

Optimizing Lecithins for Aquaculture Diets

(PL phospholipid; EFA essential fatty acid; PUFA polyunsaturated fatty acid; PE phosphatidylethanolamine; PI phosphatidylinositol; HUFA highly unsaturated fatty acid; PC phosphatidylcholine; PA phosphatidic acid)

Introduction

Phospholipids are important nutrients to fish and shrimp at all stages of growth and they are routinely included in aquaculture diets in the form of crude lecithins. This report discusses how the physical and nutritional functionalities of these important biochemicals can be optimized.

Chemistry

Lecithin is a complex mixture of various phospholipids and neutral lipids. It is mainly extracted from soya beans as a by-product of the vegetable oil and protein industry. It has a typical composition as follows:-

Component	Weight %
Phosphatidylcholine	13.9%
Phosphatidylinositol	9.8%
Phosphatidylethanolamine	10.3%
Phosphatidic acid	4.0%
Other phospholipids	2.0%
Neutral lipids	60.0%

Commercially available lecithins contain varying ratios of each particular phospholipid component, variable overall phospholipid content. Crude lecithins are viscous liquids and are generally powderized onto a number of carriers at a range of concentrations.

The abundance of each phospholipids component in a lecithin varies according to source. For example, soya beans grown in the Mississippi Delta typically contain higher levels of phosphatidylcholine than those varieties cultivated in Brazil. The overall percentage of the lecithin that is phospholipid (as opposed to neutral lipids/oil) varies according to the extraction process (e.g. hot-oil or CO₂ degumming etc). Additionally, lecithins derived from plant species other than soya have very different phospholipid profiles and a variety of chemical processes can be used to alter these characteristic profiles.

Typical Products

Companies that sell powder lecithin products into the aquaculture industry typically use the cheapest carrier available. The concentration of crude liquid lecithin that is available in a powderized product will depend on the technical properties of these carriers as well as commercial factors.

The choice of carrier will also affect the flowability of the product during storage and feed manufacture, the dispersion of the phospholipids in the animal and may

contribute to the animal nutrition in other ways. For example, calcium carbonate is a good source of important Ca^{2+} whereas calcium silicate is not.

For example, Degussa 'XCG25' is a 40% crude lecithin product powdered with dried milk whey, it has the following phospholipids profile:-

Component	Weight % of Phospholipid Component	Weight % of Lecithin Component	Weight % of Overall Product
PC	32.9%	12.3%	4.9%
PI	22.5%	8.4%	3.4%
PE	14.7%	5.5%	2.2%
PA	5.0%	1.9%	0.8%
Other PL	24.9%	9.4%	3.7%
Neutral Lipids		62.5%	25.0%
Carrier			60.0%

Optimizing Nutrition

In order to optimize any phospholipid additive an understanding of both phospholipid chemistry and the nutritional requirements of the target species is essential.

Research available in the literature indicates that phospholipid requirements often vary from species to species. For example, while the PL requirement for most fish and crustaceans is approximately 1-4% of net dry weight, freshwater prawns do not require PL in their diet at all.

However, there are some well-established trends that have been observed across a number of species.

Fish

The first trend is that the larval stages of growth are highly sensitive to dietary levels of PL [1,2]. For example, PL deficient diets caused mortality in sea-bream juveniles [3]. A requirement for PL has been established (for at least part of the life cycle) in: -

- Turbot [4]
- Salmon [5]
- Carp [6]
- Arctic charr
- Trout [7]
- Sea-bass [8]

Another trend is that all of the larval, juvenile and adult fish that have been studied appear to require only the phosphatidylcholine [9] and phosphatidylinositol [10] components of lecithin. No known nutritional benefits of the remaining fractions, such as PE or PA, have been documented.

The third trend appears to involve the utilization of essential fatty acids in the diet. Utilization of dietary EFA is highly correlated to dietary PC [11]. Some researchers believe that PC is involved in the intestinal absorption of fatty acids, but the mechanism is unknown [12]. One possible mechanism is that PC is acting as an emulsifier for EFA's. Another theory is that EFA derived lipoprotein formation is

driven by the presence of PC. A third possibility is that EFA's are able to inter-esterify with PC preferentially and are subsequently absorbed during PL turnover. Finally, choline and inositol have a direct nutritive value and PC and PI are sources of these vital functional groups with very high bioavailability. Regardless of the mechanism it seems clear that PC is important for fish development, especially in larvae and juveniles

Shrimp

Total PL content recommended for growing shrimp is 2-4% of net weight diet. Studies have shown that PC is especially important to the growth of shrimp as it is an essential component of very high density lipoprotein synthesis [13]. PC is also able to act as an acyl donor for the lecithin-cholesterol acyltransferase to manufacture cholesterol ester.

Studies also indicate that HUFA's may inter-esterify with PC and become better absorbed and transported. It has been argued that better absorption of HUFA's may translate into an economic advantage for shrimp farmers using high PC diets. With increasing levels of soybean PC, higher proportions of 20:1 n-9 EFA and total n-6 PUFA were found in shrimp tissue. Increasing PC reduced saturated fat deposition and increased EFA deposition.

The two phospholipids specifically required for shrimp growth are PC and PI [14].

Conclusions

From the literature studied in this report, it can be concluded that: -

- In most fish and shrimp species so far studied there is a requirement for PL. Specifically PC and PI appear to be highly correlated to growth and survivability.
- It seems likely that although fish and crustaceans are able to synthesize PL, the supply of PC and PI needs to be augmented for optimal growth performance: consumption exceeds supply in farm situations.
- The species of fish and shrimp studied all benefit from PC and PI supplementation especially during rapid growth.
- Although little data is available on some adult fish species it would be surprising if these species were exceptional in their PL requirements.

The Way Forward

It is proposed that the dietary value of lecithin-based additives for aquaculture diets can be improved by the following ways: -

Phospholipid enhancement

Phospholipid enhancement can be achieved in two ways. First the overall level of inclusion on the carrier can be raised and secondly, the levels of PI and PC can be enhanced.

Standardization

Quality control parameters should include total phospholipid content and individual phospholipid fractions.

Improvement of carrier

Carrier should permit heavy loading of lecithin, good flowability and contribute to the functionality of the product

Inclusion of co-factors

These could include enzymes associated with phospholipid metabolism, co-factors for these enzymes and EFA's

Bio-50 Product Range

The development of the Bio-50 range has addressed these issues and has a typical standardized formulation:-

Phospholipid	Weight %	Improvement over example product%
Phosphatidylcholine	6.6%	+35%
Phosphatidylinositol	4.7%	+38%
Phosphatidylethanolamine	4.4%	+100%
Phosphatidic acid	1.8%	+125%
Other phospholipids	3.8%	+3%
Total Phospholipid Content	21.3%	+42%

Other formulations including NGM are available as either powder or liquid products.

The Bio-50 carrier is a mixture of calcium carbonate and calcium silicate. The silicate component contributes to the physical properties of the product and the carbonate provides free Ca^{2+} that act as both a source of calcium and acts as a co-factor for phospholipases and acyltransferases.

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