ŻYWNOŚĆ. Nauka. Technologia. Jakość, 2022, 29, 1 (130), 23 – 38

DOI: 10.15193/zntj/2022/130/405

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SELECTED UNCONVENTIONAL SOURCES OF PROTEIN AND OTHER NUTRIENTS

S u m m a r y

Background. Nowadays, the world is confronted with the problem of rapid population growth and constraints on food productivity to meet the nutritional needs of all people. Agriculture and the food industry are facing difficulties in increasing food production as natural goods such as cultivable land area, water and electricity are being depleted. One of the most important dietary components that may start to become scarce is protein. Existing protein sources, especially animal protein, are very detrimental to the climate, hence not only new solutions, but also new and more sustainable protein sources must be sought.

Results and conclusion: Some possible new protein sources and other nutrients may include edible insects in the form of flour from e.g. the house cricket (*Acheta domesticus*), marine algae in the form of powdered Spirulina (*Arthrosipra platensis*), ocean krill e.g. antarctic krill (*Euphausia superba*), cultured meat or Single Cell Protein (SCP). While these raw materials have not been widely used to date, their composition and nutritional value may seem promising. Each of these sources has its advantages and disadvantages, but considering the high demand for new foods, they should be given more careful attention, especially regarding their use in the food industry. Due to their content of essential amino acids and, in the case of edible insects, complete proteins, they can be an excellent alternative to conventional food sources. Additionally, due to the fact that they are rich in certain compounds, they can become new functional food with a wide range of applications.

Słowa kluczowe: unconventional proteins, alternative proteins, edible insects, Arthrospira, krill, cultured meat, Single Cell Protein

Introduction

According to FAO (the Food and Agriculture Organization of the United Nations Agriculture), the world population is expected to grow to about 9 billion in 2050. This information raises concerns about food resources for future generations and ongoing

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environmental pollution, therefore the alternative sources of protein other than poultry, pork, beef or legumes, which are very demanding to grow and produce, should be sought. Field cultivation is not possible without arable land, water resources, energy and animal husbandry – which requires previously produced feed. The whole process of production of both crops and animals causes huge financial outlays [22]. Nevertheless, they depend on the species of animals being kept. The least demanding is poultry, in particular broilers, in which case the rearing time is usually up to two months, and laying hens in the case of eggs. On the other hand, cattle requires vast amounts of feed and water due to their long rearing time (about 1.5 years for beef cattle or 2.5 to even 3 years for dairy cattle). Cattle breeding contributes to producing significant amounts of greenhouse gases (GHG), methane, carbon dioxide and other compounds. All these factors influence the need to look for other sources of protein [18].

In 2015, Regulation (EU) 2015/2283 of the European Parliament and of the Council of November 25 on introducing novel foods was published to ensure consumer safety in this regard [48]. Novel foods, as defined in the regulation, include insects, animals, plants, fungi, microorganisms and seaweeds that were not commonly consumed in the European Union before May 15, 1997, but are used as food in more remote parts of the world. It will help enrich a diet by introducing new products or providing food in poorer countries [49].

Edible insects

Insects represent a very diverse group of animals that can be beneficial to humans, on the one hand, but also harmful, on the other. Some insects are known in medicine, such as beetles, butterflies and termites, and used in entomotherapies [17, 31]. They inhabit all natural environments, from terrestrial to marine areas. Due to their high reproduction rate and short growth time, they can be a valuable source of protein and some minerals [12, 30]. Those which are consumed most often include termites, crickets, dragonflies and beetles. These insects are consumed in different stages of development, from eggs to young larvae or adults. They are ones of the complete protein sources immediately behind meat, milk, eggs or soya beans [61].

Increasingly, there are many different organizations which appeal to promote knowledge about the possibility of the consumption of insects by people, and these include FAO (the Food and Agriculture Organization of United Nations) or IPIFF (the International Platform of Insect for Food and Feed) [42]. FAO has been involved in research into insect management for food and its safety since 2004 [61].

There are about 2,000 species of insects suitable for consumption by people, and they are consumed in 80 countries all over the world. In Asian countries, Mexico or Africa, they have been consumed for a long time and are customary [12]. There are many publications on entomophagy (insect consumption). Most often, such phenomena occur among indigenous people of many tribes from poor areas. People living in these areas pass on knowledge of the subject to each other from generation to generation. One study among Indian people estimated that 51 species of edible insects were known there. The most significant number were flying insects [13]. In Europe, edible insects are not so popular, which is mainly due to ethical reasons and consumer aversion, as well as the lack of tradition of eating insects [12]. However, insect products can be consumed unknowingly because *Dactylopius coccus* is commonly used in the production of the food coloring cochineal (E120), which in turn is permitted in the European Union [12, 36]. According to van Huis [57], the main reason for giving up insects as a food source is repulsion to this group of animals. Currently, Polish publications on edible insects and their acceptance can also be found. One such study was a sensory analysis of a fruit cocktail with powdered cricket (*Acheta domesticus*) in different concentrations. The experiment was conducted in Gdańsk among dietetics students and allowed to deduce that the most significant barrier is the appearance and psychological aspect [6].

Until now, edible insects in Europe could have been sold mostly in a freeze-dried form as whole insects, which may deter future consumers and discourage them from trying them [30]. However, nowadays, increasing knowledge and opportunities in processing allow consumers to have unlimited access to various food products containing insects in their composition. In some European countries like the Netherlands, freeze-dried insects can also be easily purchased in stationary or online stores [59].

Nutritional value of edible insects

It is complicated to consider insects as a homogeneous group in terms of nutrition because the protein content alone varies from 40 to even 77 g/100 g of dry mass (d.m.). The amino acids composition of *Tenebrio molitor,* as an example, is shown in Table 1. It can be noted that tenebriomolitor contains virtually all essential amino acids in amounts that meet the WHO/FAO/UNU recommendations. The lack of limiting amino acids combined with the high content of branched chain amino acids, isoleucine, leucine and valine, may add value when consumed by physically active, elderly or recovering individuals. In this respect, edible insects can successfully compete with egg, beef or poultry protein [1, 51]. This is similar with the amount of fat, which is estimated to range from 7 to 77 g/100 g of d.m., or at least fiber, which in the case of insects is in the form of insoluble chitin [16, 53]. According to Szeja [53], dietary fiber content ranges from 11.6 to about 137 mg/kg of d.m. Like in the case of other components, it depends purely on many factors, including the development of the insect, the feed, sex or rearing conditions.

In a study by Alves *et al.* [1] into whitefly (*Tenebrio molitor*) larvae fed with four types of feed, significant differences in body composition were observed. Depending on the type of feed, the content of a particular component was higher than that of the others, hence feeding the insects with a feed with more protein can produce products desired by consumers and food manufacturers.

In addition, the authors often use different methods to obtain protein and perform individual analyses, as well as the insects themselves come from many different sources, making it difficult to determine the nutrient and mineral content unequivocally. At the moment, it can be stated that the number of experiments conducted in Poland and Europe is insufficient, and there may be problems with the availability of various insects [64, 65].

Table 1. Amino acids composition of protein sources (mg/100 g of d.m.)
Tabela 1. Skład aminokwasowy źródeł białka (mg/100 g s.m.)

Amino acids Aminokwas	Spirulina powder Sproszkowana spirulina [21]	Ocean Krill Kryl oceaniczny [55]	Edible insects Owadyjadalne [20]	WHO/FAO/UNU (mg/100g protein) (mg / 100g białka) [60]
Threonine / Treonina	2860	2200	1830	900
Valine / Walina	3940	2600	2940	1300
Arginine / Arginina	3928	3800	2230	ND
Lysine / Lizyna	2960	4400	2010	1600
Methionine +Cysteine Metionina + Cysteina	1170[1]	2400	ND	1700
Leucine / Leucyna	5380	4000	3370	1900
Isoleucine / Izoleucyna	3500	2500	1980	1300
Phenylalanine +Tyrosine Fenyloalanona + Tyrozyna	2750[2]	5000	5210	1900
Histidine / Histydyna	1000	1100	2800	1600

Objaśnienia / Explanatory notes:
ND – brak danych / no data; 1methionine only / tylko metionina; 2phenylalanine only / tylko fenyloalanina

According to Zielińska et al. [64], only three types of insects are readily available in Poland: *Gryllus sigillatus* (cricket genus) (adult form), *Schistocerca gregaria* (desert locust) (adult form), and *Tenebrio molitor* (mealworm) (larva). In addition, an important aspect is the digestibility of proteins, which can be different depending on the species and, in particular, the content of chitin included in their skeletons. According to A. van Huis [57], chitin can combine with some of the amino acids that make up insect carapace so that the amount of protein that can be utilized may be overestimated.

Edible insects can be a good source of healthy fats, including polyunsaturated fatty acids (PUFAs). The level of these fats in insects is higher than in beef and pork, and it is similar for fish. It is believed that *Acheta domesticus* (house cricket) may contribute to the proliferation of intestinal microflora and reduce plasma levels of tumor necrosis factor (TNF-α), which is associated with inflammation. Chitin and chitosan reduce adverse intestinal microflora [39].

One of the main advantages of certain edible insects is their high zinc and iron content. For example, the large caterpillar *Gonimbrasia belina* has a high iron content (31 – 77 mg/100 g of dry mass) and so does the grasshopper *L. migratoria* (8 – 20 mg/100 g of dry mass). Caterpillars *Gonimbrasia belina* could be a good source of zinc (14 mg per 100 g of dry mass) together with palm weevil larvae *Rhynchophorus phoenicis* (26.5 mg per 100 g of dry mass) [30]. These elements perform several essential functions in the body, and the biggest amounts are found in products of animal origin. Pregnant women are particularly susceptible to deficiencies as they need to ensure adequate nutrition for both the fetus and themselves, and therefore have an increased need for these elements. Insects rich in these elements include *Tenebrio molitor* (mealworm), *Locusta migratoria* (migratory locust), *Schistocerca gregaria* (desert locust), *Acheta domesticus* (house cricket), *Gryllus assimilis* (Cuban cricket), *Gryllodes sigillatus* (tropical cricket), *Gonimbrasia belina* (mopane) or *Rhynchophorus palmarum* (palm shrew) [40, 57]. Additionally, insects contain large amounts of potassium, sodium, calcium, phosphorus, magnesium, manganese and copper [32]. Edible insects can be a source of vitamins, both water-soluble and fat-soluble. The vitamin content varies greatly depending on the type of edible insect. Examples of vitamin amounts are as follows: 0.1 – 4 mg/100 g of dry mass of thiamine, 0.11 – 8.9 mg/100 g of dry mass of riboflavin, 0.47 – 8.7 μg/100 g of dry mass of vitamin B12. For vitamin A, depending on the species, an average of 32 – 48 μg/100 g of dry mass of retinol can be found. Some species contain about 35 mg of vitamin E in 100 g of dry mass. Vitamin D can be found at 3.31 μg/100 g of dry mass in the Formicidae family [30].

In summary, the nutritional value and especially the complete protein content varies and depends on many factors. However, given the most favorable variants, some edible insect species can contain more than 60 – 70 % of complete protein. This is higher than the standard livestock products consumed so far. Therefore, edible insects nutritionally could join the dietary products consumed to provide protein. In this way, standard animal production would not have to be so intensified, which is a burden on the environment.

The threats of eating insects

As with other farm animals, there is some potential for transmitting diseases or pathogens to humans (called zoonosis). Nevertheless, if all standards are observed during breeding, this risk is low [58]. However, there are reports that insects can accumulate some harmful chemicals and heavy metals, e.g., lead, zinc, copper or cadmium.

The highest amounts of zinc and copper were observed in insect larvae. According to Zhuang et al. [63], this is related to the structure of insects and basic body processes. To a large extent, insects get rid of these contaminants through defecation. Another critical issue is that as consumers, we only have access to pre-processed insects or products enriched with them for safety reasons. There are not many studies that address the safety of commercially available insects.

A Belgian study on some of the most commonly eaten insects investigated whether chemical contaminants and heavy metals posed any real risk to consumer health. It was found that results can vary even among individuals from the same species, possibly due to the raw material source. Ultimately, the authors concluded that the amount of contaminants present in edible insects and enriched products did not pose any health-related risk to consumers. The amounts are comparable to food products from conventional protein sources such as beef, pork, poultry or fish [44, 45]. In another Belgian study of this type, authors indicated that microbial contaminants were at or near maximum levels, similar to freshly ground meat. However, with blanching, sterilization or even freeze-drying processes, these pathogens can be eliminated from food in most cases. Unfortunately, freeze-drying only inactivates microorganisms, which can be still present and pose a risk that consumers will ingest them. Therefore, some researchers advise that freeze-dried insects should be heat treated before consumption [37].

Another vital issue is the occurrence of cross-allergy risk in consumers allergic to shellfish after consuming insects, even after prior heat treatment [26, 52, 56].

It is important to remember that insects intended for human consumption should come from strictly controlled farms, which will minimize the risk of chemical and microbiological contamination that could occur in the wild [51].

Ocean krill as an alternative protein

Krill is a crustacean that is typically about 6 cm long and lives in waters surrounding Antarctica. Krill can provide food for both humans and animals. It is not well known today that it is an integral part of the food chain for other marine animals. It can be found in aggregations, which significantly reduces the fishing time and enables the harvesting of large quantities of raw material. In 2016, its catch reached more than 270,000 tons, while in the past, it was even 500,000 tons (1982) [66]. The most popular krill species are *Euphausia superba* (Antarctic krill) and *E. pacifica* (Pacific krill), and they are most often used in research. Nevertheless, the biggest problem in the production of this crustacean is its high-water content (about 77.9 – 83.1 %), as a result of which it spoils rapidly and thus requires virtually immediate processing [55].

Nutritional value of krill

The body of krill is primarily composed of water, with the remainder consisting of protein (11.9 – 15.4 %), fat (0.4 – 3.6 %), ash (3 %), and chitin (2 %). The protein content of the dry mass is estimated to be 60 – 65 %. Additionally, this crustacean contains almost all essential amino acids. The amino acids composition is shown in Table 1. However, compared to chicken egg protein, krill exhibits lower digestibility and may not be competitive [55]. On the other hand, nowadays, many protein supplements are produced in which *E. superba* can also be used, but it has to be appropriately processed first. The disadvantage is the presence of fluorine in isolates allowed for human consumption, but it should be kept in mind that the acceptable intake standards for this element should not be exceeded [55, 59]. Excess fluoride can lead to poor bone mineralization, damage the brain, kidneys and liver, as well as may harm the fetus [8, 43]. It is important to note that protein isolates are often produced from defatted krill from which the oil was previously extracted. Fat from this raw material is much more valued due to its high EPA and DHA acids content.

Studies indicate that krill oil has an excellent effect on the skeletal system and may be helpful in the treatment of secondary osteoporosis caused by certain medications [36]. Due to its n-3 family fatty acids, it has antioxidant and anti-inflammatory properties and contains significantly lower amounts of cholesterol than shrimp [55]. According to Choi *et al.* [14], due to its antioxidant activity, Krill oil can protect against DNA damage and thus the diseases it causes, including those related to the nervous system, such as Alzheimer's. In addition, although a typical characteristic of this crustacean is a higher percentage of saturated fats than, e.g. shrimp, trout or salmon, the total share of these fats is not so significant relating to their total content. Consequently, the risk of developing cardiovascular diseases is lower [55].

Ocean krill is rich in vitamins A and E, as well as folic acid and vitamin B_{12}. As little as 100 g of the crustacean satisfies an adult's entire daily requirement for vitamin E. Higher levels of cobalamin and folic acid are especially important for people with anemia, which can be caused by a deficiency of these vitamins [25, 55]. In addition to the vitamins mentioned above, *E. superba* is a good source of astaxanthin. On the other hand, as far as minerals are concerned, krill contains the biggest amount of them in the exoskeleton, usually not consumed or used in production and waste. The elements found in it are magnesium, phosphorus, calcium, fluorine, and iron. The magnesium content in krill is sufficient to meet the body's needs; however, it is found mainly in meat, and after processing, e.g. into protein concentrate, the magnesium content is negligible. In turn, the amount of phosphorus is lower in meat, while in concentrates, it increases. Nevertheless, that level is sufficient to meet the needs of the body. A different case is with calcium because data indicates that krill is rich in this element, but neither meat nor concentrates contain sufficient amount because it is mainly located in the skeleton. As for iron, krill is not a good source of this element [55].

Disadvantages and risks of using krill

It is important to note that using ocean krill may not necessarily be a more sustainable solution than livestock farming. It should be noted that harvesting krill is not without impact on the population of animals for which it provides feed, such as penguins. The widespread use of krill as food for humans could probably result in a decrease in the krill population available to penguins [33].

One of the risks associated with the consumption of marine organisms including krill is possible microplastic contamination. The exact health effects and the level of risk are not exactly known, but there are sources showing that marine organisms may contain microplastics that humans can consume along with seafood. More research is needed on the level of contamination and possible impact on human health [3]. Moreover, there is a safety issue related to the possible occurrence of allergies and food intolerances, as is the case with crustaceans and seafood, which krill undoubtedly belongs to [48].

Marine algae as a source of protein

Algae are organisms living mainly in water or a very humid environment. In Poland, the most popular varieties are Spirulina (Arthrospira) and Chlorella, while those commonly used by the industry are brown algae, green algae and red algae. Each of the above groups is morphologically diverse because they belong to different kingdoms. According to some sources, there are more than 20,000 species under the name of alga/algae [29]. Marine algae have been known for a long time, especially in Asian countries, as a standard component of cuisine [27]. Many dietary supplements containing Spirulina or Chlorella are being developed because they are rich in nutrients and minerals [62]. In addition, algae can be used as an additive to animal feed, especially fish, used to obtain fish meal used in poultry or swine farming [23].

Moreover, marine algae are often used in the cosmetics industry due to their properties slowing down the aging process (because of antioxidants) or protecting against harmful ultraviolet radiation. In addition, they can be used in the production of cosmetics, such as humectants, i.e. substances that ensure adequate skin hydration. Agar, carrageenan and alginates produced from some kelp are used as stabilizers and gelling agents in the cosmetics and food industries. The most popular is sodium alginate E401, which can be found in ice cream, marmalade, canned meat, yogurt or light mayonnaise [9, 29, 47].

Another industry using algae is the production of biofuels, such as biomethane, biodiesel, biogas or bioethanol. From the economic point of view, it is not very competitive with traditional energy sources due to the need for appropriate technical facilities and high production costs. Fort the mass cultivation of algae, organisms must be provided with the best possible conditions for growth, such as temperature in the range of 20 – 30 °C, adequate CO_2 concentration, mineral nutrients or access to sufficient light [29, 34].

Composition and nutritional value of marine algae

The composition of algae depends largely on their location and species, as well as other environmental factors. In *Chlorella vulgaris,* the fat content can reach up to 26 %, while when it comes to *Atrhrospira platensis* (Spirulina), these amounts are negligible. However, these figures often vary significantly, making it difficult to precisely determine exact constituents . It should be noted that much depends on the algae's environment, but many studies do not provide this information. The most desirable lipids from algae are polyunsaturated fatty acids (PUFAs). The most important are n-3 and n-6 fatty acids, belonging to the group of essential unsaturated fatty acids (EUFAs), which the human body cannot produce, hence they must be provided with food. Among them, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) belonging to the n-3 group play the most crucial role. They have proven antioxidant and antibacterial effects and have a beneficial influence on the cardiovascular system, as well as lower cholesterol and keep glucose in blood at a proper level [2, 38, 54].

The protein content of Spirulina (*Arthrospira*) varies between 40 and 60 % of dry weight, and for Chlorella between 20 – 60 % [37]. This is similar in respect of carbohydrates. In both types of algae, the results vary considerably. At the same time, in *Arthrospira platensis,* the authors estimated the content between 7 – 20 % of dry mass and in Chlorella between 12 and 26 % of dry mass. It is worth consuming algae, as they contain essential amino acids, which must necessarily be supplied with food. According to Guitiérrez-Salmeán et al. (2015), the content of amino acids in 100 g of Spirulina powder is as follows: Histidine – 1,000 mg, Isoleucine – 3,500 mg, Leucine – 5,380 mg, Lysine – 2,960 mg, Methionine – 1,170 mg, Phenylalanine – 2,750 mg, Threonine –2,860 mg, Tryptophan – 1,090 mg, Valine – 3,940 mg (the amino acid composition is also shown in Table 1). The limiting amino acids, compared to egg white, will be Methionine and Cysteine, which are not present in Spirulina. For this reason, Spirulina will probably not replace other sources of protein, but it can be an additional source of this macronutrient, providing valuable food, particularly for those on plant-based diets. In addition, they are a good source of vitamins in particular: A (352,000 IU/100 g), C, E, K, and B group (B_1 – 0.5 mg/100 g; B_2 – 4.53 mg/100 g; B_3 – 14.9 mg/100 g; B_6 – 0.96 mg/100 g; B_{12} – 162 μg/100 g), as well as minerals such as calcium (468 mg/100 g), iron (87.4 mg/100 g), iodine (142 μg/100 g), selenium (25.5 μg/100 g) or magnesium (319 mg/100 g) [2, 21].

In addition, algae are rich in other components with health-promoting effects, such as zeaxanthin and lutein in *Arthrospira*, which affects vision, or phycocyanin with antioxidant and anti-inflammatory effects and anti-inflammatory effects; others include β-carotene and polyphenolic compounds [5, 10].

According to Tang and Suter (2011), algae are safe for human consumption, provided that they are grown under strictly controlled conditions. They are also safe, if portions are reasonable and not consumed in excessive quantities, and if there are no health contraindications, such as food allergies [54].

Other sources of protein

Cultured meat

Cultured meat otherwise known as in vitro meat or lab-grown meat is more and more often presented as a potential solution to the problem of growing population and demand for good quality food. This product is a good alternative for people who want to eat more sustainable food products and want to reduce or eliminate the consumption of meat from slaughtered animals, but at the same time do not want to radically change their diet [15].

In vitro meat production involves taking a piece of muscle tissue from a live animal by biopsy. The material thus collected is a source of stem cells capable of proliferation. Cell multiplication occurs when the sample is placed in a suitable medium containing nutrients, hormones and growth factors, which simulates conditions in a living organism. Until recently, using fetal bovine serum (FBS) as a component of the medium has been problematic, but now it is no longer necessary, because start-ups have developed a new substance. Then, after removing the growth factor, cells differentiate to form muscle cells and form myotubes. Myotubes are placed on a special scaffold that helps form the shape of muscle fibers. The process itself is constantly being researched and refined, which contributes to lower production costs. However, these costs are still very high [7, 46].

The amino acid composition of cultured meat is the same as for conventional meat. The advantage is that the fatty acid composition can be modified, which can have a positive impact on the health aspect. Additionally, cultured meat reduces risk factors, such as microbial and parasitic contamination [15].

Unfortunately, disadvantages still include the high cost of production and the early stage of product development. A lot of research still needs to be done to assess the impact of cultured meat on human health. It should also be mentioned that red and processed meat pose certain health risks [11], and products created in a laboratory are ultimately intended to imitate conventional meat products. Therefore, the in vitro meat solution is future-proof but not ideal. More research is needed to explore this topic.

Single Cell Proteins (SCP)

Another protein source that is classified as an alternative source is SCP (Single Cell Protein). These are proteins extracted from single cell organisms such as bacteria, molds, yeast or microalgae. Production is entails growing biomass in special bioreactors. For example, waste from the food and agricultural industries is used to grow biomass. The production of microbial biomass is ensured by submerged or solid state fermentation. Biomass is harvested after fermentation and can undergo further processing steps such as washing, cell disruption, protein extraction and purification [3].

SCPs can have great potential in terms of the environment, as they have high substrate efficiency and waste management capabilities. Additionally, SCP production is independent of weather conditions, seasonality or pest incidence. Furthermore, production takes place on a small area compared to traditional food production [41].

Nutritionally, SCPs vary widely and their composition depends primarily on the type of microorganism and the medium. However, it can be stated that SCPs derived from bacteria contain the most protein (50 – 80 %), followed by microalgae and yeast (30 – 75 %), whereas molds contain the least protein (20 – 45 %). In addition, SCPs contain a lot of vitamins and minerals, especially B vitamins. In terms of amino acid composition, SCPs have a good ratio of essential amino acids, however, the most common limiting amino acids are sulfur-amino acids [12].

SCPs unfortunately have disadvantages that make them difficult to use on a large scale in human nutrition. One of them is a low content of sulfur amino acids, such as methionine and cysteine, which makes them not a source of complementary protein. Nevertheless, this also depends on the type of SCP, as the variability in composition is high [51]. Another disadvantage is the content of nucleic acids, which can be harmful to humans if consumed >2g/day. Given this limitation, only small amounts of SPC as a food additive would be possible to consume. Thus they would not be a significant source of protein [41]. On the other hand, the possible removal of nucleic acids would complicate the entire process and significantly increase production costs. The impact of SCPs on the human organism in terms of allergic reactions and food intolerances is also unknown. Nevertheless, SCPs represent an interesting alternative that can be further developed.

Conclusions

Undoubtedly, edible insects, marine algae, ocean krill, cultured meat or single cell proteins are raw materials that deserve interest in context of the food industry and their use in producing highly nutritious foods. These raw materials have so far not been used to produce food or obtain proteins on a large scale. As such, they can provide an additional sustainable raw material, which can contribute to improving the situation related to increased demand for food, continuous climate warming and constraints on existing agricultural production.

All the novel food sources described above have suitable nutritional parameters, such as high protein content, the presence of essential amino acids, a high proportion of healthy fats and the fact that they are rich in vitamins and minerals with beneficial effects on the human body. In terms of protein, the most favorable of them include some species of edible insects that contain complete proteins, which allows them to compete with traditional sources of this macronutrient, such as meat or dairy.

However, it is important to note that, as with all new products, more research needs to be done on the safety of use in human nutrition and possible health risks. Currently, there is limited scientific evidence for the complete safety of the ingredients described, especially under food industry conditions and in correlation with other food ingredients. Sources such as cultured meat and SCP need additional research to the greatest extent, as there are still too many imponderables in their case and production technology needs to be further developed. There is also no research into human health effects. Nevertheless, this is a promising line of research that may contribute to a significant improvement of the nutritional situation worldwide.

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WYBRANE NIEKONWENCJONALNE ŹRÓDŁA BIAŁKA I INNYCH SKŁADNIKÓW ODŻYWCZYCH

S t r e s z c z e n i e

Wprowadzenie. Obecnie świat musi się mierzyć z problemem gwałtownego wzrostu liczby ludności i ograniczeniami dotyczącymi wydajności produkcji żywności, aby zaspokoić potrzeby żywieniowe wszystkich ludzi. Rolnictwo i przemysł spożywczy napotykają na trudności w zwiększaniu produkcji żywności, ponieważ wyczerpują się dobra naturalne, takie jak powierzchnia uprawna, woda i energia elektryczna. Jednym z najważniejszych składników diety, którego może zacząć brakować, jest białko. Dotychczasowe pozyskiwanie źródeł białka, w szczególności pochodzenia zwierzęcego, jest bardzo obciążające dla klimatu, dlatego należy poszukiwać nowych rozwiązań i nowych źródeł białka, które będą bardziej zrównoważone.

Wyniki i wnioski. Jednymi z możliwych nowych źródeł białka oraz innych składników odżywczych mogą być owady jadalne w postaci mąki np. ze świerszcza domowego (*Acheta domesticus*), alg morskich w postaci sproszkowanej Spiruliny (*Arthrosipra platensis*), kryl oceaniczny np. kryl antarktyczny (*Euphausia superba*), mięso in vitro, czy mięso jednokomórkowców. Surowce te do tej pory nie są stosowane na szeroką skalę, natomiast ich skład i wartości odżywcze mogą się wydawać obiecujące. Każde z tych źródeł ma swoje wady i zalety, jednak wobec dużego zapotrzebowania na nową żywność należy im się przyjrzeć dokładniej, szczególnie pod kątem zastosowania w przemyśle spożywczym. Poprzez zawartość aminokwasów egzogennych, a w przypadku owadów jadalnych białka pełnowartościowego, mogą stanowić dobrą alternatywę dla konwencjonalnych źródeł żywności. Dodatkowo, dzięki bogactwu niektórych związków, mogą stać się nową żywnością funkcjonalną o szerokim zastosowaniu.

Słowa kluczowe: białka niekonwencjonalne, białka alternatywne, insekty jadalne, *Arthrospira*, kryl, mięso *in vitro*, białka z pojedynczych komórek