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Aquafeeds

Antinutrients in plant-derived fish feed ingredients

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Some secondary plant compounds have beneficial effects at low levels

Although soybeans and other plants provide protein, their chemical make-ups also include antinutrients that can retard growth and affect

metabolic functions to some degree in fish and other aquaculture species.

An important limiting factor to the inclusion of some vegetable ingredients in aquafeeds is the presence of toxic secondary compounds, or antinutrients, in the ingredients. Information on the effects of these antinutrients on cultured aquatic species is limited, and additional research will be required to better utilize the potential of plant-derived materials in aquaculture feeds.

Major antinutrients

The major antinutrients in potential aquafeed ingredients of vegetable origin are glucosinolates, phytates, protease inhibitors, nonstarch polysaccharides (NSPs) and oligosaccharides, saponins, tannins, lectins and gossypols. Others include phytoestrogens, alkaloids, cyanogens, mimosine, cyclopropenoid fatty acids, canavanine, anti-vitamins and phorbol esters.

These substances are not involved in the primary metabolism of plants, but are synthesized by them, probably to deter herbivores and pathogens. Table 1 lists the antinutrients present in some plant-based feed ingredients.

Francis, Antinutrients present in some plant components, Table 1

Plant Material	Protein Level (% DM)	Antinutrients Present
Soybean meal	40	phytic acid, protease inhibitors, oligosaccharides, lectins, saponins, phytoestrogens, antivitamins, allergens
Rapeseed meal	36	glucosinolates (low in canola), phytic acid, protease inhibitors, tannins
Lupin seed meal	34	protease inhibitors, NSPs, saponins, phyto-estrogens, alkaloids
Pea seed meal	21	phytic acid, protease inhibitors, NSPs, saponins, tannins, lectins, cyanogens, antivitamins
Sunflower oil cake	32	protease inhibitors, saponins, arginase inhibitor
Cottonseed meal	43	gossypol, phytic acid, phytoestrogens, cyclopropenoic acid, antivitamins
Mustard oil cake	36	glucosinolates, tannins
Sesame meal	43	phytic acid, protease inhibitors
Leucaena leaf meal	29	mimosine
Alfalfa leaf meal	21	protease inhibitors, saponins, phytoestrogens, antivitamins

Table 1. Antinutrients present in some plant components.

Glucosinolates

Glucosinolates are thioglucosides commonly found in plants of the family Cruciferae (e.g., rapeseed). On processing, the breakdown products of these serious antinutrients – such as isothiocyanates and nitriles – may be even more harmful. The compounds retard growth and disrupt the thyroid structure and function in fish, even at low levels. Extraction with water and moist heat has been found effective in reducing glucosinolate levels.

Phytates

Phytates (hexaphosphates of myoinositol) are common in plant seeds, and account for most of their phosphorus content (60 percent in soybean meal). Resistant to fish enzymes, phytates reduce the availability of dietary phosphorus. They also chelate with divalent and trivalent mineral ions, resulting in unavailability of these ions. Phytates form complexes with dietary proteins and reduce their digestibility.

High-phytate diets can retard growth and cause abnormalities in the intestinal histology of various commonly cultured fish species. Phytate can be reduced by dehulling cereals. In addition, heating, fermentation, addition of the enzyme phytase and supplementation with zinc can also remedy high phytate content in fish diets.

Protease inhibitors

Protease inhibitors are very common among plants like legumes, averaging 4 milligrams per gram in commercial soybean meal. They inhibit the activity of the proteolytic enzymes trypsin and chymotrypsin, and hinder feed protein utilization. Moist heat treatment at 120 degrees-C for 15 to 30 minutes almost completely neutralizes protease inhibitors.

Polysaccharides and oligosaccharides

Nonstarch polysaccharides and oligosaccharides of the raffinose family are important constituents of a wide variety of grain legumes and cereals, sometimes forming 30 percent of their dry weight. In fish, they decrease feed intake and lower feed digestibility by binding to bile acids and minerals, or by obstructing the action of digestive enzymes and movement of digesta in the intestine.

Soluble NSPs are more detrimental to fish growth than oligosaccharides. They absorb water and form gum-like masses in the intestine, and increase the viscosity of intestinal contents. Feed extrusion at high temperature can improve carbohydrate digestibility in general. NSPs in diets can be neutralized to an extent by treatment with enzymes such as glycanase. Gamma ray irradiation also shows promise in lowering their content.

Some antinutrients in soybeans and other plants improve digestibility and counter each others' effects. Photo courtesy of American Soybean Association.

Saponins

Saponins are steroid or triterpenoid glycosides found in many plants such as legumes, with concentrations of about 50 milligrams per kilogram in various legume seeds. Dietary saponins above a level of 1.5 grams per kilogram can retard growth and damage intestinal mucosa in fish.

Saponins may also affect protein availability by forming sparingly digestible saponin-protein complexes. When added to water, they are highly toxic to fish, because of the damage caused to the respiratory epithelium of the gills by their detergent action. Extraction with water or gamma ray irradiation aid in the removal or neutralization of saponins.

Tannins

Tannins occur widely in the plant kingdom as hydrolysable and condensed tannins. They can interfere with digestive processes by binding to feed proteins, vitamins, minerals, and digestive enzymes. Limited information is available about their effects on fish, although dietary hydrolysable tannins have been found to retard growth.

Dehulling seeds, soaking and autoclaving, treatment with alkali, fermentation with lactic acid bacteria, treatment with oxidizing agents, and supplementation with the tannin-complexing agent polyethylene glycol are all measures that counteract tannins.

Lectins

Lectins or phytohaemagglutinins are found in many legume seeds, and can bind reversibly to carbohydrate moieties of complex glyco-conjugates on membranes. When present in the diet, they can damage intestinal mucosa in fish. Their effect may be more potent in the presence of other antinutrients. Lectins can be destroyed by moist heating.

Gossypols

Gossypols are polyphenols found in plants of the genus *Gossypium* (cotton). They cause such negative effects as growth depression, intestinal and other internal organ abnormalities, and unbalanced sex ratio in fish. The formation of indigestible gossypol-protein complexes can produce deficiencies for some essential amino acids, such as methionine.

Many studies, however, have reported satisfactory fish growth when diets containing as high as 50 percent cottonseed meal are fed, probably because “glandless” cottonseed meal with less than 0.01 percent gossypol was used.

Beneficial effects

Some of these secondary plant compounds have beneficial effects at low levels, For example, some saponins promote fish growth at low dietary levels. Saponins might increase the digestibility of carbohydrate-rich foods because of their detergent-like activity, which reduces viscosity and thus prevents the normal obstructing action of such foods against the movement of digesta in the intestine.

Cyclical, short-term inclusion of trypsin inhibitors with diets has been shown to increase protein digestibility and growth performance in carp.

Some antinutrients counter each others' effects. For example, saponin-tannin, tannin-lectin, and tannin-cyanogen interactions reportedly reduce their individual toxicity. Interactions between certain antinutrients, however, may increase toxicity.

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