NEXTGEN PROTEINS

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

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Documentation on EU legal/regulatory landscape and the safety of alternative proteins for food

Lead author: VTT

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Contributors

Authors	**Organisations name**	**E-Mail**
Hanna-Leena Alakomi	VTT	Hanna-Leena.Alakomi@vtt.fi
Tiina Hyytiäinen-Pabst	VTT	Tiina.Hyytiainen-Pabst@vtt.fi
Marie Shrestha	TTZ-Bremenhaven	MShrestha@ttz-bremerhaven.de
Sveinn Agnarsson (SA)	Syntesa	sveinnag@hi.is
Birgir Örn Smárason	Matis	birgir@matis.is
Christophe Trespeuch	Mutatec	c.trespeuch@mutatec.com
Isaac Berzin	AlgaeInnovation	isaac@algaennovation.com
Jaakko Korpela	EntoCube	Jaakko.Korpela@entocube.com
Ricardo Ekmay	Arbiom	rekmay@arbiom.com
Melissa Tillotson	Waitrose	melissa.tillotson@waitrose.co.uk
Ann-Kristin Schwarze	Biozoon	Schwarze@biozoon.de
Kolbrún Sveinsdóttir	Matis	kolbrun@matis.is

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2 Executive Summary

In order to ensure food safety, it is important to consider the whole food chain from farm to fork. All the aspects and players within the supply chain, starting from the production of animal feed and primary production, through production, distribution and sales of food to the consumers influence food safety.

In this open report, which builds on the novel foods regulation, ((EU) 2015/2283) as well as other regulations governing the production, safety and application of alternative proteins for food, knowledge gaps and regulatory safety barriers are highlighted with a focus on the three NextGen Proteins.

Part of the work undertaken during writing of Deliverable D1.1 consisted of interviewing the industrial partners involved to gather their view and experiences. Based on these interviews the following main conclusions can be drawn:

- Consumer health is the most important and therefore scientific information about e.g. toxicology, allergens, microbiological and chemical safety and quality of the new proteins is needed.
- Traceability and labelling of the products (e.g. allergens) is important.
- Associations can be beneficial in providing information and training.
- Education of consumers and other stakeholders about new protein sources is needed. Information about sustainability, Eco footprint, LCA, safety and nutritional value should be available for these purposes. A formation of a harmonized coalition of alternative protein producers (similar to Sustainable Seafood Coalition, SSC) and stakeholders would be beneficial in sharing of information about sustainability and other relevant facts and data.
- Some novel proteins might be more easily accepted by the consumers in feed applications (e.g. aquafeed, broilers, companion animals, pet food) compared to human food.
- An organic certificate would benefit the industrial partners in food applications.
- In food application the alternative proteins need to fulfil technological properties and specifications for the intended use.
- Different retail trade operators can have their internal guidelines where they specify e.g. quality limits and requirements for the products. These can differ from the legislative limits.

3 Introduction

3.1 NextGenProteins project

Demand for proteins for food and feed applications is increasing. To meet the increasing demand, production will have to double by 2050. However, current protein production, both animal-based and vegetal-based, has severe negative environmental impacts in terms of greenhouse gas (GHG) emissions, land and water use, as well as biodiversity loss. The EU is not self-sufficient when it comes to protein production and a large proportion of the demand is met with imported proteins with concerns regarding food security and the general competitiveness of the EU. It is therefore of vital importance to find sustainable alternative protein sources that can be economically produced in EU in quantities that meet growing food and feed sectors.

NextGenProteins has identified microalgae, single cell protein and insects as three promising sources of alternative proteins that can be produced through innovative and environmentally sustainable bioconversion processes using industrial waste streams. These processes cause limited environmental impacts and pressure on natural resources. Through collaboration between industry and RTD, the project will address key barriers that currently prohibit or limit the application of the three alternative proteins in food and feed, such as production scalability and optimisation, production costs, value chain risks, safety, regulations and consumer trust and acceptance. The project will demonstrate the suitability and economic viability of the alternative proteins in food and feed value chains and explore their market opportunities with different stakeholders, incl. industry, policy makers and consumers.

3.2 Scope of the Deliverable

NextGenProteins will find means to improve the acceptability and trust of consumers towards alternative proteins and processes. The project will contribute to strengthening food security, sustainability and self-sufficiency of EU protein production with future-proof supply, as well as long-term reduction of land use, water use, GHG emissions and energy of EU food sector.

The scope of Deliverable D1.1 was to examine the Novel foods regulation, ((EU) 2015/2283) as well as other regulations governing the production, safety and application of alternative proteins for food. Knowledge gaps and regulatory safety barriers were identified with a focus on the three alternative protein sources in NextGenProteins.

3.3 EU regulation of food and feed

Several regulations control the food chain in the European Union. The general principles and requirements are set down in the **Regulation (EC) No 178/2002** of the European Parliament and the Council (General Food Law legislation). In addition, this law established the independent agency responsible for scientific advice and support, the **European Food Safety Authority (EFSA).** The General Food Law legislation is the regulatory framework and cornerstone, which lays down the procedures of food safety in the whole agro-food chain (From farm to fork), both at EU level and in national feed and food laws. Likewise, it lays down **general principles, requirements and procedures** for decision making related to food and

feed safety, covering food and feed production and distribution. The General Food Law also creates main procedures and tools for management of emergencies and crises as well as the **Rapid Alert System for Food and Feed** (RASFF). Important aspect in the General Food Law is to guarantee high level of protection of human life and health and the protection of consumers´ interests.

In order to ensure food safety, it is important to consider the whole food chain from farm to fork. All the aspects and players within the supply chain, starting from the production of animal feed and primary production, through production, distribution and sales of food to the consumers influence food safety.

> *"In order to ensure the safety of food, it is necessary to consider all aspects of the food production chain as a continuum from and including primary production and the production of animal feed up to and including sale or supply of food to the consumer because each element may have a potential impact on food safety."*
>
> General food law **Regulation (EC) No 178/2002**

Figure 1. Example of the General Food Law principles (**Regulation (EC) No 178/2002**).

3.3.1 Food Law General Principles

The general principles and requirements of the EU food law are set down in the **Regulation (EC) No 178/2002** of the European Parliament and the Council (General Food Law legislation). Examples of the general objectives of the General Food Law legislation are presented in Table 1. Important points are risk assessment principle, precautionary principle and transparency.

Table 1. General objectives of food and feed law in the European Union (https://ec.europa.eu/food/safety/general_food_law/principles).

General objectives of food and feed law
• "Guarantee high level of protection of human life and health and the protection of consumers' interests". • "Guarantee fair practices in food trade, taking into account animal health and welfare, plant health and the environment". • "Ensure free movement of food and feed manufactured and marketed in the Union, in accordance with the General Food Law Regulation". • "Facilitate global trade of safe feed, and safe, wholesome food by taking into account international standard and agreements when developing Union legislation, except where this might undermine the high level of consumer protection pursued by the Union". • Implement risk analysis (risk assessment, risk management and risk communication) in decision-making.

Risk analysis principle

In the EU, food and feed safety and law is based on science and on the three inter-related components of risk analysis: risk assessment, risk management and risk communication (General Food Law, Table 2). In EU the scientific and technical evaluations are performed by EFSA. EFSA works in close co-operation with national authorities and in open consultation with its stakeholders, provides independent scientific advice and communication on existing and emerging risks.

Precautionary principle

According to the precautionary principle (Article 7 of the General Food Law), decision makers or risk managers can take measures or actions based on the precautionary principle, while seeking for more complete scientific data. The precautionary principle refers to specific situations, e.g. there are reasonable grounds for concern that an unacceptable level of risk to health exists or the available supporting information and data are not sufficiently complete to enable a comprehensive risks assessment to be made (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52000DC0001&from=EN).

Table 2. Brief description of risk analysis principles.

Risk assessment	Risk management	Risk communication
must be undertaken in an independent, objective and transparent manner based on the best available science.	process of weighing policy alternatives in the light of results of a risk assessment and, if required, selecting the appropriate actions necessary to prevent, reduce or eliminate the risk. In the risk management phase, the decision makers need to consider a range of other information in addition to the scientific risk assessment. These include, for example: • most effective risk reduction actions depending on the part of the food supply chain where the problem occurs • feasibility of controlling a risk • socio-economic effects • environmental impact • a wide range of other factors legitimate to the matter under consideration.	interactive exchange of information and opinion throughout the risk analysis process among risk assessors, risk managers, consumers, feed and food businesses, academics, other interested parties.

Transparency and sustainability

Transparency of decision-making is most important for the EU. The General Food Law Regulation provides mechanisms to increase consumer confidence and trust, incl. effective public consultation during the preparation, evaluation and revision of food and feed law. In addition, authorities have the obligation to inform the general public, where there are reasonable grounds to suspect that food or feed may present a risk for human or animal health. A new Regulation on the transparency and sustainability of the EU risk assessment in the food chain (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019R1381) was published in the Official Journal in September 2019 and entered in to force 20 days after publication and will be become applicable on 27th March 2021.

3.3.2 Food Law General Requirements

The safety of food and feed is critical and the consumers need to have confidence and trust in the food chain. The General Food Law Regulation establishes that only **safe food and feed** can be placed on the market or fed to food-producing animals. In addition, the criteria for safe food or feed are set in the General Food Law (Table 3). Tracing food and feed throughout the food chain is vital for the protection of consumers. Therefore, **traceability** is compulsory for all food and feed operators. Traceability provides ability to track any item that will be used for consumption, throughout all stages of production, processing and distribution. Business operators have the primary **responsibility** for ensuring compliance with food law and the food safety. The national authorities support and guide companies in the activities. The business operators are obligated to **withdraw** or recall if the food or feed is unsafe.

Table 3. Main Food Law requirements.

Main Food Law requirements
Food safety requirements
Traceability of food and feed products
Responsibility of operators
Withdrawal, recall and notification for food and feed in relation to safety requirements
Import and export

Figure 1. The key obligations of food and feed business operators (https://ec.europa.eu/food/sites/food/files/safety/docs/gfl_req_business_operators_obligations_en.pdf).

3.3.3 Food Law Procedures

The General Food Law Regulation provides certain procedures and measures incl., the establishment of the Rapid Alert System for Food and Feed (RASFF), establishment of the Standing Committee on Plants, Animals, Food and Feed (PAFF Committee), adaptation of emergency measures and general plan for crisis management.

4 Novel foods regulation

The food sector is actively engaged in research and product development and new products are frequently introduced to the market. The first Novel Food Regulation of the European Parliament and the Council, Regulation (EC) No 258/97 was adopted in 1997. Novel food is defined as "food that had not been consumed to a significant degree by humans in the EU before 15th May 1997". Since 1st of January 2018, the new Regulation (EU) 2015/2283 on novel foods has been applicable. It replaced Regulation (EC) No 258/97 and Regulation (EC) No 1852/2001 which were in force until 31st December 2017. The aim of the regulation is to guarantee food safety. In addition, the aim of the new regulation is to improve conditions so

that the food industry can easily bring new, innovative and safe foods to the EU market. Important aspect is to safeguard safe food for the consumers.

The Regulation (EU) 2015/2283 states for example:

- "**Novel foods should be safe** and if their safety cannot be assessed and scientific uncertainty persists, the precautionary principle may be applied. **Their use should not mislead the consumer**. Therefore, where a novel food is intended to replace another food, it should not differ from that food in a way that would be nutritionally less advantageous for the consumer."
- "Novel food' means any food that was not used for human consumption to a significant degree within the Union before 15 May 1997, irrespective of the dates of accession of Member States to the Union, and that falls under at least one of the following categories:

(i) food with a new or intentionally modified molecular structure, where that structure was not used as, or in, a food within the Union before 15 May 1997;
(ii) **food consisting of, isolated from or produced from microorganisms, fungi or algae**;
(iii) food consisting of, isolated from or produced from material of mineral origin;
(iv) food consisting of, isolated from or produced from plants or their parts, except when the food has a history of safe food use within the Union and is consisting of, isolated from or produced from a plant or a variety of the same species obtained by: — traditional propagating practices which have been used for food production within the Union before 15 May 1997; or — non-traditional propagating practices which have not been used for food production within the Union before 15 May 1997, where those practices do not give rise to significant changes in the composition or structure of the food affecting its nutritional value, metabolism or level of undesirable substances;
(v) food consisting of, isolated from or produced from animals or their parts, except for animals obtained by traditional breeding practices which have been used for food production within the Union before 15 May 1997 and the food from those animals has a history of safe food use within the Union;
(vi) food consisting of, isolated from or produced from cell culture or tissue culture derived from animals, plants, micro-organisms, fungi or algae;
(vii) food resulting from a production process not used for food production within the Union before 15 May 1997, which gives rise to significant changes in the composition or structure of a food, affecting its nutritional value, metabolism or level of undesirable substances;
(viii) food consisting of engineered nanomaterials
(ix) vitamins, minerals and other substances used in accordance with Directive 2002/46/EC, Regulation (EC) No 1925/2006 or Regulation (EU) No 609/2013, where: — a production process not used for food production within the Union before 15 May 1997 has been applied

Table 4. The main features and improvements of the new Novel Food Regulation (https://ec.europa.eu/food/safety/novel_food/legislation_en)

The main features and improvements of the new regulation:
• Expanded categories of Novel Foods: **The Novel Food definition describes the various situations of foods originating from plants, animals, microorganisms, cell cultures, minerals, etc., specific categories of foods (insects, vitamins, minerals, food supplements, etc.), foods resulting from production processes and practices, and state of the art technologies (e.g. intentionally modified or new molecular structure, nanomaterials), which were not produced or used before 1997 and thus may be considered to be as novel foods.** • Generic authorisations of Novel Foods: **Under the new Regulation, all authorisations (new and old) are generic as opposed to the applicant-specific, restricted novel food authorisations under the old Novel Food regime. This means that any food business operator can place an authorised Novel Food on the European Union market, provided the authorised conditions of use, labelling requirements, and specifications are respected.** • Establishment of a Union list of authorised Novel Foods: **This is a positive list containing all authorised novel foods. Novel Foods which will be authorised in the future will be added to the Union list by means of Commission Implementing Regulations. Once a novel food is added to the Union list, then it is automatically considered as being authorised and it can be placed in the European Union market.** • A simplified, centralised authorisation procedure **managed by the European Commission using an online application submission system.** • Centralised, safety evaluation of the Novel Foods **will be carried out by the European Food Safety Authority (EFSA). The European Commission consults EFSA on the applications and bases its authorisation decisions on the outcome of the EFSA's evaluation.** • Efficiency and transparency **will be improved by establishing deadlines for the safety evaluation and authorisation procedure, thus reducing the overall time spent on approvals.** • A faster and structured notification **system** for traditional foods from third countries based on **a history of safe food use. To facilitate the marketing of traditional foods from countries outside the EU, which are considered novel foods in the EU, the new Regulation introduces a simplified assessment procedure for foods new to the EU. If the safety of the traditional food in question can be established on the basis of evidence of a history of consumption in the third country, and there are no safety concerns raised by the EU countries or EFSA, the traditional food will be allowed to be placed on the European Union market.** • Promotion of innovation **by granting an individual authorisation for five years based on protected data. Data protection provisions are included in the new Regulation. That means that an applicant may be granted an individual authorisation for placing on the market of a novel food. This is based on newly developed scientific evidence and proprietary data and is limited in time to 5 years**

- **"History of safe food use in a third country"** means that the safety of the food in question has been confirmed with compositional data and from experience of continued use for at least 25 years in the customary diet of a significant number of people in at least one third country, prior to a notification.

- "Novel foods should not be placed on the market or used in food for human consumption unless they are included in a **Union list of novel foods authorised to be placed on the market within the Union ('the Union list').** Therefore, it is appropriate to establish, by means of an implementing act, the Union list by including in that list the novel foods already authorised or notified in accordance with Regulation (EC) No 258/97, including

any existing authorisation conditions. That list should be transparent and easily accessible. It is appropriate to authorise a novel food by updating the Union list subject to the criteria and procedures laid down in this Regulation. A procedure that is efficient, time-limited and transparent should be put in place. As regards traditional foods from third countries having a history of safe food use, the applicants should be able to opt for a faster and simplified procedure to update the Union list if no duly reasoned safety objections are expressed."

- "Criteria for the assessment of the safety risks arising from novel foods should also be clearly defined and laid down. In order to ensure the **harmonised scientific assessment of novel foods, such assessments should be carried out by EFSA ('the Authority'**). Under the procedure for authorising a novel food and updating the Union list, the Authority should be requested to give its opinion if the update is liable to influence human health. In its opinion, the Authority should assess, *inter alia*, all the characteristics of the novel food that may pose a safety risk to human health and consider possible effects on vulnerable groups of the population. In particular, the Authority should verify that, where a novel food consists of engineered nanomaterials, the most up-to-date test methods are used to assess their safety."

- "The Commission and the Authority should be subject to deadlines to guarantee a smooth processing of applications. However, in certain cases, the Commission and the Authority should have the right to extend those deadlines."

- "The applicant may be requested by the Authority or by the Commission to provide additional information for the purposes of risk assessment or risk management respectively. In case the applicant fails to provide the additional information, as required, within the period set by the Authority or by the Commission after consulting the applicant, lack of such information may have consequences for the opinion of the Authority or for a possible authorisation and update of the Union list."

Regulation (2283/2015) also states that the "new technologies and innovations in food production should be encouraged as they could reduce the environmental impact of food production, enhance food security and bring benefits to consumers as long as the high level of consumer protection is ensured."

The scientific dossier dealing with food safety (Regulation 2015/2283) need to provide evidence that no adverse effects are elicited from consumption of the product. Therefore, kinetics, toxicology, nutritional information and allergenicity needs to be analysed. EU has implemented risk assessment processes for examination that no harm will results from the intended use (General Food Law) and the precautionary principle is the key in EU legislation. Therefore, if the safety of food or the food ingredient can´t be shown in the dossier the products are not allowed to enter the European markets (2283/2015). EU has been implementing risk assessment since the establishment of the General Food Law. The scientific risk assessment process is independent and transparent. EFSA will perform the risk assessment based on the scientific evidence and EC will provide authorisation for Novel Foods. The new regulation also provides timeframes for the evaluation process.

Several national authorities consider as a serious fault to place on market a non-authorised novel food. In that case, the industry is asked for clarification, and usually withdrawal of the product from the market.

4.1.1 Consultation process and application processes of Novel Foods

Food business operators are required to verity if the food intended to be placed on the market is novel or not (Article 4 in Regulation 2015/2283). They may also consult the competent authorities of the EU country (the recipient EU country) where they intend to place the food on the market. Details for required information are included in the Commission Implementation Regulation 2018/456. Details related to provision on the confidentiality of the request are defined in this regulation. After the consultation process the conclusion on the novel food status of the food will be published on the Commission website (https://ec.europa.eu/food/safety/novel_food/consultation-process_en). General labelling requirements (Regulation No 1169/2011) concern also Novel foods. In some cases additional requirements may apply in order to inform the consumer.

Before placing a novel food on the European Union market the applicant must submit an online application for authorisation. The application must fulfil the requirements set in Article 10 of the Novel Food Regulation. Administrative and scientific requirements for applications are presented in the Commission Implementing Regulation (EU) 2017/2469. EFSA has published several documents to assist applicants in preparation of the scientific data for the risk assessment of novel foods (e.g. https://efsa.onlinelibrary.wiley.com/doi/pdf/10.2903/sp.efsa.2018.EN-1381). These documents contain checklists and models of the summary tables for presenting data of the scientific data.

The EC prepares summaries of the applications submitted and the list the summaries are published on the European Commissions web-pages (https://ec.europa.eu/food/safety/novel_food/authorisations/summary-applications-and-notifications_en). The summary data includes name and address of the applicant the name and description of the novel food and scientific evidence demonstrating that the novel food does not pose a safety risk for human health. Statements related to the consultation process are also published in the EC webpages. The Novel Food Catalogue (https://ec.europa.eu/food/safety/novel_food/catalogue_en) lists all the products approved as Novel Foods.

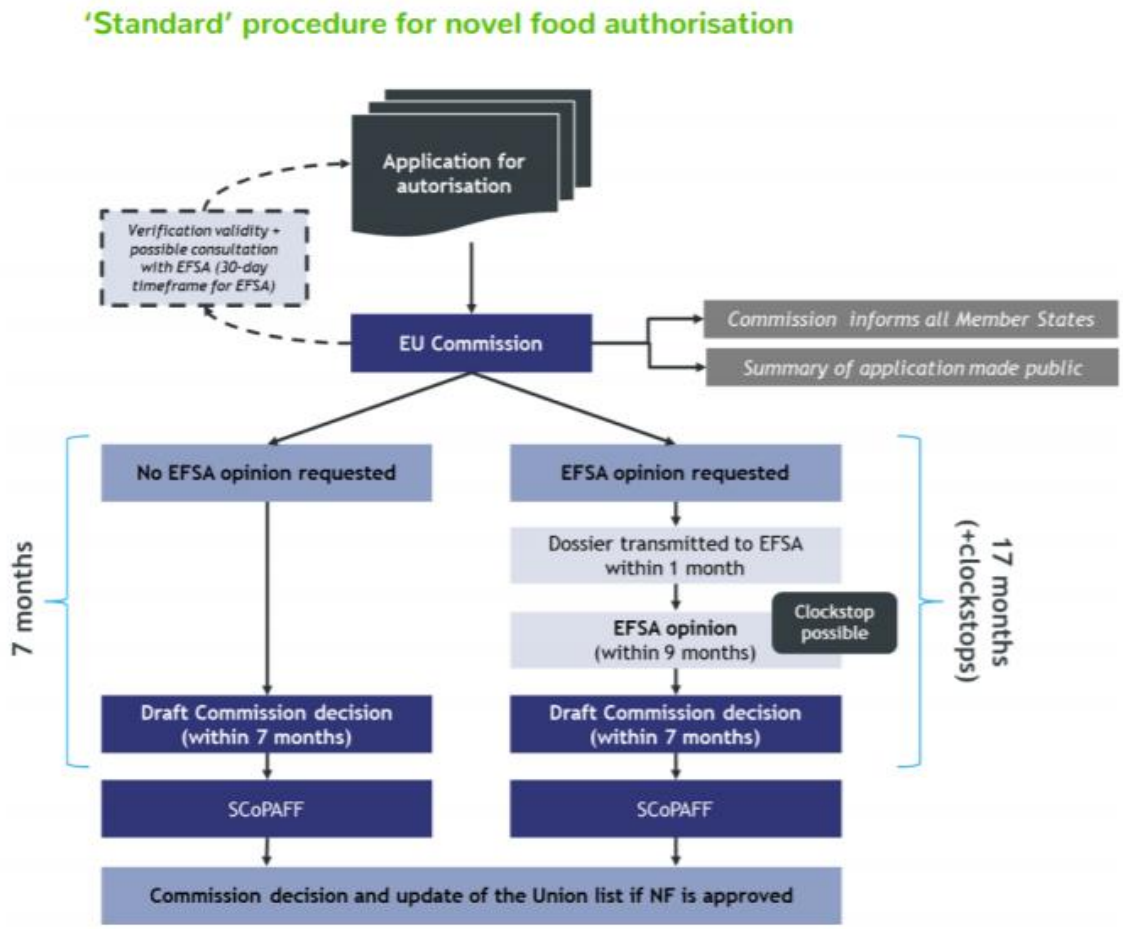

Figure 2. Schematic design of the standard procedure for novel food authorization. Figure from International Platform of Insects for Food and Feed (IPIFF) (https://ipiff.org/wp-content/uploads/2019/08/ipiff_briefing_update_03.pdf).

4.2 Qualified presumption of safety (QPS) and Generally Regarded as Safe (FDA)

EFSA assesses in EU safety of all new food and feedstuffs and microorganisms used in them. After EFSA grants a microorganism **qualified presumption of safety (QPS) status**, it is included in the list of QPS status recommended biological agents for safety risk assessments or "QPS list". A list of all notifications received by EFSA since 2007 in the context of technical dossiers submitted by applicants and considered for possible inclusion in the QPS list is also available. The qualified presumption of safety (QPS) is based on reasonable evidence (https://www.efsa.europa.eu/en/topics/topic/qualified-presumption-safety-qps). If an EFSA assessment concludes that a group of microorganisms does not raise safety concerns, the group is granted "QPS status". No microorganism belonging to that group needs to undergo a full safety assessment. The publication of the next scientific opinion updating the QPS list is planned for December 2022 and will be based on the six-month assessments carried out by the EFSA BIOHAZ Panel.

In the EU a QPS assessment is done after EFSA receives an application for market authorisation of a regulated product that requires a safety assessment. In order to be granted QPS status, a microorganism must meet the following criteria:

- Its taxonomic identity must be well defined.
- The available body of knowledge must be sufficient to establish its safety.
- The lack of pathogenic properties must be established and substantiated.
- Its intended use must be clearly described.

Microorganisms that are not well defined, for which some safety concerns are identified or for which it is not possible to conclude whether they pose a safety concern to humans, animals or the environment are not considered suitable for QPS status and must undergo a full safety assessment.

In the United States the food ingredients may be "food additives" that are approved by Food and Drug Authority (FDA) for specific uses or **GRAS (generally recognized as safe)** substances. A substance may be GRAS only if its general recognition of safety is based on the views of experts qualified to evaluate the safety of the substance. GRAS status may be based either on a history of safe use in food prior to 1958 or on scientific procedures, which require the same quantity and quality of evidence as would be required to obtain a food additive regulation. Because GRAS status may be either affirmed by FDA or determined independently by qualified experts, FDA's regulations do not include all GRAS ingredients and the specific uses described in the GRAS regulations may not be comprehensive for the listed ingredients. https://www.fda.gov/food/generally-recognized-safe-gras/microorganisms-microbial-derived-ingredients-used-food-partial-list

4.3 Microalgae proteins

Microalgae are plant-like single cell organisms, which are rich in nutrients (Caporgno and Mathys, 2018). Microalgae such as *Spirulina* and *Chlorella* can be used as dried whole cells in food products. In addition, microalgae can be used as host for producing high-value supplements (Kagan and Matulka, 2015). Microalgae can be produced in open basins or closed photobioreactor-systems (Moomaw *et al.*, 2017). Advantage of closed system is better process optimization and control, which affects the quality of microalgae products. Using open basins or natural water for producing microalgae causes a risk for algae or pathogen bacteria contamination (Tzachor, 2019). Some cyanobacteria contaminants can produce toxins in open outdoor culture basins. Three microalgae species are classified as Generally Recognised as Safe (GRAS): *Spirulina/Arthrospira* sp. belonging to Cyanobacteria, *Chlorella* sp. (Chlorophyta) and *Porphyridium Cruentum* (Rhodophyta). In addition, some algal products have been granted GRAS status e.g. docosahexaenoic acid (DHA) algal oil from *Schyzochitrium* and Ulkenia, and whole algal protein powder from *Chlorella*. Polyunsaturated fatty acids incl. eicosapentaenoic acid (EPA from e.g. *Nannocholoraphis*) and docosahexaenoic acid (DHA) are among the most valuable functional ingredients of microalgal lipids (Dineshbabu *et al.* 2019).

In addition, *Arthrospira, Chlorella* and *Nannochloropsis* have been reported as important sources of polysaccharides or oligosaccharides, being proposed as potential prebiotic candidates (Caporgno and Mathys, 2018). Likewise, bioactive compounds have been studied recently.

Photobioreactors (PBRs) are characterized by low pathogen risks, low space requirements, and minimal ecological footprint: low water losses, efficient CO_2 utilization, high variability in regards to cultivable species, high degree of control over culture processes, high biomass concentration, high efficiency in down-stream processing and no dependence of weather conditions (indoor PBRs, Tzachor, 2019). Since 2018, the integrated system has been cultivating natural strains of protein-rich high omega-3-marine microalgae for feed purposes. Production has mainly been based on *Nannochlorophila oculata*.

Definitions and principles of food/feed production and distribution are on laid down in European Community Regulation on Food Safety (EC 178/2002). If gene modification is applied in microalgae production, EU regulations (1829/2003 and 1830/2003) define the boundary conditions. European Regulation on Nutrition and Health Claims made on Foods (EC 1924/2006) will be applied for food health claims. These claims require accepted scientific evidence.

The regulatory bar facing marine microalgae to enter the food-ingredient market is relatively high and process is long. All required regulation statuses (e.g., Generally Recognized as Safe, New Dietary Ingredient Notification, Novel Food) take between months and years to gain approval and can cost millions of dollars. In addition, obtaining organic certification for algae is difficult, since the inadequacy of current guidelines, which were originally developed for terrestrial plants. E.g. most of the approved organic fertilizers are not water soluble, inhibit light penetration to the culture and may increase the likelihood of contamination.

Currently five algae are on the Generally Regarded As Safe (GRAS) list of FDA. New algae derived ingredients fall under the Novel Food Law. There is a need for fast track regulatory for algae and input from algae associations in order to get an easy way to the market. New evaluation criteria for photosynthetic algae should be developed in order to avoid unnecessary animal trials. Currently regulatory guides the research and development. In addition, for SME dossiers are expensive and help from algal production associations is needed.

Regulatory issues play a big role in the field. For example, currently some algae oil are approved but the protein from the same algae is not approved. Some algae are known to be toxigenic and produce e.g. neurotoxins. However, the strains selected for production of food and feed proteins are non-toxic. In addition, in controlled photoreactors the production is under control (HACCP), food-grade and contamination issues are avoided. In addition, in closed bioreactors no pesticides, fungicides or antibiotics are used and there are no chemical residues to the environment.

For feed, e.g. aquafeed the barrier to the market is lower than with food products. However, in order to be profitable the production volumes needed are huge and protein content should be high. Food proteins would be more profitable for the companies, but regulatory issues are slowing entry to the market.

4.4 Single cell protein

Single cell proteins (SCP) is currently produced from a limited number of microbial species and the number of sources for SCP in animal feed is broader than that approved for human consumption (Ritala *et al.*, 2014). SCP can be produced by cultivation of various microbes, incl. algae, filamentous fungi, yeasts and selected bacteria. SCP protein for human consumption is generally produced from food grade substrates, research for utilisation of side-streams, as well as from forestry and agricultural sources is increasing.

SCP as any food products need to be safe to produce and use (Ritala *et al.*, 2014) and the regulations differ based on the intended use. *Saccharomyces, Kluyveromyces, Yarrowia* and *Torula*/*Candida utilis* yeasts have GRAS status and are on the QPS list. Currently, some SCP products are entering the market as additives (e.g. providing colour) rather than protein source. The term SCP is often used to describe edible microbial biomass as whole, but it can also include non-protein compounds like lipids and carbohydrates (Ritala *et al.*, 2017).

In most of the cases the aim is to maximize cellular growth and co-product yield in economical processes. Therefore, various side-streams, by-products and industrial/agricultural residues have been utilized as feedstock for the SCP microbes (Ritala *et al.*, 2014; Jones *et al.*, 2020). Studies on bacterial SCP and production of proteins has increased during recent years especially with bacteria utilizing methane, methanol, syngas, CO_2, H_2 and second-generation sugars (Sillman *et al.*, 2019, Jones *et al.*, 2020).

The nucleic acid content of crude microbial biomass is too high for direct consumption by humans as well as for many animals and causes elevated levels of uric acid in the blood

following ingestion. Therefore, microbial biomass needs to be pre-treated to remove nucleic acids, e.g. through heat treatment (Linder, 2019).

If the SCP product is intended to food, the novel food regulations applies if the producer strain is not on the QPS list. Several EFSA opinions related to SCP are published, e.g. one related to use of "Safety of selenium-enriched biomass of *Yarrowia lipolytica* as a novel food pursuant to Regulation (EU) 2015/2283"
https://efsa.onlinelibrary.wiley.com/doi/pdf/10.2903/j.efsa.2020.5992

4.5 Insect protein

Insects possess huge potential as alternative source of proteins for both animal feed and human food uses. In Europe the interest in food insects (edible insects) has emerged only during the last decade. Insects are novel protein source in the western food culture. Despite attempts, any significant evidence of traditional consumption of insects in European region has not been discovered.

Therefore, insects are regarded as *novel foods*, pursuant to the authorisation procedure of the Novel Food Regulation (EU) 2015/2283. The EU legislation does not currently cover the requirements for insects. Therefore, the general requirements of the food legislation and the controls are applied to insect production. Operators are responsible for the safety of their products and they need to follow the Food Act. Animal welfare, hygiene practises and the information provided to the customer need to be taken into account (Evira, 2018). The food business operator is responsible for own-checks, microbiological quality and determination of the shelf life of the products they produce.

At the time of writing this report, more than 20 applications focusing on insects for food have been submitted to the European Commission for novel food authorisation. Altogether 11 applications have been passed thorough the suitability check and published in the Commission portal of Novel Foods. After publishing to member countries, the Commission transfers the dossiers for EFSA for the scientific evaluation. Following insect species are mentioned in the applications: *Acheta domesticus, Aegiale hesperiaris, Alphitobius diaperinus larvae* , *Apis mellifera male pupae, Gryllodes sigillatus, Hermetia illucens larvae, Liometopum apiculatum larvae, pupae, Liometopum occidentale larvae, pupae, Locusta migratoria*, *Schistocerca gregaria* and *Tenebrio molitor larvae.* Until now none of the food insect applications have yet reached the authorisation. It's expected that EFSA will complete the first risk assessments around mid-2020 and report back to EC for final authorisations.

Despite the pending novel food authorisations, number of EU countries (e.g. Finland, Denmark, United Kingdom) have granted a temporary market access to insect foods. These exceptions originate from the interpretations of the former Novel Food Regulation (EU) 258/97, which left some room for interpretations for animals that are consumed as whole and not slaughtered.

The International Platform for Insects for Food and Feed (IPIFF) has published a review of the insects novel food status in the European Union http://ipiff.org/insects-novel-food-eu-legislation/. In addition, the association has published several guidelines for the industry. The legal framework was identified by IPIFF in its 2019 questionnaire as the main factor impacting the growth of the insect sector.

According to EFSA opinion paper, studies on the occurrence of microbial pathogens of vertebrates as well as published data on hazardous chemicals in reared insects are scarce (EFSA, 2015). However, according to the EFSA opinion (2015), the substrate used and the farming environment strongly influence insects' microbiota, and therefore the foodborne risk is influenced by the nature and the hygienic conditions of the substrate and the farming

environment. In general, food and feed-grade substrates, if maintained in good hygienic conditions, should not pose any additional risk when fed to insects as compared with other approved foods or feeds. Insects can cause allergic reactions and this needs to be mentioned in the label. Food allergens are proteins that trigger the immune response. The symptoms of food allergy vary from harmless itch in the mouth to life-threatening anaphylaxis (Evira, 2018). Persons can become sensitised to insect proteins and the use of insect protein can lead to new allergies being developed. At the cultivation site, it is also important to ensure that individuals of one insect species cannot mix with another species, as a person can be allergic to one species but not another (Evira, 2018).

Table 4. Potential hazard linked with insect proteins and identified as points needing additional research:

• Anti-nutrients • Toxic potential (production, accumulation of plant toxins, pesticides, heavy metals, mycotoxins) • Allergenic potential (e.g. tropomyosin) • Zoonotic risk (insects act as vectors) incl. parasites • Microbial safety (pathogens, spores, intestinal flora and surface colonization) • Controlled breeding conditions (substrate, breeding, personnel) and safe and effective processing • Decontamination and storage required

In the discussion held with different stakeholders, the regulatory progress is quite focused on enlarging “authorised substrates”, access to new raw materials and “Organic production”. Organic farming status would benefit the industry. Fractionation and milling of crickets is not currently approved and needs to be taken into account in future legislation.

There is also a need for research to identify possible allergens and to process insects for the isolation of protein and / or other components. Feasibility studies and pilot projects are needed to test the potential and risks of large-scale insect production in practice. Ethical aspects of keeping insects should also be discussed early enough.

Novel protein sources and foods made from them are intended to increase sustainability in future protein supply. It does not have to be the goal to completely replace the consumption of animal products. Any reduction in the consumption of conventional animal products and their partial replacement with more sustainable protein sources can increase the sustainability of the food system. Studies show that the majority of consumers want to eat more sustainably, but the observed purchasing behaviour of consumers differs from the stated. New foods from more sustainable protein sources must therefore better meet the needs of consumers; they have to taste good, be healthy, but at the same time be affordable and usable or available as needed. With foreign products, socio-cultural barriers are often difficult to overcome.

5 Analysis of earlier cases

5.1 Industry interviews

The industrial partners participating to the project task were interviewed. The companies included Algaennovation, MUTATEC, EntoCube, ARBIOM, Naturalleva, Amadori, WAITROSE, Grimur Kokkur and BIOZOON. These companies brought into the study a broader view of industry leaders as they all have interactions with other industry players in the field through industry associations etc.

The topics discussed during the interviews included: challenges of current regulatory framework, knowledge barriers and safety barriers, potential hazards related to new proteins, industries experiences of the co-operation with the authorities, EFSA and associations, experiences with the consumers, future outlook - need for changes, improvements, training, biggest challenges in the field.

Main conclusions from the industry viewpoints

- There is a need to harmonise globally novel food regulations. Preparation of dossiers is expensive and time consuming. There are e.g. differences in the length of animal trials. The industry also feels that regulations can also be trade barriers.

- Consumer health is of utmost importance and therefore scientific information about e.g. toxicology, allergens, microbiological and chemical safety and quality of the new proteins is needed.

- Traceability and labelling of the products (e.g. allergens) is important.

- Various associations (incl. industrial, consumer) can help in providing information and training.

- Education of consumers/farmers/other stakeholders about new protein sources is needed. Information about sustainability, Eco footprint, LCA, safety and nutritional value should be available for these purposes. A harmonized coalition of alternative protein producers (similar as Sustainable Seafood Coalition SSC) and stakeholders could be a good platform sharing information on sustainability and other important issues.

- Technological properties, acceptance and sensory quality of the new alternative proteins is important, especially if the consumers are elderly or have following and chewing difficulties. The nutritional value and digestibility of the proteins needs to be good in order to avoid any difficulty for the consumers.

- Fractionation and milling of the crickets is not currently approved and needs to be taken account in future legislation.

- Novel proteins might be more easily accepted by the consumers in feed applications (e.g. aquafeed, broilers, companion animals, pet food) compared to human food.

- Organic certificate would benefit the industrial partners in food applications.

- Different retail trade operators can have their internal guidelines where they specify e.g. quality limits and requirements for the products. These differ from the legislative limits.

6 Conclusions

- Consumer health is of the utmost importance and therefore scientific information about e.g. toxicology, allergens, microbiological and chemical safety and quality of the new proteins is needed. Risk assessment can only be based on scientific data and therefore scientific information is needed e.g. for novel food products.

- Novel foods should be safe and if their safety cannot be assessed and scientific uncertainty persists, the precautionary principle may be applied.

- There is a need to harmonise globally novel food regulations.

- New proteins need to fulfil general food law requirements related to food safety. Traceability and labelling of the products (e.g. allergens) is important.

- Business operators have the primary responsibility for ensuring compliance with food law and food safety. The national authorities support and quide companies in the activities.

- Several associations (incl. industrial, consumer) can be beneficial in providing information and training.

- Education of consumers/farmers/other stakeholders about new protein sources is needed. Information about sustainability, Eco footprint, LCA, safety and nutritional value should be available for these purposes. A harmonized coalition of alternative protein producers (similar as Sustainable Seafood Coalition SSC) and stakeholders could be a good platform sharing information on sustainability and other important issues.

- Organic certificate would benefit the industrial partners in food applications.

- Technological performance, nutritional and sensory quality of the new alternative proteins is important and needs to be acceptable for applications.

- Different retail trade operators can have their internal guidelines where they specify e.g. quality limits and requirements for the products. These can differ from the legislative limits.

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