15].

3.1. Energy value

The energy value of edible insects depends on their composition, mainly on the fat content. Larvae or pupae are usually richer in energy compared to adults. Conversely high protein insect species have lower energy content [16]. Ramos-Elorduy et al. [17] analysed 78 kinds of insects and calculated their calorific value in the range from 293 to 762 kcal per 100 g of dry matter. Table 1 shows the energy value of selected species of edible insects, expressed in kcal per 100 g fresh weight [11].

3.2. Proteins

Bednářová [16] examined the total protein content of seven species of insects. Total protein content was relatively the same in all measured types of insects except for the wax moth (*G. mellonella*) where the protein content (based on dry matter) was only 38.4%. The percentage of other species ranged from 50.7% for yellow mealworm (*T. molitor*) to 62.2% for the African migratory locust (*L. migratoria*). Xiaoming et al. [18] assessed protein content in 100 insect species. Protein content was in the range of 13 to 77% by dry matter (Table 2), reflecting the large variability of tested species. Eighty-seven species of edible insects were investigated in Mexico, and the average protein content was from 15% to 81%. Insect protein digestibility, which is 76 to 96% [17] was also examined in this study. These values are on average only a little smaller than values for egg protein (95%) or beef (98%) and even higher than in the case of many plant proteins [19]. Measured amounts of nitrogenous substances of insects may be higher than their actual protein content since some nitrogen is also bound in the exoskeleton [20].

Considering the amino acid composition of edible insects, they contain a number of nutritionally valuable amino acids including high levels of phenylalanine and tyrosine. Some insects contain large amounts of lysine, tryptophan and threonine, which is deficient in certain cereal proteins. For example, in Angola the intake of these nutrients may be supplemented by eating termites of the genus *Macrotermes subhyalinus* [21]. The native people of Papua New Guinea normally eat tubers, where the content of lysine and leucine is low. The resulting nutritional gap could therefore be compensated by the consumption of larvae of the *Rhynchophorus* family beetle that have high amounts of lysine. On the contrary tubers contain a high proportion of tryptophan, and aromatic amino acids which are present in limited quantities in these larvae. Nutritional intake of such a diet is therefore balanced [11,22]. Analysis of almost a hundred edible insect species showed that the content of essential amino acids represents 46–96% of the total amount of amino acids [18].

3.3. Lipids

Edible insects contain on average 10 to 60% of fat in dry matter (Table 3). This is higher in the larval stages than in adults [18]. Caterpillars belong among insects with the highest fat content. Tzompa-Sosa