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Algae in Formulated Feeds

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Abstract

There is currently a drive to exploit algae in formulated animal feeds, both for aquaculture species and terrestrial livestock. Different strains of micro and macroalgae vary in their efficacy within formulated animal feeds, although there is sufficient evidence of good nutritional properties to promote algal biomass as a source of micronutrients or as a bulk feedstuff. This study reviewed the presence of several compounds in algae which have confounding effects, providing a source of protein, amino acids, fatty acids, vitamins and minerals, and other biologically active phytochemicals.

Key Words : Aquaculture, Formulated feeds, Macroalgae, Micronutrients and Phytochemicals,

Introduction

To date, technological developments and commercial applications have mainly focused on algae as a micro-feed ingredient, imparting specific beneficial properties rather than gross nutrients to the recipient animal. However, finite supplies of premium raw materials (particularly fish meal and fish oil) and the promise of much higher available quantities of algal biomass in future are prompting evaluation of algal biomass as a major ingredient in formulated animal feeds, especially for aquaculture.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. Careful study of the properties of numerous algae will be necessary in order to optimally exploit the great potential offered by this diverse group of organisms. But it is already apparent that algae will play an important part in the effort to move the formulation of fish feed “down the food chain” to a more sustainable future.

Various species of macroalgae and microalgae have been incorporated into feed formulations for Aquaculture and Terrestrial Livestock. Unfortunately, it has rarely been possible to determine the particular nutritional factors responsible for these beneficial effects, either because no attempt was made to do so, or poor design of the study. Often the algae chosen for fish feeding studies appear to have been selected largely for convenience, because they are low-cost and commercially available.For example,microalgae such as *Spirulina, Chlorella* and *Dunaliella* can be produced by low-cost open-pond technologies and are marketed as dry powders, and their nutritional profiles are well-documented. Macroalgae such as the kelps (*Laminaria*, *Undaria* and *Durvillea)*, and the brown rockweed (*Ascophyllum)* occur in dense stands that can be harvested economically, and use as sources of iodine and animal feed additives to supply trace elements.

Based on the results from experimental studies it was interpreted as several compounds in algae can have amazing effects, providing a source of protein, amino acids, fatty acids, vitamins and minerals, and other biologically active phytochemicals (Becker 2004, Gouveia et al. 2008).When used in feeds, algae have been attributed with enhancing stress resistance (Nath et al. 2012), immune system (Turner et al. 2002), antiviral and antibacterial action, improved gut function (Michiels et al. 2011) and lipid metabolism (Guroy et al. 2011). Due to the need of large amount of biomass, nutritional studies evaluating algae as a major feed ingredient for farmed animals are currently fewer. Thus the algal biomass(extracts are not considered as an essential feed source in most cases, but rather as enhancing standard feed formulations. Algae acts as a Supplement to Enhance the Nutritional Value of Formulated Feeds in the fallowing manner.

Vitamins and Minerals

Both micro and macroalgae have potential as mineral additives to replace the inorganic mineral salts that are most commonly used in the animal feed industry. It has been suggested that the natural forms are more bio-available to the animal than the synthetic forms and can be manipulated through bio-absorption (Doucha et al. 2009). When salmon fed with mineral rich seaweed along with commercial salmon feeds , the salmon appeared to be healthier, more active; flavour and texture were improved which may have been due to the bromophenolic compounds found in seaweeds (Kraan and Mair, 2010). Enteromorpha *prolifera* and *Cladophora sp*., when added to the feeds of laying hens, positively influenced egg weight and egg shell thickness (Michalak et al. 2011).The vitamin content of algal biomass can vary significantly among species. Ascorbic acid shows the greatest variability due to differences in processing, drying and storage of algae, as ascorbic acid is very sensitive to heat (Brown and Miller,1992). There is too much variability arising from the combined effects of different algal species, growing season, culture conditions and processing methods to reliably supply the required micronutrients in a pre-determined fashion. Algal biomass mainly offers a supplementary source rather than a complete replacement for manufactured minerals or vitamins in animal feeds.

Protein

The analyses of the amino acid content of numerous algae have found that although there is significant variation, they generally contain all the essential amino acids. Surveys conducted by Lourenco et al. 2002 (19 tropical seaweeds) and Dawczynski et al. 2007 (34 edible seaweed products) found that all species analysed contained all the essential amino acids, and these findings are consistent with other seaweed analyses (Ortiz et al. 2006). Brown et al., 1997, exemplified a comprehensive study of 40 species of microalgae from seven algal classes that found that, all species had similar amino acid composition, and were rich in the essential amino acids.

Several authors raised the potential effects of algal cell wall structure on digestibility to animals (Becker, 2004). Skrede et al., 2011 reported digestibility trial with salmon and other farmed monogastric species. Three microalgae, *Nannochloropsis oceanica, Phaeodactylum tricornutum* and *Isochrysis galbana*, were included up to 24 % dry weight in the feed. The protein digestibilities determined by linear regression for *N. oceanica*, *P. tricornutum* and *I. galbana* were found to be 35.5%, 79.9%, and 18.8 % respectively. Janczyk et al. 2007 tested the digestibility of spray-dried, spray-dried - electroporated and spray-dried - ultrasonicated *Chlorella* biomass in rats. Ultrasonication was found to increase the protein digestibility of *Chlorella* (63 %).

Burr et al. 2011, observed protein digestibility of 82 % and 84.7 % for the two fish species Arctic char and Atlantic salmon when digestibility coefficient of solar dried *Spirulina* biomass at 30 % dietary inclusion level has been tested. These relatively high digestibility coefficients compare favourably with terrestrial plant ingredients, confirming the high potential of *Spirulina* as a protein source for farmed fish. Nandeesha *et al*. (2001) observed improved growth rates for Indian carp fry with increasing levels of *Spirulina platensis* in feeds. In contrast, Coutinho et al. 2006, reported a negative effect on growth and survival of goldfish fry when supplementd feeds with freeze dried biomass of *Isochrysis galbana*, as a substitute for fish meal protein. One of the reasons may have been that the feeds were not iso-nitrogenous; dietary protein levels decreased with increasing algae inclusion level and it is known that protein is a limiting factor, especially in the small fast growing larval stages. Silva-Neto et al. 2012 have suggested that kelp meal works as an excellent additive in pelleted feeds for penaeid shrimps and thus improved feed utilisation efficiency in this slow feeding species. Valente et al. (2006) recommended that macroalgae such as *Gracilaria* and *Ulva* can be incorporated in sea bass feeds without affecting the performance of fish.

Arieli et al. 1993 indicated that seaweed could be categorised as a low-energy high-nitrogen feedstuff in ruminants based on performance parameters of lambs when fed *Ulva lactuca*. Ruminants are unable to digest the carbohydrate fraction of *Chlorella sp.* and *Scenedesmus sp.*, which may have been due to the specific characteristics of these algal strains (Hintz et al.1966).

Taurine

Taurine is the non-protein sulphonic acid , which is sometimes lumped with amino acids in discussions of nutrition.Taurine is usually an essential nutrient for carnivorous animals, including some fish, but it is not found in any land plants. However, although taurine has been less often investigated than amino acids, it has been reported in significant quantities in macroalgae such as *Laminaria,* Undaria, and *Porphyra* (Dawczynski et al. 2007) as well as certain microalgae, for example the green flagellate *Tetraselmis* , the red unicellular alga *Porphyridium* (Flynn and Flynn 1992), the dinoflagellate, *Oxyrrhis* (Opik and Flynn, 1989), and the diatom *Nitzschia* (Jackson et al. 1992).

Pigments

Most species of farmed fish display pigmentation of the skin rather than the flesh, which contributes to their attractive appearance and thus satisfies customer demand. Farmed salmon fish require supplementation of dietary astaxanthin to achieve the pink colour of the fillet. Synthetic carotenoids are mainly used for this purpose in commercial aquaculture, although algae-derived carotenoids can also impart pigmentation effectively (Soler-Vila et al. 2009). Astaxanthin obtained from Haematococcus pluvialis has been approved as a colour additive in salmon feeds and is typically used for organically certified salmon production. Algal carotenoids have been successfully used to augment the yellow skin colouration in gilthead sea bream (Gomes et al. 2002). Spirulina is used as a source of other carotenoids that fishes such as ornamental koi can convert to astaxanthin and other brightly coloured pigments. (Zatkova et al. 2011). The orange colour of the gonads of sea urchins was enhanced by *Ulva* sp. and *Gracilaria* sp. in feeds (Shpigel et al. 2005).

Seaweed biomass has been reported to increase the pigmentation of egg yolk when used in a dietary inclusion (Strand et al. 1998). Chlorella vulgaris biomass produced yolk pigmentation comparable to other commercially used pigments (Gouveia et al. 1996). *Chlorella vulgaris* (Halle et al. 2009) and *H. pluvialis* (Waldenstedt et al. 2003) has good potential in improving the health status of laying hens with improving egg quality and pigmentation.

Lipids

Algae have been recognised as an obvious alternative source of fish oil fatty acids for use in feeds , especially eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), and arachidonic acid (ARA). Relatively few studies have been carried out to date to evaluate microalgal lipids in feeds for farmed fish (Ganuza et al. 2008). Algae can directly produce HUFA (highly unsaturated fatty acids) such as arachidonic acid (Porphyridium), eicosapentaenoic acid (*Nannochloropsis, Phaeodactylum, Nitzschia, Isochrysis, Diacronema*) and docosahexaenoic acid (*Crypthecodinium, Schizochytrium*). Most of these algae are not suitable for direct human consumption, they might indirectly boost their nutritional value for humans if added to animal feeds. Despite the typically low lipid content of seaweeds, Dantagnan et al. 2009 reported that *Macrocystis pyrifera* meal enhanced the level of poly unsaturated fatty acids in trout flesh, when included in the diet. Micro and macroalgae have been tested as alternatives to fish oil for boosting the HUFA content of hen's eggs (Kassis et al. 2010).

Raw materials other than fish meal are selected for their nutritive value, balance of amino acids, digestibility of proteins, lipids and quality of fatty acids, availability of algal biomass is being considered as one of the alternative ingredients of the future (Lupatsch 2009).The costs of fish meal and fish oil are increasing steadily. Thus, if a source of protein-rich or lipid-rich algal meal came onto the market at an affordable price, the animal feed industry would certainly consider it based on existing evidence of the nutritional value of algal biomass.

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