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Abstract

This review commences by briefly describing the importance of microalgae as a potential feed ingredient in the fish diet. Microalgae are a source of nutrients for fish as well as shrimps. Live microalgae for feeding are being practised in the aquaculture for long ago; but the concerns of using this technique are economics, preservation and storage. It is suggested that instead of using microalgae as live feed, dried microalgae can be used in the feed. It has been noticed that, dried microalgae have a capacity to alleviate those major problems inherent with live microalgae for feed and its suitability to replace the conventional protein ingredients in the fish. Moreover, the production system for freeze dried non-living microalgae is commercially available which ensures the cost efficient dried microalgae will be easily accessible in the market for feed application in animals. The review also highlighted some of the recommendations for future research.

Introduction

Microalgae are tiny organisms composed of nutrients such as carbohydrates, proteins, lipids, micro-nutrients and other biologically active components. They are further rich in colouring agents such as beta carotene, made it to be used for cultivable fishes like salmon and other ornamental fishes to enhance the colour of fish. In general, fish consume it to attain nutrition and other biologically active substances. Using live microalgae in the feed of fishes are very old technique in the aquaculture. It is being mass cultured and used as a live feed for many years. Despite, live microalgae are important to fish, they are not a good choice to the farmers due to its difficulties in manufacturing, drying and storing them (Borowitzka, 1997; Becker, 2004). Due to these disadvantages, live microalgae are criticized and so make farmers reliant on the ready-made usage of commercial feed for the fishes. It is suggested that dried microalgae in the feed can potentially lessen the usage of other demanded ingredients for aquaculture.

Management of aquaculture practices is dependence on cost effective, better-quality ingredients and feeds. Recent years, fish meal and the other main ingredients used in aquaculture are limiting; thus, feed formulators are looking for substitute ingredients. Newly, the costless, improved qualities of dried microalgae are commercially accessible in the market which will entice feed formulators to be incorporated this in the artificial feed (Muller, 2000; Borowitzka, 1997). Current research is relying on the biotechnological approaches to further improving the quality and cost effective freeze-dried microalgae production for its sustainable usage in the fish feeds.

Commonly used microalgae

Despite, thousands of microalgae exist on the earth; only few strains are used in the aquaculture. This is due to differences in the culturing techniques, toxicity, nutritional importance, shape, size and digestibility (Raja *et al.,* 2004b; Patil*et al.,* 2007). The species such as *Isochrysis, Tetraselmis, Chlorella, Pavlova, Chaetoceros, Phaeodactylum, Skeletonema, Thalassiosira* and *Nannochloropsis* are frequently cultured for animal feed. According to Spolaore *et al.,*(2006) most of the commercially cultivable marine fishes retrieve nutrition principally from the microalgae such as *Nannochloropsis sp.*, *Pavlova sp.* and *Isochrysis sp.* It is commonly practiced by using the mixture of different microalgal strains for feeding by saying that they are more nutritionally balanced than single strain; thus, resulting in further improvement in the quality and growth performance of the animal.

Nutritional profile of microalgae

It is the fact that microalgae possess adequate amounts of biologically active nutrients (Pulz& Gross, 2004; Becker, 2004, Gouveia *et al.,* 2008). They are nutritionally enriched with micronutrients and carotenoids as well. They are also rich in high-quality proteins, amino acids and fatty acids such as docosahexaenoic (DHA), eicosapentaenoic (EPA) and arachidonic acid (AA) which are prerequisite to the animal health (Nell *et al.,* 1991). Omega-3 fatty acids and amino acids are the major demand for animal feed as well as pharmacological industries. A key advantage of focusing on microalgae as an ingredient is due to their higher nutrient profile; including omega-3 fatty acids and the presence of essential amino acids. The table shows the nutritional profile of some selected microalgae as compared with high quality fishmeal.

Comparative nutritional profile of microalgae vs. high quality fishmeal (%)

	Nannochloropsis oceania	*Isochrysis galbana*	*Phaeodactylum tricornutum*	High quality fishmeal
Crude protein, %	47.7	20.1	49.0	74.7
Crude fat %	8.4	16.2	7.4	9.7
EPA, C20:5	2.3	0.08	2.8	1.5-2.0
DHA, C22:6	-	1.6	0.02	0.7-1.3
Amino acid profile (g/16 g N)				
Lysine	4.8	3.1	4.2	6.8
Methionine	1.8	2.5	2.0	2.5
Tryptophan	1.7	2.5	1.3	0.7
Threonine	3.6	4.6	3.7	3.5
Valine	4.6	6.1	4.6	4.0
Isoleucine	3.5	5.1	3.8	3.7
Leucine	6.7	9.2	6.2	6.2
Phenylalanine	3.9	5.7	4.2	3.3
Arginine	4.9	4.1	4.4	5.4

Source**:** Overland (2012), Becker (2004), Raja *et al*., (2004).

Scope of microalgae in fish diet

Around 30% of the algae production is utilized in the animal feed. The nutritional and toxicological evaluations have proved the suitability of algal biomass as a feed supplement (Becker *et al.,* 2004). According to Spolaore *et al.,* (2006) consumption of microalgae is linked to supplementation of nutrients, antioxidants and polyunsaturated fatty acids (PUFA). Microalgae are naturally adequate with omega 3 fatty acids. During early larval stages, animals need more omega-3 fatty acids. Many studies showed the essentiality of microalgae in the fish hatcheries as the small fish larvae are efficiently utilizing this as a feed. Apart from the role in nutrition, it also acts as a colouring agent to improve the coloration in the fishes. Commonly used feed ingredients is lacking with the carotenoid pigments such as astaxanthin. Hence, in salmon and other ornamental fish feeds its inclusion will be particularly important.

Study attempts of microalgae as fish feed ingredient

Some efforts have been made by shifting animals from live microalgae to dry microalgae. Coutteau *et al.,* (1993) suggested that the products of marine algae in the feed can potentially replace requirements of protein sources. It has been proved that aquaculture and livestock diets containing dried microalgae as an ingredient enhanced the immunity (Turner *et al.,* 2002), antibacterial and antiviral effect (Michiels *et al.,* 2012), lipid metabolism (Nakagawa, 1997; Guroy *et al.,* 2011), stress mitigation (Nath *et al.* 2012; Sheikhzadeh *et al.,* 2012).

A report from the Kyle *et al.,* (1991) indicating that animals fed with microalgae in the diet clearly improved the weight, immunity, fatty acids, vitamins and mineral profiles. Also, a report from the Azaza *et al.,* (2008) showing that tilapia feed formulated with microalgae as ingredient augments the protein efficiency and growth performances. Besides these, Enright *et al.,* (1986) noticed increased growth rates in the shrimp when shrimp feed were supplemented with *Hypnea cervicornis* and *Cryptonemia crenulata*. Feed prepared with Arthrospira which contains 5% to 20% of carotene pigments improves the colouration in the carp. It wasalso established that the supplementation of Spirulina meal @ 0.5% in shrimp feed act as a potent feeding attractant (Montaini *et al.,* 1995).

Commercial production systems

Microalgae can be manufactured almost in a wide variety of environments, even the place where the land and/or water is nil (Raja, 2009). It is produced worldwide for a variety of purposes. Production of algal products in the world is 5 million kg/year. Among that 1 million kg is used for aquaculture purposes (Muller-Feuga, 2004). In the past, culture of microalgae had discrepancy in the cost of production, quality, preservation technique and storage which significantly prevents this for aquaculture applications. However, the substantial advancements have been made over the last five decades for the commercial production systems of culturing microalgae. Continuing research discovers the sophisticated tools such as large-scale biocoil type tubular photobioreactor for the large-scale production of the greater yield of microalgae, which ensures their reliable, sustainable usage to aquaculture. The development also made in order to concentrate, dry and preserve the algal biomass. In addition to the events raised in the photobioreactors for large scale production, post harvesting and processing tools like spray-dryer and algal biomass concentration were developed for the development of freeze-dried microalgae which have more shelf life which will make microalgae as one among the major fish feed ingredient. So, in the future, it would be expected that microalgae can be a potential feed ingredient in the aquaculture.

Conclusion

Microalgae can meet all criteria to be a part of the major fish feed ingredient. However, its supplementation in the artificial diet is criticized as they require larger proportions of biomass. But, now biotechnological tools help in cultivation of higher quantity of algal biomass which attracted feed industry in some areas. Few studies have already proved its capacity to utilize as one of the major feed ingredient in the aquaculture. Therefore, recommendation has to be done to place this as one of the essential feed ingredient in fish diet. If the brief information available from this article would met, it would be expected that microalgae will be more popularized in the fish feed industry as one of the essential feed ingredient.

As the quality differs for different strains, improved variety must be further explored. Future investigation should also be focused on the development of modified variety of strains and improvement in the manufacturing systems. The transgenic variety of microalgae may have noteworthy potential which needs to be studied. Microalgae are naturally high in polyunsaturated fatty acid (e.g. docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA). However, manipulating the processing methods can further improve its content which needs to be thoroughly explored. It is also recommended that further research has to be carried out to utilize microalgae for fish feed application for the sustainability of aquaculture.

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