Legume quality requirements for fish feed

Legumes Translated

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The dependence on fish meal and oil obtained from wild fisheries raises serious risks to the development of aquaculture. Alternative raw materials are sought to minimise this threat. For years, agricultural products such as soya in a primary role and pea, faba bean or lupin in secondary role support this effort. Increasing their use remains a challenge that can offer European farmers a potentially high-value market for grain legumes. This note sets out the quality requirements of grain legumes for fish feed. The purpose is to support farmers and grain traders who wish to supply to this market.

Applicability

Theme: Quality requirements for fish feed

For: Grain legume growers and traders

Where: Grain legume cultivating & trading

Timing: Post-harvest

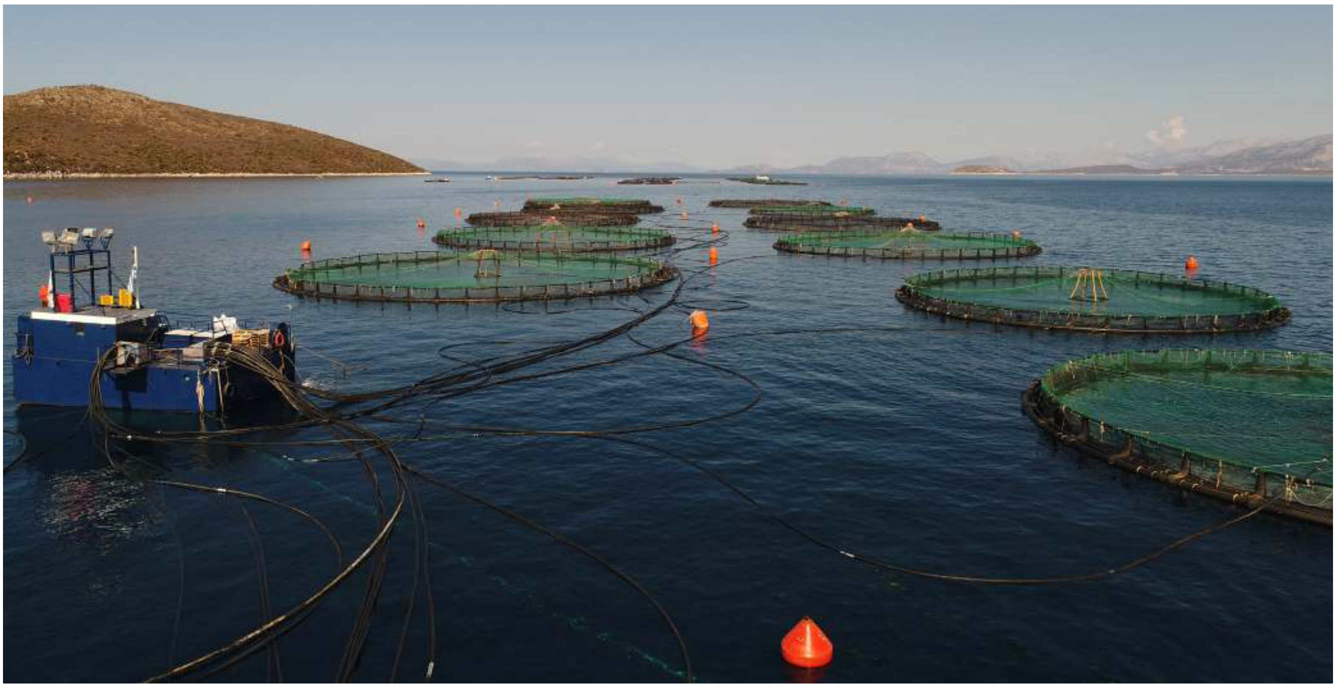
Equipment: Laboratory analysis

Follow up: No follow-up action required

Impact: Opportunity for grain legumes farmers to enter a new value chain

Outcome

The operation of an efficient market for grain legumes in aquaculture value chains helps growers and suppliers of grain legumes who are interested in supporting the fish feed industry. Understanding the requirements is the foundation of tailoring crop production and processing for this growing market. With this attention to quality requirements, European legumes can support the sustainable development of the European aquaculture sector. The sector has specialised requirements dictated by the physiology of farmed fish which, if met, can support premiums for farmers who meet these needs. This practice note presents the needs of the Mediterranean marine farmed fish, currently the top farmed fish produced in the European Union.



A fish farm in Greece

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Basic nutritional requirements

Mediterranean marine farmed (MMF) fish species are mainly carnivorous in nature and as such have high requirements for proteins and fats. Proteins are the main components of the fillet and fats are needed to cover the energy needs as well as the essential omega-3 and omega-6 fatty acids as much as possible. To achieve this, fish feed is typically 42–48% crude protein and 14–22% crude fat depending on the fish species and on the growth stage of the fish. MMF fish have a low capacity to digest carbohydrates and hence low requirements, which can be covered only by gelatinized starch from cereals. Crude fibre is indigestible and it is a critical limiting factor in selecting the raw material for fish feed (Figure 1). With these requirements met and with a proper feeding management on the farm, a high feed conversion rate (FCR) of 1.6 to 1.8 kg of feed fed per kg of fish produced is achieved in Mediterranean aquaculture today.

Grain legumes can significantly contribute to the protein needs and to the starch fraction of the fish feed, reducing the inclusion of cereals such as wheat. In the early days of aquaculture, fishmeal provided the foundation of the protein component of the diet. Replacing the fishmeal with legume-derived protein is a cornerstone of the sustainable development of the sector. With this shift to legumes, which in contrast to fishmeal, all contain starch, the starch processing characteristics are important, especially for grain legumes such as faba bean and pea. Furthermore, content and quality of starch are critical points for the extrusion process as fish feeds are extruded

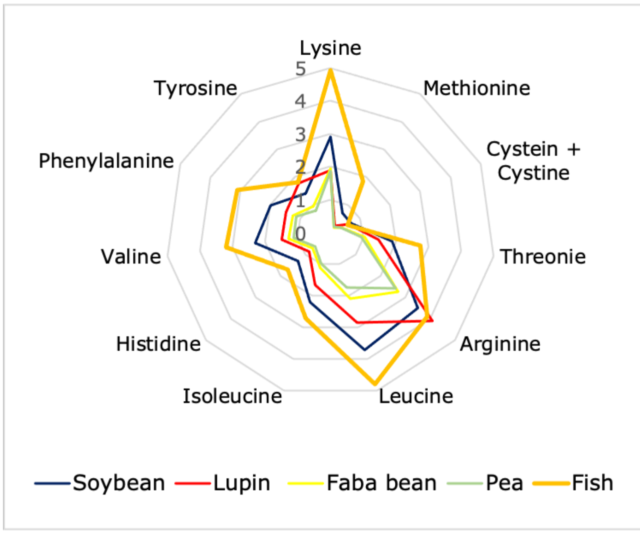

Figure 2. Essential amino acid profiles of grain legume meals and fish meal. Values are given as % content of the raw material.

feeds. In practice, this means that legume grains containing 25–45% protein and up to 40% starch could be included from about 8% to 25% in fish feed (Figure 3).

In addition to a high protein content, a balanced amino acid profile that meets the nutritional requirements of the fish is crucial for replacing fishmeal. Of the 20 amino acids, 10 are essential that fish cannot synthesise. Therefore, so-called essential amino acids must be supplied by the feed (Figure 2). Comparing the amino acid profile of fishmeal as a benchmark to that of a number of legumes, it is clear that legumes can supply varied quantities of essential amino acids. However, the concentrations are lower than in fishmeal. Among the essential amino acids, lysine and methionine are the first limiting amino acids.

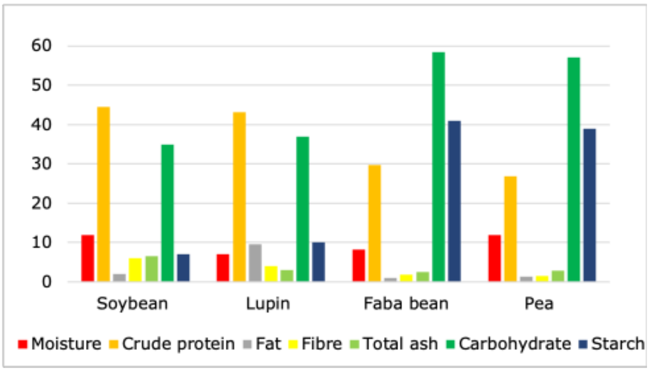

Figure 1. Constituents (%) of legume-based raw materials suitable for use in fish feed

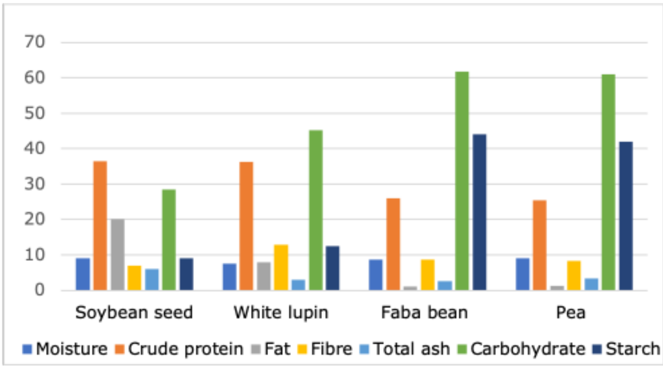

Figure 3. Constituents (%) of legume meals suitable for use in fish feed

Table 1. Trypsin inhibitor activity of seeds of different legume species

Scientific name	Common name	Trypsin inhibitor activity (U/g)
Phaseolus vulgaris	Kidney bean	3.10 ± 0.24
Phaseolus lunatus	Lima bean	5.89
Phaseolus acutifolius	Terapy bean	11.5 to 18.0
Cicer arietinum	Chickpea	8.10 to 12.1; 9.90 to 15.7
Lens culinaris	Lentil	7.40 ± 0.00
Pisum sativum	Pea	2.20
Vigna mungo	Black gram	0.61 to 1.03
Vigna radiata	Mung bean	1.83
Vigna unguiculata	Cowpea	7.52 ± 0.34
Vigna subterranea	Bambara pea	13.0
Vicia faba	Faba bean	4.47 ± 0.21
Glycine max	Soybean	94.1
Lupinus spp	Lupin	1.48 ± 0.04; 1.74 ± 0.07

Source: Aviles-Gaxiola et al., 2018

The special role of antinutritional factors (ANFs)

Legumes have chemical constituents which form a defence mechanism in the plant against diseases and consumption by animals. While they are beneficial in protecting the plant itself and some contribute to the flavour for human consumption, these substances have negative effects on the performance of livestock. These are what we call ‘antinutritional factors’ (ANFs) with ‘protease inhibitors’ (PIs) being the main part.

The most important PI is trypsin inhibitor (TI). Table 1 presents the trypsin inhibitor activity of different legume seeds. PIs impair protein digestibility and reduce the bioavailability of amino acids by inhibiting protein digestive enzymes. They can severely affect vital functions resulting in significant mortalities of farmed fish populations. In addition to direct impacts on the fish, there is a negative environmental impact due to increased nutrient emissions into the sea water. Indigestible plant components, such as non-starch polysaccharides present in high concentrations, increase faecal production and alter faecal properties.

Table 2. The content of different antinutritional factors (ANF) of feed grains as g/kg unless otherwise stated

Common species name	Processing state	Alkaloids	Lectins (U/mg)	Phytate	Protease inhibitors (ug/g)	Oligo-saccharides	Lignin	Saponins	Tannins	Polyphenols
Chickpea	Whole/ raw	-	ND	3.9-12.1	0.2-44.8	26-44	16.5-21.5	3.6-4.6	-	3.0-10.8
Faba bean	Whole/ raw	-	-	1.2-9.8	<0.2-12.8	34-54	2.0-5.0	13-39	0-15.0	0.03-0.37
Blue lupin	Dehulled	0.02	ND	5	6	89	2-22	0.573	0	3
White lupin	Dehulled	0.23	ND	4	6	78	7	ND	1	15
Yellow lupin	Dehulled	0.03-4.09	ND	7	3	102	7	ND	0	2
Pea	Whole/ raw	-	5.1-6.2	5.7-13.3	<0.2-11.1	24-66	0-3	0.7-1.9	0.07-7.50	0.09-0.92
Soybean	Solvent extr.	0.04	ND	9.0-19.5	1.8-10.0	55-99	-	49	0	5
Soybean	Cooked	-	ND	20.1	0.65	-	-	-	-	-
Soybean	Whole/ raw	0.29	5-20	8.0-20.1	0.2-86.1	40-88	-	56	8	5

Source: Glencross et al., 2020

In addition to PIs, a variety of other ANFs are found in legume seeds (Table 2). ANFs such as non-starch polysaccharides (raffinose, stachyose), phytic acid, saponins and alkaloids derived from legumes and from cereal glutens may reduce palatability and feed consumption. Once consumed, they absorb water and increase intestinal motility and feed passage, resulting in reduced nutrient uptake and increased nitrogen excretion into seawater.

Processing is necessary to meet the requirements

Grain legumes must be processed to tailor them for use in fish feed. Dehulling removes the outer coat of the seeds and with it a large proportion of indigestible fibre and anti-nutritional tannins in the case of faba bean (Figure 4). At the same time, this increases the protein concentration of the raw material. The oil content of soybean is higher than required and oil extraction is performed, which further increases the protein concentration of soybean meal. Different processes have been developed to inactivate or to reduce ANFs below threshold limits. The thermal treatments have become the most used since they can gradually and precisely reduce trypsin inhibitor levels. However, heat treatment is costly and may damage the nutrients, including protein. Alternative options have been developed such as fermentation, ultrasound, gamma irradiation, germination and soaking. In general, thermal treatments such as cooking or/and extrusion as well as chemical and biotechnological approaches such as fermentation are the most effective treatments currently used. Finally, milling homogenises the material, increases digestibility and improves the quality of feed that is fed as pellet.

Plant breeding also offers a solution to the challenge of ANFs. Cultivars of soybean with low TI content have been developed. The successful use of unprocessed soybean varieties with reduced content of TIs creates additional options for fish feed manufacturers while reducing the costs for thermal treatment.

Figure 4. Raw, dehulled and milled species Vicia faba (left) and species Lupinus albus (right)

A range of grain legume species can be used

Based on these requirements, the aquaculture sector can use a range of protein sources. All the major grain legume species can be used successfully. Soybean is the main crop used. Soybean products (soybean meal, soy protein concentrate etc.) are the ingredients that have successfully reduced the use of fish meal in fish feed diets over the last twenty years. Faba bean meal and pea (mainly as protein concentrate) are also used in substantial quantities along with smaller quantities of lupin and chickpea. Pea, chickpea and faba bean successfully replaced wheat in seabass diets resulting in improved growth performance.

Basic quality requirements

The quality requirements of MMF fish feed are determined by market status, processing mill specifications and nutritional performance. In particular, the quality parameters of legumes required for use in fish feed are:

1. Protein content: Protein content is the most important characteristic in determining the competitiveness of a raw material compared with other protein sources. Legume grains and products with a high protein content are preferred.

2. Protein quality: selection of species/cultivars with a balanced profile of essential amino acids and high protein bioavailability, i.e., protein that is easily hydrolysed in the presence of water and the digestive enzymes of the MMF fishes.

3. Low levels of anti-nutritional factors: low levels of PIs to ensure good function of digestive enzymes and high dietary protein bioavailability.

4. Content and quality of starch: This is a critical point for the use of legumes with protein concentrations below 35% e.g., faba bean and pea meal. Such legumes with high starch contents can be used in fish feed that include high protein raw materials like animal by-products to balance the protein level while covering the demand for starch for the extrusion process.

5. Moisture content: Grain moisture content of legumes delivered to a feed mill should not exceed 12%. In addition to reducing the stability of the grain in store, the moisture content has a large effect on dehulling, which is necessary to remove the indigestible fibres contained in the seed coat.

6. Impurities (foreign matter) content: The level of impurities in each batch (load) should not exceed 1.5% by weight. Impurities include fragments of the other parts of the crop, sand or stones, other seeds, etc. 1.5% is the upper limit to prevent price reductions due to contamination.

In addition, most fish feed producers exclude GMOs from the supply chain. Only non-GM legume crops are permitted for cultivation in the EU and so all crops legally grown in the EU meet this requirement.

Transportation, warehousing and delivery

Transportation is done by truck, either in bulks or in big-bags of 1-tonne each. The following should be ensured:

1. The load meets basic physical standards of moisture content and impurities.

2. Proof that the truck and loading equipment has not been used for genetically modified soya in at least the last three shipments.

3. Protection in store with temperatures below 22°C and relative humidity less than 75%.

4. In accordance with the domestic and European legislation, quality management systems and feed safety (ISO 22000:2005 HACCP) accompanying documents or certificates of analysis for heavy metals, mycotoxins & aflatoxins, dioxines & PCBs, pesticides residues and microbiological content are required before the first delivery.

Further information

Feedipedia. Animal feed resources information system, www.feedipedia.org/

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