Alternative and New Protein Sources

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- Barbara Sawicka (1)
- Krishnan Umachandran (2)
- Noori Abdul-nabi Nasir (3)
- Dominika Skiba (1)

1. Department of Plant Production Technology & Commodities Science, University of Life Science in Lublin, , Lublin, Poland
2. Nelcast Ltd., , Chennai, India
3. Department of Marine Vertebrates, Marine Science Center, Basrah University, , Basrah, Iraq

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Abstract

Alternative protein sources include: wheat protein, protein of lentils, chickpeas and other legumes, fish protein, chicken products, eggs, spray dried plasma and processed red blood cells, which serve many functions, including provision of essential and nonessential amino acids which enhance immune and are also highly palatable. Alternative protein sources include spray dried plasma, wheat protein, fish protein, Chicken products, eggs, and processed red blood cells serve many functions, including provision of essential and nonessential amino acids which enhance immune and are also highly palatable. Edible insects and marine organisms are promising alternatives. They have a large potential as a diet component due to their high nutritional value, complete protein content, fat, minerals and vitamins. The benefits from placing insect-based foods on the market are also reflected in positive environmental, economic and health issues. Currently, in most European countries the main problem limiting the usage of insects in human diet is the lack of acceptance of this type of food and its safety. Sensitizing people on the ecological liability of animal rearing and to escalate their interest in alternative proteins is important to create the change.

Keywords

Protein Alternative protein Animal proteins Plant protein Biofood

7.1 Introduction

Alternative sources of protein have been utilized to a limited extent by certain sections of the population but its universal use and acceptability to the rest of mankind remains a challenge. The commonly known alternative sources of proteins are single-cell organisms (yeast), aquatic organisms (krill, algae) (Doshi et al. 2007; Deng and Chow 2010; Ohikere and Ejeh 2012; Piasecka-Kwiatkowska and Stasińska 2016), and insects, which have amino acid composition similar to that of the traditional animal proteins consumed as diet with protein 77.9–98.9% as digestible (Bukkens 1997; Shockley and Dossey 2013). The alternative protein sources in food production have benefits associated to social, economic, health and environment (Wociór et al. 2010; Udenigwe and Aluko 2012; Yadav et al. 2017). The progression of the biofood concentrates on the feedstocks facilitates more of technology innovation with biopolymers and biocomposites (Ayadi Rosentrater and Muthukumarappan 2012; Buckhalt 2016). The combination of new applications by biotechnology on agriculture has altered the agricultural economics to benefit the people (Ohikere and Ejeh 2012). Genetically modified organism (GMO)/crop varieties also address the food security requirements and boost exports. It does this by reducing the cost of farming, improve output, decrease in the use of pesticide, reduction in deforestations, ease low-till or no-till cultivation and thus cut the emissions of greenhouse gases to offer better food for the consumers (Stewart 2009; Udenigwe and Aluko 2012). Solid development in biotechnology offered in addition cutting-edge expansions in genomics and bioinformatics made it possible to develop and discover drugs, diagnosis and early treatment of diseases and disorders affecting animal health, livestock and agricultural crop therefore to improve their well-being, production and conserve the use of existing resources to sustainability (UN ECA 2015). However, encouraging results of novel sources of nutrients such as insects, algae and in-vitro meat, though are unconventional to animal proteins for human consumption and animal feed production, still required to enhance in quantity and quality as nutrient sources that could face upfront the potential encounter on food security an inordinate stress thereupon. New technologies are emerging that allow for the upgrading of wastewater treatment plants to 'factories' in which the incoming materials are deconstructed to units such as ammonia, carbon dioxide and clean minerals, and followed by a highly intensive and efficient microbial re-synthesis process where the used nitrogen is harvested as microbial protein (at efficiencies close to 100%), which can be used for animal feed and food purposes (Shockley and Dossey 2013; Matassa et al. 2015; Wiza 2019). Bioavailability process follows food element consumption, including digestibility and solubility of the food element in the gastrointestinal tract, absorption/assimilation of the food element across the intestinal epithelial cells and into the circulatory system, and finally, incorporation into the target site of utilization (Bleakley and Hayes 2017). The enzymes which improve weight gain and feed conversion in monogastric animals, have been engineered for improved activity and deliver high levels of thermal stability to enable direct use of the grain in feed pelleting processes (Matassa et al. 2015).

7.2 Daily Demand of Human Organism to Protein

For an adult, the daily dose of protein is 50–80 g (including 1/3 is animal protein). In a span of 1 year, a man takes 27.4 kg of protein, which is calculated on the basis of nitrogen at 4.38 kg/kg/year. For the world's population, approximately 30.8 million tons of nitrogen per year is needed. It is estimated that around a billion people are starving all over the world. This hunger particularly affects third world countries attributed in part from political instability and very low agricultural production combined with over-population. Currently, about 40,000 people die every day in Africa due to hunger (Fig. 7.1).

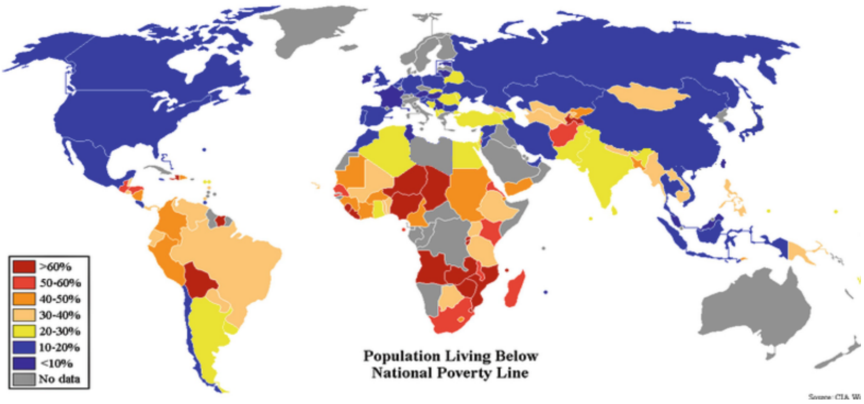

Fig. 7.1

Part of society (%) below the abundance of poverty. (FAO 2016)

Hence, the demand for protein in the world is enormous. Proteins provide the raw material compulsory for constructing additional muscle fibers and rebuilding broken fibers with thicker composition resulting to greater muscular strength and endurance (Schoenfeld 2010). Adding protein to an already balanced diet promotes healthy living. Animal protein is a complete protein that provides all nine essential amino acids, while some plant proteins may lack one or more essential amino acids. Animal products are high in protein but also contain high amounts of saturated or trans fats. Not everything from animals is good to our health. Consuming animal blood for instance can cause a number of problems. The human body can dehydrate when drawing its own water reserves to digest the protein contained in the blood. Furthermore, animals frequently carry diseases in their blood which may also cause infections among humans. On the other hand, tofu and tempeh are great non-animal protein sources which when consumed as meals are a healthier protein boost without the saturated fats found in animal proteins (Smith 2009).

7.3 The Need and Sources of Alternative Proteins

Economic, health and environmental demands stress the need for alternative sources of proteins in the production of food. Large areas of grassland and cropland are already needed to meet the demand of meat and dairy consumption. Agricultural sector development is essential to ensuring food security and good nutrition for all, but are additional environmental challenges (emissions and energy trends continue, global warming). There are concerns over the depletion of fish stocks and impacts on marine biodiversity (Westhoek et al. 2011). Shared fresh water resources and food security are critical to human security concerns, while worldwide, cropland is being lost to cities, industry, erosion, flooding. Salinization that accompanies big irrigation schemes, is described as one of the gravest threats to irrigation agriculture and food security. Water withdrawals are met at rate of natural groundwater recharging. Increasing reliance on nonrenewable groundwater is resulting in falling water tables being recorded on every continent. Soils when degraded towards agricultural production, the biodiversity of the region are reduced, leading to a loss of genetic resources that could contribute to a diverse and sustainable agricultural system. These losses jeopardize the food security of the local populations and ultimately result in high economic and social costs. Alternative proteins are estimated to make up 33% of global protein consumption by 2054, with algae and insects accounting for about 18% and 11% of the alternative protein market, respectively. In part, sales of insects and algae are expected to each account for 2% of the alternative protein market share by 2024 (European Commission 2018). Alternative proteins must be evaluated for nutritive value, safety, and economic considerations before mass production are undertaken. There are good alternative protein sources which include spray dried plasma, wheat protein, fish protein, chicken products, eggs, and processed red blood cells serve many functions, including provision of essential and nonessential amino acids which enhance immune and are also highly palatable. Reproductive biotechnologies changed molecular genetics were sequenced and annotated in various animals such as cattle, pigs, chicken, sheep, poultry, and bee (Odongo et al. 2010; United States Department of Agriculture 2016; National Institutes of Health 2016; Raab 2016).

7.3.1 Proteins of Unicellular Organisms

From a nutritional point of view, microorganisms can be a valuable source of protein with a high biological value. Depending on the type, strain and conditions of microbial growth and composition of the medium, the protein content in the dry mass of unicellular biomass may vary within 40–80%. Most proteins contain bacteria (50–80%), then algae and yeast (30–75%), and least molds (20–45%). Single-cell proteins are a rich source of lysine; however, they are deficient in some essential amino acids, mainly sulfuric (methionine and cysteine) (Table 7.1).

Table 7.1

Amino acid profile of proteins derived from alternative sources (g/100 g)

Amino acids	Sources of protein						
	Algae	**Bacteria**	**Yeast**	**Mushrooms**	**Krill**	**Insects**	**FAO pattern**
Isoleucine	4.7	3.3	2.5	1.8	2.5	3.8	2.8
Leucine	8.6	5.4	3.6	2.9	4.0	6.5	6.6
Valine	6.2	4.2	2.7	2.2	2.6	5.2	3.5
Lysine	6.3	4.3	3.5	3.0	4.4	5.1	5.8
Phenylalanine	9.0	5.8	4.1	3.1	5	9.7	6.3
Metionine	3.1	2.2	1.5	1.0	2.4	3.5	2.5
Tryptophan	0.9	0.8	0.6	0.3	0.7	1.2	1.1
Threonine	5.4	3.3	2.5	2	2.2	3.7	3.4
Arginine	6.9	3.7	2.3	2.7	3.8	4.5	nd
Histidine	2.1	1.5	1.2	1.0	1.1	2.2	nd
Aspartic acid	9.7	nd	nd	nd	5.3	nd	nd
Glutamine	10.9	nd	nd	nd	6.7	9.7	nd
Glycine	6.2	nd	nd	nd	3.4	5.1	nd
Proline	4.3	nd	nd	nd	2.3	4.6	nd
Serine	4.3	nd	nd	nd	1.9	4	nd
Alanine	nd	nd	nd	nd	2.9	5.9	nd
Total protein (% DM)	40–60	50–65	44–55	30–45	60–65	5–77	nd

Source: Becker (2007), Nalage et al. (2016), Nasseri et al. (2011), Piasecka-Kwiatkowska and Stasińska (2016), Rumpold and Schlüter (2013), Tou et al. (2007), and Zielińska et al. (2017)

DM dry mass, *nd* no data

The large-scale process of obtaining Single Cell Protein (SCP) proteins from dried cells of microorganisms such as bacteria (*Cellulomonas, Alcaligenes*), yeast (*Candida, Saccharomyces*), algae (*Chlorella, Spirulina, Scenedesmus*) and molds (*Trichoderma, Fusarium, Rhizopus*) (Becker 2007; Deng and Chow 2010), generates numerous opportunities in food production technology. The diversity of methods, raw materials and microorganisms used, high substrate conversion efficiency and efficiency associated with the rapid growth of microorganisms and lack of dependence on seasonal and climatic factors (Nasseri et al. 2011) attach great importance to these microorganisms from a nutritional point of view as a protein source of high biological value (Table 7.1).

The nutritional value of these proteins is higher than those of vegetable origin, and when supplemented with methionine, become comparable to proteins of animal origin (Nalage et al. 2016). It has also been proven that SPC obtained from microorganisms are a rich source of B vitamins and minerals, such as: zinc, phosphorus, magnesium, selenium, chromium (Adedayo et al. 2011). In addition, some yeast species, e.g. Saccharomyces cerevisiae, have a probiotic effect in the human body (Muszyńska et al. 2013). Nucleic acid component (2–18% dry matter) is also a component of biomass, which is a potential danger for the human body, because it may lead to the accumulation of uric acid crystals in the kidneys or joints, leading to gout. Their content is highest in bacterial cells and the lowest in algae cells (Nasseri et al. 2011). It was also proved that SPC obtained from microorganisms are a rich source of B vitamins and minerals, such as zinc, phosphorus, magnesium, selenium, chromium (Adedayo et al. 2011). Some yeast species, e.g. Saccharomyces cerevisiae, have a probiotic effect only in the human body (Muszyńska et al. 2013). Nucleic acid component (2–18% of dry substance) is also a component of biomass, which is a potential danger for the human body, as it may lead to the accumulation of uric acid crystals in the kidneys or joints, leading to gout. Their content is highest in bacterial cells and the lowest in algae cells (Nasseri et al. 2011). Nucleic acids are also present in conventional foods and constitute a permanent component of the diet, both meat and vegetarian (Głazowska et al. 2016). The content of nucleic acids in the diet should not exceed 2 g per day, so the consumption of SCP cannot exceed 30 g per day (Piasecka-Kwiatkowska and Stasińska 2016). Yadav et al. (2017) proved that the use of a combination of two chemical substances: N-Lauroiol sarcosine and NH_4OH allows to reduce the content of nucleic acids in biomass to the desired level (<2%). The proteins of unicellular organisms may also adversely affect the human immune system, causing allergies (Nasseri et al. 2011). An obstacle in the use of microbial protein in human nutrition is the presence of anti-nutritive substances, such as nucleic acids, as well as residues of atypical biomass components and the possibility of microbial contamination difficult to eliminate during the production process (Nasseri et al. 2011; Bueschke et al. 2017). SPC on an industrial scale is mainly produced as an additive to animal feed, because the cost as production costs of microbiological proteins that could be a component of human food are too high (Nasseri et al. 2011, 2016).

7.3.2 Proteins of Marine Organisms

Algae do not compete with traditional food crops for space and resources, they are seaweeds and microalgae, rich in nutrients and a sustainable source for protein. Macroalgae (seaweed) and microalgae are examples of underexploited crops. Macroalgae are a diverse group of species as oxygen-producers, photosynthetic, unicellular or multicellular organisms excluding embryophyte terrestrial plants and lichens. Exploited for human consumptions are *Undaria pinnatifida* (wakame), *Hizikia fusiformis* (hijiki), and *Laminaria japonica* (kombu) (Van der Spiegel et al. 2013). Seaweeds can be consumed directly as whole algae, whereas microalgae are mainly used for the extraction of food and feed complements. Certain species of seaweed and microalgae contain protein levels similar to those of traditional protein sources, such as meat, egg, soybean, and milk. Even though microalgae are unicellular microscopic organisms they are still considered as a viable alternative protein source. Seaweeds are a valuable source of protein, amino acids, minerals and vitamins, negligible fat and cholesterol content, hence they accompany many health benefits when consumed, such as to lower blood pressure and prevent strokes, while microalgae are extracted mainly for high-value food/feed supplements and colorants, compared to its protein. In terms of nutrition, marine algae are excellent an alternative to conventional vegetable proteins. However, the popularity of protein from algae in the food sector is still under development, among others due to high production costs and technical difficulties in developing products acceptable in terms of taste (Becker 2007). Currently, algae are found mainly used as supplements on the market of food with pro-health effects. The consumption of algae is safe for humans when the correct breeding conditions are maintained. Although the algae are high ability to bind heavy metals, breeding in appropriate quality and purity of water, does not pose a threat to consumers (Doshi et al. 2007; Tang and Suter 2011).

7.3.3 Sea – A Potential Source for Alternative Protein

Meat and fish are partly interchangeable, in culinary as well as in nutritional terms, both being suppliers of protein (Westhoek et al. 2011). Fish remains to be accepted for high presence of protein and omega-3 fatty acids. Popular fatty fish include Cod, Tuna, Salmon (wild), Tilapia, and Halibut (US Food and Drug Administration 2008; Haslett and Smith 2009). Krill, or species of crustaceans living in the oceans around the world, is an important link in the food chain, as a food for marine animals and birds, and to a much lesser extent for humans. Krill in appearance resembles shrimp, it reaches mass from 0.01 to 2.0 g and a length from 0.8 to 6.0 cm. It creates large clusters in its natural environment, over million individuals/m^3. For the best studied krill species for consumption by humans are Antarctic Krill (*Euphausia superba*) and Kryl Pacificaly (*Euphausia pacifica*). This species is a rich source of full-value protein in the amount of 60–65% in dry matter (Nicol et al. 2000), whose content in muscle tissue depends on the species and the season and varies between 15–17%. This protein has in its composition the majority of essential amino acids (Table 7.1). The main problem that is associated with the use of these raw materials on an industrial scale in human nutrition is the low stability of protein preparations and the presence of anti-nutritive substances, such as chitin and other small molecules in products made of krill (Jakubiec-Puka 1987). Nutritional studies have proven that algae are also a source of high quality, comparable to conventional plant proteins (Becker 2007). Algae are found in the aquatic and terrestrial environment, with high humidity, all over the world. Algae, such as Chlorella sp., And Spirulina sp. (Tang and Suter 2011; Becker 2007) are used for large-scale production. The nutritional value of Spirulina varies and depends on the growth conditions. The bioavailability of nutrients from Spirulina may be greater than from other sources of vegetable origin, due to the construction of the cell wall, which consists of protein, carbohydrates and fat. Spirulina is characterized by a particularly high protein content (60–70% in dry matter) with high digestibility (90%). It contains all the essential amino acids in significant quantities (Table 7.1). Spirulina is also a rich source of vitamin B12 and carotenoids. The health-promoting properties of Spirulina are also known, among others in hypercholesterolemia, hyperglycemia, cardiovascular diseases, anemia, inflammatory diseases, cancer and viral infections (Deng and Chow 2010; Selmi et al. 2011; Tang and Suter 2011). From algae with high protein content, you can also distinguish between chlorella (about 60% of protein in dry matter). Chlorella is also a source of many vitamins, including vitamin A, B12 and folates and minerals, such as iron. Its cell wall is rigid and indigestible, therefore, chlorella cells, in order to increase the nutritional value, require special preparation to remove or destroy indigestible cell walls. A number has also been shown health-promoting properties of chlorella, including hypotensive, antioxidant and immunosuppressive effects and reducing the onset of anemia (Halperin et al. 2003; Merchant et al. 2002; Nakano et al. 2010; Tang and Suter 2011).

7.3.4 Edible Insects in Human Nutrition

Harvesting insects is like hunting and collecting activity which is becoming a threat to both the target species and the environment and therefore consuming edible insects has become marginalized. Insect breeding requires which requires no secondary energy hence certain countries have imposed austere breeding methods of insect species categorically to be gathered from free living insects in order to protect the endangered species, biotopes and biodiversity as a whole (Jiri et al. 2014). The influence of globalization has weaned away a large number of protein-hungry people of the third world from animal protein towards insects as an alternative (Heinrich and Prieto 2008). Harvesting insects in nature and solving the problem of famine are followed in some cultures as a seasonal source of proteins, not only an emergency resource but are valued as appetizing and tasty among substantial part of human population (Shockley and Dossey 2013; Jiri et al. 2014). Insects are cooked, roasted or boiled or with other culinary techniques (Yen 2010), while in some parts insects are a gourmet dish which are attractive and savory (Nonaka 2009). An alternative source of wholesome protein, often currently discussed by the FAO and the European Commission (2018), are edible insects (Shockley and Dossey 2013). The number of insect species living on earth is estimated at about two million, which are an important element of the natural environment, but mainly serve as food for many species of animals (Boczek and Pruszyński 2013). Insects and their products are used in the food, pharmaceutical and chemical sectors, and also textile. In the industry are used, among others honey, putty, wax, natural silk, halantine, cochineal, shellac, gels. In many regions of the world, e.g. in China, Japan, Thailand, South Africa, Mexico, insects are also a component of the diet. About 2000 species are edible for humans (Rumpold and Schlüter 2013). It is estimated 1.9 thousand species of insects are consumed by about two billion people in about 80 countries (FAO 2013). Almost all insect groups are used for food purposes, i.e.: beetles, caterpillars, wasps, bees, ants, crickets, locusts, termites, bugs, dragonflies, flies and other, both adults, but also chrysalis, larvae and eggs (Boczek and Pruszyński 2013). Until recently, insects in Europe have not been seen as a part of the diet, and their consumption is limited to the unconscious consumption of products in which they are used as a food additive (e.g. cochineal). The most commonly consumed edible insects include: crickets and Orthoptera, bee brood (eggs, larvae and bee chrysalis), beetles (*Coleoptera*), mealworm mill (*T. molitor*) used for the production of fodder for fish and poultry and termites (*Isoptera*) commonly eaten in African countries (Bąk and Wilde 2002; Boczek and Pruszyński 2013; Nonaka 2009; Resh and Cardé 2009). Insects are a significant, underrated alternative to nutrients supplied from conventional animal sources. They are characterized by high nutritional value, being a source of energy, protein, carbohydrates, fat and vitamins and minerals. The chemical composition of edible insects shows high variability between species, developmental stages, and type of food (Rumpold and Schlüter, 2013). The protein content in insects ranges from 5–77 g to 100 g (Rumpold and Schlüter 2013). In many species, the protein constitutes over 60% of dry matter, and its highest content was recorded for Orthoptera species (crickets, locusts, grasshoppers) (Yi et al. 2013). The insect protein has a digestibility comparable to egg white (77–98%) and is considered to be of full value, comparable to proteins, milk and beef (Shockley and Dossey 2013). Insect proteins are a good source of threonine, valine, histidine phenylalanine and tyrosine, and for some species also tryptophan, lysine and threonine (Table 7.1) (Rumpold and Schlüter 2013; Zielińska et al. 2015a). Edible insects are also a source of fat, the content of which varies from 10 to 50% (Zielińska et al. 2015b). For Orthoptera species it is on average 13%, from the order Coleoptera (beetles) 33% (Rumpold and Schlüter, 2013), and in larvae of *Rhynchophorus phoenicis* beetles belonging to the *Curculionidae* family, the fat content is 67% of dry matter and is greater than in the majority conventionally consumed high-protein products, such as beef, poultry or eggs. The composition of fatty acids in insects is comparable with the composition of poultry fat and fish in terms of their unsaturation, however, insects are characterized by a higher content of polyene fatty acids (Rumpold and Schlüter 2013). Jang et al. (2006) showed that the fatty acid composition can be modeled by applying appropriate modifications to the insect diet, and in the process of defatting meal from insects, it is also possible to obtain an oil that can be widely used in human nutrition (FAO 2013). Insects are characterized by low content of carbohydrates (0.1–5.3% of dry matter) and high content of fiber, most commonly in in form chitin (Ekpo and Onigbinde 2005; Finke 2007; Zielińska et al. 2015a). Finke (2007) estimated the content of chitin in species of edible insects at 2.7–49,8 mg per kg of fresh insects and 11,6–137,2 mg per kg of dry matter. Zielińska et al. (2015b) asset also folic acid and in smaller amounts of retinol and β-carotene (Bukkens 2005; Finke 2002; Rumpold and Schlüter 2013). In addition, edible insects are a source of peptides with properties antioxidant. In an experiment conducted by Zielińska et al. (2017) investigated the antioxidant activity of peptides obtained by gastrointestinal digestion in vitro derived from edible insects, belonging to five species. The authors showed that the consumption of edible insects can bring potential health benefits due to the strong antioxidant effect of the peptides derived from them. The obtained results showed that the insects subjected to digestion have a higher antioxidant activity than other protein hydrolysates obtained from animal and vegetable products. However, the amount of fiber found in crickets (*G. sigillatus*), beetles (*T. molitor*) and locusts (*S. gregaria*), which shrank at 1.97–3.65% on a dry matter basis. The high nutritional value of edible insects is also influenced by the presence of vitamins and minerals, mainly iron and zinc (Bukkens 2005), but also copper, manganese, magnesium and calcium (Ekpo and Onigbinde 2005). Insects are also a source of thiamine (0.1–4.0 mg per 100 g dry matter), riboflavin (0.1–8.9 mg), cobalamin (0.5–8.7 μg per 100 g), and some species. Insect production, according to FAO experts (2008, 2009, 2011, 2013, FAO et al. 2015), is characterized by:

1. 1.

   low greenhouse gas emissions such as ammonia, methane or nitrous oxide, and insect droppings can be used in agriculture in the form of fertilizer. Insect farms produce 10 to 100 times less gas per kg body weight than pig farms, which has a beneficial effect on global warming (Shockley and Dossey 2013).

2. 2.

   lower requirements as to farming and low costs associated with saving agricultural land, feed and drinking water consumption. Insect farming is not required to have arable land or high feed and drinking water consumption. The economic costs of breeding insects are significantly lower than the costs of raising farm animals (Smith 2009). Cold-blooded insects can use plant biomass to increase their body weight (Van Huis et al. 2013);

3. 3.

   easy distribution, high diversity factor and short reproduction cycle (Tan et al. 2015; Wiza 2019).

7.3.5 Prospecting Insects in Food Sector

Insects offer sufficient quantity of energy, protein, amino acid requirements for humans and are high in unsaturated fatty acids, minerals and vitamins. Freeze-dried, sun-dried or boiled edible insects can be consumed after being wild-harvested or reared, can be processed as fried and ground into a paste form, or as an extract of protein, fat or chitin for enriching food and feed products. Entomophagy causes numerous nutritional benefits with high protein content, minerals and vitamins, they have comparable properties to traditional feed components such as fishmeal. The spinal fluid, eyes and the fluid in the meat of the sea fish, turtle blood contains protein, and many types of seaweed are edible and contain carbohydrates (Smith 2009; Haslett and Smith 2009; Wiza 2019). In addition to nutritional and health benefits, there are a number of other advantages associated with the use of edible insects in the food sector. One of the most important is the protection of the environment, which is why the protein of edible insects is often called “ecological protein”. Breeding of insects is associated with aspects that are important in terms of environmental protection, as smaller than in the case of farm animals use of drinking water, feed, which can constitute waste of the agri-food industry, meeting the requirements for ensuring food and feed safety, which solves another problem related to their utilization. In addition, breeding of insects is associated with lower greenhouse gas emissions (methane, nitrous oxide, ammonia) and faces. Insects can be used in agriculture as a fertilizer (Boczek and Pruszyński 2013; Krzywiński and Tokarczyk 2011; Rumpold and Schlüter 2013; Zielińska et al. 2015b). Saving agricultural land, fodder and drinking water also means significantly lower farming costs (FAO 2013). Another positive aspect is certainly increasing the economic potential of insect breeding is the ease of distribution, high fertility rate and short reproduction cycle (Schabel 2010). The main obstacle to using insects as food in European countries is cultural barriers and the associated lack of acceptance among potential consumers, and even reluctance and fear. Consumers in European countries react with disgust at the perspective of consuming organisms that are not commonly known as food and as pests (Yen 2010; Tan et al. 2015). However, their introduction into the diet does not have to involve insect intake in the form in which they occur naturally. There are many possibilities of processing insects to a form more acceptable to society in developed countries, e.g. flours, crisps. Tan et al. (2015) argue that the method of preparation of this type of products has a big influence on sensory acceptance among consumers who have not eaten insects until now. Given in a form resembling products known to consumers or used in processed form, as an addition to traditional products, they have a positive effect on organoleptic sensations (Hartmann and Siegrist 2017; Tan et al. 2015). Similar results were obtained in studies carried out in the Netherlands. Consumption of insects in total was associated with rejection by the respondents, while the form resembling conventional food gave rise to acceptance. it was mostly accepted (House 2016). According to House (2016), the key to increasing the motivation for repeated consumption by consumers of western countries containing insects is therefore the form of the product, but also the taste, price and ease of integration with individual nutritional practices. One of the few studies on the attitudes of the Polish population towards consuming edible insects, as an alternative source of food, showed a positive or neutral attitude of consumers towards entomophagia (Bartkowicz 2017). Powdered insects can also be used in food processing as a functional additive that binds water or creates emulsions, and the development of methods of processing insects for food purposes enables isolation of pure protein or extraction of fat. Another factor hindering the introduction of insects into the food sector is microbiological safety, toxicity and the presence of other organic pollutants (FAO 2013; Zielińska et al. 2015b). In the United Nations Food and Agriculture Reports for several years, discussions on the use of edible insect proteins in the aspect of solving the growing problem of hunger in the world (FAO et al. 2015; FAO 2009, 2013). In European countries, there are no legal regulations that allow insects for human consumption. Pursuant to Regulation (EU) No. 2015/2283 of November 25, 2015, insects belong to the so-called “New food”, in other words according to Regulation (EC) No. 258/97 of the European Parliament, which was not consumed on a large scale in the European Union before May 15, 1997, and registration of such food is difficult, time-consuming and requires a lot of research. One of the few countries in Europe that introduced some species of insects into consumption is Belgium (FASFC).

7.3.5.1 Safety of Insect Consumption

Food and feed security are prophesied to be under siege, owing to the sharp increase in the population besides the resultant upsurge in animal protein demand. Promotion of food security can influence the progress of local food structures and trade, the encounters that avert local foods from enjoying a larger share of the per capita food consumption, therefore they must comprise the guard of livelihoods, provide safety net for food insecure people and to inspire then join in mainstream participation (US JES COC 2012). In the case of new food sources, which are edible insects, safety is of particular importance (Van Huis 2016). From research the safety of insect consumption shows that they may, like conventional food, pose a potential threat to humans, due to the presence of endo- and exogenous allergic and toxic substances, anti-nutritional substances and pathogens in them (Rumpold and Schlüter 2013). Risk factors of origin endogenous can be, among others, allergens and anti-nutritive substances. Nishimune et al. (2000) describe an African silkworm containing thiaminase (thiamine-degrading enzyme) that is resistant to high temperatures. Ingestion of insects may be associated with the occurrence of reactions allergic, caused by the presence of inhalant, contact or food allergens in them. The greatest danger is therefore farmers and people employed in production (Rumpold and Schlüter 2013; Mlcek et al. 2014). Ekop et al. (2010) found low content of oxalate, phytate and tannin products in these products, below the levels considered to be toxic to humans. External factors can also affect the safety of insect consumption. For example, there are information about botulism, parasitic diseases and food poisoning caused by insect consumption. It is therefore important to maintain adequate conditions for the preparation of insects for consumption (Schabel 2010). In addition, some insects may sequester toxins from feed and synthesize them, e.g. cyanoglycosides, steroids or highly toxic amides, produced as chemical defense against other insects (Rumpold and Schlüter 2013; Zagrobelny et al. 2009). It was also observed that insects feeding on areas covered by the action of pesticides also contained them in their composition (Schabel 2010). Investigations of bacterial microflora of insects revealed the presence of pathogens such as: Bacillus cereus, Pseudomonas aeruginosa and Staphylococcus aureus, as well as non-pathogenic Bacillus species (Banjo et al. 2006). In addition, as in the case of dishes prepared from other raw materials of animal and vegetable origin, the storage of insects and their products after heat treatment at reduced temperatures prolongs their microbiological durability (Klunder et al. 2012; Mlcek et al. 2014). Insect microflora can be a potential danger for humans, therefore it is important to develop optimal processing conditions for each species intended for consumption insects so as to ensure the highest possible microbiological purity of the finished product (Rumpold and Schlüter 2013).

7.3.6 Animal Proteins

Animal proteins are wholesome proteins that contain all amino acids in the body's proportions. Zoonoses include: milk and dairy products, animal meat (including fish), eggs. In most developed countries, animal protein is the main source of dietary protein, not vegetable protein. Therefore, there is often a differently increased choice when the total protein intake increases. However, the consumption of animal products, especially red and processed meat, is associated with an increased risk of diseases such as cancer, T2D and cardiovascular diseases (Abete et al. 2014; Demeyer et al. 2015; Malik et al. 2016). The optimal ratio of vegetable protein to animal protein in the diet has not yet been determined. However, can higher protein intake be associated with lower glycemic hemoglobin (HbA1c). We do not know that yet. HbA1c levels measure mean blood glucose levels above 6–8 weeks. High hemoglobin is a risk factor for T2D. The long-term positive effect of a diet with higher protein content on the body, weight management, may in turn lead to a reduction in HbA1c (Clifton et al. 2014). Dietary studies have also shown that higher doses of protein may reduce HbA1c directly, especially in patients with T2D (Frank et al. 2009; Gannon et al. 2010). However, the question remains whether higher protein intake may be associated with an increased estimation of glomerular filtration rate (eGFR), an unfavorable indicator of renal function, because it is carefully controlled. Dietary studies also show that higher doses of protein may increase this rate of renal function (Brenner et al. 1982). Caring for kidneys in a diet with higher protein content results from the harmful effect of the induced glomerular hyperfiltration effect (Nothlings et al. 2008). The quality of animal protein is also problematic. Meat *in vitro*, in other words meat for breeding in cells or pure meat, is an animal product produced after isolation and identification of cells, cell culture according to tissue engineering protocols (Langelaan et al. 2010). Several cell sources may be used, including embryonic cells prior to implantation or adult stem cells. Proponents of this meat argue that an in-vitro meat bioreactor with a pool size could feed 40,000 people a year and that it would use 99% less arable land than the average for beef. The first hamburger from in vitro cultures was created by Mark Post from Maastricht University in 2013. It cost £ 200,000, and it took 2 years to set (WRAP 2018). Mosa Meat, a Dutch start-up, is still developing, focusing on improving the taste by co-culturing fat cells and reducing costs. Other companies, both in the US and other countries of the world, are pursuing similar goals. It is estimated that current costs are around USD 11. Innovative financing mechanisms for research, for example public financing, will support further technical development of farmed meat. An alternative source of animal protein is whey protein. Its chemical composition is shown in Table 7.2. Whey protein is a by-product of residues from the cheese making process. Currently, both proteins, both casein and whey are considered viable alternatives to animal proteins (Table 7.2). However, they are not compatible with the diets of vegetarians and vegans who try to avoid products derived from animals.

Table 7.2

Chemical compositions of Whey

Specification	Whey powder	Whey concentrate	Whey isolate
Protein	11–14.5	25–89	90+
Lactose	63–75	20,363	0.5
Milk fat	1.0–1.5	43,141	0.5

Own research based on: Colgan (1993), and Geiser (2004)

Whey protein is complete, contains a lot of cystine (GSH), increases the function of the immune system, and has a high content (branched chain carbohydrates (BCAA) Whey concentrate, in addition to the isolate, contains more biologically active ingredients. Rapid digestion and transport to cells and biostimulation of biosynthesis of proteins (Colgan 1993).

7.3.7 Plant Proteins

Animal products are not able to meet the global demand for protein and energy in a sustainable way – on the Earth there will be a shortage of water and soil suitable for pasture and for growing crops for feed. Animal husbandry causes higher greenhouse gas emissions than transport, water pollution from wastewater from piggery and sheds, and desertification of soils used as pastures and fields (Henchion et al. 2017; Shewry and Halford 2002). Transport itself will also be significantly reduced, because we focus on local food production. What's more, recently, the need to constantly use antibiotics in animal husbandry on a scale several times greater than the therapeutic demand for humans is a growing topic (Anonymous 2018a). Currently, vegetable sources of protein dominate in the supply of protein in the world (57%), with meat (18%), dairy (10%), fish and shellfish (6%) and other animal products (9%) constituting the remainder (FAO et al. 2015). The protein of plant origin is preferred in relation to animal protein from the point of view of environmental protection, because it is associated with a lower requirement for land use, the production of a smaller amount of greenhouse gases (GHG), than food of animal origin (Anonymous 2018a). Due to the high production costs and the limited availability of animal protein, increased attention is focused on the use of vegetable proteins as potential sources of cheap, dietary protein.

7.3.8 Cereal Proteins

Cereal proteins are the most important part of protein intake in diets all over the world and they constitute an important source of protein for animals as well as for humans (Bradley and Folkes 1976; Bleakley and Hayes 2017; Boczek and Pruszyński 2013), especially in the diet of developing countries. Common wheat (*Triticum aestivum* spp. *vulgare*) and durum wheat (*Triticum durum*) constitute the largest group of vegetable protein sources in the European diet (Van Spiegel et al. 2013; Shewry and Halford 2002). Wheat bread is a key element of protein in Europe with a typical loaf of 8 grams protein per 100 g. The protein content in wheat grain varies from 10% to 15% (Shewry and Halford 2002). These spare proteins include prolamins, globulins and germins (Cunsolo et al. 2012). Maize (*Zea mays* sp.), rice (*Oryse* sp.) and wheat (*Triticum aestivum* ssp. *vulgare*) are the main protein products consumed around the world. In some regions, such as in West Africa, millet is the most important protein product. In turn, in southern India, where malnutrition of infants and children is common, rice and millet are eaten regularly, and in Ethiopia the preferred cereal is Teff, with a protein-like amino acid profile. A typical Ethiopian diet consists of 65 g of protein, of which 41 g comes from Teff, and only 6 g from the consumption of animal protein (Jansen et al. 1962). Maize (*Zea mays* sp.), as a source of food, represents respectively 25% and 15% of the total consumption of maize in developing countries and around the world. This species is very similar in terms of share in calorie consumption worldwide: from 61% in Central America, 45% in East and South Africa (ESA), 29% in the Andes, 21% in West and Central Africa (WCA), to 4% in South Asia (Shiferaw et al. 2011). Oat protein (*Avena sativa* sp.) is of very high quality, and the content and quality of amino acids in the seed is comparable to soy protein (Cavazos and de Mejia 2013). It contains much more lysine, an essential amino acid, compared to other types and species of cereals, but has a lower content of proline and glutamic acid. This means that after digestion, oat protein can be tolerated by people with gluten intolerance and sensitive to allergies (Klose et al. 2009). The rice, in turn, does not contain large amounts of protein, but the rice protein flour is prepared beforehand using enzymatic treatment with carbohydrate-hydrolyzing enzymes to obtain products containing up to 91% of protein (Shih and Daigle 2000; Cavazos and de Mejia 2013). Cereals can bring great health benefits as a rich source of BIOPEP bioactive peptides (Cavazos and de Mejia 2013). Bioactive food-derived peptides gained increased interest as control factors for chronic diseases and reduced the risk of side effects resulting from the use of synthetic drugs (Colgan 1993; Gobbetti et al. 2004; Hernández-Ledesma et al. 2011; Pihlanto and Mäkinen 2013). Bioactivity associated with cereal proteins is: antioxidants, anti-inflammatory effects, cholesterol lowering, satiety, antidiabetic and other (Cavazos and de Mejia 2013). They affect the physiological effects demonstrated on animal models. However, prolaminates from some cereals, including wheat, barley and rye, cause biologically active anti-nutritive peptides after proteolysis that are able to adversely affect in vivo the intestinal mucosa of celiac patients, while prolaminates from other cereals, such as corn and rice is not. Bioactivities associated with peptides derived from oat, barley and wheat proteins include opioid activity, while rice protein contains the RGD sequence and no visceral toxicity, which may be beneficial for health and nutrition (Colgan 1993; Iwaniak and Dziuba 2009; Buczyńska and Szadkowska-Stańczyk 2010; Deng and Chow 2010; Cunsolo et al. 2012; Malaguti et al. 2014; Demeyer et al. 2015; Gangopadhyay et al. 2016; Dietary Guidelines for Americans 2015–2020). From an agricultural point of view, the use of varieties, environmental conditions and agricultural practices can affect the bioactive content of peptides in cereal proteins.

7.3.9 Productivity of Legumens

Some plants have unique advantages, e.g. legumes have a unique ability to bind nitrogen of the legumes, soy is a very important source of protein, but 85% of its production is used to produce animals and fish (Sawicka et al. 2000; Anonymous 2018b). However, the desire to increase soy production in response to increased demand for animal protein is associated with deforestation and habitat loss, especially in South America. Ethical issues are connected with this, because about 12 million hectares of arable land, outside Europe, is necessary to ensure feed for European livestock production (Klunder et al. 2012; Kalembasa et al. 2014; Szymańska et al. 2017; Symanowicz et al. 2018).

The amount of nitrogen from the biological reduction process in the yellow lupine biomass harvested in the flowering phase was lower after using a larger dose of this component, while in the phase of full maturity this relationship was reversed (Kalembasa et al. 2014) proofs that. The amount of nitrogen from the fertilizer increased with increasing nitrogen dose. The percentage share of nitrogen from the biological reduction process in the yellow lupine biomass was similar in the flowering phase (53.4%) and full maturity (51.6%). However, the share of nitrogen from fertilizer was higher in the first day of the lupine harvest than in the II period, while in the case of nitrogen collected from the soil the dependence was reversed. Diversified nitrogen fertilization therefore does not significantly affect the percentage of nitrogen from biological reduction in yellow lupine (Tables 7.3 and 7.4). This species fertilized with a higher dose of nitrogen contained a higher percentage of this element originating from fertilizer, and a smaller one from soil stocks than after using a smaller dose. It is possible, therefore, to increase the nitrogen content of seeds not only through the natural binding of nitrogen from the air. However, an increase in the outlay on industrial means of production in higher-intensity technologies caused a decrease in the gross agricultural income value (Kalembasa et al. 2014; Szymańska et al. 2017).

Table 7.3

Seed and biomass yield (tons · ha^{-1}) and nitrogen and protein content (kg · ha^{-1}) in yellow (*Lupinus luteus*) and narrow-leaved lupins (*Lupinus angustifolium*), depending on the soil cultivation system

	Yellow lupinus (*Lupinus luteus*)			**Narrow-leaved lupins (*Lupinus angustifolius*)**		
Specification	**Cultivation systems**					
	Traditional	**Simplified**	**Direct sowing**	**Traditional**	**Simplified**	**Direct sowing**
Yield						
Seeds	2.83	2.94	2.76	3.2	3	2.51
Whole biomass	12.73	13.48	11.97	9.86	9.71	7.61
The total amount of nitrogen						
In seeds	160.2	162.5	156.2	132.8	109.2	99.8
In biomass	245.2	251.5	238.5	181.5	152.4	136.9
Amount of nitrogen from the atmosphere						
In seeds	96.1	110.8	108.4	66.5	55.9	55.2
In biomass	137.3	149.2	147	85.5	62.4	63.8
The amount of protein in seeds	600.6	692.5	677.5	415.6	349.3	345

Source: Sawicka et al. (2000), and Kalembasa et al. (2014)

Table 7.4

The yield of seeds, biomass and vegetable protein in 3 species of legumes

Specification	Beans (*Vicia faba* ssp. *minor*)	White lupine (*Lupinus albus*)	Soya bean (*Glycine max*)
Yield (tons · ha^{-1})			
Seeds	5.89	4.16	2.57
Biomass	12.74	11.85	9.73
The amount of total nitrogen (kg·ha^{-1})			
Seeds	289.7	213.8	123.1
Biomass	354.1	248.8	168.2
The amount of biologically reduced nitrogen (kg·ha^{-1})			
Seeds	208.9	131	99.3
Post-harvest remnants	31.1	11.9	10.4
Total	240	142.9	109.7
The proportion of biologically reduced nitrogen in the total nitrogen content (%)			
Seeds	72.1	61.3	80.7
Post-harvest remnants	48.3	34.1	23.1
Weighted average	67.8	57.4	62.5
The amount of vegetable protein in the seed yield – 6,25 × N (kg · ha^{-1})			
	1305.6	818.7	620.6

Source: Sawicka et al. (2000), and Kalembasa et al. (2014)

Despite the favorable agricultural income generated from the production of leguminous plants, e.g. pea and yellow lupine, in relation to cereals, in practice, this does not encourage agricultural producers to become more interested in growing pulses as commodity production. So far, legumes for grain have been grown mainly for their own needs, and the commodity of their production was only a few percent. An important limitation of the use of legume seeds in the feed industry is the lack of the possibility of providing a larger supply of raw material with standard parameters, as their production is fragmented. Purchase from numerous small producers, for example in Europe, is cost-intensive and increases the price of the raw material (Sawicka et al. 2000; Florek 2017; Symanowicz et al. 2018). In order to increase the possibility of using native protein in the production of feed, it is also necessary to integrate entities operating on the market, both horizontally and vertically. Establishing closer cooperation between farmers producing legume seeds (creating producer groups, clusters) would facilitate making joint purchases, organizing consultancy, selling seeds to the processing plant. Cooperation between the producer and the recipient within the framework of vertical integration would also bring great benefits. Farmers could produce seeds in accordance with the needs of feed plants, according to a uniform technology required by the recipient, while ensuring their sales. Processing plants they would receive large batches of a single raw material with the required quality standard. On the basis of the analysis, it can also be stated that the current financial support from the state encouraging the production of leguminous plants only fulfills the function of stabilizing the income of producers, without translating into the commodity of seeds. Positive changes should be seen in linking subsidies to leguminous plants with the size of the production, and not the area of cultivation (Reckling et al. 2016; Florek 2017; Szymańska et al. 2017).

7.3.10 Productivity of Perennial Butterfly Plants

The productivity of perennial legumes is one of the important features determining their utility value. This term, understood as the intensity of the production of dry matter from the surface unit during the growing season, in the case of fodder legumes refers to their yield. The genetic determinants, natural and agrotechnical factors and methods of use have a significant impact on the productivity of plants in this utility group. Genetic factors influence the diversity of yields between species, forms and cultivars, and the habitat elements that most modify the productivity of the species are mainly soils and weather conditions, whereas from cultivation operations they are primarily: the quantity, the method and date of sowing, fertilization, care and frequency of mowing. Among the many species, the greatest economic importance on arable lands is red – meadow clover (*Trifolium pratese* L.), cross-linked lucerne (*Medicago media* Pers.) and sowing (*Medicago sativa* L.) and locally sainfoin (*Onobrichis viciaefolia* Scop.). The area of cultivation of these species amounts to million ha and covers about 95% of the area of cultivation of all legume plant species (FAO 2016). It is estimated that alfalfa and esparceta constitute 1/3, and red clover 2/3 of this area. Other leguminous plants, such as: Persian clover (*Trifolium resupinatum* L.), shamrock (*Trifolium incarnatum* L.), white melilot (*Melilotus albus* Desr.), Serradella (*Ornithopus sativus* Brot.) Have a negligible share in the field of fodder production, and white clover (*Trifolium repens* L.), hornbeam (*Lotus corniculatus* L.), lucerne hoppeas (*Medicago lupulina* L.) and white-leaf clover (*Trifolium hybrydum* L.) play an important role as components of meadow and pasture mixtures. Butterfly small-seedlings are a group of plants with a very large diversity of species in terms of: biological (durability, regrowth, and multicellularity), morphological (plant height, degree of foliage, habitat of shoots), habitat requirements (type and type of soil, humidity, temperature, insolation) and use (cattle, pasture) (Sawicka et al. 2000).

The basic species are characterized by the highest productivity in field cultivation, and the yields of their dry matter are on average 8–12 tons ha^{-1}. The first year of cultivation (sowing year) decides about the productivity of these species, although the main yield in full years of use. The biological properties of red clover enable our 2-year exploitation in most of our conditions (year of sowing and full year of use), whereas in the case of alfalfa this period can be 2–3 years, not including the sowing year, and depends mainly on the number of cuts per year. The main method of sowing red clover is sowing in a protective plant, and alfalfa both sowing clean, as well as under sown. Sowing red clover into a protective plant (spring barley for grain or oats for green) is used primarily for economic reasons. Regrowth of the undercapture on the equipment of the protective plant is called a stubble, and its yield, collected most often at the end of September, depends mainly on the course of weather conditions in the summer months. Drought and high air temperature after the harvest of the protective plant limit the yielding of the abrasive, while high and proportionally distributed precipitation at high temperature stimulates the crop. Under favorable conditions one can get about 1 tons of dry matter, very good quality, from 1 ha. The abundance of alfalfa abundance cultivated as a spring barley yield is about 1–2-3 tons ha^{-1} of dry matter, while grown in pure sowing about 5 tons per ha. Sowing the legume plants into a protective plant, an additional 3.5 tons are obtained ha^{-1} of barley grain. Lucerne, cultivated as a disgrace, reacts worse than red clover to unfavorable development conditions, and especially to the lack of light. In such conditions, it germinates less, grows more slowly and more plants die. In addition, early mowing of alfalfa with grain before the flowering phase results in weaker root system development and weakens plants that are worse in winter and lower yield in the next year compared to alfalfa sown in pure sowing. Also, summer sowing without a protective plant that can be performed by mid-July is usually less favorable for the development and yielding of legume plants. In addition to annual plants (Persian clover, red clover, seradella), most butterfly species, yields best in the second year, and species with greater durability, such as: alfalfa and seed alfalfa, sainfoin and hornbeam, can also yield well in second and third year of full use. In crop for fodder, the productivity of plants depends on the structure of crop density, which is formed by the planting of crops and shoots on the surface unit. The relationship between the planting density and the density of the shoots is not directly proportional, because in practice from a different number of plants on a specific surface grows a similar number of shoots. Thus, within certain limits of the amount of sowing seeds, there is a similar crop density structure and similar yield. In addition to the sowing rate, the number of shoots per m^2 was differentiated by swaths and the age of the plantation. In addition to the density of plants and shoots in the field, the productivity of perennial legumes is influenced by their individual (genetic) characteristics, such as: height and stalk size, branching degree, leaf arrangement on the stem, which determine the intensity of light penetration in different parts of the field. The LAI leaf index, responsible for the intensity of photosynthesis and the productivity of biomass, also depends on these elements (Sawicka et al. 2000; Sawicka and Kalembasa 2013).

In the cultivation of lucerne and red clover, a marked decline has recently been noted. In relation to the eighties, in recent years their production for fodder decreased by about 30%, comparing the efficiency of feed units (JP) from 1 ha. In turn, the results of varietal experiments indicate that the potential production possibilities of alfalfa, for example, are high and amount to 18–28 thousand. JP, and red clover 16–24 thousand. JP from ha We see very large production reserves inherent in genetic material and agrotechnics and exploitation. The difference is over 200% and is the highest compared to other fodder plants. Small-winged butterfly plants can be harvested at different frequencies. This applies mainly to red clover and hybrid and seed alfalfa. The harvesting intensity is regulated by the quality of the feed, the yield and the durability of the plantations. Plants mown in the early stages of development (before stalking) are characterized by high protein content, low fiber and dry matter, and are mainly suitable for drought or leaf protein, while collected at later stages of development give higher yields of dry matter, but contain less protein, and more fiber. Breeding achievements affecting the productivity of field crop species mainly concern red clover and hybrid and seed alfalfa. The cultivated tetraploid varieties of red clover in comparison to diploid ones are characterized by higher green and dry matter yield, larger size of morphological body organs (stems, leaves, inflorescences, seeds) and higher protein yield. They are more durable and more useful for more frequent (3-fired) harvest in earlier development phases. Other breeding works, e.g. in the area of red clover, are carried out over increasing the resistance of clover and powdery mildew varieties and increasing their durability, while in alfalfa they include works on the durability of varieties for frequent mowing and kneading with heavy mechanical equipment, resistance to venous diseases, greater tolerance to lower soil pH and high concentration of aluminum, as well as suitability for pasture use (Sawicka et al. 2000; Sawicka and Kalembasa 2013). The disadvantage of some perennial legume plants is the presence of anti-nutritional substances that reduce the nutritive value of feed and may even be toxic to animals. Due to their role and function in life processes, plants are classified as so-called secondary metabolites. These include: cyanogenic glucosides, saponins, coumarins, tannins, estrogens. These substances, from the nutritional point of view, are considered unfavorable, but for plants they are a natural protection against pests and diseases. Plants selected to lower the level of secondary metabolites lose these protective barriers and are more exposed to the negative effects of the environment. Secondary metabolites play an important role in the nutrition of both humans and animals. It has been shown that in addition to adverse effects, such substances as: phytic acid, phenolic compounds, enzyme inhibitors, saponins, glucosinolates, etc. have the ability to lower the sugar content, cholesterol and triglycerides in the blood plasma, regulate insulin activity and the formation of excess free radicals. Therefore, the anti-nutritional substances also have a beneficial effect, which is why it is very important to set the rates of their collection so that the risk of ingestion is low, and the action is optimal. Due to the potential nutritional benefits resulting from the presence of secondary metabolites in the feed and their importance in ecology, they do not always have to be anti-nutritional, because their role is multifaceted and depends on various factors. These substances, from the nutritional point of view, are considered unfavorable, but for plants they are a natural protection against pests and diseases. Plants selected to lower the level of secondary metabolites lose these protective barriers and are more exposed to the negative effects of the environment. Secondary metabolites play an important role in the nutrition of both humans and animals. It has been shown that in addition to adverse effects, such substances as: phytic acid, phenolic compounds, enzyme inhibitors, saponins, glucosinolates, etc. have the ability to lower the sugar content, cholesterol and triglycerides in the blood plasma, regulate insulin activity and the formation of excess free radicals. Therefore, the anti-nutritional substances also have a beneficial effect, which is why it is very important to set the rates of their collection so that the risk of ingestion is low, and the action is optimal. Due to the potential nutritional benefits resulting from the presence of secondary metabolites in the feed and their importance in ecology, they do not always have to be anti-nutritional, because their role is multifaceted and depends on various factors. Particularly high intensity of the negative impact of these substances may occur in the case of feeding single-species feed in large quantities or for a longer period of time. High disposable doses of feed containing anti-nutritive substances may cause acute poisoning, whereas feeding such feed for a longer period may cause chronic diseases or disturbances in the reproduction of animals (Sawicka et al. 2000; Reckling et al. 2016).

Plant proteins are usually derived from legumes plant. Commercial acceptance of genetically modified (GM) food and plants called genetically modified organisms (GMOs), created as a result of recent innovations in agricultural biotechnology, has caused widespread controversy related to the environmental and economic benefits of food and animals in a wider social range, cultural values and ethical (Stewart 2009). Many initiatives have been taken to sensitize people to the ecological responsibility of breeding animals and to increase interest in alternative proteins. Plant-based proteins are also typically harder to digest than animal proteins, due to their high concentration of insoluble polysaccharides. Despite this, there are increasing concerns about the high levels of saturated fats and cholesterol found in foods of animal origin, which are linked to the development of cardiovascular disease and diabetes, leading the nutritionists and organizations to recommend more varied diet rich in plant-based proteins (Reckling et al. 2016; Anonymous 2018a).

Commercial adoption of genetically modified (GM) foods and crops called as genetically modified organisms (GMO) created through recent innovations in agricultural biotechnology has triggered widespread controversy over the environmental and economic benefits and risks of food crops and animals on a wider range of social, cultural, and ethical values (Stewart 2009). Many initiatives to sensitize people on the ecological liability of animal rearing and to escalate their interest in alternative proteins, is to be carried before inducting into the food cycle. There is already the first information on obtaining rapeseed protein by new, innovative methods. NapiFeryn BioTech paves the way in Poland and around the world. It implements it as part of a grant from the largest EU program financing research and development, Horizon 2020. However, scientists are measuring much higher and want to build in Poland the world's first biorefinery producing rapeseed protein. The protein from this plant will be differentiated by the method of obtaining from soy protein. The technology of obtaining soy protein is quite outdated (it comes from the 1940s). In addition, hexane, a solvent still widely used in the oil industry, is used for soybean processing. The new technology for obtaining protein from winter oilseed rape will not be based on it, and on very mild biomass processing methods – it will be a "delicate" process, without drastic changes in pH and without any solvents. It is a more modern solution, safer and giving a higher quality product. In addition, the conditions under which rapeseed protein is isolated do not damage it (protein denaturation). Thanks to this, the protein obtained by the innovative method, in Poland, will be natural and functional. The use of vegetable protein is of civilized importance – now animals are fed plants to produce protein. The authors of this project want to direct the protein to people. Animals are a kind of filter through which most of the protein is lost, i.e. they are an ineffective source of its processing. Not counting that 4 kg of plants are needed for 1 kg of pork and 1 kg of beef for 7 kg of plants. Instead of wasting calories, it is worth turning to the protein obtained from plants, in this case from rape, which is characterized by a high content of full-value proteins (Voisin et al. 2014; Anonymous 2018b). The protein is obtained from the remains of the oilseed rape oil, the seeds of which contain about 20% of protein with high nutritional values, but until now it has not been used as a food ingredient. Meanwhile, innovative Polish technology allows the recovery of about half of this protein in the form of an isolate with high qualitative and functional parameters. An innovative element of this technology is that the starting material is biomass, which is formed after extrusion of oil from rape seeds. Until now, the potential of this biomass was not fully used, it served only as animal feed, because there were no solutions that would isolate the protein for edible purposes from this biomass. New technology is able to do this, and it makes it unique in the world (Reckling et al. 2016; Anonymous 2018b).

7.3.11 Protein Diet

Determining the protein requirement is difficult because it is metabolized with other nutrients. In addition, there is a need to supply with food the right amount of essential amino acids, which the human body does not synthesize. Plant proteins are usually more difficult to digest than animal proteins due to their high concentration of insoluble polysaccharides. Nevertheless, there are growing concerns about the high levels of saturated fat and cholesterol in animal foods that are associated with the development of cardiovascular diseases and diabetes, leading dieters and organizations to recommend a more varied diet rich in vegetable proteins. A diet rich in protein, from 1.2 to 1.6 g protein /kg/day, may improve the regulation of body weight (Skov et al. 1999; Larsen et al. 2010; Austin et al. 2011). Protein-rich diets also seem to complement other strategies, such as reducing energy and physical activity, to combat the global obesity epidemic (Leidy et al. 2015). Because obesity is an independent risk factor for type 2 diabetes (T2D), higher doses of proteins for mass regulation and maintenance may also be beneficial for the prevention of T2D (Shang et al. 2016). Although the total amount of protein can be important, the source of protein affects other diet components, such as dietary fiber and micronutrients. According to Song et al. (2016) and Møller et al. (2017) protein sources will probably be an important determinant of health. In the last few years, a high-protein diet was recommended to regulate body weight. However, the potential health risks of these diets are still uncertain. In the last few years, a high-protein diet was recommended to regulate body weight. However, the potential health risks of these diets are still uncertain. Møller et al. (2017) investigated this aspect based on the amount and source of the protein and the study of the compound's result with glycated hemoglobin (HbA1c) and estimated glomerular filtration rate (eGFR). The analysis were performed on the basis of three population studies included in the PREVIEW project (PREVEMENT of diabetes through lifestyle Intervention and population studies in Europe and around the world): 'NQplus', 'Lifelines' and 'Young Finns'. The protein effect was assessed on the basis of two components: (1) percentage of total energy protein and (2) the ratio of vegetable protein to animal protein. A positive association was found between protein and eGFR results in Lifelines lines (slope 0.17 –0.02 ml/min/1.73 m2, $p < 0.0001$). Thus, protein evaluation can be a useful tool to assess both the impact of the amount and the source of the protein on health parameters. However, further research is needed to confirm this newly developed protein assessment. Therefore, the source of protein will probably continue to be an important determinant of health (Reckling et al. 2016; Song et al. 2016). American nutritional guidelines suggest switching to a diet more based on foods of plant origin (Dietary Guidelines for Americans 2015–2020). Vegetable diets provide many phytochemicals that have been associated with protection against many chronic diseases. However, when compared to animal proteins, plant proteins lack sufficient amounts of essential amino acids. The optimal ratio of plants to animal protein in the diet has not yet been determined. Møller et al. (2017) developed a new protein diet using cross-sectional data from three large European population studies. It has been proven that both the amount and source of proteins (the ratio of vegetable protein to animal protein) are determinant factors affecting HbA1c and eGFR. However, further research is necessary to clarify the usefulness of the protein result in long-term population studies, as well as in other health conditions.

7.4 Research Priorities

1. 1.

   Development of the possibility of increasing the process of biological reduction of nitrogen in various soil and climate zones of the world as the cheapest source of nitrogen for the production of plant protein,

2. 2.

   Development of ways to increase the nitrogen utilization rate of fertilized plants in the process of vegetable protein synthesis,

3. 3.

   Increasing the efficiency of protein processing of microorganisms and vegetable protein on animal protein.

7.5 Conclusion and Future Perspective

The global meat substitutes market is growing from year to year. Projections for the development of the protein substitute market are also based on data on population growth, which is expected to increase to 8.9 billion by 2050. With such a high population growth, the demand for protein will increase dramatically, however, it is much harder to increase meat production because it requires large expenditures (water consumption, fodder), and also promotes waste production, rather than crop production or other possibilities of protein production. Satisfying the nutritional needs of an ever-growing human population it requires searching for alternative sources of protein. Currently, only in some regions of the world presented in the work organisms are used in the food sector. The production of SCPs and marine organisms can contribute to improving food security in the world, although at present they are used to a greater extent in feeding farm animals as feed components. A promising alternative to conventional protein sources is edible insects, which have great potential as a component of human diet due to their high nutritional value. The breeding of insects instead of pigs or poultry is also supported by the fact that it is more beneficial for the environment, economical and efficient. The problem is the lack of acceptance of insects as a foodstuff among the population of developed countries, as well as difficulties in introducing insect food products to the market. The use of insects in the food industry on a large scale is also difficult due to the safety of their consumption, which must be confirmed by further research. However, globalization of the use of insects and other unconventional sources of protein in human nutrition requires decisive action to improve public demand and acceptance and increase consumer awareness of the benefits of their consumption. The search for new insects as a source of protein and the technology of their processing requires further research. In spite of fewer commercial approvals by limited number of countries, the international trade GMO constituents has created labeling the foods products and animal feeds in most countries in the world, to indicate the evidence of acceptance by many farming communities across the world. China, Brazil, and India, have substantial public sector GMO R&D program on new GM crops which include rice, cotton, maize and cassava, where the efforts are supported by US donors. There are uncertain conflicts which dilate the acceptance of GMOs, like the advent of domestic labeling and traceability requirements for food imports, which seriously inhibit the use of GM crops in exporting countries even where those crops are consumed internally or exported to third countries. In addition to this is the dramatic increase in food prices which has boosted the interest in the production of GMO crop varieties which led to some softening of regulatory restrictions and consumer attitudes in Europe and some developing countries. New proteins require the development of new value chains and attention to issues such as production costs, food safety, scalability and consumer acceptance. Positive impact on the environment is important and cannot be assumed only as a new source of protein. Care should be taken to ensure that the novel and existing protein source is compared. Greater convergence of political forces and involvement of broader stakeholders in the role of management, as well as the role of development/commercialization, it is required to refer to both sources of protein and ensure food safety.

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