Eng. Anna IGNACZAK
Dr hab. Hanna KOWALSKA, prof. of WULS
Department of Food Engineering and Process Management
Institute of Food Sciences, Warsaw University of Life Sciences (SGGW-WULS)
Warsaw, Poland

NUTRITIONAL VALUE OF EDIBLE INSECTS IN RELATION TO CONSUMER ACCEPTANCE®

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Due to the fact that the world population is constantly growing, it is necessary to provide adequate amount of food. Research is ongoing to find new food sources. The following articles provide an overview of the current literature data on edible insects as an alternative source of ingredients with high nutritional value. The forms of processing insects were analyzed in terms of their safe consumption, consumer acceptance and legal requirements.

Key words: unconventional food sources, insect breeding, processing methods, safe consumption.

Liczba ludności na świecie stale rośnie, istnieje więc konieczność zapewnienia odpowiedniej ilości pożywienia. Badane są nowe źródła żywności. W artykule przedstawiono przegląd aktualnych danych literaturowych dotyczących owadów jadalnych jako alternatywnego źródła składników o wysokiej wartości odżywczej. Analizowano formy przetwarzania owadów pod względem bezpieczeństwa ich spożywania i akceptacji konsumentów oraz wymogów prawnych.

Słowa kluczowe: niekonwencjonalne źródła żywności, hodowla owadów, metody przetwarzania, bezpieczeństwo spożywania.

INTRODUCTION

Taking into consideration many factors like the growing need for increasing the production of food, and at the same time searching for and creating new products because of the cost of production of livestock and their determinants, in the related pollution of the environment, the limited resources of fresh water, and changes in climate, need is the search for new sources of food [5, 50, 55]. Currently, in this regard, unicellular organisms (yeasts), marine organisms and edible insects [55] are of great interest. Edible insects are of the greatest importance and are considered a traditional food in over 100 countries in Asia, Africa and South America. They are a source of protein, fat, vitamins and minerals in amounts comparable to traditional animal raw materials [3]. There are many aspects to their wider use. Edible insects can be a source of physical, chemical and microbiological hazards and allergens. They may contain pesticides and heavy metal residues. Another aspect is the approach to ideas related to their breeding or harvesting, production technology and the global establishment of legal principles. Socio-economic and ethical issues are also important. The issues of using edible insects as food and feed are present in many regulatory institutions, which in relation to food production and breeding of insects should ensure the quality and safety from the products made of them, and take into account environmental factors and animal welfare [50]. Consumer acceptance of insect products is likely to be associated with the development of an appropriate processing strategy as well as appropriate marketing and incentives.

The aim of the article is to review the available literature on alternative sources of protein, in particular edible insects, their nutritional value and their use in human nutrition.

YEASTS, MOLDS AND ALGAE AS A SOURCE OF FOOD?

Yeasts, algae and molds are a valuable source of lysine, protein, B vitamins and minerals such as phosphorus, zinc and magnesium [1, 8]. Saccharomyces cerevisiae are also a source of probiotic bacteria [32]. The content of nucleic acids (2–18% of dry weight) present in the biomass of unicellular organisms makes it impossible to use them as a potential source of protein in human nutrition. Uric acid deposition in the kidneys or joints may lead to gout [8, 55]. Moreover, some proteins of unicellular organisms, causing allergies, adversely affect the immune system [33].

Sea algae can be an alternative source of protein in human nutrition. *Chlorella sp.* and *Spirulina sp.* algae, which contain about 60-70% protein in dry matter, are used on a large scale for production. *Chlorella sp.* it is also a valuable source of vitamins A, B12, folic acid and minerals, mainly iron, it also has an antioxidant effect. *Spirulina sp.* is characterized by high protein digestibility (90%) and favorable health properties, especially in the prevention of cardiovascular diseases, cancer and hypercholesterolemia. Due to technical difficulties in developing new products with an acceptable taste and high production costs, the use of algae protein in the food industry is not of much interest [9, 55].

Corresponding author – Adres do korespondencji: Hanna Kowalska, Szkoła Główna Gospodarstwa Wiejskiego w Warszawie, Instytut Nauk o Żywności, Katedra Inżynierii Żywności i Organizacji Produkcji, ul. Nowoursynowska 159c, 02-776 Warszawa, e-mail: hanna_kowalska@sggw.edu.pl

Various species of insects occurring all over the world have the greatest importance as a potential source of human food and feed for animals. Numerous studies have shown that insects are consumed by about 2 billion people in some countries of Asia, Africa and Latin America [9, 12, 48], with over 2,100 species already cataloged as edible. For consumption purposes, almost all groups of insects in the form of adults, pupae and eggs are used. Fried, boiled, baked or dried, as well as raw, the world's main food eaters are crickets, beetles, locusts and termites [3, 9].

CHARACTERISTICS OF POPULAR SPECIES OF EDIBLE INSECTS

Insects are the most numerous and widespread group of animals in the world. The small size, the presence of wings and trachea, the ability to transform, high fertility and the ability to protect against harmful pathogens, predators and parasites make these organisms quite common. They have the ability to quickly assimilate to the prevailing environmental conditions [25]. There are two types of insects, the so-called transformations as complete and incomplete. In the case of incomplete transformation, the pupal stage is skipped and the larva immediately turns into an adult (imago). The type of transformation and the stage of development of an insect determine the possibility of its consumption [48]. Butterflies belonging to the order Lepidoptera are the most numerous group of insects in the world. Their larvae (caterpillars) are often eaten by gourmets of this type of food. The larvae of these insects reach European countries, e.g. Belgium or France, previously dried in the sun. In South Africa and Botswana, butterfly caterpillars are most commonly produced in cans [58].

Termites (order *Isoptera*) are another species of edible insects popular in African countries. These insects are high in fat, so they are often eaten fried or in the form of a dried snack [58].

Crickets and locusts (of the order *Orthoptera*), grasshoppers, are among the most consumed insects. Before thermal treatment, their legs and wings are removed. They are mainly eaten fried or baked. Chitin and chitosan present in the shells of crickets prevent the development of harmful microflora in the human intestine [30, 58].

Beetles (of the order of *Coleoptera*) can be eaten at all stages of development, except in the adult form, due to their hard, chitinous shells. The mealworm of millers belongs to this group of animals, a popular pest of cereal products, as food for humans on a large scale is used in Asia and many European countries [17, 58].

Adult bees and wasps (*Hymenoptera* order) are not eaten due to the presence of a hard, chitinous shell, and thus low taste. The larvae and pupae of these insects are eaten most often in Japan and southern China [58].

ACQUISITION AND METHODS OF BREEDING INSECTS

Over 90% of edible insects are collected in the wild, and they are specially bred only in small numbers. The safety of collected insects is more difficult to guarantee, and wild species may become extinct, moreover, not every type of insect can be bred in artificial conditions, especially when a pathogen appears [3]. Harvesting edible insects can be of benefit, especially when grown organically.

Baiano [3] presented two methods of breeding edible insects as raw material for human food and animal feed; by full domestication and captive breeding, or partial captivity (semi-cultivation), modifying the habitat of insects, but without separating them from the wild population. Domesticated insects include mealworms, cockroaches and some beetles. Locusts, wasps, bamboo caterpillars, palm weevil larvae, and dragonflies belong to the second category. Activities related to semicultivation contribute both to the protection of the habitats of edible insects and to food security [50]. Mealworms and cockroaches work well in home and industrial breeding, because their breeding conditions are well known. Insect breeding is rare in Western countries, while the practice of insect breeding has been around in China for over 5,000 years [7]. It is possible to conduct cultures under controlled conditions in suspension in a closed bioreactor, which ensures consistent quality with a low risk of contamination and the possibility of breeding insects in various environments [7]. The aspect of sustainably breeding is important, especially in the transition to an industrial scale [39]. According to Veldkamp et al. [51], insects such as the soldier's black fly (Hermetica illucens), housefly (Musca domestica) and yellow mealworm (Tenebrio molitor) can process 1.3 billion tonnes of biowaste annually. Large list of already tested wastes like spent grain and brewer's yeast; leftovers of bread and pastries; potato steam peelings, egg waste, wheat bran; plant waste can be used as food for insects [3].

Zielińska et al. [59] demonstrated the ability of insects to digest polystyrene. It was found that the use and degradation of polystyrene did not affect the health status of the tested insect species *Tenebrio molitor* and *Zophobas morio*, but further studies were needed to confirm the nontoxicity of the insects that degrade polystyrene. This way of using the potential of edible insects is promising, both for the breeding of insects used in human or animal nutrition, their use in many other areas of life, and the management of waste products.

PROCESSING OF EDIBLE INSECTS

Edible insects, due to their valuable source of protein with a favorable composition of amino acids, vitamins, mono- and polyunsaturated fatty acids and minerals (iron, zinc), can be used as a component of conventional foods to increase the nutritional value of products [42, 55]. They can be eaten whole (raw, boiled, boiled and dried, fried, baked) [2, 3]. Another direction is the processing of insects into an unrecognizable form by peeling, drying, grinding into powders, pastes or using more complex technologies aimed at obtaining proteins. Insect flour can be used to enrich food, such as crisps, bread, pasta, confectionery, and even beverages [3, 28]. These publications present many conventional and innovative methods used in the processing of insects, incl. bed drying, microwave, vacuum and conventional drying. Traditional and novel techniques for protein, fat and chitin extraction using water, organic solvents and enzymes as well as techniques using ultrasound and supercritical CO2 extraction as well as cold plasma were also tested. The costs of some processes are currently too high to be applied industrially, but research in various research centers is ongoing. In the studies of Zhao et al. [57], the freeze-dried yellow mealworm larvae contained approximately 33% fat, 51% crude protein and 43% true protein on a dry weight basis. The article analyzed the simultaneous effect of four variables during the extraction of yellow mealworm larvae proteins with NaOH, i.e. the concentration of 0.1 M to 0.5 M and the ratio of NaOH to defatted larvae (from 6: 1 ml / g to 20: 1 ml). / g) at a temperature of 20 and 80° C for 30 to 120 minutes. The actual protein content of the protein extract was about 75% with an extraction yield of 70% (extraction in 0.25 M NaOH, NaOH: lean larvae ratio 15: 1 ml / g, 40° C, time 60 min). The lowest solubility of protein in distilled water was obtained between pH 4 and 5, but increased at pH above or below this range. Lower solubility was observed in the samples treated with 0.5 NaCl solution. This proves that the performance properties of mealworm larvae can be modified in the food industry depending on different applications. Processing activities aimed at the production of protein hydrolysates, especially bioactive peptides, are important. Protein hydrolysates are proteins broken down into smaller fragments, peptides and amino acids. These peptide fragments may contain 2–20 amino acids, inactive in the sequence of the primary protein, which can be released by enzymatic hydrolysis, solvent extraction and microbial fermentation [12, 35].

The available scientific publications analyzed the possibility of using a cricket meal, widely available in some European markets. Research by Montowska et al. [30] showed that in terms of dry weight, cricket meal is a rich source of protein (42.0–45.8%), fat (23.6–29.1%), fiber and minerals, therefore it can become a valuable ingredient in traditional food products. Bread containing 10 and 30% (in relation to wheat flour) of cricket flour addition showed higher nutritional value than the control bread. Baked goods with the addition of cricket flour were characterized by a more favorable profile of fatty acids and a higher content of proteins, including essential amino acids. However, microbiological analysis revealed the presence of sporulating bacteria in the bread with the addition of cricket flour, which poses a risk to consumer safety. Therefore, when processing insect flour as a food component, preventive measures are recommended, eg microwave drying or high-pressure treatment [37]. A relatively small addition of flour (at the level of 5%) to products such as pasta or muffins increased their consumer appeal. Moreover, the color of pasta and muffins with the addition of insects was similar to the color of whole grain products considered "healthier" [15, 40, 55]. In studies by González et al. [18], three different insects (*Hermetia illucens*, *Acheta domestica* and *Tenebrio molitor*) were ground and up to 5% replaced with wheat flour in cakes and breads. The addition of insect flour influenced the rheological properties, mainly the absorbability and stability of the dough during mixing, which is characterized by lower water adsorption. Breads containing *Acheta domestica* flour showed similar volume and texture parameters to wheat bread, but had a higher protein and fiber content. Da Rosa Machado and Thys [11] showed that in combination with hydrocolloids and / or enzymes, cricket powder (*Gryllus assimilis*) can be used as an alternative protein source for gluten-free bread. The product was characterized by acceptable technological properties and a high content of protein and lipids. Similarly, gluten-free sourdough bread enriched with the addition of cricket flour increased the content of wholesome protein and improved the antioxidant properties of baking [34]. Insects are also used to obtain edible oils using Soxhlet or Folch extraction or supercritical CO_2 extraction [12].

Baiano [3] showed that work is underway to extract and restructure insect proteins into a variety of food components, such as soluble protein powders for beverages and textured insect proteins for meat analogs, and substitutes for eggs or dairy products in bakery and food applications [46]. A form of innovative technology that has been proposed for the development of the edible insect market is 3D printing, as it can change both the aesthetics and texture of food [27].

EDIBLE INSECTS IN HUMAN NUTRITION

The history of the use of edible insects in human nutrition was extensively presented by Baiano [3], dating to ancient times, and even millions of years. Starting from the 70s of the previous century, the interest of researchers in edible insects was significant, as evidenced by the large number of scientific publications (637) from this period (1975–2020) compiled by Baiano [3], with about 90% of publications written after 2010.

Edible insects are characterized by high nutritional value, being a source of wholesome protein and all essential amino acids, fats (high content of unsaturated fatty acids), B vitamins, and minerals (including iron, zinc). Most edible insects are fairly low in carbohydrates. According to da Silva Lukas [12], these insects have a balanced nutritional profile and amino acids useful in human diets. The nutritional value of insects depends on the species, stage of development, method of killing, habitat, and even the method of preparing the dish and the type of culinary treatment used before consumption [3, 6, 48].

The protein content in edible insects is 5–77 g per 100 g. The highest protein content in dry matter (over 60%) was recorded in locusts and crickets. The protein content alone does not reflect its usefulness in human nutrition. Its digestibility is also important. In the case of edible insects, the digestibility of the protein is higher compared to many proteins of vegetable origin and is similar to that of egg white (77–98%). Moreover, the nutritional value of insect protein is comparable to that of milk protein and beef protein [9, 29, 48].

Lipids are the second largest fraction in the food composition of edible insects. Their content is higher in the larval phase of the life of insects. Depending on the insect species, the fat content in dry matter ranges from 13 (*Orhopter's order*) to 67% (beetle larvae or *Rhynchophorus phoenicts*) [29, 44, 56]. Fats mainly consist of triacylglycerols (about 80%), and among others present in smaller amounts, there are phospholipids (up to 20%), cholesterol, glycerides, free fatty acids and wax esters [12]. Triacylglycerols serve as an energy deposit during periods of high energy demand, phospholipids play an important role in the construction of the cell membrane. Essential fatty acids are linoleic (18: 2n-6) and α-linolenic (18: 3n-3), which are not synthesized by mammalian cells and therefore should be consumed with food [12]. In terms of the degree of unsaturation, the composition of fatty acids in edible insects is comparable to that of fish and poultry [55]. These fatty acids are present in greater amounts compared to other sources and are essential for the maintenance of cell membranes, brain function and the transmission of nerve impulses.

Insects are characterized by a low carbohydrate content (0.1–5.3% in dry matter). Most of them are chitin, which has a healing effect. Chitin has been shown to lower blood cholesterol, act as a hemostatic agent for tissue repair, promote wound healing, and as an anticoagulant. In addition, it soothes allergies and has antiparasite properties. Chitin may also play a role as a dietary fiber in the human diet. In most insects, chitin, which is part of their outer shell, constitutes 5–20% of their dry mass [8, 29, 58].

In terms of minerals, insects are characterized by a high content of iron and zinc, and slightly less copper, magnesium, manganese and calcium. For example, caterpillars *(Imbrasia belina*) contain 31–77 mg iron per 100 g dry weight, while beef has an iron content of only 6 mg per 100 g dry weight. Edible insects are also a good source of most B vitamins, including thiamine, riboflavin and cobalamin [8, 58].

Anaduaka et al. [2] examined the nutritional value of *Oryctes rhinoceros* and *Zonocerus variegatus*. Both insects showed approximately 34.8 and 30.7% protein, 10.5 and 5.4% carbohydrate, and both approximately 20% fat, respectively. Both insects contained vitamins B12, B1, B2 and B6; in *Oryctes rhinoceros* 70.4, 5.9, 27.2 and 0.8 mg / 100 g, respectively, and in *Zonocerus variegatus* 276.1, 45.4, 11.1 and 4.4 mg / 100 g. Both also showed vitamin A (0.17 and 0.8 mg / 100 g), vitamin C (0.5–0.6 mg / 100 g), vitamin D (21.4–24.1 mg / 100 g), and in *Oryctes rhinoceros* also vitamin K (7.4 mg / 100 g). Among the minerals, significant amounts of potassium and sodium were found in both insects, i.e. around 1905 and 1656 mg / 100 g in *Zonocerus variegatus* and 1070 and 931 mg / 100 g in *Oryctes rhinoceros*, and a comparable calcium content (368 mg / 100 g). Lower amounts of magnesium (39 and 182 mg / 100 g) and iron (1.2–2.3 mg / 100 g) were found.The antinutritional factors present in some insects can be toxic, discouraging their use. In both insects, the content of antinutritional components (mainly oxalate) was within acceptable limits, so they were not life-threatening.

POTENTIAL NUTRITIONAL COMPONENTS OF EDIBLE INSECTS

Many authors emphasize that insect proteins can serve as functional ingredients in food preparation. Edible insects and foods enriched with them, especially in the form of hydrolyzed proteins (peptides), show antioxidant, antimicrobial and antidiabetic properties [12, 13, 58]. Gravel and Doyen [19] reviewed the articles in detail in terms of insect flour production methods as well as insect-derived ingredients such as protein concentrates and isolates. To increase the functionality of the protein from crickets, Hall at al. [20], whole insects (Gryl-lodes sigillatus) were hydrolyzed with alkase at the concentration of 0.5, 1.5 and 3.0% for 30, 60 and 90 minutes. This treatment increased the solubility of proteins by more than 30% at pH 3 and 7 and by 50-90% at alkaline pH, compared to the control. The emulsion activity index varies from 7 to 32 m^2 / g, and the foam ability from 100 to 155% for all hydrolysates.

Del Hierro et al. [14] obtained extracts from edible insects *Acheta domesticus* and *Te-nebrio molitor* by means of ultrasound-assisted extraction and pressurized liquid extraction with the use of ethanol or ethanol and water. All extracts showed antioxidant activity which correlated with the values of total phenolic compounds. All showed lipase inhibitory activity, although those from *Tenebrio molitor* and obtained by pressurized liquid extraction were the most effective. Therefore, bioactive insect extracts can be selectively obtained by advanced extraction methods.

FOOD SAFETY WITH ADDITIONAL INSECTS

Studies on the safe consumption of edible insects confirm the presence of endogenous and exogenous microbiological, allergenic and toxic substances in them [8, 13, 55]. Insects also have a specific wealth of animal viral pathogens, but do not pose a threat to humans [3]. The presence of viruses introduced into the culture by arthropods (arboviruses), which can cause diseases (eg, West Nile disease, haemorrhagic fever) or other viruses through the medium cannot be excluded [3, 6]. Microbial contamination can be dangerous, but if insects are properly fed, processed and stored, they can be considered safe [3]. Insects can be responsible for mycotoxin contamination when stored under suboptimal conditions. De Castro et al. [13] provided a detailed review of articles on microbial testing in fresh and heat-treated insects. Some studies have shown high microbial content in certain commercial insect species. In fresh insects, i.a. Enterobacteriaceae and spore bacteria, but no pathogenic species were detected. Boiling the insects for 5 min adequate to eliminate Enterobacteriaceae, but had no effect on bacterial spores. The attention was paid to tropical diseases transmitted by insects of the Reduviidae family. Parasites may also be present in edible insects. The relationship of insects with crustaceans and the presence of proteins in their composition may contribute to the fact that some insects and foods with their addition become a potential source of allergens [24, 55]. Therefore, the consumption of edible insects may pose a potential threat to human health. Studies have confirmed that the consumption of edible insects may cause allergic reactions [8, 44]. Moreover, insects have defense mechanisms by producing carbonic acids, alcohols, aldehydes and phenols, which may be irritants, and in the case of alkaloids, steroids, cyanogenic glucosides, (benzo) quinones and alkenes, they are capable of exerting a negative systemic effect [6].

The safety of insect consumption is also determined by external factors. Due to the documented cases of botulism, food poisoning and parasitic diseases, the conditions for the preparation of dishes with the addition of insects, i.e. temperature, time and place of preparation, are important. For this reason, it is essential to maintain the maximum microbiological purity of products with the addition of insects [8]. To ensure the safe consumption of edible insects, it is required to develop and apply specific HACCP procedures [43].

ACCEPTANCE OF EDIBLE INSECTS IN THE OPINION OF CONSUMERS

According to the Codex Alimentarius, which is responsible for international food safety, insects are not treated as food, but as contaminants. In the European Union, edible insects are considered "novel foods" [Regulation 2283/2015]. Insects and products based on them must be authorized before being placed on the market, and the procedure takes at least 17 months. There is also a simplified procedure (5 months) for the authorization of novel foods as long as the traditional food is safe (consumption for more than 25 years in the diet of a significant number of people in at least one third country) and that there are no safety concerns reported by EU Member States or EFSA [3].

Insects are a promising alternative to existing food sources, especially protein, but the literature has shown that insects are not accepted as food by many consumers [54]. Due to cultural barriers, Europeans are reluctant to consume insects. At present, despite the many advantages of edible insects as potential food, even among societies in countries that have traditionally eaten insects or food supplemented with them, there are doubts about the legitimacy of their consumption. Low acceptance in these countries may result, among others, from from the perception of insects as a primitive food, intended for people with low social status and unattractive sensory features of insects eaten as a whole [8, 38]. It is worth emphasizing, however, that dietary stereotypes are constantly changing. Currently available literature sources concern consumer behavior in terms of factors determining the acceptance of edible insects as food [10, 45].

Edible insects are a product still unknown in most societies. Food neophobia, the fear of trying something new or unknown to the consumer, is one of the key determinants of rejecting insects as food [41]. Neophobia largely results from the native culture of a given society. A different approach can be observed among the inhabitants of Northern Europe, who constitute a society more open to the possibility of trying new foods, including edible insects, compared to the inhabitants of Central Europe. The low social acceptance of insect eating is the main obstacle to their introduction to the food market. Consumers in European countries often react with disgust to the possibility of eating insects, which are commonly perceived as pests and not as food. Awareness of the benefits of consuming edible insects, constant awareness of consumers by informing them about the properties of previously unknown products, as well as increasing direct taste contact with new products increases consumers' readiness to eat insects [8, 41, 45, 48, 53].

Many studies have emphasized that the inclusion of edible insects in traditional food, and thus reducing the degree of their visibility in the product or products based on insects, may contribute to increasing their acceptance among consumers [26]. According to a study by Tan et al. [49], the inclusion of mealworm larvae, whether visible or not, as part of well-known dishes, e.g. beef stew, does not achieve high product acceptability. Products with the addition of mealworm, visually identical to the carrier product, in the opinion of consumers, were less attractive. Similarly, Barsics et al. [4], they gave samples of the bread to a group of tasters, falsely telling them that an insect meal had been added to its production. As a consequence, the assessment of the taste of the bread was very low.

Research conducted among German consumers indicated that paying more attention to the processed form of insects and adding it to products will reduce their visibility in ready meals. This is a promising prospect of entomophage implementation in Western countries [36]. According to House [21], creating products with the addition of insects with an acceptable taste, product form, and also, at an affordable price can increase the regular consumption of insects by consumers and their inclusion in their diet.

Other studies have suggested that distinguishing insects by species, rather than aggregating them as a whole, may promote greater consumer acceptance of edible insects, since acceptance of edible insects is often tied to a specific insect species. Insect species vary widely and consumers have different experiences with some, some more accepted than others [45]. For example, among Czech consumers, cockroaches are more accepted than crickets. On the other hand, the Chinese distinguish between crickets and silkworms known in their culture, the Germans do not have such a custom [16].

It should be emphasized that the acceptance of edible insects is related to their sensory quality [3]. The taste of insects depends on the environment in which they live, their food and the method of preparation, as insects lose their taste when cooked. The color of the insect changes from original, e.g. blue / green / gray to red (when cooking), gold / brown / black (when drying). The texture of insects can also be related to the cooking method, but also to the stage of development. The exoskeleton of most adult insects makes them crunchy.

When analyzing the acceptance of edible insects by consumers, it is also worth mentioning their readiness to replace traditionally consumed meat and accept insects as its substitute, i.e. consumers' attachment to eating meat. Opinions are divided on this point. People who consider the production of environmentally friendly food, which cannot be attributed to meat production, will be more favorable to the use of edible insects as a meat substitute. The inverse relationship is easy to notice in the case of people with a positive attitude towards the health and taste of meat [10, 45]. Research conducted by Verbeke [52] shows that an increase by one unit of the belief that meat is healthy, nutritious and tasty causes a decrease in the acceptance of insects as a meat substitute by 64 and 61%, respectively. Moreover, men show a higher propensity than women to introduce edible insects in their diets as a meat substitute. This is probably due to the greater openness of men towards trying new, previously unknown products. The study by Tan et al. [49] prove that younger consumers are more willing to consume insects [45, 47, 52].

Bartkowicz [5] conducted research on the potential consumption of insects among nearly 800 Polish consumers. It was found that men, more than women, would be inclined to eat traditional food with added insects to increase the content of nutrients (proteins, vitamins, minerals). Many people are interested in consuming edible insects as an alternative form of food. House [22] described many factors that made it possible to develop a Dutch commercial network of edible insects. It showed a disconnect between edible (basically) and routine consumption (in practice), so products can be positioned as "edible," but that does not mean people will eat them. Hwang and Choe [23] described the low interest of consumers in insect dishes and the reluctance to visit restaurants offering dishes with insects. They felt it was important to study the risks and dangers of consuming such products. They found 21 perceived risk items, which they grouped into seven factors such as quality, psychological, health, financial, environmental, time, and social risk. Five sub-dimensions of perceived risk had a negative impact on the image, except for financial and environmental risk.

PROFITABILITY OF EDIBLE INSECTS CULTIVATION AND ENVIRONMENTAL IMPACT

Animal breeding poses real threats to the natural environment, e.g. excessive emission of greenhouse gases (methane and ammonia) to the atmosphere, increased consumption of water resources. The breeding of edible insects is environmentally friendly [24, 31]. From the environmental and economic point of view, important is the issue of using insect faeces as fertilizer in agriculture [8], low requirements for the breeding area, as well as low financial outlays for breeding, which are associated with lower consumption of drinking water resources and economy in using agricultural land and forage. Insects are cold-blooded animals, therefore they more effectively use plant biomass to increase body weight compared to warm-blooded animals. Literature data show that crickets use feed very efficiently, turning it into„meat"; compared to poultry – 2 times more efficient, pigs - 4 times more efficient and cattle – 12 times more efficient. Considerably lower costs of breeding insects compared to livestock allow the introduction of edible insects to the diets of poor societies [5, 24, 48].

Insect breeding significantly reduces the use of plant protection products, which reduces the negative impact on the natural environment and the possible presence of pesticides in food. The consumption of edible insects, which are also pests, such as bearberry, will limit the use of pesticides in agriculture, which will consequently reduce their residues in food of plant origin [24].

Edible insects are becoming increasingly popular not only because of their high nutritional value and the ability to reduce the negative impact on the environment, but also because of the profitability of their production and sales [55]. The practice of using insects in Europe is still under development and is regulated by separate provisions of European Union law [10, 47].

CONCLUSIONS

Edible insects are a source of protein, fat, vitamins, minerals and dietary fiber. They have already become a popular food in many countries. It is also a cheaper way to provide food to starving people. There is a growing interest among consumers looking for new flavors, as well as producers, due to their easy production without negative environmental effects. A significant problem is the lack of acceptance of edible insects as a form of food among consumers of European countries. This makes it difficult to bring insects to the market. Future research should address the aspect of entomophagy to pass the barrier of disgust and treat the insects on the plates as a delicacy in the future. It is also a cheaper way to provide food to starving people. Based on the current literature, there is a clear need for detailed research to overcome food safety concerns throughout the food chain based on edible insects, including collections of wild insects. The use of edible insects on a large scale must be regulated in terms of the safety of their consumption on a global scale, therefore it is very important to continue research on the possibilities of their use in human nutrition.

WNIOSKI

Jadalne owady stanowią źródło białka, tłuszczu, witamin, związków mineralnych oraz błonnika po-karmowego. W wielu krajach stały się już popularnym pożywieniem. Jest to też tańszy sposób zapewnienia żywności ludziom głodującym. Rośnie zainteresowanie konsumentów poszukujących nowych smaków, a także producentów, ze względu na łatwość ich wytwarzania bez negatywnego wpływu na środowisko. Istotnym problemem jest brak akceptacji owadów jadalnych jako formy pożywienia wśród konsumentów krajów europejskich. Powoduje to trudności we wprowadzaniu owadów na rynek. Przyszłe badania powinny być powiązane z entomofagią, aby przejść przez barierę braku akceptacji do owadów jako żywności i w przyszłości mogły gościć na talerzach jako przysmak. Opierając się na aktualnej literaturze, istnieje wyraźna potrzeba przeprowadzenia szczegółowych badań by wykluczyć obawy związane z bezpieczeństwem żywności w całym łańcuchu żywności na bazie owadów jadalnych, w tym zbiorów dzikich owadów. Stosowanie owadów jadalnych na dużą skalę musi być uregulowane pod względem bezpieczeństwa ich spożycia w skali globalnej, dlatego bardzo ważne jest kontynuowanie badań nad możliwościami ich wykorzystania w żywieniu człowieka.

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