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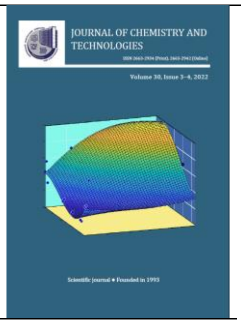

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ENTOMOPHAGY AS A PROMISING AND NEW PROTEIN SOURCE OF THE FUTURE FOR SOLVING FOOD AND FODDER SECURITY PROBLEMS

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Annotation

Insects as a new form of food: is it a trend or reality today? During the two decades that have passed since the beginning of the third millennium, the world's need for food has been steadily increasing against the background of an increase in the population. With the growth of the planet's population, the number of environmental, social, and economic problems is increasing. The coming decades are predicted to increase the pressure on the environment, expand the use of land resources on a global scale, and increase the demand for nutrients and non-renewable energy sources. An analysis of literary sources on food and environmental security was carried out and real threats arising on planet Earth were determined. The opinion of various scientists regarding the use of insects as a promising potential source of protein and essential substances, as opposed to animal husbandry, is given, considering the greater efficiency, the smaller amount needed to obtain resources, higher food security, and ecological and economic stability. It is expected that by 2050, the number of people on the planet will increase to 9 billion, respectively, the demand for proteins will increase by 40 %, water – by 40 %, energy – by 50 %. Mankind is forced to search for new sources of protein. Cultivating insects can be part of the decisions made. If we want to save the planet, the future of food is insects

Keywords: edible insects; entomophagy; cultivation; white; quality; food and feed security.

ЕНТОМОФАГІЯ – НОВЕ І ПЕРСПЕКТИВНЕ ДЖЕРЕЛО БІЛКА МАЙБУТНЬОГО ДЛЯ ВИРІШЕННЯ ПРОДОВОЛЬЧОЇ ТА КОРМОВОЇ БЕЗПЕКИ

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Анотація

Нова форма їжі – комахи: тренд чи реальність сьогодення? Протягом перших двох десятиліть третього тисячоліття, світова потреба в продовольстві неухильно зростає на тлі збільшення чисельності населення. На найближчі десятиліття прогнозується посилення тиску на навколишнє середовище, розширення використання земельних ресурсів у глобальному масштабі і збільшення попиту на поживні речовини та джерела енергії. Проведено аналіз літературних джерел щодо продовольчої та екологічної безпеки та визначені реальні загрози, що виникають на планеті Земля. Наведено думку різних вчених стосовно використання комах як перспективного потенційного джерела білку, есенціальних речовин на противагу тваринництву. Очікується, що до 2050 року кількість людей на планеті зросте до 9 млрд відповідно попит на білки збільшиться на 40 %, води – на 40 %, енергії – на 50%. Протягом останніх п'яти років наукові знання про комах як їжі та корму зростали в геометричній прогресії. У сучасному світі виробництво харчових продуктів і кормів з комах є перспективним направленням, тому що зростання попиту на м'ясо та обмежена площа землі спонукають до пошуку альтернативних джерел білка. До 2050 року очікується збільшення споживання продуктів тваринного походження на 60–70 %. Це потребує величезних ресурсів, причому корми є найскладнішими через обмежену доступність природних ресурсів, постійні кліматичні зміни та харчові продукти, корми, паливо. Витрати на звичайні кормові ресурси, такі як соєве та рибне борошно, дуже високі, до того ж їх доступність у майбутньому буде обмеженою. Вирощування комах може бути частиною прийнятих рішень. Якщо ми хочемо врятувати планету, майбутнє їжі – за комахами.

Keywords: їстивні комахи; ентомофагія; розведення; білок; якість; продовольча, кормова безпека.

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Introduction

Hunger and malnutrition are major health threats worldwide. Food supplies are depleting, the sharp rise in oil prices has driven up the cost of fertilizers and increased costs associated with food production. Climate change is one of the main modern challenges: the unpredictability of weather conditions, which endangers food production, rising sea levels, warming oceans and melting ice increases the risk of natural disasters of a global nature and unprecedented scale. A century and a half of industrialization, as well as extensive deforestation and the use of certain agricultural methods, have led to an increase in greenhouse gas emissions into the atmosphere. Together with the growth of the population and the development of the economy of the countries, the volume of greenhouse gas emissions increases. Taking into account the existing concentration of greenhouse gases and their ongoing emissions, it is quite likely that by the end of this century the average global temperature will rise by 1–2 degrees compared to the level of 1990 and by 1.5–2.5 C compared to the pre-industrial era. According to scientists, by 2065 the average world sea level will rise by 24–30 cm, and by 2100 – by 40–63 cm compared to the level of 1986–2005. Global emissions of carbon dioxide (CO_2) caused by human activity must be reduced by 2030 by almost 45 % compared to 2010 level. There is a question of finding both new sources of raw materials and reviewing cultivation, technology, and both the use of raw materials and the creation of completely new products.

Since it is expected that by 2050 the global demand for livestock products will almost double (from 229 million tons in 2000) to 465 million tons of meat, it is necessary to adopt innovative production solutions. There is a shortage of meat – people in the world consume more meat. If twenty years ago they consumed an average of 20 kg, now this indicator is 50 kg, and in 20 years it will be 80 kg. If we continue like this, we will need another planet. Professor Arnold van Huis, an entomologist (who eats insects himself) from the University of Wageningen in Belgium, the author of the UN document, believes that insects are a promising and new source of protein for the future, a preliminary resource for closing the lack of protein, the consumption of which has certain advantages – a high content of protein, vitamins and minerals. Because raising cattle for meat takes up almost two-thirds of the world's agricultural land, using 75 % of all fertile land for livestock grazing, and 35 % of the food produced in the world goes to feed these same animals, in addition, it creates 20 % of all greenhouse gases that cause global warming while breeding insects such as locusts, crickets and mealworms on farms produce 300 times less nitrous oxide, 10 times less methane, much less ammonia than livestock. Insects have a higher nutritional value than farm animals (meaning they use fewer resources to produce the same amount of nutrients) and produce fewer greenhouse gases. Therefore, the UN together with the FAO are searching for an alternative to meat. Insect breeding is proposed as an alternative to traditional animal husbandry for future food production [1]. Futurologists, who specialize in the food of the future, are sure that traditional chicken, pork and beef will soon be replaced by insects, from which sausages, wieners, and hamburgers will be made. According to the UN, out of 7.3 billion people on the planet, about 821 million inhabitants (a ninth of the population) suffer from chronic malnutrition. In fact, hunger and malnutrition are the number one health threat worldwide, ahead of AIDS, malaria, and tuberculosis. The solution to the problem of hunger by traditional methods is associated with the risks of ecosystem degradation and climate change. The demand for animal protein will increase the pressure on the Earth due to the need to produce a large amount of animal feed, which will lead to the conversion of forests, wetlands and natural pastures. It is necessary to look for alternative ways of "extracting" sources of calories for animal husbandry. Insect feed can make production cheaper. Over the past five years, scientific knowledge about insects as food and feed has grown exponentially. In today's world, the production of food and feed from insects is a promising direction, because the growing demand for meat and the limited area of land encourage the search for alternative sources of protein. Insects are the most widespread and diverse multicellular organisms on planet Earth and make up about 80% of all species [2; 3]. From prehistoric times until now, people have used eggs, larvae, pupae and adult insects of certain species as food. Insects and arachnids that are eaten around the world include crickets, cicadas, grasshoppers, ants, a variety of beetles, larvae of various types of caterpillars, scorpions and tarantulas. Eating insects is a real way to fight hunger in the world [4; 5]. Numerous agricultural crops are pollinated by insects, and this is of great importance, both for managing the national economy and for ensuring human health [6; 7].

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By 2050, consumption of animal products is expected to increase by 60–70 %. This requires enormous resources, with feed being the most challenging due to the limited availability of natural resources, ongoing climate change and the food-feed-fuel trade-off. The costs of conventional feed resources such as soy flour and fishmeal are very high and their availability will be limited in the future.

Discussion of the results of the analysis

Insects are a common food for many animals, including birds and fish that eat insects naturally. Their protein can replace from 25 % to 100 % of existing feeds - depending on the type of animal. It is easily digested and is not inferior in its nutritional properties to analogues. Protein from insects will stop the rise in feed prices. The main thing is that the breeding of these insects does not require land resources and large investments. here is an FAO Insect Farming Project in Laos that is providing skills to 15 000 domestic locust farmers in Thailand. In Laos, there is an FAO insect farming project that involves the skill transfer of 15,000 domestic locust farmers in Thailand. Locusts and crickets are rich in calcium and 90 % of people in Laos have eaten insects at some point [8]. FAO's priority is to increase the consumption of insects where it is already accepted. As a type of fast food (that's how people refer to them in countries like Thailand), insects are a more acceptable food source given the water and other resources required to breed them. Below is a visual example of the consumption of raw materials for growing animals (Fig. 1)

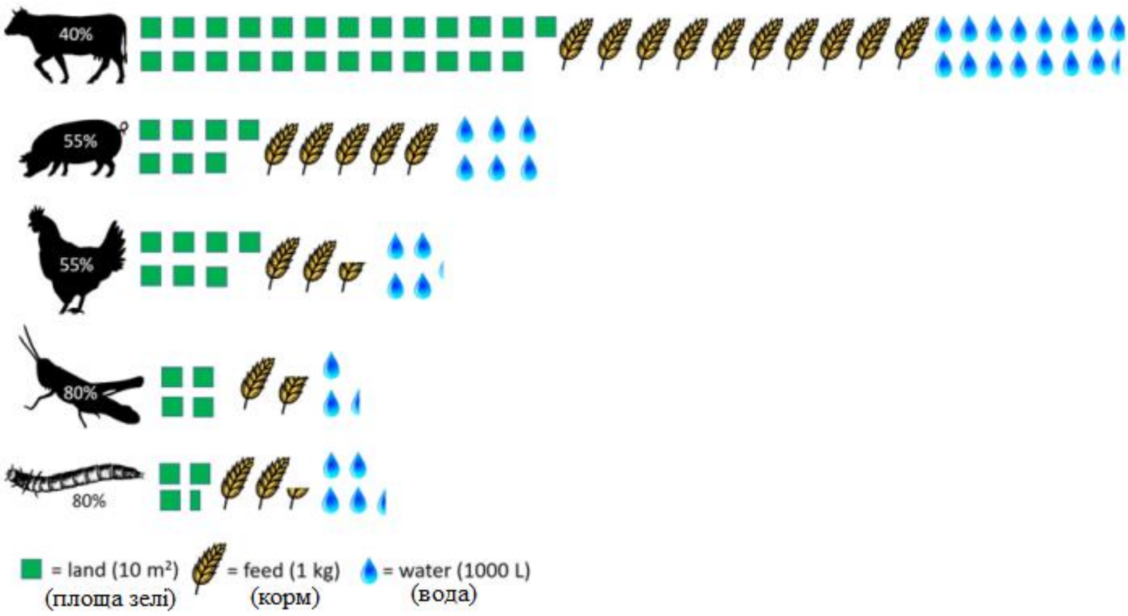

Fig. 1. The amount of land, fodder and water required for the production of 1 kg of animal live weight compared to the percentage of the edible part of reared animals [9].

The consumption of insects by humans, as a phenomenon, has existed in the world for a long time. Insectivory is characteristic of many cultures in North, Central and South America, Africa, Asia, Australia, and New Zealand. In more than 80 % of the world's countries, more than 1000 different types of insects are eaten voluntarily [4]. Insects are the most popular in the tropics, where they grow to large sizes and can be easily collected. The total number of ethnic groups in which insectivory is documented is close to three thousand [5]. People eat 235 species of butterflies and moths, 344 species of beetles, 313 species of ants, bees, and wasps, 239 species of grasshoppers, crickets, and cockroaches, 39 species of termites, and 20 species both of dragonflies and cicadas [10; 11]. Two billion people in the world, mainly in Southeast Asia and Africa, constantly eat insects: locusts, grasshoppers, spiders, wasps and ants. For today, with the constant threat of food shortages, efforts are being made to turn the concept of entomophagy, i.e. eating insects, into the norm, for the remaining 5 billion people of the planet. In 2012, the Food and Agriculture Organization of the United Nations (FAO) published a list of more than 1900 species of edible insects. In particular, in 113 countries of the world insects were registered as part of the human diet by various authors. The practice of eating insects is not yet widespread in the West. However, supporters of the popularization of insectivory see in it a solution to the problem of environmental degradation caused by animal husbandry [12; 13]. At the same time, eating insects for food is not acceptable, or even prohibited, among certain peoples. Today, the consumption of insects is not typical for the countries of Europe and Ukraine in particular, but is very popular in many regions of Latin America, Asia and Oceania [14; 15]. However, there is a growing trend in the popularity of insect consumption. Specifically, in North America ASPIRE Food Group became the first major industrialized company to grow environmentally friendly crickets for human consumption using automated equipment in a 25 000 square meter warehouse [16]. The European Union, for its part, offered its member states three million dollars for research on the introduction of technological processes using insects in cooking. There are a number of reasons for such serious steps. For example, insects, compared to farm animals and fish, are a more reliable source of food. There are enough of them: there are 40 tons of insects for every person on earth. Hunger and undernourishment are a serious problem for an ever-growing population. With the high rate of population growth on the planet, the world's food supply must grow at the same rate, if not faster. In much of the world, especially in Africa and Latin America, food resources are becoming scarcer and food imports more expensive. In addition, the war in Ukraine significantly reduced the export of its products to African countries. Therefore, it is very important to identify and develop local food resources. In order to effectively respond not only to rapid population growth, but also to other pressing issues, researchers have turned their attention to insects, not only because of their abundance, enormous biomass, and high-quality protein, but also because of the time-honored practice among many culturally diverse peoples in Africa and Latin America providing themselves with nutritious protein of good quality and high digestibility [17; 18]. The most popular edible insects include beetles, caterpillars, bees, wasps, ants, grasshoppers, crickets, cicadas, bugs, termites, butterflies and flies. Most insects provide farm animals and humans with a sufficient amount of energy, protein, amino acids, mono- and polyunsaturated fatty acids. They are rich in micronutrients such as copper, iron, magnesium, manganese, phosphorus, selenium and zinc. In addition, insects contain riboflavin, pantothenic acid, biotin, and some - folic acid [4]. There are thousands of varieties of insects that have been used all over the world since ancient times. For example, people willingly eat the secretion of bees – honey and use the secretion of silkworm caterpillars – silk, even in countries where it is not customary to use insects as food. Insects have been around for at least 400 million years and are among the oldest land animals. Edible insects are presented to humanity as a new and environmentally friendly source of protein. In addition, nutritionists found a significant amount of antioxidants and bioactive substances in grasshoppers, silkworms, ants, and other insects. It turned out that common grasshoppers and ants, as well as cicadas, silkworm caterpillars, and African butterflies are very healthy. They contain 2 times more antioxidants than orange juice and olive oil. Insects have a high protein content (40...75 g per 100 g of dry weight), which is very well digested (77...98 %). Table 1 shows the comparative content of protein in various species of insects, fish, and mammals [19–22].

According to entomologist Arnold van Huis [23], 246 species of edible insects have been registered in 27 African countries. Another study conducted 2 years later by Ramos Elorduy suggests that Africa is one of the most important hotspots of edible insect biodiversity in the world, with 524 species recorded in 34 African countries [24].

Table 1

Protein content of different species of insects, fish, and mammals, g / 100 g of dry weight [20]

Species	Product	Protein
Locusts and grasshoppers	Full-grown	13-28
Bombycid	Caterpillars	10-17
Flour beetle	Larva	14-25
Crickets	Full-grown	8-25
Termites	Full-grown	13-28
Poultry	Chicken (fresh)	17-22
Cattle	Beef (fresh)	19-21
Fish	Mackerel	16-28
Fish	Catfish	17-28

These species mainly belong to Orthoptera, Lepidoptera, Rigoptera, Hymenoptera and Isoptera. Among the most important groups of insects consumed in the world are Hymenoptera,

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Hymenoptera, Isoptera, Lepidoptera, and Orthoptera, which have a high nutritional value (Fig. 2) [25].

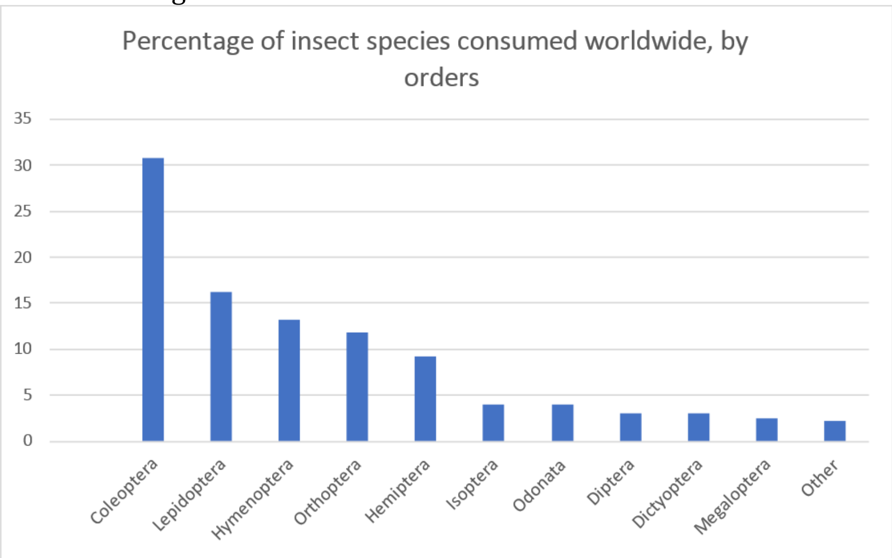

Fig. 2. Types of insects that are used for food on planet Earth [26]

The most common edible insects in the world are beetles (Coleoptera – 31 %) (Fig. 2). This group contains about 40 % of all known insect species. The consumption of caterpillars (Lepidoptera) is particularly popular in sub-Saharan Africa and is estimated at 18 %. Bees, wasps and ants (Hymenoptera) occupy the third place – 14 % (these insects are especially common in Latin America), grasshoppers, locusts and crickets (Orthoptera – 13 %); cicadas, scale insects, and real bugs (Hemiptera – 10 %); termites (Isopter – 3 %); dragonflies (Odonata – 3 %); flies (Diptera – 2 %) other species (5 %). Lepidoptera are eaten as caterpillars, and Hymenoptera mainly in the larval or pupal stage. Insects from the order of orthoptera, homoptera, isoptera, and hemiptera are eaten in the full grown stage. (Cerritos, 2009).

Below is a list of the most consumed species of edible insects in the world and they location (Fig. 3).

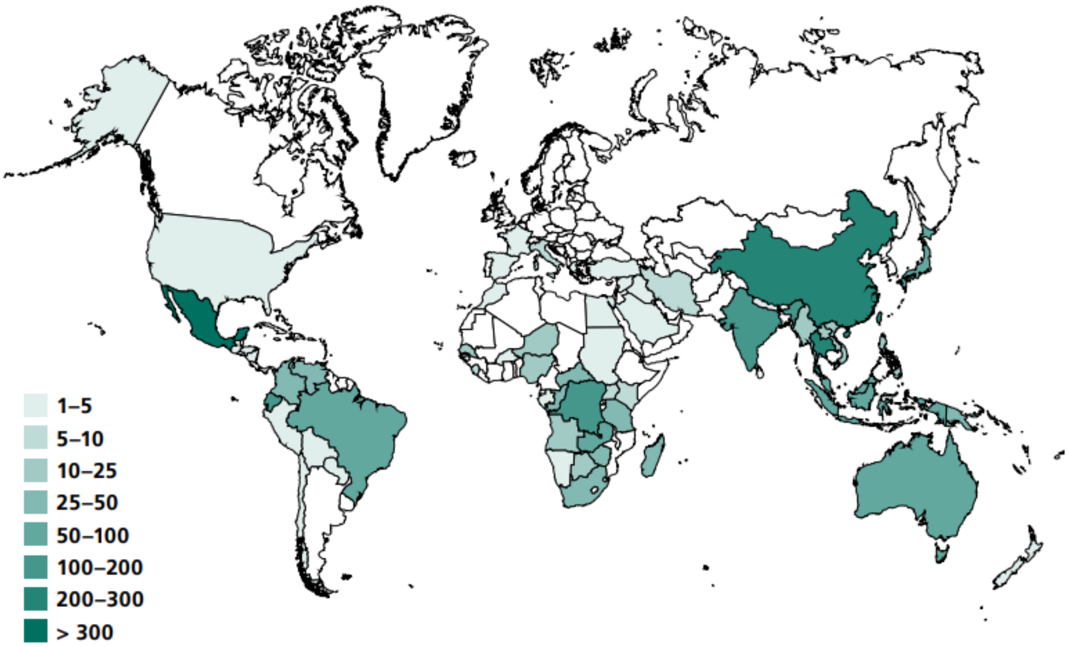

Fig. 3 Registered number of species of edible insects in the countries of the world. Source: Center for Geoinformation, Wageningen University, based on data compiled by Jongema, 2012. [26].

More than 1900 species of insects are known to be part of the diet of more than 2 billion people who consume insects on a regular basis, and insect diets provide a significant proportion of

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animal protein consumed in some regions [23]. In fact, in many developing countries and among different cultures scattered around the world, insects remain a vital food and an important source of protein, fat, minerals and vitamins [16]. This is because some edible insects have a high biological value, comparable to the nutritional value of meat and fish, while other insect species have a higher content of fats and micronutrients [27]. This has become particularly important as the need for alternative protein sources increases due to rapid urbanization in developing countries and changes in the composition of global food demand. The edible insects market is segmented into: whole insects, insect powder, insect meal and insect oil. The market offers a selection of protein bars, drinks and cocktails, flour and confectionery products made from insects. Insect-based food products certainly show potential for use as alternative sources of protein in the human diet. The development of the market for protein products from insects can solve not only social, but also environmental problems. Every year there are more proposals for food products using insect protein (Table 2a, 2в) [28].

Table 2a

Overview of Functional Insect Products

Company name	**Product**	**Country**
Fazer	Bread with the addition of flour from crickets	Finland
«Onto-biotechnologies» + «Onega»	Cricket chips	Belarus
BBQ Flavour	Crispy snack made of silkworm	USA
Green Bugs	Canned larvae flour crunch in tomato or carrots	Belgium
One Hop Kitchen	Cricket sauce	Italy
Essento	Bars, cutlets made of crickets	Switzerland
Insect Bar incredible burger	Insekten burger Burgers with schnitzel and nuggets. This burger looks like a regular beef burger, but instead of beef it consists of a mixture of insects and vegetables	Belgium
Yora	Flour from oats and potatoes, with the addition of insects	Great Britain
Atelier a Pates	Fusilli pasta made from cricket flour	France
Cricket Lab	Flour from crickets	Thailand
Bitty Foods	Muffins, cookies and many other bakery products with the addition of flour from crickets	USA
Chapul	Protein from crickets in the form of powder	USA
Exo	Protein bars with cricket flour	USA
Sens	Energy bars and crackers with cricket flour	Czech Republic
Bugsolutely	Macaroni made of cricket flour	Thailand

Table 2b

Characteristic of a functional product from insects

Product	Product name	Appearance	Producer	Characteristic
Bitter (alcoholic tincture)	Critter bitters"		The Trouble Makers inc	Unique taste due to crickets

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Cricket loaf	Crunchy Cricket loaf		British bakery Roberts	Roberts bread is made from a mixture of wheat and cricket flour. Compared to ordinary bread, it contains more protein, less fat, is enriched with calcium, iron, vitamins B_{12} and C.
Insect burger	Insekten burger		Incredible burger	This burger looks like a regular beef burger, but instead of beef, it contains a mixture of insects and vegetables.
Frozen semi-finished products from crickets	Naukas Pannu Sirkka		Griidy & K-citymarket	Pre-cooked and then frozen crickets that you just throw into the pan
Crispy bread	Crispbread		The Swedish company Kafka	Crispy bread in which 1/3 of the flour is replaced with insect powder (mealworm or cricket). An excellent snack.
Insects for gourmets	Hiroshima Crickets		Takeo, Japan	"Hiroshima Crickets" are crickets that have been fed almonds to give them a savory almond flavor. Crickets are sold in two versions: a semi-dried and frozen version and a fried version. Price: 2,080 yen for a pack of 19 grams of crickets, about 900 euros per kilogram.
Bioactive supplements (BAS) from crickets	The Original Cricket Pills		Paradox Protein (USA), Grig (Czech Republic)	Crushed mass of crickets in the form of pills containing complete protein, vitamin B_{12}, calcium, magnesium, and iron.
	Immunity Booster			

Flour and protein powders can be made from edible insects. Insect flour is usually obtained by dehydrating or frying whole insects, followed by grinding them into a fine powder – flour. The process of insect protein extraction by enzymes is a longer proteolysis (the process of gradual splitting (hydrolysis) of proteins into peptides and amino acids by enzymes) and a higher concentration of enzymes leads to the formation of peptides with a lower molecular weight and different degrees of functional properties. Similarly, the choice of protease specificity will influence the sequence of peptide amino acids and/or amino acid residues, which lead to unique nutritional and techno-functional properties in protein hydrolysates [29–31]. The nutrient content of insects varies considerably between species. Even within the same group of edible insects, values can vary depending on the insect's stage of metamorphosis, habitat, and diet. The methods of preparation and processing (such as drying, boiling or frying) before consumption also affect the nutrient composition. There are different ways of processing insects into familiar products. In Kenya, termites and lake flies are baked, boiled, steam cooked under pressure, and processed into crackers, muffins, sausages and meat loaf [15; 32]. In Thailand, restaurants include fried giant red ants, crickets and June beetles on the menu.In Colombia Hormigas Culonas is a popular snack made of fried and salted insects. Papua New Guinean sago larvae in a banana leaf are a local delicacy. Winged termites in Ghana are collected and fried or baked into bread. In Japan, the menu includes candied larvae of water flies and grasshoppers. In Mexico, agave worms are eaten on tortillas (tartlets), and grasshoppers are fried. In Cambodia, deep-fried tarantulas are popular among locals and tourists. In the Republic of South Africa, locusts are added to maize cereal, and in Australia, Witchetty larvae are traditional part of the diet of native people. Larvae of the African palm weevil, Rhynchophorus phoenicis (Coleoptera: Curculionidae), are a popular food item in the humid tropics. An approach to obtaining nutritional and sustainable benefits from consuming insects is to grind the insects into powder form or use insect-derived ingredients such as protein, fat, and chitin. Including insects in a product in an unrecognizable form (for example, in the form of powder to ordinary flour when baking bread, or to minced meat in the manufacture of sausage products and semi-finished meat products) can facilitate negative perception and allows to associate them with more familiar basic food products.

Table 3

Protein content of different types of insects (per 100 g of product)

Species or subspecies	Latin name	Stages of insect development	Protein content (% of dry matter)
Beetles	Coleoptera	Full grown and larvae	23–66
Butterflies	Lepidoptera	Pupae and larvae	14–68
Hemiptera	Hemiptera	Full grown and larvae	42–74
Homoptera	Homoptera	Full grown, larvae, and eggs	45–57
Hymenoptera	Hymenoptera	Full grown, pupae, larvae, and eggs	13–77
Dragonflies	Odonata	Full grown and naiads	46–65
Orthoptera	Orthoptera	Full grown and nymphs	23–65

Table 4

Fat content in the dry matter of edible insects

Insect name	Latin name	Stage of insect development	Fat content (% in the dry matter)
Silkworm (Bombyx mori)	Bombyx mori	Chrysalis	29
Western honey bee	Apis melifera	Brood	31
African migratory locust	Locusta migratoria	Nymph	13
Wax moth	Galleria mellonella	Caterpillar	57
Jamaican grasshopper	Gryllus assimilis	Nymph	34
Yellow mealworm	Tenebrio molitor	Insect larva	36
Giant mealworm	Zophobas atratus	Insect larva	40

Studies have shown that the non-acceptability of edible insects is related to emotional factors (disgust) as well as unfamiliar tastes and textures, which suggests that the inclusion of insects as an ingredient in a product can be a potential "gateway" for a wider acceptance of edible insects by consumers in the West [33; 34]. For example, European and American consumers have shown interest in food products made from insects, where the insects are added in the form of protein powders or flour and, thus, are not in a visible (recognizable) form [35; 36]. Insects are rich in proteins (20–70 %), amino acids (30–60 %), fats (10–50 %), carbohydrates (2–10 %), mineral elements, vitamins and other biologically active substances (BAS), which contribute to human health. The choice of insects as food is further enhanced by the fact that they are potential sources of protein, fat, vitamins and minerals, especially iron and zinc [37–43].

The protein content is in the range from 13 to 77 % of dry matter [42]. The fat content in the dry matter of edible insects is low [44].

Fat is present in insects in several forms. Triacylglycerols make up about 80 % of fat. They serve as a reserve of energy for periods of high energy consumption, such as longer flights.

It should be noted that the content of vitamins and minerals in the wild range of edible insects is seasonal, and when growing insects on farms, it can be controlled with feed. In many countries of the world, insects are eaten alive immediately after they are caught. After keeping insects hungry for 1–3 days, they are scalded with hot water [40] and further culinary processing is carried out – cooking with/or adding insects to the product, baking, frying or drying. The three most common types of insects that will be offered in specialty stores that breed and process edible insects for human consumption include: yellow mealworm larvae, smaller mealworm larvae, and migrating locusts [37; 45; 46].

Organoleptic properties are important criteria when consuming edible insects. The taste and aroma of insects are very diverse (Table 4.), from the smell of fish to sweet nutty. The taste is mainly influenced by pheromones located on the surface of the insect's body [46]. It depends on the environment in which insects live, and the feed they consume. The choice of feed can also be adapted depending on what we want the taste of the finished product to be. If insects are scalded, they practically lose their taste, as the pheromones are washed away. During cooking, insects acquire the aroma of the added ingredients, which give piquancy and exquisite taste to the finished product(s).

Table 5

The taste and aroma of different types of edible insects

Edible insects	Taste and aroma
Ants, termites	Sweet, almost nutty
Dark beetle larvae	Whole grain bread
Larvae of wood-destroying beetles	Fat brisket with skin
Larvae of dragonflies and other aquatic insects	Fish
Cockroaches	Mushrooms
Striped shield beetles	Apples
Wasps	Pine seeds
Wood caterpillars	Raw corn
Floury crunch	Fried potatoes
Water boatman's eggs	Caviar
Butterfly caterpillars	Herring

Source: J. Ramos-Elorduy [46]

Insect exoskeleton affects texture. Insects crunch, and the sounds that occur when they are eaten resemble the sounds of crackers or pretzels [46]. Edible insects in the stage of pupae, larvae (caterpillars) and nymphs are the most consumed, as they contain a minimal amount of chitin and are better absorbed by the human body. During cooking, the color of insects usually changes from primary shades of gray, blue or green to red [46]. Insects containing a significant amount of oxidized fat or improperly dried can be black. Properly dried insects are golden or brown in color and can be easily crushed with your fingers [45]. When considering insects as animal feed, they are an ideal alternative source, because the costs of producing meat, fish, and soybean meal as animal feed account for more than 70 % of the cost of the finished product in the production costs of livestock production. Considering the fact that insects have a relatively high content of nutrients, require smaller areas for cultivation, and are already part of the natural diet of pigs, poultry, and fish, including them in the feeding diet for growing broilers does not lead to a decrease in growth rates, and in some cases, even to the opposite - to an increase in the weight of chickens [47–49]. Aquaculture (breeding of fish, crustaceans, and other aquatic animals) is one of the fastest growing industries. However, the main obstacle to the sustainable development of the industry is the cost of feed, in particular fishmeal and fish oil. About 10% of fish production is processed into fishmeal, and ocean fish stocks are depleted by overfishing to feed the fish themselves. Increasing restrictions on unregulated catches and catch quotas have forced the aquaculture industry to look for alternative sources of high-quality feed protein, where insects can play an important role. The use of insects in fish feed is not new and is widely practiced by smallholder farmers in Africa and Asia. Black soldier flies, housefly larvae, silkworms, and mealybugs are mostly used in aquaculture feed, but studies conducted by scientists on fish feeding have yielded mixed results on protein content and the ratio of EPA and DHA lipids to other nutrients. Freshwater fish respond better to insect feed, and after conducting research, scientists recommend replacing 25 % of fishmeal with black soldier fly flour or locusts. Similarly, up to 75 % of fishmeal in the diet of Nile Tilapia was replaced with housefly maggot flour without any adverse effects [46; 50].

Conclusions

Insects are promising from the point of view of food material, and in the future they can be included in the general diet of the EU population, as well as used as a food additive for the production of functional food products. The inclusion of potentially suitable edible insect species in the human diet requires certain standardized conditions for their cultivation, detailed monitoring of their chemical composition, quantitative and qualitative analysis of the content of biologically active substances. Methods for determining food safety and quality should also be standardized. Accordingly, the solution requires close cooperation of scientists from the fields of cognitive neuroscience, medicine, agriculture and food industry. Insects have great potential in food and feed production, and this could become a new sector of agriculture and food industry. In addition, the acceptability of insects for food should be ensured by technologists, whose goal is to make the product gastronomically attractive and tasty. Edible insects, whose safety and quality are guaranteed, should be available to the general population with an appropriate acceptable and affordable price.

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