Resource efficiency champions

Co-products, an essential part of animal nutrition

About FEFAC

The European Feed Manufacturers' Federation (FEFAC) was founded in 1959 by five national compound feed associations from France, Belgium, Germany, Italy and the Netherlands. Today, FEFAC membership consists of 23 national associations from 23 EU Member States as full members as well as associations from Switzerland, Turkey, Norway, Serbia and Russia as observer or associate members. FEFAC is the only independent spokesman of the European Compound Feed Industry at the level of the European Institutions. FEFAC holds observer status in CODEX Alimentarius.

FEFAC

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Disclaimer

This publication provides an introduction to the co-products that FEFAC considers to be the most representative and valuable in industrial compound feed manufacturing. For a more detailed (but not exhaustive) inventory of feed materials used in compound feed manufacturing, see the EU *Catalogue of feed materials*. During the compilation of this brochure, FEFAC consulted in-house experts, as well as those from the industries that supply the co-products described. FEFAC does not guarantee the accuracy of any of the information provided, and in particular information on the nutritional value of the co-products and their manufacturing process, which may differ significantly across plants and may be known under different names. A more detailed description can be found in the *Best Available Techniques (BAT) Reference Document in the Food, Drink and Milk Industries*. The brochure is intended to provide a general overview of co-products used in compound feed manufacturing and should not be used as the basis for a risk assessment or as a manual for feed formulators.

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Shifting from a by-product to a co-product mentality

Though there is no legal clarification of the difference between these two terms, FEFAC has always advocated for a shift from a by-product to a co-product mentality among suppliers. A by-product is typically an unavoidable residue that needs to be disposed of in a low-cost way. A co-product is recognised for its value as a nutrient resource and is treated with the same care and attention as the main product. Harnessing a co-product goes beyond simple legal compliance with safety requirements and often triggers an adjustment in the main processing techniques to ensure a better quality co-product. It recognises that there is an added socio-economic value in preserving the nutritional integrity of the resource, and is underpinned by an integrated value chain that is designed to support this.

Introduction

Food-producing farm animals, especially ruminants such as cattle and sheep, have the unique capacity of being able to keep the co-products of arable product processing that are not consumed by people as food or drink, or used to produce biofuels or other industrial products, in the food chain. As a result, the livestock sector makes a vital contribution to the circular economy. This benefit is generally overlooked and these elements of agricultural production are often unknown. The resulting feed materials are typically derived from a process where the main activity is the creation of a different consumer product, such as beverages, food, biofuels or other industrial applications. They are called co-products as their existence is an unavoidable consequence of the lead process, but they are nonetheless extremely valuable. Harnessing co-products supports the sustainability and profitability of the entire food production system, and they are associated with the manufacture of all types of food, whether meat-, dairy- or vegetable-based.

Animal nutrition science is used to extract nutritional and economic value from these co-products, and to formulate them into high-performance, healthy feedstuffs for food-producing animals. The process involves skilfully analysing the nutritional components available in co-products, then matching them with the physiological and nutritional requirements of specific farm animals at specific life stages. It includes controlling any naturally occurring substances that may have a negative effect on animal health or performance – so-called anti-nutrients – while ensuring that the taste, quality and safety of animal products produced and purchased by consumers is not negatively affected, and where possible enhanced.

The use of co-products fits the fundamental ethos of the compound feed industry, which identifies the nutrients that are available from a plethora of safe individual feed ingredients – such as cereal grains, pulses, and co-products – and delivers the most cost-effective feed resources, where possible using elements which would otherwise have gone to waste. As well as contributing to the environmental sustainability of the food chain, the use of co-products in the feed market adds economic value to the original feed material. At the same time it boosts the competitiveness of the livestock farming sector through increased availability of alternative cost-effective feed materials.

Of course, the value of co-products as feedstuffs depends on producers maintaining their nutritional integrity and safety when producing, handling, storing and transporting them. In other words, treating them like 'products' and not as discarded 'waste'. It is FEFAC's ambition to encourage – and where possible assist – suppliers of co-products to reach next-level awareness and manage their manufacturing processes to optimally preserve and even upgrade the nutritional quality of the materials destined for feed.

> "Few other sectors so rigorously identify and reuse resources resulting from other manufacturing processes"

The compound feed industry sees itself as a 'resource efficiency champion', and there are few other sectors that so rigorously identify and reuse resources resulting from other manufacturing processes that are mostly geared towards other high-end products. To take one example, beer production results in the co-product brewers' grains. These have no role in human consumption, but thanks to animal nutrition science have become a valuable feed material.

The European compound feed industry is working hard to raise awareness about the role it plays in the circular economy, and hopefully the next time you make use of the consumer products you see in this publication, you will remember that the industry was there to make the best use of the co-products.

Wheat and rice milling

Origins of the compound feed industry

It is appropriate to begin this report with the co-products that result from wheat milling, as this is where the European compound feed industry has its origins in the early twentieth century. In fact, compound feed manufacturing was initially carried out by flour millers themselves, which is where the term 'feed mills' comes from. Surplus particles from grinding grains to produce flour were initially considered to be a waste product, but conserving these and diverting them as co-products for feed has become an integral part of the manufacturing process for one of the biggest industrial food ingredient sectors. During the production of non-whole-wheat bread, breakfast cereals and pasta, only the endosperm (flour) is used, leaving the hard outer layer (bran) behind.

Wheat bran can have different definitions and compositions depending on the region where it is produced. Flour millers generally have good links with nearby feed markets, supporting local or regional supply chains. In bread manufacturing wheat bran is used in wholemeal bread, so people are generally aware that bran is richer in protein (14–19%), fibre, minerals (particularly calcium and phosphorus) and oils than the endosperm. These nutritional traits are also beneficial to the feed industry. Wheat bran can be consumed by all types of farm animals, although the amount fed to poultry should be limited, as the high fibre content can impact digestibility. The inclusion of wheat bran in feed for sows and ruminants is extremely common. It is associated with improved milk fat yield in the latter.

Rice grains are also surrounded by bran, human consumption of which is a lot less common than consumption of wheat bran. This is despite claims that roughly 80% of the nutrients are in the bran, even though it only makes up 10% of the grain. **Rice bran** is separated from the endosperm in a process that converts brown rice to white rice. As with wheat bran, it contains a useful amount of protein and fibre. The oil in rice bran usually still has a role in food production so it is very common to come across defatted rice bran as a feed material. Rice bran is also a good source of B and E vitamins and certain trace minerals such as manganese and zinc. As with wheat bran, rice bran is particularly suitable for dairy cattle due to its high fibre content.

Feed safety

Feed safety requirements are applied horizontally across all feed materials, whether they are made from co-products or primary raw materials. Manufacturing processes have to control for good hygiene, hazard analysis and critical control points (HAACP) and chemical residues, in line with Regulation (EC) No 183/2015, Regulation (EC) No 767/2009 and Directive 2002/32/EC.

Raw materials | **Co-products** | **Consumer products**

Paddy rice

Rice bran

White rice

Brown rice

Whole wheat grain

Wheat bran

Pasta

Bread

Sugar production

Beet pulp pellets, molasses and pressed pulp

Sugar that is used as table sugar or as an ingredient in food and drink products comes from sugar beet and sugar cane. The European Union is the world's biggest producer of beet sugar. This is refined by being cut into small strips or slices, and the sugar is then extracted as juice using water at approximately 70°C. The remaining **beet pulp** is rich in fibre and energy and has outstanding feed value for different types of livestock. It is most commonly used in dairy feed due to its ability to promote milk yield and increase fat levels, as well as reducing the risk of acidosis in the rumen (which is caused by excessive grain starch). In its dried form, beet pulp is an international commodity that is transported by trucks or ships. Dried beet pulp is sold as either unmolassed pellets or as molassed pellets.

During further refinement and crystallisation of the sugar juice, a syrupy co-product called **molasses** is produced. Molasses provides a rapid source of energy and is rich in certain minerals, but its feed qualities go beyond the nutritional benefits. It is a highly valued energy-rich taste enhancer which increases the palatability and homogeneity of compound feed. The viscosity of molasses makes it unsuitable for feeding directly to livestock, but it has good pellet-binding qualities that can control the many fine particles that are part of compound feed processing, preventing post-production pellet deterioration. Molasses is commonly used in ruminant feed, but is also included in pig feed, and to a limited extent poultry feed. Molasses from both beet and cane has a similar nutritional value: the main difference is that cane molasses is typically imported to Europe from overseas, whereas beet molasses is produced within Europe.

The incredible powers of ruminants

Ruminants are the only animals that are capable of digesting many co-products, particularly those that are rich in fibre. As a result they play an essential role in creating a food use for agricultural biomass that would otherwise be wasted.

Pressed beet pulp is also sold as a fresh product. This can either be fed directly to animals or be ensiled (conserved by being put into a silo or silage clamp). It is a high quality feed for all ruminants.

"The EU beet sugar sector has a long tradition of maximising value from all products arising from the sugar process, minimising waste as far as possible. As well as common household white sugar, the EU sugar industry is also a major producer of feed materials stemming from sugar beet and sugar cane. Sugar industry co-products such as pulp and molasses are generally highly valued feed materials as a result of their sweet taste and high energy content."

CEFS EU SUGAR

Raw material | **Co-products** | **Consumer product**

Sugar beet

Sugar beet pulp

Molasses

Sugar

Beer brewing

Creating a nutritious alcohol-free feedstuff for animals

The main ingredients in beer are water, malted barley, hops and yeast. During the brewing process, the soluble parts of the malted barley are dissolved in water to create wort, which is processed into beer by fermentation. The remaining solid residue, made up of spent brewers' grains, has been used as an animal feed since before the Industrial Revolution, when farms and monasteries in Europe brewed their own beer and fed the resulting by-products to their livestock. With nearly 40 billion litres of beer brewed in Europe each year, and brewery by-products making up 20–24% of the original input, their role in feed is significant.

Brewers' grains are an excellent feed material that are rich in proteins and highly digestible fibre, making them particularly beneficial to cattle and other ruminants. The fibre supports the functioning of the rumen (the biggest chamber of a ruminant's stomach), complementing forage-based diets that are high in starch and lack readily fermentable fibre. With crude protein content ranging from 19–31% on a dry matter basis, brewers' grains are also a good source of protein. Due to their high moisture level they are perishable, so livestock activity in the proximity of a brewery is also desirable.

Brewers' yeast is the component that converts sugars and starches into alcohol during beer brewing. After its removal at the end of the brewing process, the yeast is deactivated using heat treatment or organic acids and is then suitable for use as animal feed. Brewers' yeast is rich in protein (36–50% on a dry matter basis), and has a valuable amino acid profile that is similar to soya. It is an extremely versatile feed for all types of farm animals. When used in poultry feed, it is recognised as an excellent source of B vitamins.

> "Whilst brewing high quality beer is a brewer's main focus, reducing wastage and minimising environmental impact is also key. Ensuring that secondary materials such as brewers' grains and brewers' yeast have a sustainable outlet as protein, fibre and vitamin-rich animal feed is integral to the brewing sector's constantly improving environmental performance."
>
> The Brewers of Europe

Raw material | **Co-products** | **Consumer product**

Barley

Brewers' grains pellets

Brewers' yeast

Beer

Starch and ethanol production

High-performance bio-refining serving many sectors

Starch

Starch is a high-value product that is used in a wide range of sectors including food, pharmaceuticals, fuel, paper and textile manufacturing. It can be produced using wet and dry milling processes. Milling separates starch, fibres and proteins from cereals such as maize, wheat, barley and rye, as well as starch potatoes which are specially grown for the purpose. Different feed co-products are produced at different steps of the milling process.

Wet milling separates and purifies the main components of the grain, namely protein, starch, fibre, solubles and oil (depending on the type of cereal). Wet milling of maize generates several valuable feed co-products: maize gluten feed; maize gluten meal; and maize germ meal. **Maize gluten feed**, which usually has **maize germ meal** blended into it, is a medium-protein, medium-energy feed material. It is widely used as an ingredient in ruminant diets because of its relatively high levels of digestible fibre. **Maize gluten meal** contains 60–75% crude protein. Although lower in the essential amino acid lysine compared with soya, it is rich in another essential amino acid, methionine.

Wheat gluten feed, wheat gluten meal, wheat germ meal and wheat gluten are obtained from the wet and dry milling of wheat. **Wheat gluten feed** is composed of bran and gluten, and may have wheat germ added to it. It is a fibre-rich ingredient that contains nutritious protein and starch that is used in feed for ruminants, pigs and poultry. **Wheat gluten meal** is a wheat protein concentrate with high protein digestibility (containing 75–80% crude protein).

Wheat germ meal consists mainly of wheat germ, together with some bran and 'middlings' or 'shorts'. It contains at least 25% protein and 9% fat. It is rich in digestible protein and contains vegetable oil, along with essential fatty acids. Wheat germ meal is an excellent source of vitamin B1 and vitamin E. **Wheat gluten** contains even more protein (80%) and is used in aquafeed or in hydrolysed form in calf milk replacers.

During the processing of starch potatoes, potato protein and potato pulp are obtained. **Potato protein** is a high-quality and highly digestible protein source, rich in the essential amino acids lysine, methionine and cyst(e)ine, and particularly suitable for piglet diets. Dried **potato pulp** provides a digestible fibre source for ruminant and monogastric animals.

Ethanol

Ethanol is best known as an ingredient in spirits, such as vodka, but is increasingly also used as a biofuel. Distiller's grains are the 'spent grains' that are left over following the fermentation process that is used to distil ethanol from cereals. They are a highly valued feed co-product that is rich in protein, fibre, fat and soluble sugars, and are traded globally as **dried distillers grains (DDGs)**. DDGs are mostly produced from maize, but can also be obtained from wheat, barley, rye, or a combination of all three, sometimes depending on cereal prices. The nutritional characteristics and quality of DDGs varies depending on the production process and the grain used, but they are generally suitable for all types of farm animals. DDGs are a good source of phosphorus, zinc and potassium, and their fibre component is beneficial in reducing ruminal acidosis in high-grain rations.

Raw materials | **Co-products** | **Consumer products**


Maize


Dried distillers grains pellets


Maize gluten feed pellets


Starch


Wheat


Potato


Potato protein

Ethanol

Citrus fruit processing

Squeezing value from the peel

Billions of litres of juice from citrus fruit such as oranges, lemons and grapefruit are consumed globally. After the juice has been extracted, a solid residue made up of the peel and seeds remains. Called citrus pulp, this is a valuable feed co-product. Fresh pulp can be fed to animals locally, but very often it is pressed and dried into pellets, usually at the fruit pressing facility itself, before being exported globally as a commodity (particularly from Brazil and the United States).

Citrus pulp is rich in energy and fibre, with good digestibility for ruminant species. Like sugar beet pulp, its highly digestible fibre content induces good rumination in cows' stomachs, leading to the production of large quantities of saliva that have a buffering effect on the pH of the rumen. Citrus pulp containing oranges gives a sweet and aromatic flavour to the feed, aiding palatability. When the pulp contains lots of lemon or grapefruit pulp, the taste is usually more bitter.

In dairy cattle, citrus pulp is known to maintain milk quality, especially milk fat. It is particularly well suited to ruminants, which are able to digest high-fibre feeds, and is a good example of how an additional element of agricultural crop production can be kept in the food chain. Due to its high fibre content and the presence of the anti-nutrient limonin, citrus pulp is much less suitable for pigs and is rarely used in poultry.

What is meant by palatability?

Taste! Farm animals (especially young piglets) can be picky eaters and compound feed manufacturers need to ensure that they create nutritionally balanced diets that will be eaten. Taste is a factor in this process. It is also important to produce homogenised feed so animals do not go through their feed trough selectively. This is why compound feeds are often created as pellets.

Raw material

Citrus fruit

Co-product

Dried citrus pulp pellets

Consumer product

Fruit juice

Industrial fermentation biomass

The circular story of micro-organisms

Industrial fermentation uses micro-organisms such as bacteria, yeasts and fungi to create an increasingly wide range of substances. Examples include amino acids, vitamins, carotenoids, flavourings, enzymes, organic acids and alcohols. Producers of detergents, cosmetics, pharmaceuticals and bioethanol depend on industrial fermentation, with some outputs also destined for food manufacturing.

The elements of interest for the animal feed industry result from the metabolic activity of the micro-organisms. These are grown under carefully controlled conditions, either in liquid or solid-state bioreactors, and fed with a source of carbohydrate and nitrogen, such as sugar or molasses. The primarily products are either excreted by the micro-organisms into their surrounding medium (from where they are isolated and concentrated) or produced inside them and extracted from their cells. Both the **spent medium** and the **microbial biomass** that remain at the end of the separation process have considerable value as feed. These biological processes save significant amounts of resources and energy compared with chemically-based processes, as well as delivering both the desired end products and accompanying co-products under highly sustainable and circular conditions.

The efficacy of industrial fermentation is also inspiring a growing sector that focuses primarily on generating **microbial biomass** from various microorganisms and renewable carbon sources, without the objective of producing specific metabolites. The output from this process and the co-products produced are both known as **single cell proteins** (SCP). They consist of crude or refined protein that is derived from the cells of microorganisms such as yeast, fungi, algae, and bacteria, which are grown on various carbon sources for synthesis. SCP contains over 40% crude protein and is also rich in lipids and vitamins.

Fermentation biomass is one of the richest sources of proteins and amino acids, both in terms of content (approximately 75% protein) and amino acid profile (well-balanced without amino acid profile gaps). It is particularly suited to aquaculture or poultry feeding, as it does not have digestibility limitations, anti-nutritional factors, or a limiting amino acid profile. Different forms of fermentation produce specific co-products, each with potential for future development.

What are essential amino acids?

There are 20 amino acids. Depending on species, about 10 can be synthesised de novo through an animal's metabolic pathway and the rest of them must be acquired through feed and are known as 'essential amino acids' (lysine, threonine, tryptophan, methionine, leucine, isoleucine, histidine, valine, arginine and phenylalanine), or 'semi-essential amino acids' (cyst(e)ine and tyrosine, which are synthesised from essential amino acids). The amino acid composition of plant protein sources varies widely, along with their digestibility. Relying solely on crude protein as a source of essential amino acids results in significant spoilage. Instead, industrial compound feed production uses supplementation to achieve the desired amino acid profile through feed additives in the compound feed.

Raw material

Micro-organisms grown in industrial fermenter

Co-product

Microbial biomass granules

Consumer product

Food and feed additives

Oilseed crushing and vegetable oil refining

The gold standard in protein sources

The oils extracted from soybeans, rapeseed, sunflower seeds and linseed are high-value food ingredients, and are also increasingly used in the production of biodiesel. The meal that results from oil extraction contains a high concentration of protein. Oilseed meals represent the most important source of proteinaceous feed materials for food-producing farm animals. Traditionally, oil was obtained by mechanically crushing seeds (a process called 'expelling'), resulting in cakes. Today, crushing followed by solvent extraction has become the most common method as it yields a higher proportion of oil compared with protein meal separation. Toasting is used to reduce the presence of any anti-nutritional factors that could have a negative impact on the digestibility of the protein meals, while also minimising the risk of biological contamination.

The oil from soybeans, rapeseed, sunflower seeds and linseed is the product with the highest economic value, but it can be argued that the protein content of soybeans has become the main driver for cultivating them. As a result of market factors, **soybean meal** has become the principal source of protein for the feed industry worldwide, setting the benchmark for all other vegetable protein sources. Its position as the gold standard is down to the excellent characteristics of soybean meal, which scores uniquely high for its amino acid profile, protein concentration, nutrient density, digestibility and palatability. In addition, soybean meal's affordability, consistency and all-round availability – including the option to use price-hedging tools – makes it the first choice for both animal nutritionists and feed buyers, particularly for pig and poultry feeds.

Protein is an essential element in feed formulation and food pellets typically include a proportion of vegetable protein meal. Soybean meal is particularly versatile and can broadly be used for all types of farm animals. Research and development on soybean meal has led to a multitude of versatile products for different animal nutrition purposes, such as soybean protein concentrate, which has over 70% protein and is particularly suitable for aquafeed and young animals whose digestive system is less well-developed. Another example is extruded full-fat soybean meal, which contains less protein but includes more digestible energy and is particularly useful in poultry feeds.

Rapeseed meal is the most common alternative to soybean meal, as well as the most important EU-grown vegetable protein source. With a higher fibre content and lower amino acid availability than soya, rapeseed meal is more suitable in ruminant feeds than in monogastrics or fish, which is also the case for sunflower meal.

The use of **sunflower and linseed cakes** in feed for ruminants has a long history, dating back to the seventeenth century. One of their beneficial traits is the absence of intrinsic anti-nutritional factors, meaning that they do not need further specific treatment for feed use. Sunflower cake has high levels of the amino acid methionine, making it a very useful feed material for egg-laying birds.

Raw materials | **Co-products** | **Consumer products**


Soybeans


Soybean meal


Rapeseed meal


Vegetable oil


Rapeseed


Sunflower seeds


Sunflower oil cake pellets


Biodiesel

Gelatine production

Unlimited possibilities from a few ingredients

The history of gelatine dates back thousands of years, with gelatine-like mixtures produced in Egypt during Pharaonic times. Written records show that fish and fruit specialities prepared with gelatine were considered to be delicacies and served at feasts. Gelatine is indispensable in modern cuisine, as well as in the cosmetic and pharmaceutical industries.

Edible gelatine is produced from raw materials that originate from healthy animals which have been slaughtered in a slaughterhouse, and whose carcases have been found fit for human consumption following ante-mortem and post-mortem inspections. The co-products from edible gelatine production include highly valued feed ingredients. These can be safely used in feed for both food-producing[1] and non-food-producing animals, and are in full compliance with Animal By-Products Regulations (EC) No 1069/2009 and 142/2011.

Dicalcium phosphate dihydrate is a valuable source of calcium and phosphorus for food-producing farm animals that is obtained from the gelatine manufacturing process. Crushed bones are degreased and demineralised using diluted hydrochloric acid before the calcium phosphate is precipitated. The end product is suitable for use in feedstuffs for pets, poultry, pigs and aquafeed. Scientific studies have shown that the use of processed bone phosphates as a source of phosphorous in poultry diets contributes to sustainable animal husbandry, as it reduces reliance on limited rock phosphates and minimises the excretion of phosphate into the environment due to its superior digestibility.

The edible gelatine manufacturing process also generates large amounts of **animal fats**. Fat is an essential nutrient in livestock diets and, like other nutrients such as protein, fibre, starch and sugar, is important to ensure optimum performance. It also makes feed more palatable and represents a high-value energy source.

Gelatine process derived proteins are dried animal proteins which result from the production of edible gelatine obtained from raw materials according to Regulation (EC) No 853/2004. Gelatine process derived proteins are a source of highly digestible amino acids including lysine, valine, arginine and leucine suitable for animal diets.

The gelatine manufacturing process does not only create a valuable food ingredient. By maximising the value of by-products, it also supplies the feed industry with high value protein products, greases and minerals. As such, gelatine manufacturing has a positive impact on overall environmental sustainability, and supports the circular economy."

GME
GELATINE MANUFACTURERS OF EUROPE

1 Subject to certain restrictions laid down in Regulation (EC) No 999/2001

Raw materials | **Co-products** | **Consumer products**

Hides and skins

Animal fat

Gelatine process derived proteins

Gelatine

Bones

Dicalcium phosphate

Collagen hydrolysate (collagen peptide)

Dairy processing

No need to cry – no milk is spilled!

Most people know that cheese is produced from milk, but fewer are aware that following the coagulation process induced by the added rennet or the lowering of the pH value a liquid co-product called **whey** remains. Depending on the method used and which animals the milk has come from, different types of whey are produced, including sweet whey and acid whey. Whey products contain little or no fat, which is used in the cheese, and instead have a concentration of lactose, protein and minerals.

Processing of liquid whey leads to the creation of different products, both for use in human food (such as food supplements and sports drinks) and animal feed. The latter include whey powder, whey protein concentrate, fat-filled whey and whey permeate, which typically have variable lactose to protein ratios. **Whey powder** is a logistically handy solution given the size and growth of the cheese industry.

Whey-derived products are most commonly used as a milk replacer feed material for infant ruminants such as calves and lambs. They are highly palatable and digestible dairy-based feed components that stimulate appetite and feed intake, while promoting gut health and animal performance. Whey has an excellent amino acid profile and is relatively rich in calcium, phosphorus, sodium, potassium and chloride. It contains no anti-nutrients.

Skimmed milk, usually in powder form, is also a well-known milk replacer feed material for infant ruminants, although its use has decreased steadily in Europe over the past decade because of its role in human food products. Skimmed milk is milk from which most of the fat has been removed for butter production and contains very little fat, although all the protein remains. This has a high biological value and is very digestible. Skimmed milk is a good source of water-soluble vitamins, although most of the fat-soluble vitamins (A and D) are removed with the fat. In recent years **skimmed milk powder** has gradually been replaced by alternative vegetable feed materials, while the amount of milk replacers fed to young ruminants, such as veal calves, has increasingly been replaced with concentrated feed and roughage.

The evolution of animal nutrition science

The early days of animal nutrition science focused on individual elements such as crude proteins, crude fats, crude fibre and minerals. Nowadays feed formulations are based on factors including the proportion of digestible amino acids, the bioavailability of minerals, and the net energy released. The science continues to evolve, and research into the interactions between nutritional constituents of different feed ingredients continues to be studied, along with other factors such as the neutralisation of anti-nutritional factors and the effect of certain micro-ingredients.

Raw material

Milk

Co-products

Whey

Skimmed milk powder

Consumer products

Cheese

Butter

Meat production/animal by-products

Creating valuable ingredients for the feed industry

As well as providing meat, animals are a source of high value co-products such as leather and gelatine. A wide range of animal by-products that are not destined for human use can also be processed animal by-products not destined to human consumption. The animal rendering industry processes a range of by-products into useful materials for the feed industry. The resulting feed materials are all made from animal materials that are classified as 'fit for human consumption at the point of slaughter' (referred to as 'category 3 animal by-products' in the EU context) and are processed in accordance with the requirements of the Animal By-Products Regulations (EC) No 1069/2009 and 142/2011.

Rendering uses heat and pressure to sterilise and stabilise animal materials, making them suitable for storage and reprocessing. The two main products of rendering are animal fat and processed animal protein (PAP). Several other niche products that are used in the feed industry are also derived from animal by-products. The use of these feed ingredients, including restrictions for certain species, is also defined by Regulation (EC) No 999/2001.

Rendered products are particularly beneficial to feed producers for a number of reasons. Firstly, they are a source of highly digestible nutrients like proteins, fat and minerals. Moreover, European legislation is the most rigorous in the world, so feed ingredients are consistently high-quality and safe. Feed producers can also rely on a consistent supply of ingredients produced within Europe. There are environmental benefits too: these materials have a low carbon footprint because most of the environmental impact is attributed to the main product (meat and dairy), not the animal by-product.

Processed animal protein (PAP) from non-ruminant livestock has been approved for use in aquaculture since 2013, and is particularly suitable for inclusion in the feed of carnivorous fish such as salmon. PAP contains essential amino acids, including lysine and methionine, as well as fats and minerals such as calcium and phosphorous. It is also highly palatable and digestible for fish, and has no anti-nutritive constituents. At the time of writing, a further lifting of the feed ban introduced in 2001 is under discussion. The next possible relaxation regards the use of pork PAP in poultry diets and poultry PAP in pig diets. An essential precursor to this is the effectiveness of controls based on analytical tests to verify the identity of particular types of PAP.

Animal fat is an important ingredient for the feed and pet food industry. It is the most commonly used type of fat in the feed industry and has both nutritional benefits and physical properties that are important for feed producers. Animal fat is suitable for use in feed for all types of animals. Tallow is the only hard fat produced in Europe. Liquid poultry oil, which is another important animal by-product, resembles the linolenic content of rapeseed oil.

Spray-dried blood plasma is an important ingredient in the diet of young animals, especially piglets that are weaning. The immunoglobins it contains support the piglets' developing immune systems, strengthening health performance and improving feed conversion ratios.

Raw material | **Animal by-products** | **Consumer product**

Carcasses

Processed animal protein

Animal fat

Meat

Spray-dried blood plasma

Food manufacturing

The feed formerly known as foodstuffs

During the production of foodstuffs such as bread, biscuits, chocolates, breakfast cereals, crisps and pasta, some of the output typically fails to meet the manufacturer's required standards and becomes a 'former foodstuff', destined for use in animal feed. Food can fail to meet the appropriate standards through production errors that lead to items being broken or incorrectly shaped, coloured, flavoured or labelled. Surpluses of unsaleable goods can also occur following seasonal events such as Christmas or Easter, or after a product line is discontinued. Former foodstuffs can also result from the challenges of daily delivery of certain foods.

When **former foodstuffs** cease to be saleable for human consumption, and after the manufacturer or retailer has considered donating them to charity (for instance to a food bank), any remaining stock is typically still suitable and safe for animal feed production. Different foodstuffs can be collected and converted into an energy-rich feed which can take the place of ingredients that are normally selected for their energy value (such as wheat, barley or maize). Some former food products like chocolates, crisps and croissants have an oil content that means they may even be considered as 'fat-fortified' compared with cereal grains, offering further nutritional value. Because former foodstuffs have also typically undergone heat processing, the starch and other nutrients are more digestible. In addition, well-preserved former foodstuffs are not troubled by mycotoxins. Former foodstuffs represent a very broad category of feed materials, although as they are destined for food-producing animals they must not contain any meat or fish. It is also important to point out that as they are sourced from food manufacturers and retailers, they are not the same as catering waste.

Co-products … nothing to do with waste

With the adoption of the revised Waste Framework Directive (EU) 2018/851 'substances that are destined for use as feed materials' are clearly excluded from the scope of waste legislation. The co-products used in feed for food-producing animals are therefore not considered as waste. The directive also makes it clear that there is absolutely no relation between co-products and catering waste, which is not allowed in feed for food-producing animals

Processed former foodstuffs are used in feed for all species of farm animals, but they are most frequently destined for pig feed. Some people may have concerns about feeding chocolate to farm animals, but fortunately they metabolise theobromine (a compound that can be fatal to dogs) in the same way as humans.

Former foodstuffs stand out from the other examples in this publication as they are not co-products in the traditional sense. However, they demonstrate that at every stage of the food production chain the feed industry is able to offer solutions and make the best of the available resources.

> "Former foodstuffs resulting from food manufacturing can be processed into a high-quality feed that fits perfectly into a balanced diet for healthy animals. Food producers therefore have a consistent and sustainable outlet for any foodstuffs that are no longer suitable for human consumption, and can thereby reduce food wastage"

FOODDRINK EUROPE

Raw material

Manufactured food

Co-product

Processed former foodstuffs

Consumer products

Chocolate bars

Biscuits

Other co-products

Grape seeds and pulp

Co-product of the pressing of grapes for making wine or grape juice. A source of polyunsaturated fatty acids and beneficial antioxidants.

Cotton seed meal

Co-product of oil extraction from cotton seeds. Cotton seed meal is a good source of protein, however lower amino acid availability and presence of anti-nutrient gossypol.

Glycerine

Co-product from the production of fatty acids and esterification. An energy-rich feed material that is particularly suitable for dairy cows.

Palm kernel meal

Co-product of the palm kernel oil extraction process. A high-fibre medium-grade protein feed, most suited to ruminants.

Olive oil cake

Co-product from olive oil extraction. After being defatted and destoned, frequently used as pig feed in areas local to where olive oil is produced.

Groundnut meal

Co-product from peanut oil extraction. Has a high protein and oil content.

Feed beer

Beer that is not destined for human consumption.

Broken eggs

Broken eggs from hatcheries and egg packing stations are typically used to produce egg powder.

Other co-products

Fish trimmings

These include the food-grade parts left over after fish has been filleted, along with the frames (heads and backbones) and the viscera. Collectively, they make up about 54% of the fish meal used in Europe (2016, IFFO).

Linseed meal

Co-product from linseed oil extraction. The meal is protein-rich and contains omega 3 fatty acids.

Apple pomace

The solid residue that remains after milling and pressing of apples for cider, apple juice or puree production

Malt residuals/culms

Co-product from the malting industry. Provides a good source of protein, energy and fibre.

Wheat middlings

Made up of the elements of the wheat milling process that are not flour (screenings, bran, germ, flour remnants). Richer in digestible fibre and protein than flour itself.

Copra meal

Co-product from coconut oil production. Rich in fibre with mid-range protein levels.

Oat hulls

Co-product of oat rice or oat flake production. Very high fibre content, low in protein and energy. Widely used in the diet of some ruminants.

Hydrolysed feather meal

A protein-rich co-product from poultry processing operations (broiler, turkey and other). For food-producing animals in the EU only allowed in aquafeed.

FEFAC members

Active members

Organisation	Country	Member since
VFÖ	Austria	1995 (1964)
BFA	Belgium	1959
BFMA	Bulgaria	2013
CFIA	Croatia	2013 (2008)
CAFM	Cyprus	2004 (2003)
SKK	Czech Republic	2004 (2000)
DAKOFO	Denmark	1973
FFDIF	Finland	1995 (1993)
EUROFAC*	France	1959
DVT	Germany	1959
HGFA	Hungary	2012
IGFA	Ireland	1973
ASSALZOO	Italy	1959
LGPA	Lithuania	2005
NEVEDI	The Netherlands	1959
IZP	Poland	2004 (2001)
IACA	Portugal	1986 (1976)
ANFNC	Romania	2014
AFPWTC	Slovakia	2004 (2003)
GZS	Slovenia	2004
CESFAC	Spain	1986
FS	Sweden	1995
AIC	United Kingdom	1973

*EUROFAC took over from SNIA in 2016

Dates in brackets indicate 'Observer from'

Information correct as of 1 January 2018

Observer members

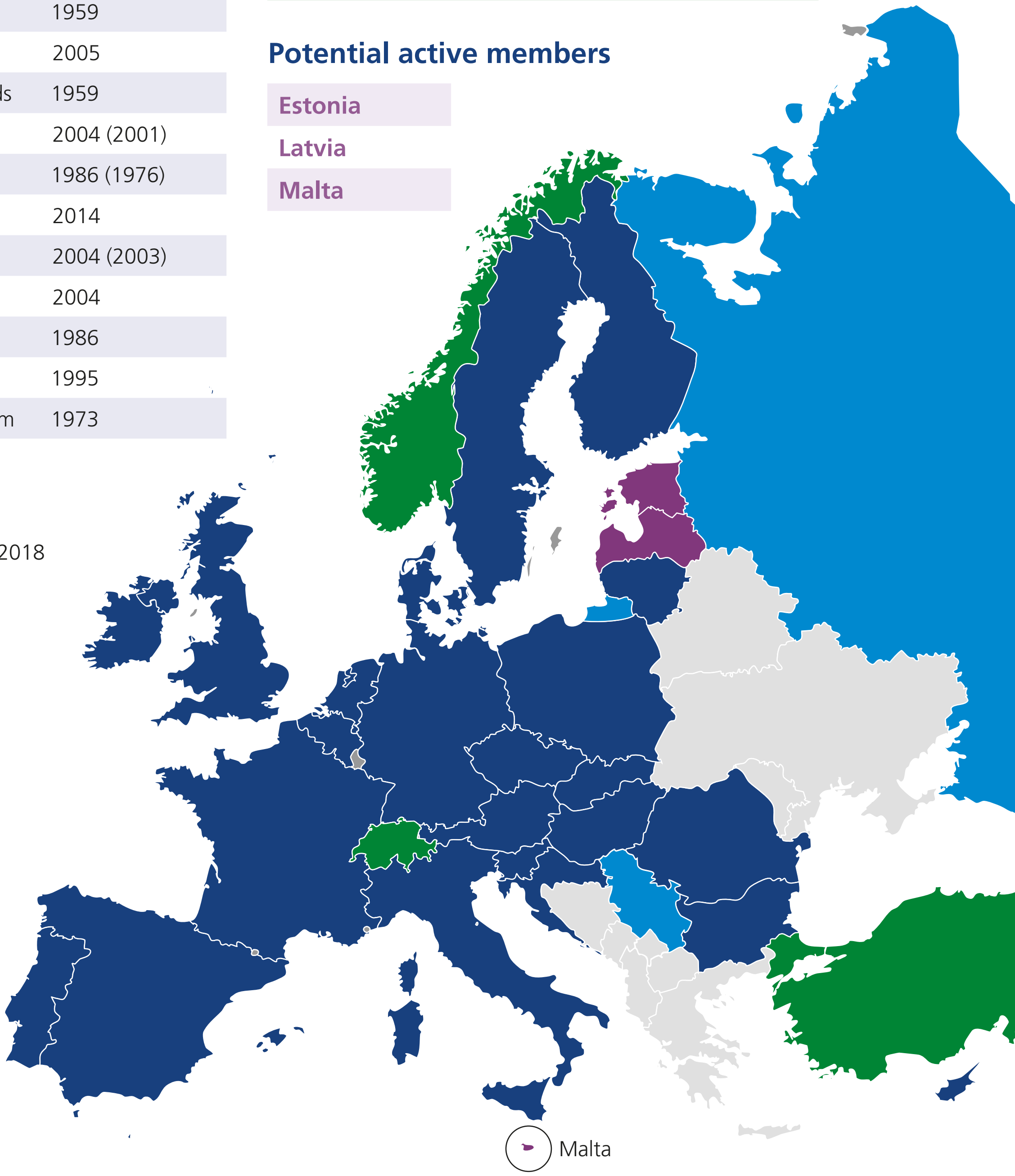
Organisation	Country	Member since
RUFM	Russia	2010
SFMA	Serbia	2009

Associate members

Organisation	Country	Member since
EFFPA		2014
EMFEMA		2003
NSF	Norway	2003
FKF AS	Norway	2014
Norkorn	Norway	2014
VSF	Switzerland	1966
TURKIYEM	Turkey	2014 (2005)

Potential active members

Estonia
Latvia
Malta



Co-products provide high-quality, nutritionally balanced animal feed for cattle, aquaculture, pigs, poultry and other sectors.

Resource efficiency champions

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