NEXTGEN PROTEINS

Bioconversion of Underutilized Resources into Next Generation Proteins for Food and Feed

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2 Executive summary

The global population is expected to peak at nearly 11 billion around 2100. A larger population, higher general income levels, and changing consumption patterns will increase the demand for food.

Protein is an essential macronutrient, made up of amino acids. As such, protein is therefore an essential part of any diet. World protein consumption, measured as grams per capita, has been growing, mostly due to a vastly increased consumption of animal-based proteins, although more plant-based proteins are also consumed of. Consumption of animal-based proteins has been linked to various diseases and consequently health costs but is also more demanding in an environmental sense; GHG emissions related to the production of meat and dairy products are generally much higher than those associated with production of plant-based proteins and land-use is more intensive. Agriculture in general is also responsible for 70% of global freshwater withdrawals, causes 78% of all ocean and freshwater eutrophication, and is a major threat for biodiversity. Proteins also constitute an important part of feed used in animal husbandry and aquaculture. Most of the proteins used for this purpose come from soybean, rapeseed, and sunflower seed meal, as well as from fishmeal.

The market for alternative proteins is expected to grow fast in the coming years provided consumers and investors remain interested in sustainability, and alternative proteins reach parity with animal-based proteins on taste, texture, and price.
The proteins produced by the four firms taking part in NextGenProteins are defined as alternative proteins. Two of the proteins are made from insects – crickets and black soldier flies – and the other two from microalgae and single-cell proteins (SCP). It is, however, impossible at this stage of the project to have a clear idea of the impact that shifting protein production to these alternative proteins will have on the economic system in which the firms operate. The production aims of the NextGenProteins producers are relatively modest in terms of quantity. The combined production of the four firms could be 15-20,000 tons in the not-too-distant future, and total employment associated with that level of production could equal 150-200 FTE (Full-time equivalent). Most of the employees would be skilled. Neither the level of production nor employment is likely to have but a very minor impact on the market for proteins and employment in general. However, the importance of the producers could be quite large at a local or even regional level.

3 Introduction

The world population is expected to increase from 7.7 billion currently to 9.7 billion in 2050 and could peak at nearly 11 billion around 2100 (UN, 2021). This development is mainly due to an increasing number of people surviving to reproductive age and increasing longevity, while at the same time fertility rates have generally been declining and are projected to continue falling. Increasing urbanisation has also contributed to a smaller population growth, but the overall impact of accelerating migration is more uncertain (Koczan et al., 2021).

A larger global population, changes in consumption patterns, and rising income levels will increase the demand for food. Food production may even have to double by 2050 in order to keep pace with demand (Hunter et al., 2017).

Agriculture and land use are major sources of greenhouse gas (GHG) emissions. A recent study estimates that GHG emissions from food systems account for 35% of global total anthropogenic GHG emissions. These estimates do not account for food-related emissions, such as savannah burning, peat drainage and peat fires, but by adding these emissions the share of food-related emissions rises to 37% of total world emissions (Xu et al., 2021). Of these, 57% can be related to the production of animal-based food (including livestock feed), 29% to plant-based foods and 14% to other utilisations.

Besides GHG emissions and land use, there are other important environmental impacts of food and agriculture. Half of the world's habitable (ice- and desert-free) land and 70% of all global freshwater withdrawals are used for agriculture (Ritchie and Roser, 2021). Agriculture also causes 78% of global ocean and freshwater eutrophication, and agriculture and aquaculture constitute a major threat for 24,000 out of the 28,000 species considered to be threatened with extinction on the IUCN Red list, established by the International Union for Conservation of Nature in 1964.

4 Consumption of protein

Protein is an essential macronutrient that is found throughout the body. Protein is made from amino acids, nine of which – the so called essential amino acids – must come from food. As such, protein is therefore a key part of any diet.

In the scientific opinion of the European Food Safety Authority (EFSA), the average requirement of protein for healthy adults should equal 0.66 g protein/kg body weight per day. This rate is applicable to both high quality protein and to protein in mixed diets. A person weighing 80 kg should therefore consume 53 g per day (EFSA, 2012).

The global protein consumption has increased by 35% in the last decades, from 61.5 grams per capita per day in 1961 to 82.9 grams in 2018 (see Figure 1). In Europe, protein consumption averaged 90.4 g per capita per day in 1961 and increased to 102.7 g in 2018 (FAOSTAT).

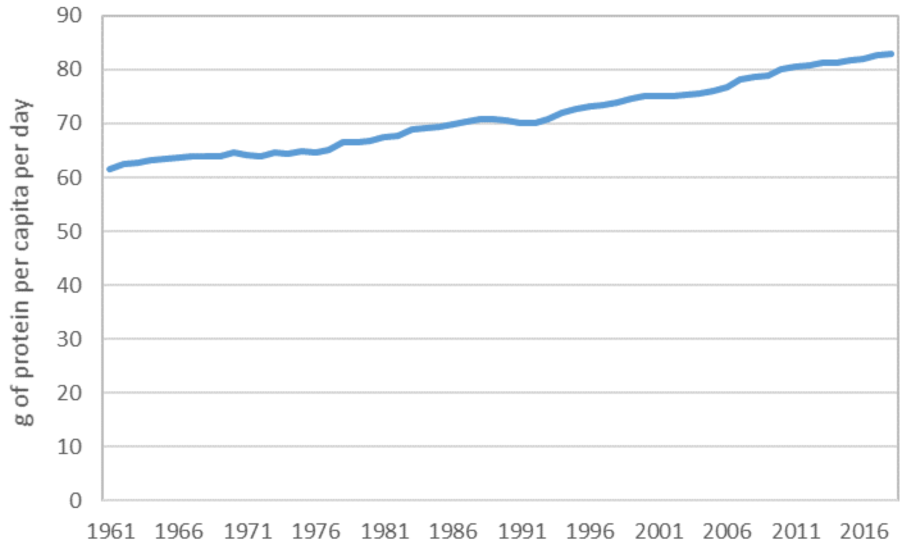


Figure 1. World protein consumption 1961-2018. Grams per capita per day. Source: FAOSTAT.

Although protein may be found in an abundance of food sources, the protein contents of food differ vastly. Good sources of animal-based proteins are found in seafood, various types of eggs, cheese, milk, whey, some red meat, and poultry, while examples of protein-rich plant-based food include grains, nuts, soy, rice, peas, beans and lentils (Friedman, 1996; Harvard, n.d.).

As shown in Figure 2, the increase in protein intake is mostly due to a vastly increased consumption of animal-based proteins, which grew by 68% over the period 1961-2018. By contrast, consumption of plant-based proteins only increased by 19%. In 2018, people consumed on average 33.1 g of animal-products, compared to 19.7 grams in 1961, while consumption of vegetal products had increased from 41.8 grams in 1961 to 49.8 grams in 2018 (FAOSTAT).

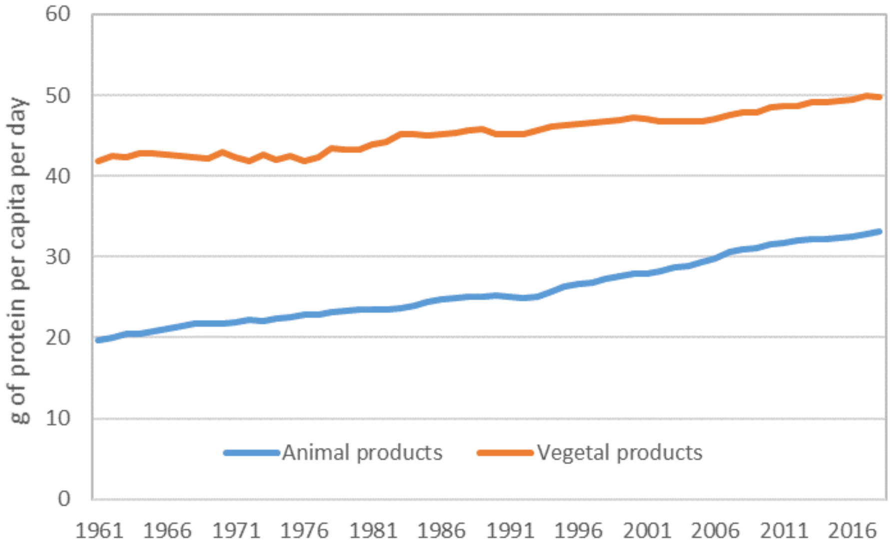


Figure 2 World animal-based and plant-based protein consumption 1961-2018. Grams per capita per day. Source: FAOSTAT.

The composition of protein intake differs between world regions. In 1961, consumption in Europe of plant-based proteins averaged 50.7 g per capita per day and proteins from animal products averaged 39.7 grams (see Figure 3). By 2018, consumption of plant-based proteins had declined to 44.4 grams, but consumption of animal-based proteins increased to 58.3 grams (FAOSTAT).

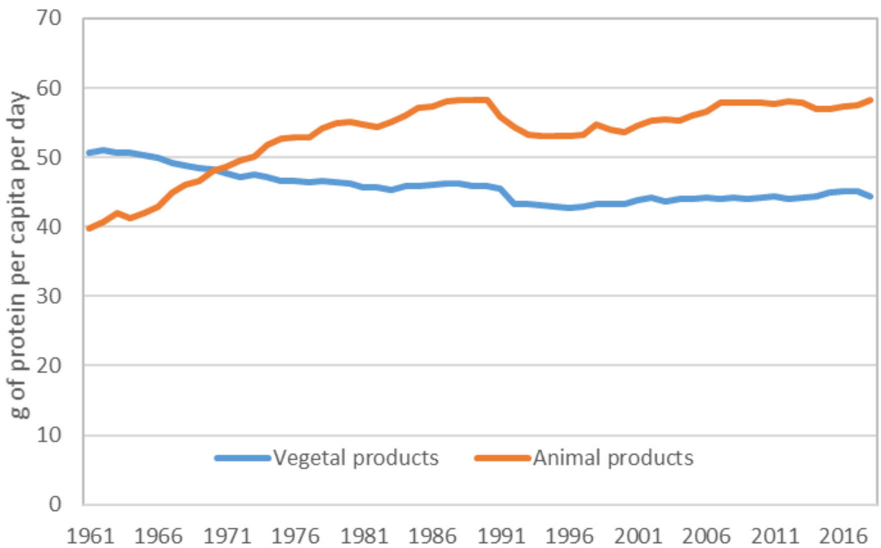


Figure 3 Protein consumption in Europe1961-2018. Grams per capita per day. Source: FAOSTAT.

In Europe, the average protein intake is now about 70% higher than recommended (Aschemann-Witzel et al., 2020), and in many Western counties the average intake is 50-100% above recommended values (Westhoek et al., 2011).

Excessive consumptions of animal protein, in particular high consumption of red meat and processed meat, has been linked to higher total mortality, cardiovascular disease, colorectal cancer, and type 2 diabetes (Richi et al., 2016), and is also correlated with obesity (You and

Henneberg, 2016). Evidence is more controversial concerning other roles played by animal-based protein in health (Andreaoli et al, 2021).

GHG emissions related to the production of meat and dairy products are generally much higher than those associated with production of plant-based products (Poore and Nemecek, 2018). Producing 100 g of protein from beef (beef herd) causes GHG emission of 50 kg of CO_2 eq. and producing 100 g from lamb and mutton 20 kg. (see Figure 4). By contrast, producing 100 g of proteins from pulses, peas and nuts leads to less than 1 kg of CO_2 eq. of GHG emissions.

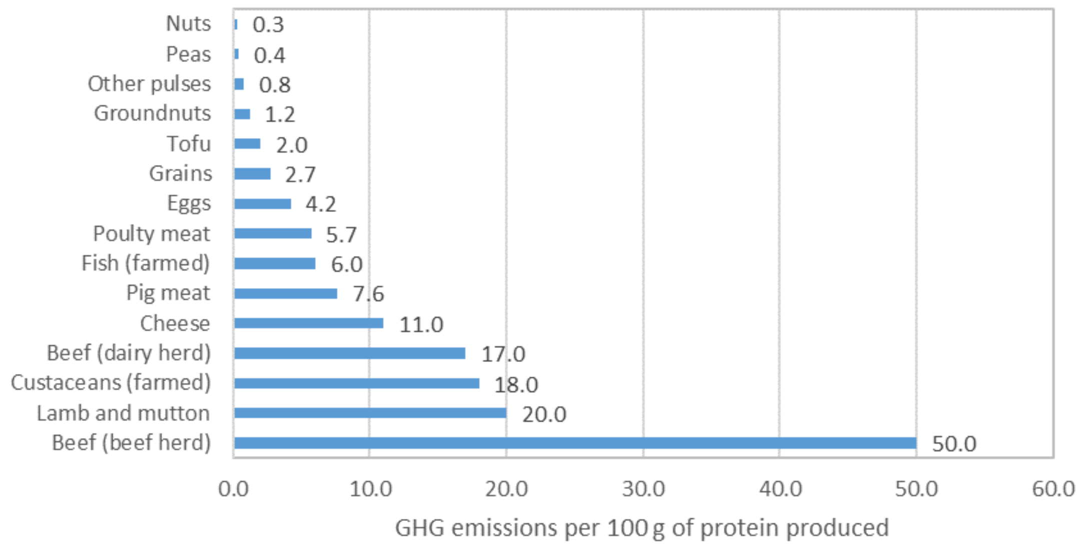


Figure 4 GHG emissions (kg CO_2 eq.) per 100 g of protein. Source: Poore and Nemecek (2018).

A similar story emerges when land use, measured as area (in square meters, m^2) multiplied by the number of years land is used for the activity, is compared between the different protein production methods (Poore and Nemecek, 2018). Producing 100 g of protein from lamb and mutton requires 185 m^2 and producing the same amount of protein from beef (beef herd) requires 164 m^2 (see Figure 5). By contrast, producing 100 g of proteins from farmed crustaceans – mainly shrimp – and tofu requires around 2 m^2.

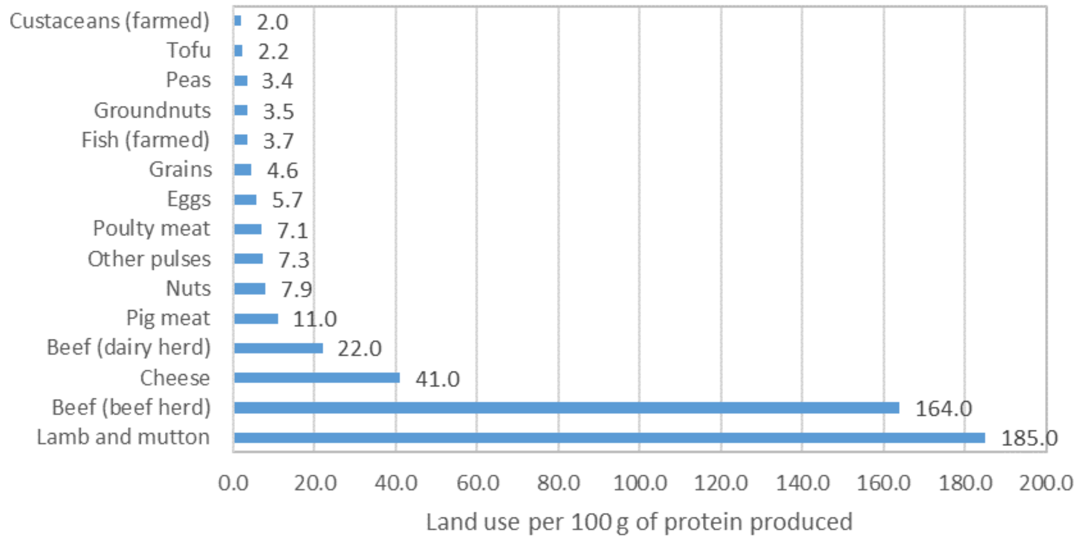


Figure 5 Land use (m² multiplied by years occupied) per 100 g of protein. Source: Poore and Nemecek (2018).

Ever since the pioneering study by Engel in the mid-19th century, it has been very clear that consumption of food is primarily determined by the level of income (Engel, 1857). Engel's law may be stated as

> "The poorer is a family, the greater is the proportion of the total outgo [family expenditures] which must be used for food. … The proportion of the outgo used for food, other things being equal is the best measure of the material standard of living of a population." (Engel quoted in Zimmerman, 1932)

Engel's law does therefore not assume that spending on food remains constant as income increases, but rather that the relative income spent of food will decline and the absolute expenditure converge to a certain level. Thus, low-income countries will tend to spend a larger portion of their budget on food and are more sensitive to income changes than higher-income countries (Regmi et al., 2001). Low-income countries generally spend a higher proportion of their budget on staple food products, i.e. cereals, and then move up to higher-value food items such as dairy and meat as their income increases (Smil, 2002).

Andreoli et al. (2021) explored the relationship between per capita income and animal and vegetal protein consumption. Using a sample of 142 countries in 2017, animal-based protein, meat protein and vegetal-based proteins were specified as independent variables in regression models that included per capita income, temperature, population age structure, religion and urbanization as explanatory variables. Both models indicate that animal-based and meat protein consumption grow with income per capita up to a turning point, after which they begin to decrease. Conversely, the demand for vegetal-based proteins decreases to a lower limit, and then increases. However, the results indicate that the level of income at which vegetal-based protein consumption begins to increase – if it exists at all – is quite high. The authors find these results rather disappointing, bearing in mind the negative impact consumption of animal-based protein, in particular meat protein, has on health and the environment. Urbanization is shown to have a positive impact on the consumption of both animal-based and meat protein and a negative effect on vegetal-based protein consumption. The share of Muslim population has a positive impact on vegetal-based protein consumption and a negative impact on consumption of meat protein.

5 Use of proteins in feed

Global production of the main types of protein meal amounted to almost 280 million tons in 2013/2014 but is projected to have increased to almost 350 million tons by 2020/2021 (USDA, 2021). As shown in Figure 6, soybean meal remains the most important source of high-quality vegetable protein for animal feed manufacture. In 2013/2014, global production was 190 million tons and increased to 253 million tons seven years later. Production of rapeseed meal increased from 38 to 39 million tons over the same period and production of sunflower seed meal from 17 to 21 million tons.

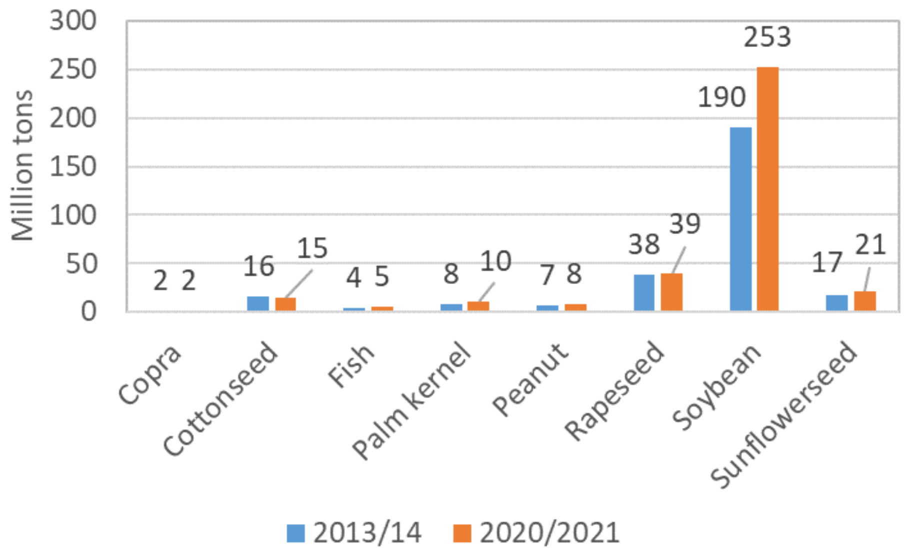


Figure 6 World protein meal supply in 2013/14 and 2020/21. Million tons. Source: U.S. Department of Agriculture (2021)

Protein meal is exclusively used as feed and the growth of consumption therefore depends on animal production. While intensification of animal production will increase demand for protein meal, feeding efficiencies will work in the opposite direction and lead to a reduction of protein feed per animal production output (OCED-FAO, 2021). Composition of animal husbandry and herd sizes will also impact demand.

The OECD-FAO (2021) report also stresses that the link between animal production and protein meal consumption is associated with a country's level of economic development. "Lower income countries, which rely on backyard production, consume less protein meal, whereas higher income economies which employ intensive production systems use higher amounts of protein meal. Because of a shift to more feed-intensive production systems in developing countries in response to rapid urbanisation and increasing demand for animal products, growth in protein meal consumption tends to exceed growth in animal production. In less developed countries where the use of protein meals is very low, intensification in livestock production with growing use of compound feed is expected to continue. With intensification, the use of protein meal per unit of livestock production increases considerably, leading to fast growth in total demand" (p. 146).

Demand for protein meal is expected to grow by 1.2% per annum in the next decade, which is considerably slower growth than in 2010-2020 when demand grew annually by 3.8%.

World production of fishmeal has in the last decade averaged around 5 million tons per annum, and the production of fish oil has ranged between 0.8 and 1.3 million tons each year (EUMOFA, 2021). While soybean meal and most other type of protein meal is mostly used as feed for animals, fishmeal is primarily used in aquaculture, but also used for rearing pigs and poultry (EUMOFA, 2021). The share of aquaculture has generally been around 70% of world production but has been closer to 80% in recent years (see Figure 7).

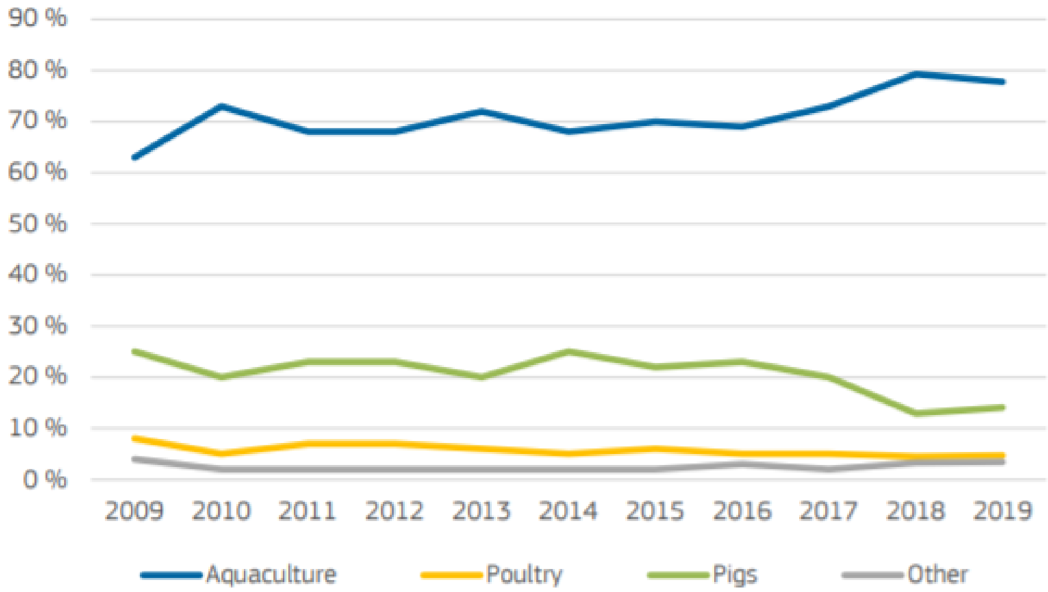


Figure 7 World fishmeal use by sector. Percentages. Source: EMOFA (2021).

Most of the fish oil produced is also used in aquaculture, but a substantial share, or around 20%, is also used for human consumption. Fish oil is generally not used in pig or poultry production.

World aquaculture has almost trebled in the last two decades. In 2000, world production amounted to 43 million tons, but by 2019 global production had reached 120 million tons (FAO, FISHSTAT). As aquaculture is expected to continue to grow, demand for fishmeal and oil is also expected to remain strong.

6 Alternative protein market

Alternative proteins may be defined as protein-rich ingredients sourced from plants, insects, fungi, microalgae, or through tissue culture to replace conventional animal-based proteins (Bashi et al., 2019).

A recent study estimates that in 2020, alternative proteins accounted for 2% of the total protein market (Morach et al., 2021). However, that share could rise to 11% by 2035, provided consumers and investors remain interested in sustainability and alternative proteins reach parity with animal proteins on taste, texture, and price. Step changes in technology and regulatory support to speed up the transition from animal-based proteins could further hasten the development.

Demand for insect protein is expected to grow fast in the next decade. According to the International Platform of Insects for Food and Feed (IPIFF), production of insect processed animal proteins (PAPs) for feed amounted to several thousand tons in 2020, but total production capacity of the European insect sector may reach 1 million tons in 2030. The sector currently employs 1,000 FTEs but the number of direct and indirect jobs could rise to 25,000 by 2030 (IPIFF, 2021).

In 2019, the European Insect Food Business Operators jointly accounted for about 500 tons of insect-based proteins, but that is forecast to grow to 260,000 tons by 2030. Most of the production will take the form of powder/insect ingredient (IPIFF, 2020). In 2019, around 9 million Europeans consumed insects and their derived products, and this figure is forecast to reach 300 million by 2030. The number of jobs created by the insect food industry could grow from a few hundred FTEs in 2020 to 4,000 in 2030.

Two recent reports on the value of the global microalgae protein give slightly different estimates of the current size of the market, but both expect the market to expand rapidly in the next years. While Allied Market Research (2021) expect the market to grow from $360 million in 2020 to $710 million in 2028, with a compounded annual growth rate of 8.9%, Global Market Insights (2021) value the market in 2020 at $700 million and expect it to grow annually by 6% and reach $1,060 million in 2027. This represents a total growth of 50-100%. As the price of algae proteins is expected to fall in the coming years, in line with increased production, the quantity produced will probably increase much more, or by 100-200%.

The global single-cell protein market generated $5.3 billion in 2019 but it expected to reach $6.8 billion by 2026 (360 Research Reports, 2021). This corresponds to annual growth of 5.5%.

Four partners in the NextGenProteins project are currently engaged in the production of alternative proteins. VAXA produces microalgae and microalgae proteins, Arbiom produces a single-cell protein, while Entocube and Mutatec produce proteins from insects; crickets in the case of Entocube and black soldier flies in the case of Mutatec. The production process in each of the four cases is described in deliverable 6.1 and is here briefly summarised. Additional information on prospective production and prices, labour utilisation of the production process and main competing proteins was obtained directly from the four protein producers. The survey questions are provided in Annex 1.

6.1 VAXA Technology

VAXA produces microalgae and microalgae proteins through a continuous process (see Figure 8). First, a very small amount of algae biomass is introduced into the system and allowed to continuously reproduce. Water and CO_2 are provided to the algae, as well as LED lighting to allow for photosynthesis to occur. The light generates heat and to counter that cooling water pumped through the system. Once the algae has been produced, the production is sent off-site for protein extraction processing.

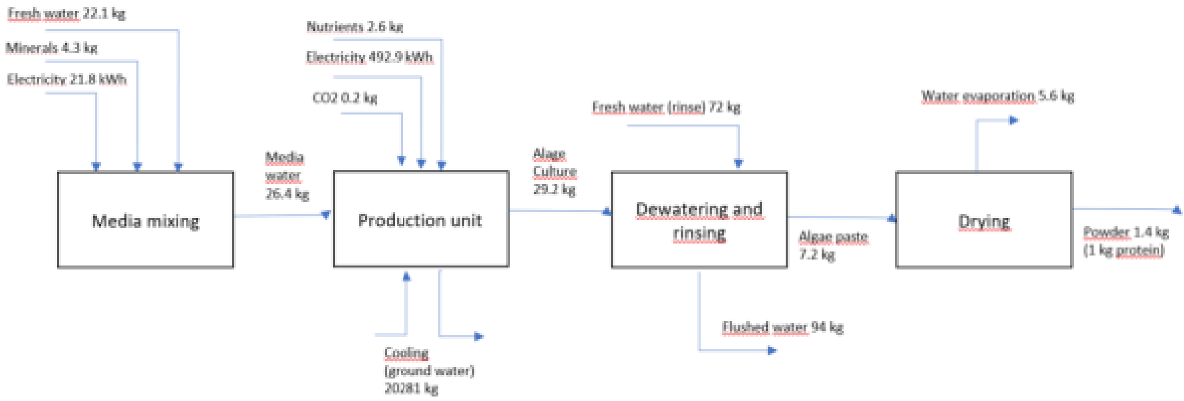


Figure 8 VAXA foreground system process diagram. Source: NextGenProteins D6.1 (2020).

The final product will take the form of dry powders and is expected to sell for 10$/kg or € 8.5 using an exchange rate of $ 1.00 = € 0.85. The company aims to achieve long-term supply agreements with steady pricing. Theoretically, there are no limits on the amount that can be produced as the production does neither depend on fresh water or fertile land.

A production facility able to produce up to 1,000 tons per year can be expected to employ 27 people, including chief executive officer (CEO), chief technology officer (CTO), product manager and chief financial officer (CFO) (see Table 1). Other staff will include biologists, engineers, staff working in sales, administration and finance and technical support.

Table 1 Table 1 Number jobs created by VAXA's production of 1,000 tons.

Occupation	Number of jobs
Lead biologist	3
Production biologist	2
Engineer	4
CTO	1
Sales	2
Production engineer	2
Administration / finance	6
Product Manager	1
CEO	1
Technical suport	4
CFO	1
Total	27

Whey protein and chickpea protein are expected to be the main protein products competing with the microalgae protein produced by VAXA.

6.2 Arbiom

Arbiom produces a single-cell protein (SCP) which is composed of dried inactive yeast microorganisms which are grown using wood substrates to feed the yeast via a fermentation stage of the production process (see Figure 9).

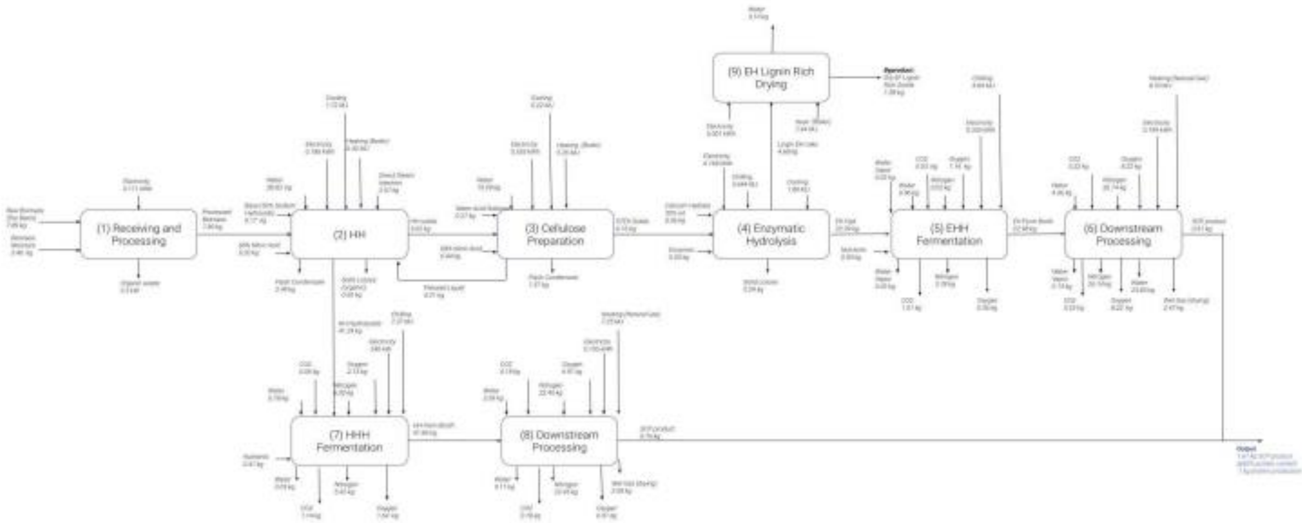


Figure 9 Arbiom foreground system process diagram. Source: NextGenProteins D6.1 (2020).

The final product will take the form of powder. According to information provided by Arbiom, a production facility capable of producing 10,000 tons per year will employ 44 people, including plant manager, production manager and plant engineer (see Table 2).

Table 2 Number jobs created by Arbiom's production of 10,000 tons.

Occupation	Number of jobs
Plant Manager	1
Production Manager	1
Plant Engineer	2
Maintenance Superintendent	1
Maintenance Supr	2
Maintenance Tech	5
Lab Manager	1
Lab Technician	2
Shift Supervisor	5
Shift Operators	10
Process Operators (Control Room)	5
HS&E/QA QC Manager	1
Inventory/Mgt/Procurement Manager	1
Inventory/Mgt/Procurement Specialist	1
Accounting Manager	1
Accounting Specialist	1
Secretaries/Admin/HR	2
Clerks	2
Total	44

The product is expected to sell for $ 1,400-1,600 or € 1.200-1.350 per ton. The price is expected to stay steady throughout the year, as Arbiom will have a stable supply of biomass with wood.

Arbiom expects the main competing proteins to come from insects, fungi, bacteria, and algae. It should, however, be noted that given the early state of many alternative protein sources and the alternative protein market in general, and that many potential competitors have not yet scaled up their production to a commercial scale, it can be hard to determine which products will be the main competitors.

6.3 Entocube

Entocube produces protein from crickets. The insects are reared, with the process beginning with the crickets being propagated by placing adult crickets with the egg-laying substrate, where the cricket eggs are then incubated and hatched (see Figure 10). The crickets are then grown out over approximately 30 days, after which the insects are inactivated through either a boiling or freezing process. The crickets are then processed into dry cricket protein.

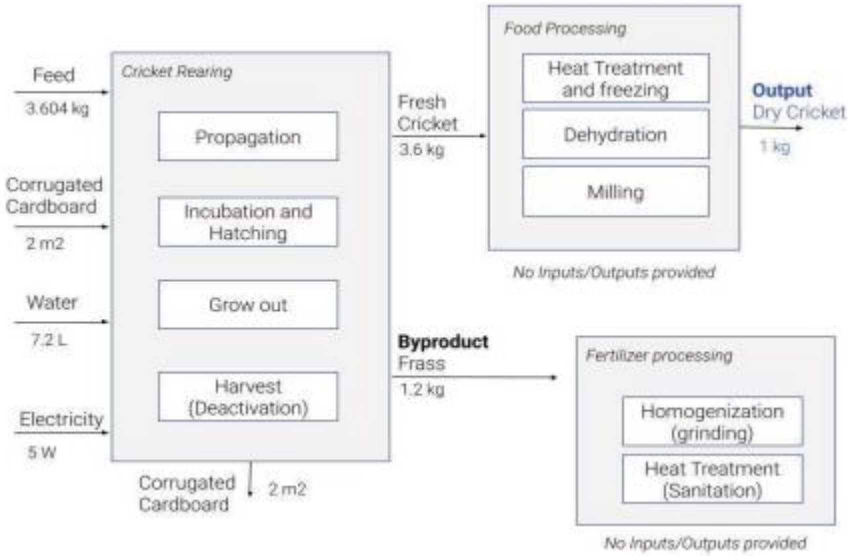


Figure 10 Entocube foreground system process diagram. Source: NextGenProteins D6.1 (2020).

Entocube's production will typically take the form of dehydrated powder for food ingredient and direct consumption. This is 100% cricket with no parts removed or ingredients added.

Information on direct employment is incomplete at this stage but will include skilled or professionally trained farm workers with at least vocational education. For downstream processing, food technologists or food engineers would make the best qualification.

The product will probably be sold wholesale at € 25 / kg. By comparison, the average price of cricket powder is currently around € 40 € / kg. The price does, however, vary, but is typically in the range € 35-60 / kg.

Entocube does not expect prices to vary seasonally. Indeed, the market price has remained stable for the last 2-3 years. Increasing large-scale production and market competition is likely to put a downward pressure on prices in the coming 1-2 years.

There are no upper limits on production, which will primarily be governed by demand. The current production system of Entocube can easily be scaled up to produce 10-20 tons per year for a single production unit. There is no obvious limit on the number of production units. The downstream process is therefore not limiting production.

From a consumer perspective, protein in conventional meat products may be regarded as the main competitor, but from the perspective of the protein user, soybean, and pea (legumes) protein can compete with protein from crickets.

6.4 Mutatec

Mutatec produces protein from the black soldier fly. In the first stage, a powdered, liquid, and solid biomass is received and prepared into a substrate, which is then handled and placed in trays (see Figure 11). As the larvae begin to grow, the oviposition and fattening process starts, and this is then continued until the insects can be processed in protein concentrate.

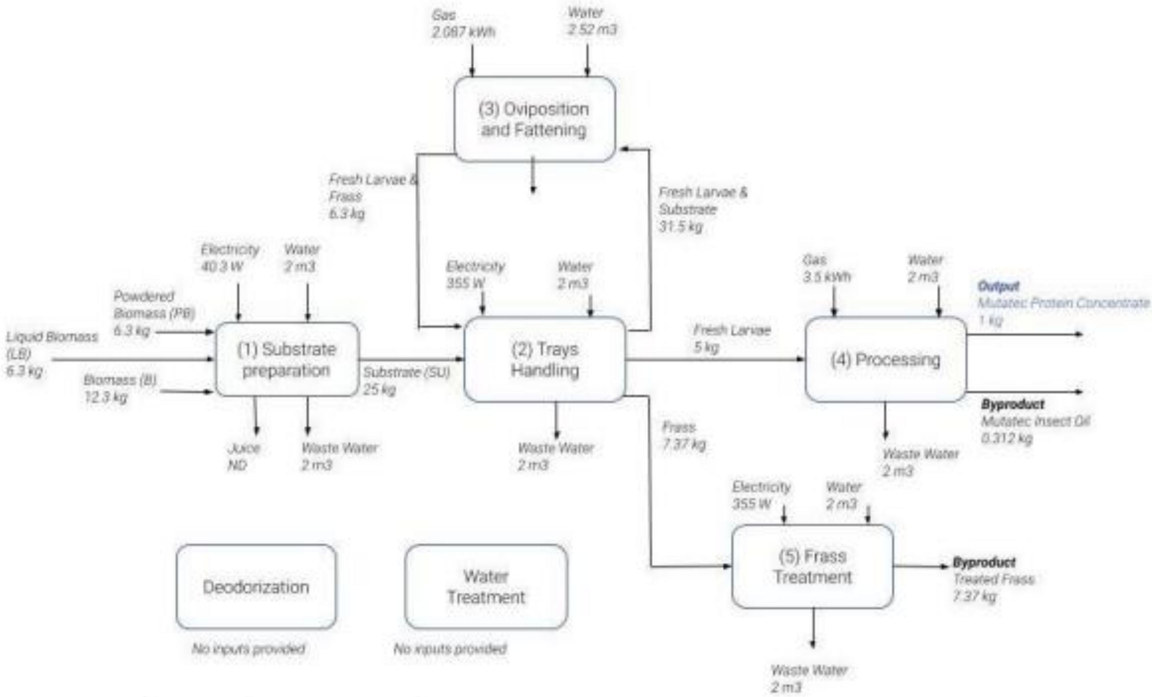


Figure 11 Mutatec foreground system process diagram. Source: NextGenProteins D6.1 (2020).

The final product consists of insect meal form, which is a grinded powder with a 55-60% protein content.

A processing facility able to produce 250 tons of insect meal per year would employ around 17 people, including managers, and skilled and unskilled labour (see Table 3).

Table 3 Number jobs created by Mutatec's production of 250 tons.

Occupation	ımber of jo
Unskilled operators	5
Technicians	2
Middle-managers	2
Operation Director	1
Administration and direction assistant	1
QSE Manager	1
Sales and marketing manager	1
Reserach and dvelopment manager	1
Engineer	2
General management	1
Total	17

The protein production is constrained by bio-waste availability on the farm territory, which can be defined as the area within a distance of 50 km from the farm, as well as their costs. Theoretically, there is though no upper limit.

Insect meal will primarily replace fish meal, which is used in aquaculture, and soybean meal which is used as feed for poultry and pigs. Insect meal containing 55% proteins should sell for € 3,000-3,500 / ton. The price of insect protein is probably going to decline over the next 5-8 years, due to more large-scale production and thus a larger supply on the market. The price could fall to € 1,700-2,300 / ton.

6.5 Producer comparison

In this section we compare the operations of the four protein producers (see Table 4).

The size of the production units varies considerably between the four protein producers taking part in the NextGenProteins project. While Entocube intends to have units that can each produce 10-20 tons per year, there is no limit on the number of units the firm can have in operation. The processing facilities of the other three producers are more conventional, with a capacity of 250-10,000 tons per year. Like Entocube, these firms could though operate more than one processing facility at a time.

As revealed in Table 3, Mutatec's production process appears to be more labour intensive than those of VAXA and in particular Arbiom. None of the four firms believes there is any upper limit on the amount of protein that can be produced using the technology chosen.

For comparison, all prices have been converted to € per ton. As can be seen the prices of products produced by VAXA and Entocube are considerably higher than the reported prices of Arbiom and Mutatec.

Table 4 Comparison of the production characteristics of the four protein producers taking part in NextGenProteins.

Producer	Production (tons)	Final product	Employment (FTE)	Upper limits on production	€ per ton	Main competing proteins
VAXA	1,000	Dry powder	27	No	8,500	Whey and chickpea
Arbiom	10,000	Dry powder	44	No	1,200-1,350	Insects, fungi, bacteria and algae
Entocube	10-20 per unit	Dry meal		No	25,000	Soy and pea (legumes)
Mutatec	250	Insect meal	17	No	3,000-3,500	Fishmeal and soybean meal

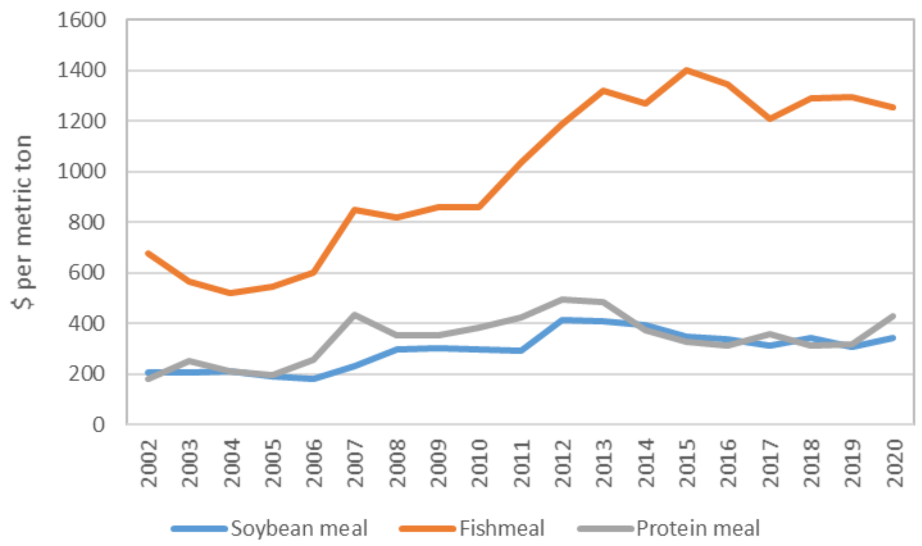
Source: Information from the protein producers taking part in NextGenProteins

7 Price comparison

In 2020, a metric ton of soybean meal sold for $ 345, while the price of protein meal, which OECD defines as the weighted average of the price of soybean meal, sunflower meal, and rapeseed meal, was $ 430 (Indexmundi, n.d.). Each ton of fishmeal then cost almost four times as much as soybean meal, or $ 1256. As shown in Figure 12, prices of all three kinds of meal have doubled since the early 2000s, but fishmeal has become relative more expensive in the last few years as the prices of the other two types of meal have fallen.

By comparison, the price of the protein powder produced by Arbiom is expected to be $ 1,400-1,600 per ton and the price of the insect meal sold by Mutatec $ 3,500-4,100 per ton. The price of Mutatec is though projected to fall quite rapidly in the near future. The price of the products sold by Arbiom and Mutatec is therefore expected to be somewhat higher than the price of fishmeal, and much higher than the price of meal made from soybean, sunflower seed or rapeseed. As mentioned in Section 6.5 above, the prices of the products produced by VAXA and Entocube are expected to be considerably higher; € 8.5 per kg in the case of VAXA and € 25 per kg in the case of Entocube, or € 8.500 and € 25.000 per ton

Figure 12 Price of soybean meal, protein meal and fishmeal 2002-2020. $ per metric ton.



Source: Indexmundi.com (n.d.) and OECD (n.d.).

Soybean meal, sunflower meal, rapeseed meal, and fishmeal are produced in large quantities and prices determined in well-functioning markets. The prices of other protein products, such as those sourced from chickpea, whey, pea (legumes), insects, bacteria, fungi, and algae may not be as well determined. Many of these products are sold in niche markets, and the protein products are therefore not as homogenous as the protein meal products produced at an industrial scale. Rapid technological development may also push the prices for some of these products down in the coming years.

8 Market and economic impact

The NextGenProteins project aims at enabling efficient production and processing methods for three highly promising alternative protein sources and evaluate their potentials for commercial utilisation in both food and feed. For this purpose, the three NextGenProtein sources – microalgae, SCP, and insect proteins – will be tested in partial substitution to traditional raw materials in feeding trials in aquaculture and poultry production (chicken and turkey). In addition, the potential of the proteins will be demonstrated through applications in four different types of food: ready meals, bakery products, imitation meat, and functional food supplements for elderly people.

Consumers' views towards the application of the three NextGenProteins proteins in food have been investigated through two methods; focus-group interviews and comprehensive surveys. The interviews were carried out in Finland, German, Iceland, and Italy, while the surveys were carried out in Finland, Germany, Iceland, Italy, Poland, Sweden, and the UK.

As discussed in deliverable D5.1, consumers were generally positive or neutral towards the application of the NextGenProteins in human foods. However, the reactions to the insect proteins developed in the project were clearly and significantly more negative than towards the concepts based on microalgae or single-cell protein in all countries.

Participants were generally interested in testing the products, but their use interest will depend on certain preconditions, first and foremost on sensory pleasantness and on other product characteristics. The respondents´ attitude towards the proteins was mostly formed by the perceived benefits associated with these proteins, e.g. environmental sustainability, animal welfare and health in general. Interest in use stems though primarily from personal benefits achieved.

Throughout the discussions in each country, the participants pointed out, that their interest to buy the product application will depend on certain preconditions, primarily sensory pleasantness, but also on other product characteristics such as usability for certain contexts and price. Competitive pricing is seen as a crucial element.

Andreyeva, Long and Brownell (2010) reviewed 160 studies on the price elasticity of demand for major food categories. The results for some of the categories are shown in Table 5. The own-price elasticities range from 0.27 for eggs to 0.75 for beef, indicating that demand for all the food categories is inelastic, and that demand will fall by less than 1% when prices increase by 1%.

Table 5 Own-price elasticity of selected food categories.

	Mean	Min	Max
Beef	0.75	0.29	1.42
Pork	0.72	0.17	1.23
Fruit	0.70	0.16	3.02
Poultry	0.68	0.16	2.72
Dairy	0.65	0.19	1.16
Cereals	0.60	0.07	1.67
Milk	0.59	0.02	1.68
Vegetables	0.58	0.21	1.11
Fish	0.50	0.05	1.41
Fats/oils	0.48	0.14	1.00
Cheese	0.44	0.01	1.95
Eggs	0.27	0.06	1.28

Source: Andreyeva, Long and Brownell, 2010

While these results indicate that consumers are, in general, not likely to reduce consumption by the same relative amount as the rise in prices, they do indicate that consumers will reduce consumption when prices go up. However, the own-price elasticity of a good, i.e. how sensitive consumers are to changes in price of the good in question, can depend on a number of factors, including the range of substitutes. In general, the price elasticity will be higher, the easier it is for consumers to switch to substitute goods when the price of the good in question rises. The substitution possibilities depend on how broadly the good being analysed is defined. Thus, the elasticity will be low for food in general, as there are no substitutes for food, but will be higher for a particular food type, say poultry, and even higher for a particular kind of poultry, say chicken raised on Tom's farm. Demand for a particular type of food, say ready meals, bakery products, imitation meat, and functional food supplements for elderly people, will therefore be more elastic and consumers more able – and willing – to turn to substitutes should prices become too high.

Although there is most certainly business potential for each NextGen protein, the business case may not be found in mainstream applications. As stated in D5.1, it is much more likely that the firms will be able to carve out a niche position in the market. However, as there are no upper limits on the production for each partner, increased demand for the proteins offered by the producers could be saturated.

However, it should be noted that production of the four protein producers taking part in NextGenProteins is in early stages. So far production has mostly consisted of small batches to be used in several feed and food trials in the project. The reports on the effect of feeding alternative proteins on productive traits, physiological indicators, gut health and product quality and safety in chickens and turkeys, salmon and seabass and seabream will not be ready until in months 40-42 (February-April 2023). The reports on the development of ready meals, bakery products, advanced food supplements and imitation meat containing alternative proteins are also not due until late in the project, or in month 44 (June 2023). Once the trials have been completed, pre-market approval for the three NextGen proteins must be obtained. This entails the preparation of dossiers containing the necessary scientific information on the compositional, nutritional, toxicological, and allergenic properties of the novel food, as well as information on respective production processes and the proposed uses and use level. The dossiers will then be sent to EFSA to assess the safety of the alternative proteins, if needed, for use in foods on the EU market. Similarly, feed ingredients will be assessed for the EU feed register. After gaining pre-market approval, the firms will be in a position to implement the business plans that will be developed in NextGenProteins.

At the writing of this deliverable, it is therefore not clear when and how much will be produced of each protein. Although the four producers have indicated the price at which their proteins will be sold, final decision on prices can not be made until the production is more advanced and market opportunities have been identified more clearly. It is therefore impossible at this stage of the project to have a clear idea of the impact that shifting protein production to these alternative proteins will have on the economic system in which the firms operate. However, the production aims of the NextGenProteins producers are relatively modest. The combined production of the four firms could be 15-20,000 tons in the not-too-distant future, and total employment associated with that level of production could equal 150-200 FTE. Most of the employees would be skilled. Neither the level of production nor employment is likely to have but a very minor impact on the market for proteins and employment in general. However, the importance of the producers could be quite large at a local or even regional level.

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10 Annex 1

Survey for protein producers taking part in NextGenProteins

Your production

1. What form will your protein take?
2. What kind of employment – quantity and type of skills – is used in the production of one unit (kg or different unit) of your protein products?
3. What will be the price of your position?
4. How do you believe your price will fluctuate?
5. Are there any upper limits (upper boundaries) on the production of your protein?

Main competing protein products

1. What kind of protein products that would compete with your protein dominate the market at the moment? Name 2-3.
2. Where would I find information on supply and prices on these products?