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Socio-Economic Factors of the Edible Insects' Market Development

Zarema Musaevna Dzhalyukova[1], Victor Aleksandrovich Fursov[2*], Valentina Ivanovna Rodionova[3], Lyudmila Alexandrovna Shvachkina[3], Tatiana Alekseevna Zolotareva[4]

[1]Department of Therapy, Faculty of Medicine of Dagestan State Medical University, Makhachkala, Republic of Dagestan, Russia.
[2]Department of State and Municipal Management and Labor Economics, Institute of Economics and Management of the North Caucasus Federal University, Stavropol, Russia.
[3]Department of Social and Humanitarian Disciplines, Faculty of Law, Social Technologies and Psychology of Don State Technical University, Rostov-on-Don, Russia.
[4]Department of Social Philosophy and Ethnology, Humanities Institute of the North Caucasus Federal University, Stavropol, Russia.

ABSTRACT

Due to the increase in the population on the planet, there is a question of an acute shortage of food. A particularly global problem is the lack of protein – the primary building material for all body tissues, organs, and systems. Modern scientists consider algae, microorganisms, and insects to be alternative protein sources. Studies of insect protein show a complete amino acid composition with a fairly large proportion of essential amino acids. In addition to protein, the insect body contains fats, including in the form of polyunsaturated fatty acids, as well as copper, zinc, calcium, and some other trace elements. In some countries (Asian and African), edible insects are taken for food; in some American and European countries, insects are bred in order to process them into pet and bird feed. However, many researchers do not doubt that only eating insects will be able to solve the problem of protein deficiency associated with overpopulation in the future. This article describes the advantages of insect biomass as a source of high nutritional value, which can be produced in large quantities without much harm to the environment. The social factors influencing the potential willingness of residents of different countries to consume insects for food are also described.

Keywords: Entomophagy, Insects, Protein, Chitin, Trace elements, Edible insects' market.

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Corresponding author: Victor Aleksandrovich Fursov
E-mail ✉ ruslankalmykov777@yandex.ru
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INTRODUCTION

Every year the world's population increases by 70 million people. Already, many people are suffering from malnutrition: according to FAO estimates, in 2017, the number of hungry people was 821 million [1]. The shortage of fats and complex carbohydrates is felt in a number of countries. However, the most acute issue is protein starvation. Approximately half of the 7 billion people currently living on Earth suffer from a lack of dietary protein. Its total deficit on the planet is now estimated at 10-25 million tons per year [2].

Currently, about 70% of all agricultural land is used for breeding domestic animals (as a traditional source of protein), and 30% of the entire land is occupied for cattle breeding. At the same time, a third of these land resources account for the cultivation of feed for livestock itself [3]. It is also impossible to ignore the fact that meat production has a serious negative impact on the environment: CO_2 emissions from cattle alone amount to 7.1 gigatons per year. Accordingly, the growth in traditional meat production will exacerbate this problem. In this situation, humanity is forced to look for other types of food and, above all, protein [4, 5].

Over the past 15 years, even a separate term has been formed in the field of alternative sources of raw materials — "neoprotein products." They are created on the basis of vegetable protein and microorganisms. Already, such products are widely represented on the Asian market in the form of tofu, seitan, soy meat, as well as lean products based on lupin. In addition, there are drinks based on vegetable protein — soy, nut, oat milk, etc. Alternative protein refers to three types of products: cultured (artificial) meat, vegetable meat, and insects [6-8].

Insects are already a traditional part of many regional and national diets. About 2 billion inhabitants of Asia and Africa currently eat about 1.9 thousand species of edible insects. Most edible species live in China, Thailand, India, and Mexico. **Figure 1** shows the most consumed insects in the world. Insects have a high protein content (40-75 g per 100 g of dry weight), which is very well absorbed (77-98%) [9].

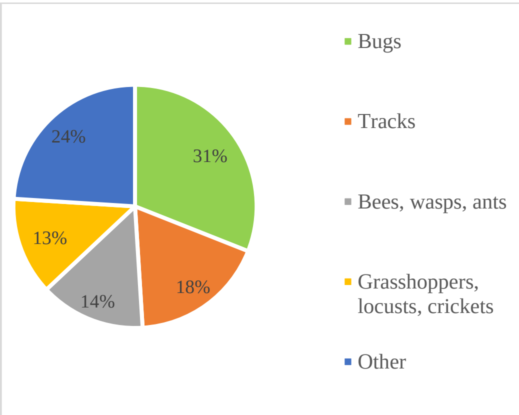

Figure 1. The most commonly used insects [9]

Insects contain high levels of protein, and fats are quite high in calories. In addition to their nutritional value, they also represent an effective way of disposing of biomass of food waste, updating it to valuable feed ingredients that become full-fledged food along the technological chain [10].

It should be noted that in the European Union, since 2017, it has been allowed to use insects as fish food. These are proteins derived from some insects: American soldier fly (*Hermetia illucens*), yellow mealworm beetle (*Tenebrio Molitor*), lesser mealworm beetle (*Alphitobius diaperinus*), tropical house cricket (*Gryllodes sigillatus*), Jamaican field cricket (*Gryllus assimilis*), etc. Yellow mealworm beetle (*Tenebrio Molitor*) is one of the most promising insects for human consumption and is already used for forage. However, to date, the use of insect proteins for any other animal species other than fish is not allowed in the EU.

Insects as a feed ingredient have great potential for several reasons: high content of nutrients – proteins, fats, vitamins, and minerals; comparative simplicity of their fattening; low requirement for their maintenance space; naturalness of feeding birds and fish with insects. Futurologists specializing in the future of food are confident that the traditional chicken, pork, and beef will soon be replaced by insects, from which organoleptically flawless sausages, sausages, and hamburgers will be made. The idea they promote in the media is that eating insects is a real way to fight global hunger [11, 12].

Nutritional value of insect biomass

Insect protein has a full-fledged amino acid composition, and the proportion of essential amino acids in it is quite large. So, in 1 kg of dry matter, raw materials from the larva of the yellow mealworm beetle (*Tenebrio Molitor*) contain 24.7 g of isoleucine, 52.2 g of leucine, 26.8 g of lysine, 6.3 g of methionine. **Figure 2** shows the protein content in some insects relative to other foods.

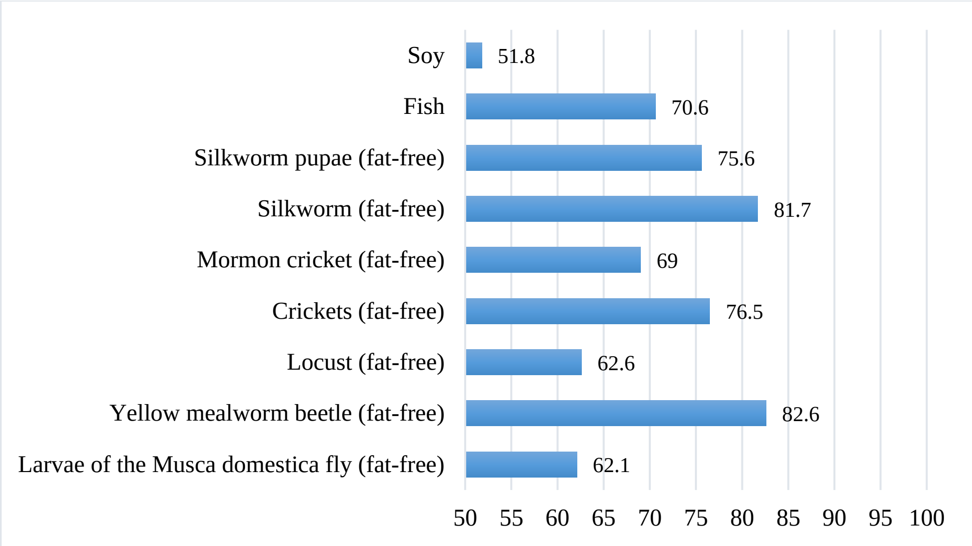

Figure 2. Protein content in some insects and other products

Nutritional parameters depend not only on the type of insect but also on the substrate on which it is cultivated. Thus, from houseflies grown on chicken manure, a feed product that was not inferior in nutritional properties to analogs produced using husk grains mixed with yeast was obtained. The nutritional value of feed raw materials from the mealworm beetle larva increased with the use of a substrate with the addition of yeast [13, 14].

In addition to protein, the insect body contains fats, including in the form of polyunsaturated fatty acids. Their level varies between 11-36%. For example, in the mealworm beetle larva, the fat concentration reaches 35.2%, with omega-6 and omega-3 polyunsaturated fatty acids accounting for 91.2 and 3.3%, respectively. Insects are a natural source of fiber. It is represented by chitin (2.7–49.8 mg/kg in live insects and 11.6–137.2 mg/kg in dry matter). Chitin has been found to have an antiparasitic effect. Feeding it to pets and poultry has a beneficial effect on their immune system. In addition, the insect body contains copper, zinc, calcium (it is most in the larvae of American soldier fly (*Hermetia illucens*), phosphorus, potassium, sodium, iron, magnesium, vitamins A and B (riboflavin (B2), calcium pantothenate (B5), biotin (B7) and folic acid (B9). Some insect species (mealworm beetle, American soldier fly, etc.) and their larvae contain a significant proportion of antimicrobial peptides, particularly defensin. Like prebiotics, antimicrobial peptides normalize the composition of the intestinal microbiota by blocking the reproduction of pathogenic microorganisms and stimulating the growth of the native (own) microflora of the host organism. Therefore, antimicrobial peptides can be considered an alternative to antibiotics. The antibacterial effect is most pronounced when growing larvae on an organic substrate, including cow manure or guano (decomposed remains of seabird and bat droppings) [15-17].

The use of insects by the inhabitants of some countries of the world

Insect-based foods certainly demonstrate the potential of being used as alternative sources of protein in the human diet. For example, insects have been consumed in China for more than 2 thousand years. In general, the acceptance rate for insect consumption in China is very high. Over the past 20 years, many studies of edible insects have been conducted, the scope of which included, among others: entomophagy culture and insect identification, nutritional value, agriculture and breeding of edible insects, as well as food production and safety. Currently, 324 species of insects have been documented that are either edible or are associated with entomophagy in China or medicinal. The nutritional value of 174 species available in China, including edible, forage, and medicinal species, has been studied. Edible insects have been directly consumed and continue to be consumed by various ethnic groups in many parts of China. Also, people indirectly consume insects by eating livestock-fed insects. However, even in China, data on the food safety of insects are limited, cases of allergic reactions have been reported after eating silkworm pupae, cicadas, and crickets. At the same time, insect breeding is a unique industry in rural China and serves as a source of income for the local population. Insects are raised and bred for human food, medicine, and animal feed using two approaches: they are either entirely domesticated and raised entirely in captivity or partially raised in captivity, and the insect habitat is specifically maintained to increase production [18].

To date, close attention is paid to edible and medicinal insects in India: consolidated lists of insects that have long been used in Northern India by local tribal societies have been prepared and carefully verified. The lists include 81 species of native insects belonging to 26 families and 5 orders of insects. Depending on the species, only individual stages or all stages of insect development are consumed. Some food insects can be included in the local diet throughout the year, others – only in a certain season. Usually, insects are prepared for consumption by roasting or boiling. Twelve species of insects are considered therapeutically valuable by residents and are used to treat various disorders in both humans and pets [9].

Currently, the task of changing the attitude of Europeans toward insects and worms is being set in Europe. It is necessary to overcome food aversion to solve the problem of using insects as food for the European population. Therefore, the team of one of the Danish nutrition laboratories is looking for ways to convince Europeans of the benefits, as well as the excellent taste qualities of grasshoppers, ants, and caterpillars, and chefs are developing attractive recipes [2].

In one of the papers, the perception of insect-based products by consumers in Germany was investigated. A nationwide online survey focused on what factors have the greatest impact on the willingness to eat a burger with insects and worms. In addition to the socio-demographic factors of meat consumption and the "classic" variables in the field of entomophagy (familiarity, previous insect consumption, food neophobia, food technology neophobia), the study focuses on the sustainability of food aversion. A total of 42% of the participants were ready to eat a hamburger with insects. At the same time, only 16% of the participants were willing to consume worms as the main ingredient of a hamburger with insects [19, 20].

Hierarchical multiple regressions have shown that food aversion is the most important predictor of the acceptance of edible insects, followed by previous insect consumption, food neophobia, gender, sensation seeking, and cooking neophobia [21]. Edible insects are presented as a new and environmentally friendly source of protein. In addition, nutritionists have found in the body of grasshoppers, silkworms, ants, and other insects a fair amount of antioxidants and other beneficial BAS [16].

Insects as food and its ingredients are not at all a distant future, as it may seem. In Russia, for example, several enterprises already grow insects for animal feed and plan to produce products for humans from them – functional nutrition, protein bars, and bread.

The economic situation in the market of edible insects

Last year, FAO estimated the market capacity of edible insects at $400 million. In 2018, 6 thousands of tons of insects were produced worldwide for human food use. Even in countries with a developed culture of consumption of such food, this is an insignificant share of the diet, not comparable to hundreds of millions of tons of grain, meat, and other traditional products. The undisputed leaders in the number of insect species used are Thailand, Laos, Indonesia, China, Vietnam, Mexico, Brazil, and Australia. But even in the USA, Argentina, and a number of Western European countries, there are traditions of eating insects [22, 23]. **Figure 3** shows the main branches of insect consumption. **Figure 4** shows the forecast of the insect market for 2023 in monetary terms.

People do not eat insects (excluding accidental ingestion of humans) in Northern and Eastern Europe, Russia and the former USSR countries, and some countries of the Middle East. Most religions prohibit the use of insects, including Islam, Christianity, and Judaism.

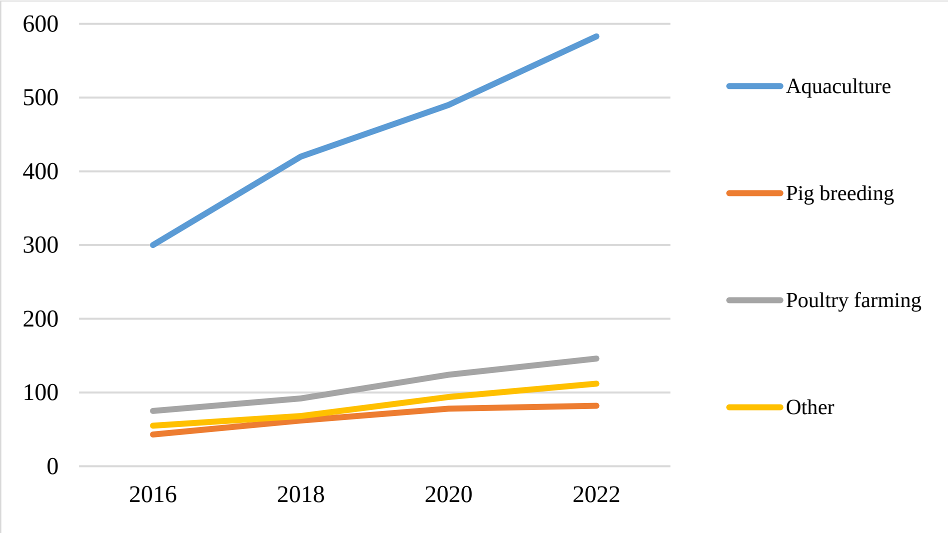

Figure 3. The main consumers of insect feed from 2016 to 2022, thousand tons

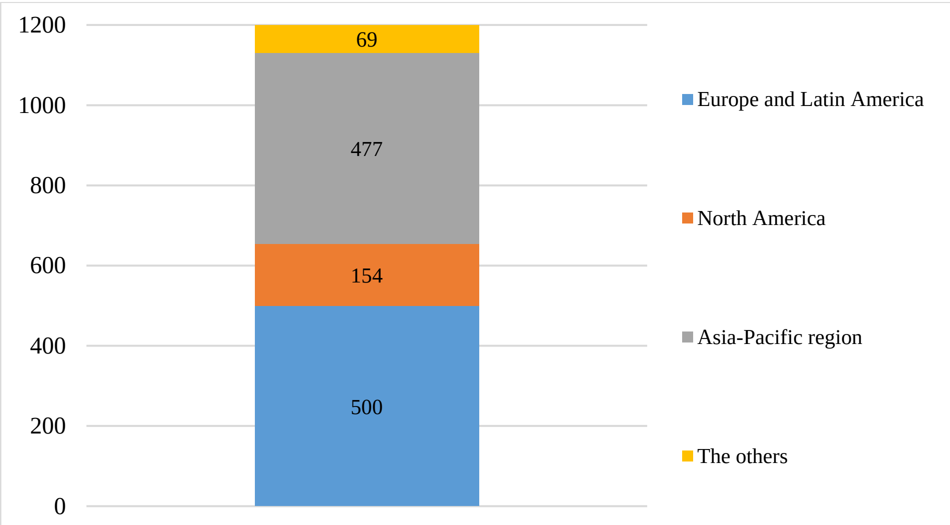

Figure 4. Insect market forecast for 2023 in monetary terms, millions of US dollars

Meanwhile, the FAO predicts the growth of the edible insect market to $1.2 billion by 2023 **(Figure 3)**. The main market players of insect biomass products include Entomotech (Spain), Meertens (Netherlands), Agriprotein (UK-South Africa), Ynsect (France), Proteinsect (Netherlands), Protix (Netherlands), Enterra (Canada), Big Cricket Farms (USA). In particular, the Spanish company Entomotech is developing a pilot project for obtaining an alternative protein feed product and fat from insects. The Dutch Meertens receives up to 800 kg of larval biomass per day and processes it. In South Africa, the British corporation Agri Protein in 2014-2015 built a large plant where, on an area of 8.5 thousand m2, 8.5 billion flies daily process 250 tons of bio-waste into 50 tons of feed. In the future, the company is going to build 25 similar enterprises in the next ten years. Big Cricket Farms, a company that processes crickets, works with insect biomass as part of the Boston startup SixFoods [22, 24].

According to the association "BioTech2030 Technical Platform" assessment, the most suitable insects for industrial breeding are the American soldier fly, housefly, migratory locust, desert locust, house cricket, two-spotted cricket, mealworm beetle, zofobas and marble cockroach. American soldier fly is one of the most promising species in terms of the rate and amount of biomass accumulation, protein and fat content, indicators of sanitary-epidemiological and environmental safety. The insect is characterized by unpretentiousness, and its larvae are omnivorous, with the ability to develop in wide temperature ranges (20-50 ℃) and humidity (40-

90%), that is, high technological efficiency in breeding. American soldier fly adults are not attracted to human habitation, they do not have a developed oral apparatus, do not eat, do not bite, are not carriers of diseases, and do not bother people, unlike houseflies. The larvae of this fly contain about 40% protein and about 40% fat, rich in calcium and phosphorus. The flour obtained from them is non-toxic in a bioassay on laboratory animals, does not contain conditionally pathogenic fungi, salmonella. The issues of breeding American soldier flies to obtain feed protein are already actively engaged in the USA, Canada, Holland, Austria, Greece, Germany, South Africa, India, China, and other countries [25].

Edible insect market in Russia

In Russia, we are not talking about the use of insects for human food yet. The few insect-growing projects existing in the country specialize in the processing of animal waste by the latter and the production of animal feed based on insect biomass.

For example, the Entoprotek enterprise (Moscow) grows American soldier flies and specializes in processing agricultural waste into animal feed additives. Flour is in great demand among livestock enterprises.

According to some manufacturers, the volume of production of entomological protein for animal feeding will grow rapidly. Already, at least the Moscow market offers crickets, mealworm beetle, and locusts for food. Theoretically, Entoprotek's products are also suitable for humans. Another thing is that, at the moment, there is no such market in Russia.

Nevertheless, for humans, almost all insects are suitable for food. The question is about scaling and culture. In addition, it is not clear whether it is profitable to develop such a business from an economic point of view. For example, investors have taken on the industrial production of locusts more than once, but it is more difficult to grow it than flies – it must eat a special juicy diet. It is also difficult to produce crickets – their growing cycle reaches up to three months. So far, there is no documentary base for human consumption of insect products that would regulate the sale of such a protein [26].

There are scientific developments on the creation of food additives and medicines for humans based on the biomass of flies. Insect biomass can be used, for example, in the manufacture of bread. Functional and specialized food is already being supplied to the Russian and Asian markets: suspensions, loaves, and bars [27].

The biomass of fly larvae can be used as a raw material for the production of functional protein products for human nutrition. As a rule, we are talking about adding insect flour (which is 70% protein) to the standard ingredients for the production of chips, bars, and cookies. In the future, it is planned to introduce some raw or dry larvae into the composition of minced meat or sausages instead of meat or to replace soy flour. Larva biomass is also used as a valuable raw material for the pharmaceutical, microbiological, cosmetic, and food industries [28-30].

There are no legal restrictions on the consumption of insect protein in Russia, except for psychological ones peculiar to specific individuals. Although there is no tradition of eating insects by humans in Russia, some ingredients obtained from insects have been eaten by us for a long time and are not considered something exotic. Thus, the additive carmine (a natural dye obtained from carminic acid, which is produced in its body by insects – representatives of the genus Porphyrophora) is allowed and has been used for the production of food products for a long time.

CONCLUSION

Due to the high content of protein, fats, and trace elements, insects have a huge potential for human consumption. Residents of some countries (India, China) have been using insects since ancient times for nutritional and therapeutic purposes. In many countries of Asia and Africa, the use of insects for food is ubiquitous and traditional. The countries of Europe, South, and North America are actively working with the biomass of some insects to create a food base for pets. At the same time, the population of these countries is not ready for the mass consumption of insects for food for a number of reasons. Firstly, most religions, including Islam, Christianity, and Judaism, prohibit the use of insects for food. Secondly, there is a culture of rejection and food aversion. Thus, while some residents of the poorest regions are trying to survive, residents of more affluent countries use traditional sources of protein (fish, meat) or switch to alternative sources of protein that have already become familiar (vegetable protein).

Nevertheless, the constant increase in the world's population, the total shortage of drinking water and natural resources will inevitably lead to the fact that some species of insects will be used everywhere as additional food for humans. Insect feeds are rich in fats, fiber, valuable macro-, and microelements, and vitamins, contain a large amount of protein with a full amino acid composition, have antibacterial properties (including against enteropathogenic salmonella — the causative agent of enteritis), contribute to the normalization of the intestinal microbiota. The human diet is evolving; not only nutritious but also environmentally friendly and healthy products are in demand.

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