Interest in using algae as fish feed ingredients

In recent years there has been great interest in the potential of algae as ingredients in aquaculture feeds. Even a cursory Internet search of the topic will find numerous web sites describing studies of the nutritional value of algae, or touting the potential of algae as a feed ingredient, or even announcing the launch of new aquaculture feeds made with algae as ingredients, although technical information about the products may be conspicuously absent. All this attention is largely driven by the need to find replacements for fish meal and fish oils, as awareness grows of the unsustainability of the practice of feeding wild-capture fish to support a rapidly growing farmed fish industry. Demand for aquaculture feeds that provide the high nutritional value found in fish meal and oils is also spurred by the expansion of aquaculture of high-value fish such as Sea Bass, Sea Bream, Red Drum, Seriola, Grouper, etc. These carnivores require high-quality protein and omega-3 fatty acids in their diets, nutrients that are difficult or impossible to supply from conventional plant-based feeds.

Why Algae?

Algae, including both macroalgae ("seaweeds") and microalgae (e.g. phytoplankton), are the base of the aquatic food chains that generate the nutritional resources that fish are adapted to consume. Certain algae are already recognized as premium aquaculture feeds, for both direct feeding and to produce zooplankton (e.g. rotifers, copepods, Artemia) for fish and shrimp larviculture, and for bivalve larviculture. So it is not surprising that many algae are nutritionally superior to the land plants used in formulated aquaculture feeds.

Which Algae?

It is often not understood that the term "algae" commonly refers to what is really an arbitrary grouping of organisms that encompass a bewildering variety of forms, and an even more bewildering biochemical diversity. Algae may vary in the properties of their cell walls, which can impede digestion or extraction of nutritional components, presence of toxins or anti-nutritional factors, as well as desirable nutritional components. It is therefore impossible to make meaningful generalizations about the nutritional
value of this extremely diverse group of organisms, so it is always necessary to consider the particular qualities of specific algae.

Nutritional value of Algae

Protein

Fish meal is so widely used in feeds largely thanks to its substantial content of high-quality proteins, containing all the essential amino acids. A critical shortcoming of the crop plant proteins commonly used in fish feeds is that they are deficient in certain amino acids such as lysine, methionine, threonine, and tryptophan (Li et al. 2009). By contrast, analyses of the amino acid content of numerous macro- and micro-algae have found that they generally contain all the essential amino acids (Brown et al. 1997, Dawczynski et al. 2007, Ortiz et al. 2006, Rosell & Srivastava 1985, Wong & Peter 2000).

Lipids

Certain fish oil lipids, called “PUFAs” (polyunsaturated omega-3 and omega-6 fatty acids), have become highly prized for their contribution to good cardiovascular health in humans. But it is not always appreciated that these “fish oil” fatty acids are in fact originated by algae at the base of the aquatic food chain. These desirable algal fatty acids are passed up the food chain to fish, and they are indeed essential nutrients for many fish.

Algae have been recognized as an obvious alternative source of these “fish oil” fatty acids for use in fish feeds (Miller et al. 2008), especially eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), and arachidonic acid (ARA). There is a substantial literature devoted to analysis of the PUFA content of microalgae, particularly those used in aquaculture, because they have long been recognized as the best source of these nutrients that are essential for production of the nutritious zooplankton necessary for the first feeding of larval fish (Holt 2011), as well as filter-feeding shellfish.

Tests of Algae in formulated fish feeds

Various species of macroalgae and microalgae have been incorporated into fish feed formulations to assess their nutritional value, and many have been shown to be beneficial for fish such as Tilapia (Tartiel et al. 2008), Korean Rockfish (Bai et al. 2001), Sea Bream (Yone et al. 1986, Mustafa & Nakagawa 2003).
1995), European Sea Bass (Valente et al. 2006), Striped Mullet (Wassef et al. 2001), Gilthead Sea Bream (Wassef et al. 2005), Atlantic Cod (Walker et al. 2009, 2010), and Salmon (Norambuena et al. 2015). But unfortunately, it is often impossible to determine the particular nutritional factors responsible for these beneficial effects, either because no attempt was made to do so, or due to the poor design of the studies.

In recent years there has been great interest in the potential of algae as a biofuel feedstock, and it has often been proposed that the protein portion remaining after lipid extraction could be a useful input for animal feeds (e.g. Chen et al. 2010). However, the algae chosen for biofuel production may not be optimal for use as a feed input, and the economic pressure for the lowest-cost methods of fuel production can result in protein residues with contamination that makes them unfit for use as feed (e.g. Hussein et al. 2012).

Choosing the right Algae

Just as it would be senseless to arbitrarily substitute one conventional crop plant for another (e.g. potatoes for soybeans) when formulating a feed, the particular attributes of each alga must be carefully considered. In addition to the protein/amino acid profile, lipid/PUFA/sterol profile, and pigment content, there are important additional considerations. The type and quantity of extracellular polysaccharides, which are very abundant in certain algae, can interfere with nutrient absorption, or conversely be useful binding agents in forming feed pellets. The thick cell walls of microalgae such as Chlorella can prevent absorption of the nutritional value of the cell contents. Inhibitory compounds such as the phenolics produced by some kelps, and brominated compounds produced by red algae, can render an alga with an excellent nutritional analysis unsuitable for use in a feed. Depending on growth and processing conditions, algae can contain high concentrations of trace elements that may be detrimental.

Economic constraints

Despite the high nutritional value provided by some algae, their adoption as ingredients for aquaculture feeds remains constrained by the high cost of production and processing. Recent economic analyses (Beal et al. 2015, Maisashvili et al. 2015, Voort et al. 2015) provide useful insights toward understanding how technological progress and market forces will determine whether algae will soon become significant inputs into the aquaculture feed market. Such factors as the current moderation in fishmeal prices (Byrne 2017) will continue to have a strong influence on how rapidly such changes in feed formulation are adopted by the aquaculture industry.

More information

Eric Henry, Ph.D., Research Scientist, Reed Mariculture Inc.
E: techsupport@reedmariculture.com

References available by request.