EIP-AGRI Focus Group
New feed for pigs and poultry

STARTING PAPER – REPORT May 2018

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Objective

The objective of this paper is to provide a starting point for input, reflection and discussion for the first meeting of the EIP-AGRI Focus Group on New Feed for Pigs and Poultry. The Focus Group will place its attention on the pig and poultry value chains in the European Union. The objectives and tasks of the Focus Group are to:

- Make an inventory of alternative strategies and sources for pig and poultry feed, including both new and underused sources.
- Analyse the most important pros and cons of these alternative feed sources, strategies and supply chains.
- Analyse their general economic and environmental sustainability, analyse their technical viability and safety, and identify potential tools/barriers affecting a broad uptake.
- Propose potential innovative actions and ideas for Operational Groups (funded under the Rural Development Programmes) to stimulate the use and improvement of alternative resources.
- Identify needs from practice and possible gaps in knowledge which may be solved by further research.
- Identify how new and emerging alternatives may be transferred to other conditions (location, type of production) and how they may be checked and standardised in a cost-effective way to obtain safe and steady products at farm level.
- Identify innovative business models for farms and/or third parties.

This paper describes the main drivers, highlights new feed candidate and addresses current knowledge related to legislation, sustainability and implementation of new feed for pigs and poultry.

Main drivers

According to the International Feed Industry Federation (IFIF) the global production of compound feed for livestock (including dairy and fish) was estimated at 1 billion tons in 2016 with the European region accounting for approx. 159 million tons (IFIF, 2017).
The United Nations Food and Agriculture Organization (FAO) estimate that the growth in the world’s population will take place in urban areas; and by 2050 more than 70% of the world's population is expected to be urban (FAO, 2009). With increasing urbanization and increase in income levels the demand for particularly animal proteins is expected to grow by approx. 1.7% per year between 2010 and 2050. Over the next 30 years, the global production of meat is expected to rise with almost 70% (aquaculture by 90% and dairy by 55%). Within meat production, pig and poultry are the fastest growing livestock subsectors; and the demand for pigs and poultry are expected to increase by 38% and 104%, respectively as compared to current production levels (IFIF, 2017; Alexandratos & Bruinsma, 2012).

The EU agricultural outlook for the agricultural markets and income for 2017-2030 has been assessed recently in a report by the Directorate-General for Agriculture and Rural Development and the Joint Research Centre (JRC). Here the EU per capita consumption of meat is expected to level at current consumption levels as we approach 2030, with poultry will taking some market share from other meats (European Commission, 2017). Regionally, in the EU, there is also a tendency in some members states toward a decline in meat consumption and increased focus amongst consumers on sustainable and ethical food production. For instance, sales numbers from one of the largest food retail chains in Denmark, COOP, show an annual decline of 1-1.5% in sales of meat products since 2011.

Unsurprisingly, price is also a main driver that puts the global feed and livestock sector under heavy competition; and price is a major market entry barrier that puts new candidate feeds under great pressure as they need to be able to compete against the ‘economy of scale’ that many of the mass-produced feeds have established over decades. Figure 1 below provides and overview of the price levels of two of the currently most important protein feeds, soybean meal and fishmeal. In general, new feeds that are being introduced to the feed sector need to be priced at a level between, or below, soybean meal and fishmeal to be competitive.

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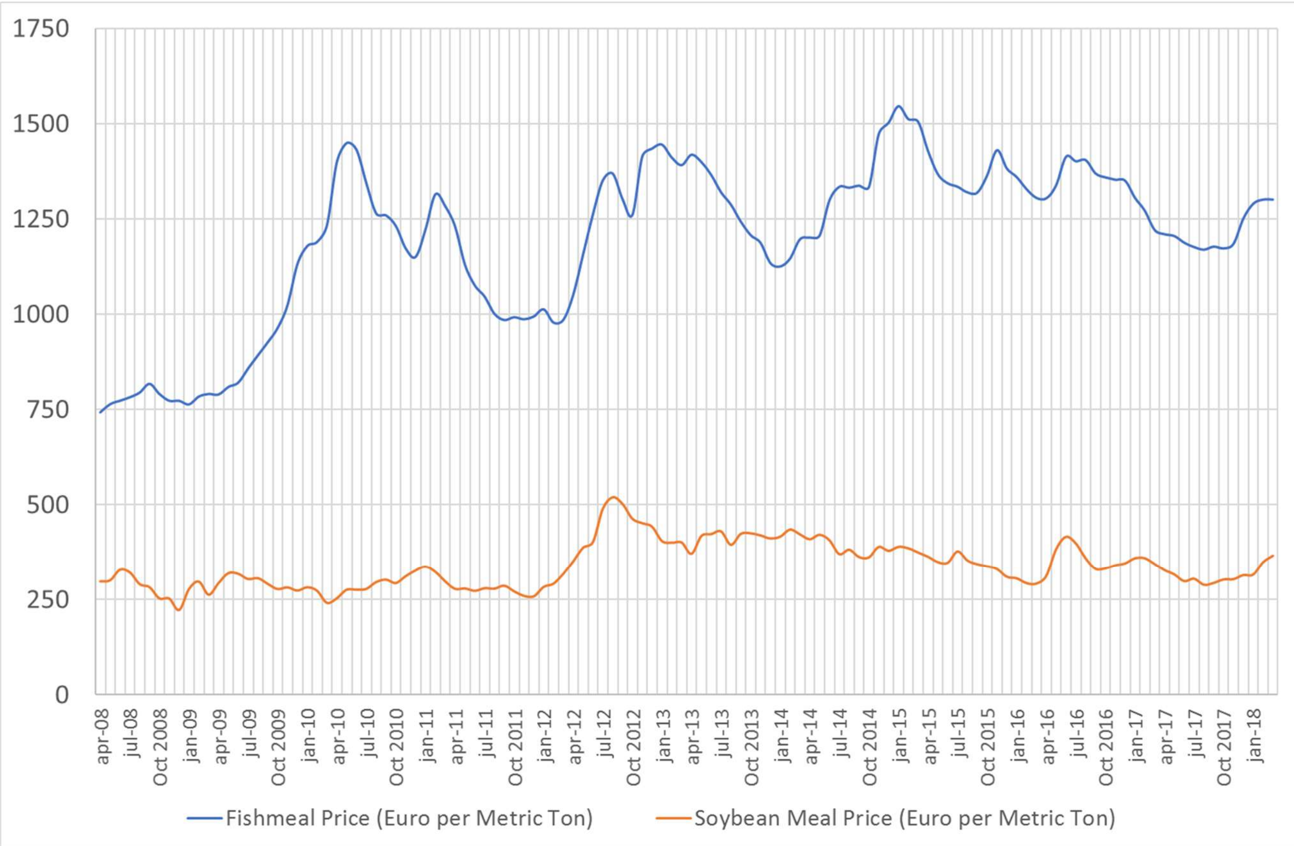

Figure 1. Price development (EUR/Metric ton) of soybean meal and fishmeal over the last decade (data from Index Mundi).

The main drivers outlined above highlight opportunities for both pig and poultry farmers, with the latter having particularly good prospects both regionally in the EU as well as globally. With increased consumer focus on sustainable and ethical food production there is a general opportunity for both pig and poultry farmers to implementing (more) sustainable production methods at farm level; for instance, by focusing on new feed that may add value do to either ethics and/or low climate- and environmental footprint. Moreover, new feed may also offer an opportunity to incorporate circular economy at farm level by e.g. creating local partnerships or establishment of on-farm co-production.

New feed candidates

To be an eligible feed candidate in future farming systems, new feed for pigs and poultry should be able to meet several of the requirements listed below:

- Moderate to high protein content (this is a major advantage as protein is in high demand)
- Good protein digestibility and nutritionally relevant amino acid profile
- Moderate to high content of relevant micronutrients (minerals and vitamins)
- No (or limited content of) anti-nutritional factors
- Health-benefitting properties (e.g. pre-biotics, feed fibres etc.)
- Sustainable production (this may also cover ethics – see section on sustainability below)
- Competitive price (preferably comparable to soybean meal but depending on the feed it may also be relevant at fishmeal price levels).

Pricing is generically an important parameter and in general pricing levels follow those of established commodities. As outlined above (Figure 1), feed material with moderate to high protein content will have to be priced within the pricing level of soybean meal and fishmeal to be competitive. When it comes to carbohydrate-rich feed materials, the price will be fixed around the level of different grain-based crops such as e.g. wheat, rye, barley, corn and rice; however, the price level may well be somewhat lower such as is the case for certain industrial residuals and former food stuffs. Feed materials that have specific characteristics such as a high level of essential micronutrients or known health benefits (e.g. boosting immune health) may be priced at somewhat higher level than even protein-rich feed material.

The new feed candidates that have been included in this starting paper are not intended to constitute a non-exhaustive list, but rather an introduction to some relevant feed materials. The expert group are expected collectively to add further information on the listed candidates as well as suggesting additional new feed candidates of relevance.

Aquatic biomass

Aquatic biomass constitutes a range of different plant and algae species that have a potential as new feed. In general, there are only a few studies available on the digestibility of aquatic biomass-based feed for pigs and poultry. However, a reasonable number of studies indicate that several feed candidates in this category have potential, although some processing is required for some of the feeds. In this starting paper, duckweed and certain micro- and macroalgae will be briefly outlined.

Microalgae can produce high biomass and protein on a very limited area. The main input to production is light, CO_2 and nutrients; including using by-product or residuals (e.g. nitrogen applied from ammonia collected from stall ventilation). Generally, microalgae have a high protein content of approx. 50-60% with an amino acid composition corresponding to soya. The production systems of microalgae are still limited, but currently cultivation systems in Northern Europe have achieved protein yields between up to approx. 20 tons protein/ha/year. Microalgae also have a high content of polyunsaturated fatty acids and are relative rich in e.g. omega-3 fatty acids and are a good source of micronutrients such as mineral and vitamins (Madeira et al., 2017). It is estimated that development and further implementation to full-scale production will take another 5-10 years. Production of microalgae is characterized by a long growing season, but there will be a seasonal variation due to varying solar radiation and temperature.

Macroalgae, or seaweeds, are commercially important foods and sources of feed. Over the last approx. 50 years, around 100 macroalgae species have been tested in sea farms but only a dozen of these species (mainly brown and red macroalgae) are commercially cultivated today. Currently, the global macroalgae production amounts to approx. 30 million tons annually with 99% of the production being in Asia. In Europe, production of macroalgae is likewise ongoing, although the volumes are very small. Here it is more common to collect macroalgae biomass from beaches and coast lines (so-called beach cast), which has been practised for use as

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soil fertilizer and animal feed in certain European regions (e.g. United Kingdom, The Baltics and Scandinavia) for centuries; particularly collection of macroalgae known as *kelp* (brown algae from the orders Laminariales and Fucales) is relatively widespread (Makkar et al., 2016). For instance, in Norway, kelp is harvested fresh along the coastline. The wet kelp is passed through hammer mills, passed through a drum dryer and subsequently stored in sealed bags. Under these conditions the kelp meal can be stored for a year. Kelp has been assessed as having only 30 percent of the feeding value of grains, as most of the carbohydrates and proteins are not digestible. However, kelp is a very good source of micronutrients contributing with important minerals and vitamins to the diet of animals. Moreover, there is evidence of benefits to animal immune health when fed on kelp and other macroalgae. Back in the early 1970s, Norway alone was producing about 15,000 tons of kelp meal annually; and although these production levels have declined over the last decades a renaissance is on the move with a lot of interest and (re)investment in production of kelp.

Duckweed constitute a group of aquatic freshwater plants that belong to the family Lemnaceae. Compared with most other conventional crops, duckweed has a relative high percentage of nutrients (based on a dry matter basis) and is very digestible, even for monogastric animals. A duckweed production system can produce a yield of 10-40 tons dry matter per ha with a protein content of approx. 45% (good amino acid profile), 20% fibres, 5% fat, 25% carbohydrates and 20% ash - depending on the culturing conditions (Heuzé & Tran, 2015). However, production systems for duckweed are still undergoing intense development.

Industry residuals and former foodstuffs

This category constitutes a wide range of potential of new feed candidates that are available throughout Europe, but which vary throughout the region depending on the industries that are present locally. From a legal perspective, only vegetable-based industrial residuals and former foodstuffs are eligible for use as feed for pigs and poultry (see section on legislation below). Although there are many underutilized industrial residuals available, several industrial residuals are already being used as feed for pigs and poultry. In general, the nutritional profile of many of the new feed candidates in this category will likely dominated by carbohydrate-rich substrates such as residuals from the bakery industry (including mills), sweets and confectionary industry and snack industry. This is also the case for residuals from agri-based industries that process e.g. potato, sugar beet and horticultural products such as vegetables and fruit. An exception to these carbohydrate-dominated residuals are by-products from breweries, such as spent grains and yeast cream. These by-products have a relative high protein content (20-40% on a dry matter basis), and in the case of yeast cream also contain important micronutrients such as B vitamins. The annual volumes of several of the industrial residuals (and by-products) mentioned above are available at million tons levels in Europe; e.g. spent grains alone are available at >3 million tons annually. As part of the Circular Economy Package, the European Commission is focussing on food waste in the EU; and a recent assessment funded by the European Commission shows that, of the approx. 88 million tons wasted in the region annually, about 30% (approx. 26 million tons) is originating from loss in the processing/food production and wholesale/retail segments (Stenmarck et al., 2016). Some of the industrial residuals mentioned above will likely also be considered as former foodstuffs. Particularly considering so-called intermediate batches, which is residual biomass 'in between batches' that do not meet product specifications in a given batch-based production system.

Insects

Currently, seven species of insects are legally approved as feed – although only for aquaculture, at present, with regards to using the whole animal or the insect protein fraction (see section on legislation below). These include e.g. Black Soldier Fly (*Hermetia illucens*), Yellow Mealworm (*Tenebrio molitor*) and Lesser Mealworm (*Alphitobius diaperinus*) to mention those that have the biggest potential to be produced cost-efficiently and hence be competitive regarding e.g. fishmeal. When it comes to using the fat fraction there are no legal limitations to using the seven approved insect species for pigs and poultry, just like feeding live insects to free-ranging livestock is also legal within the EU. The insect species mentioned above contain on a dry matter basis approx. 40-60% protein (good amino acid profile comparable to soybean meal), 10-35% fat (mainly comprised of fatty acids, and particularly unsaturated fatty acids) 5-10% fibres and 5-10% ash (Makkar et al., 2014). Like aquatic biomass, insect production for feed and food is still in its infancy having emerged in Europe within the last decade but primarily during the last 5 years. Hence, current production volumes are still relative low in the

EU region estimated at a low thousand-ton level annually. However, high interest amongst private investors and public funding bodies will boost innovation and development in the sector; and is expected to result in a vast increase in annual production volumes of this new industry within a short- to medium-term time frame. Currently, the protein yield on a dry matter basis is potentially >1000 tons protein/ha/year for the Black Soldier Fly, which is one of the most efficient insects used.

Single cell protein

Single cell protein (SCP) covers a wide spectrum of technologies for producing feed and food based on microbial systems, i.e. fungi (including yeast), bacteria and microalgae. The latter has been covered under aquatic biomass (see above), hence focus will here be put on fungi and bacteria. During the last 15 years, SCP technology has improved dramatically with focus on using both mixed populations of microorganisms, but also pure strains in the production of SCP. Interestingly, the use of methane as a carbon source for SCP is reaching commercial scales opening the coupling of biogas production as a feedstock for feed production (Ritala et al., 2017). The protein content (dry matter basis) is dependent on both species and on the substrate(s) used for producing SCP; ranging from 10-50% for fungal SCP and 10-80% (generally 50-80%) for bacterial SCP. The amino acid profile is good regarding animal feed, and for bacterial SCP can have methionine content up to 3.0%. Both fungal and bacterial SCP may also be very good sources of a wide range of micronutrients. Depending on the substrate material and intended application, various processing steps are required prior to formulation of the final SCP product. In general, the production steps include: i) preparation of nutrient media, possibly from waste; ii) cultivation, including solid state fermentation; iii) separation and concentration of SCP, in some cases drying; iv) final processing of SCP into ingredients and products. Globally, several commercial SCP plants are producing at a >10,000 tons biomass/year.

European legislation in brief

From a legislative perspective, the rules on the marketing of feed materials and compound feed are established in **EC Regulation 767/2009** on the placing on the market and use of feed. To implement this, the Commission has adopted several acts to this Regulation:

- **Catalogue of feed material**
- **Revision of the tolerances for analytical constituents and provisions for the labelling of feed additives**
- **Guidelines for the distinction between feed materials, feed additives, biocidal products and veterinary medicinal products**
- **Guidelines for the feed use of food no longer intended for human consumption**

For a new feed to be eligible to be marketed as feed material or compound feed, it will have to comply with the Regulation as well as e.g. being listed in the Catalogue of feed material. Currently, microalgae species *Spirulina maxima*, *Spirulina platensis* and species of the genus *Chizochytrium* are registered as feed or feed ingredients in the EU. Moreover, Directorate-General for Health and Food Safety (DG SANTE) recently published a strategic safety concept for insects as feed followed by the adoption of **Commission Regulation (EU) 2017/893** (in application since July 2017) authorizing the use of processed insect protein from certain species in feed for aquaculture animals. Based on communications from DG SANTE, it is expected that the same insect species will be authorized for use in pigs and poultry within 2020. Other new feed candidates that are not on the Catalogue of feed material or meet the criteria of the above-mentioned acts will have to undergo revision to ensure future adoption as feed for pigs and poultry. It will likely, be easier (relatively speaking) for vegetable-based feed candidates to opt straight for use as feed for pigs and poultry as compared to animal-based feed candidates, which in the case of insect had to prove their safe use in aquaculture feed first. This is generally due to safety issues (i.e. such as BSE or 'Mad cow disease') that are related to animal by-products. Several of the new feed candidates mentioned above are already eligible, but the legal status should be consulted on a case by case basis to assess if any legislative barriers may lead to a delayed implementation.

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Sustainability remarks

According to the Brundtland report, "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their needs. It contains within it, two key concepts. One, the concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given. Two, the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs." (Brundtland et al., 1987). Moreover, sustainability is often defined as covering three main pillars: the environmental, economic and social pillars. Generally, emphasis is often placed on environmental and economic sustainability, which is also the most relevant pillars to address in the current context.

Several of the suggested new feed candidates have great potential in this regard as compared to some of the currently used feeds - particularly regarding environmental sustainability (e.g. water consumption, CO_2-emission, land use and use of agri-chemicals – see below). However, a comprehensive life cycle sustainability assessment (LCSA), that covers all the above-mentioned three pillars, is still scarce for several, if not all, of the new feed candidates. Hence, more data is needed before a robust comparison can be made to currently used feeds (for which good LSCA studies may also be missing).

Environmental sustainability is analysed by life cycle assessment (LCA) and recent studies by Mackenzie et al. (2016) and Tallentire et al. (2018) on both pigs and poultry highlight that several of the above-listed new feed candidates have great potential to replace the use of e.g. soybean meal. Tallentire et al (2018) state that soybean products can be completely replaced by novel feed, such as micro- and macro-algae, duckweed, yeast protein concentrate, bacterial protein meal, leaf protein concentrate and insects, whilst reducing the greenhouse gas emissions and arable land requirements for feed provision relative to conventional diets formulated for both fast- and slow-growing chicken. Switching from conventional diets to diets that incorporate novel feed components was also shown to mitigate the increased environmental burdens associated with moving towards higher welfare livestock systems. Mackenzie et al. (2016) focused using co-products from the supply chains of human food and biofuels in pig diets for the environmental impacts of Canadian pig systems. Overall, the authors did find some positive environmental impact of these industrial residues, particularly regarding non-renewable energy use and non-renewable resource use (Mackenzie et al., 2016). However, the impact was not as potent as those highlight in the poultry LCA study. Moreover, there are important factors that are intangible and difficult to quantify, e.g. such as the impact on local (global) biodiversity caused by deforestation and maintenance of large crop monocultures.

The social sustainability aspect of the new feed candidates will not be outlined as it is very dependent on local/regional factors, and hence will be too comprehensive to describe here. Economic sustainability is, however, a more tangible parameter; a general definition of economic sustainability is the ability of an economy to support a defined level of economic production 'indefinitely'. Several of the new feed candidates have aspects of either bio-economy and/or circular economy (see next section) and hence should be eligible as being economic sustainable. The general knowledge level of several of the new feed candidates is still limited. Hence, it will take a lot of innovation and development to enable the full economic potential of a new feed candidate, both regarding making its production and use cost-efficient as well as unfolding the total nutritional value of macro- and micro-nutrients present. Moreover, application of alternative business models may further amplify the economic and environmental sustainability of new feed candidates (see below).

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Implementation remarks

As stated briefly above, many of the new feed candidates will at present have the disadvantage of being immature regarding swiftly becoming part of the pig or poultry value chains. This relates either to e.g. knowledge and/or infra-structure gap(s) that exists for including the new feed at the needed level. For instance, many new feed candidates may have current production volumes that are not 'at par' with the supply needs of feed formulators (10,000+ tons/year); or knowledge regarding best practices for processing and/or storage, including ensuring that the nutritional value of the new feed is retained, may also be missing. These issues are very relevant currently for e.g. insects, some of the aquatic biomasses and single cell protein. While industrial residues and former foodstuffs may not have supply issues, it may be that best practice on processing and storage can be a challenge. Hence, identifying and assessing the 'biggest gaps' of the individual new feed candidate is necessary to ensure a smooth transition of the new feed into the pig or poultry value chains; implemented through relevant innovation and development efforts.

At farm-level it may also be possible, at smaller scale, to implement some new feed candidates through local cooperatives or in co-production with other on-farm activities. Several of the new feed candidates offer great potential in this regard, e.g. micro-algae may be produced on slurry on-farm in co-production with pigs or poultry and subsequently be used as feed supplement (similar to plant production for animal feed); or insects can be (partly) produced on on-farm vegetable residuals from plant or horticulture production and/or in combination with using surplus energy from straw heating or biogas production. These alternative models provide innovative ways to ensure a competitive business for modern farmers.

Many of the new feed candidates likewise have great potential to implementing circular economy (or bio-economy) in the pig and poultry value chains (see the conceptual diagram below, Figure 2). This may, initially, be most obvious regarding application of industrial residuals and former foodstuffs; yet, is also very feasible with for instance insects as 'indirect integrators' of on-farm vegetable residuals or industrial residuals and former foodstuffs enabling bioconversion of the bioavailable nutrients.

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Figure 2. Conceptual overview of circular economy with examples of interactions along value chains (adapted from EIP-Agri/European Commission).

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Final remarks

The road to implementing new feed for pigs and poultry will, in some cases, be long as the so-called technology readiness level of several of the new feed candidates is still at a pre-commercial scale. There will also, as outlined above, be regulatory barriers that will need revision of legislation; however, it is beyond the scope of the expert group to work on new legislation or recommendations for revision of legislation.
The overall main objective of the expert group is to identify the 'knowledge gaps' and needs, and to generate recommendations on how to ensure future implementation of new feed for pigs and poultry; particularly regarding proposing innovation actions and ideas for Operational Groups.

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