Use of environmental friendly feed additives and probiotics in Chinese aquaculture

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The production of fish feed additives for the aquaculture industry is a thriving sector in China. These natural substances are being used for several purposes including the enhancement of the immune systems of farmed fish, promoting growth, attaining the desired flesh and skin pigmentation, as well as improving the organolepctic properties of the farmed product. At the same time, the use of such additives has no negative impacts to the farming environment.

A few decades ago, fish farms made use of large volumes of antibiotics, chlorides, and other substances that negatively impacted the environment as a whole. With the expansion of the industry at the global level and the increased knowledge gained on the impacts resulting from poor farming practices, policy makers urged and supported the industry to research on and increasingly make use of environmentally-friendly feed additives. In view of the above and also due to growing consumer conscientious for safe and healthy products, the Chinese aquaculture industry is actively pursuing the improvement of its products from a qualitative point of view and not simply focusing on increasing outputs.

The type of feed additives and probiotics currently produced in China used by the aquaculture industry are listed in the table below.

Probiotics and PSB. As early as 76 A.D., the Roman historian, Plinius, found that yogurt can be used to treat human enteritis and in 1907, a Russian biologist revealed that consuming fermented milk was good for the health. The above "discoveries" were reconfirmed in the twentieth century and, in 1996, scientists from around the globe got together to renew discussions on the values and benefits of probiotics. A Joint Food and Agriculture Organization/World Health Organization Working Group on drafting "Guidelines for the evaluation of probiotics in food" has recommended that probiotics be defined as "live micro-organisms which, when administered in adequate amounts, confer a health benefit on the host"[1]. Results from numerous applied aquaculture research trials have effectively confirmed that the use of some bacteria species such as the rod-shaped *Bacillus* (e.g. *B. licheniformis, B. natto, B. subtilis*)

Table 1. List of feed additives and probiotics currently used in Chinese aquaculture

Item	Products	Use
Probiotics	*Bacillus* spp. – *B. licheniformis*, *B. natto*, *B. subtilis* and other species	Water treatment and feed additive
Photosynthe tic bacteria (PSB)	*Rhodopseudomonas* – *R. palustris*, *R. capsulatus* and other species	Water treatment and feed additive
Poly-unsaturated fatty acids (PUFA)	Meal and DHA oil isolated from the marine fungus, *Schizochytrium*, or from the heterotrophic microalga, *Crypthecodiniu m cohnii*	Fatty acid supplement
Pigments	Astaxanthin pigment isolated from the *Phaffia* yeast, the green algae, *Haematococcus pluvialis*, or extracted from crustacean exoskeleton, or chemically produced	Pigmentation of fish flesh and skin, and enhancement of the immune system
Vaccines	Live viral vaccines, inactivated viral vaccine, inactivated bacteria vaccine, subunit vaccine, and inactivated trivalent bacteria vaccine	Anti -viral
Herbal medicines	*Rheum palmatum* (*Chinese rhubarb*) (and other species in same genus), *Isatis indigotica* (*woad*), *Houttuynia cordata* (*lizard tail*), *Stemona japonica* (*stemona*), *Pulsatilla chinensis* (*bai tou weng*) *and others*	Anti -bacterial and anti-fungal
	Isatis indigotica (*Chinese woad*), *Polygonum cuspidatum* (*Japanese knotweed*), *Belamcanda chinensis* (*blackberry lily*), *Chrysanthemum indicum* (*mums*), *and Corydalis bungeana* (*yan hu so, a native Chinese herd*)	Anti -viral
	Amomum tsao -ko (*type of ginger*), *Dichroa febrifuga* (*blue evergreen hydrangea*), *Areca catechu* (*betel nut palm*)	Insec ticide
	Allium sativum (*garlic*), *Rosa lavigata* (*Cherokee rose*), *Cyanotis arachnoidea* (*a perennial herb*), and *Gentiana flavomaculata* (*a perennial herb*)	Stimulates growth and regulation of the ecdysis rhythm in crustaceans

and photosynthetic bacteria can improve the farming environment and help increase the survival rate of a wide range of different farmed aquatic organisms including crustaceans, finfish, bivalve molluscs and echinoderms. To date, there are over 10 Chinese companies producing and distributing these products throughout the country clearly indicating that the use of probiotics is widely accepted by fish farmers.

Pigments. Astaxanthin is the major carotenoid responsible for the pink-red pigmentation of many fish and shrimp species. As aquatic animals are unable of producing this pigment, farmed animals must be supplied with this natural nutritional component in the diet in order to obtain the natural colouration of wild fish. This pigment has been long used by feed producers catering for the salmon and trout industry. In China, the production of this natural pigment has been neglected mainly because of the small contribution of salmonids to the national aquaculture industry. However, only recently, the astaxanthin has been shown to have other biological and nutritional functions, linked to its ability to act as a powerful antioxidant.

In China, the astaxanthin pigment is currently being produced using the *Phaffia* yeast (*Xanthophyllomyces dendrorhous*, formerly *Phaffia rhodozyma*), the unique freshwater microalga (*Haematococcus pluviali*)[2], extracted from crustacean carapace or synthetically produced. Among these, the yeast and the microscopic green-algae are considered as the most promising resources for the extraction of this natural dye due to the high level of accumulated astaxanthin. Furthermore, studies have demonstrated that the astaxanthin derived from *Phaffia* yeast results in the highest deposition levels in farmed fish and shrimp. One Chinese company located in Xiamen (Amoy), Fujian Province, has become a leader in the production of this carotenoid (Figure 1).

As mentioned the freshwater microalga, *Haematococcus pluviali*, is another important source of astaxanthin. There are currently a handful of facilities producing algal astaxanthin in China with the largest one located in Jingzhou, Hubei Province. The cost of producing the pigment from this algal species is higher than if using the yeast as it requires some expertise among the personnel (Figures 2 and 3). From this point of view, the producers of microalgal astaxanthin are facing strong competition in both domestic and international market.

In China, the production of astaxanthin from crustacean shell or through chemical synthesis is only carried out at a small scale mainly due to problems related to the availability and supply of large quantities

Figure 1. View of a workshop producing Phaffia *Astaxanthin and probiotics in Xiamen, China*

Figure 2. An outdoor tank for the production of the astaxanthin microalgae in China

Figure 3. Astaxanthin powder

of the raw material (crustacean exoskeleton) and technical issues. A further source of the pigment is from the aerobic Gram-negative astaxanthin-producing bacterium (*Paracoccus carotinifaciens*) which is, however, only produced in Japan.

The free-floating filamentous cyanobacteria *Spirulina*[3] is also an important pigment source and food supplement. This blue-green algae is cultivated around the world, and is used as a human and farmed fish dietary supplement. Studies have shown that *Spirulina* significantly enhances the pigmentation in *Penaeus monodon* and other farmed shrimp. Besides its pigmentation properties, *Spirulina* as a feed supplement has shown to have other benefits such as increasing feed efficiency. This cyanobacteria is cultured on a commercial scale and is widely utilized in Chinese aquaculture[4].

PUFAs as nutrient supplements. Poly-unsaturated fatty acids (PUFAs) such as the arachidonic (ARA), eicosapentaenoic (EPA) and the docosahexaenoic (DHA) acids are all considered essential fatty acids. Among the three listed, the DHA is the more important one as it can be broken down to EPA or ARA, while the carbon chain of the EPA and ARA cannot be prolonged to form DHA. During the early stage of marine fish, the larvae are able to complete metamorphosis and develop the nervous system when the EFA in the yolk is exhausted. Marine fish are not capable of bioconverting C18 PUFA to their C20 and C22 homologues. Consequently, marine fish invariably obtain EPA and DHA from their natural diet which is rich in these particular fatty acids. It is therefore indispensable to supply farmed fish with diets enriched with fish oil. These oils can also be produced from sources such as marine fungus, *Schizochytrium* spp., or salt water microalgae such as *Nannochloropsis* spp. Due to various technical issues, the production of the marine fungus through fermentation is cheaper than the microalgae. Dried *Schizochytrium* meal has been widely used in Chinese marine fish seed production particularly in species such as the turbot and flounder. At present, selected strains with a high DHA level (>25% in dried cells) are available from the Xiamen Biotech Company. Besides the marine fungus, the microalga *Crypthecodinium cohnii* is also rich in PUFA. The current production of this species is at small scale and the products are mainly used as an additive for infant foods. To date, it is not used by the aquaculture sector.

Fish oil is a traditional source of PUFAs which has been used as a feed additive particularly in eel farming. The price of fish oil is considerably lower than other sources of PUFA, however, fish farmers tend to prefer the use of *Schizochytrium* products as they contain high level of DHA and are of suitable size for enriching rotifer and *Artemia*, while avoiding the emulsification process. Hence, *Schizochytrium* DHA meal is widely accepted by the aquaculture sector for raising marine fish and crustacean broodstock and seed material.

Vaccines. Dr Zhibing Huang, an immunologist based at the Pearl River Fisheries Research Institute in China, mentioned that the "incidence of diseases in aquaculture in 2004 was as high as 50 percent with an estimated production loss of up to 1.5 million tonnes equivalent to a financial loss of about RMB 151". He further reported that since the 1970s, the grass carp hemorrhagic virus has caused havoc with losses of

Figure 4. A plant of Rheum palmatum *(Chinese rhubarb)*

Figure 5. A plant of Pulsatilla chinensis *(bai tou weng)*

up to 90 percent for some years." This problem has since been dealt with as a result of the development of an effective vaccine. Dr Zhibing Huang also indicated that in China "numerous vaccine products have been studied and among them, eight have been tested in the field; 23 vaccines are still being tested in the laboratories while an additional 23 vaccines are still at the research stage". Four new vaccine production lines have recently been put into place in Guangzhou, Guangdong Province, producing live viral vaccines, inactivated viral vaccine, inactivated bacteria vaccine, subunit vaccine and inactivated trivalent bacteria vaccine. It is expected that the use of vaccines as an effective therapy and treatment for fish diseases will expand countrywide.

Herbs as medical feed additives in aquaculture. Chinese fish farmers have long used herbal plants for the prevention and treatment of fish diseases. Due to the global discussions on the use of antibiotics and other chemical substances such as malachite green, Chinese farmers and scientists are once again paying attention on the use of these herbal products. These traditional medicines have been used to enhance the immune system of the farmed fish; as anti-viral, bacterial and fungal agents; as insecticides and pesticides; and for stimulating growth and regulation of the ecdysis rhythm in crustacean. Some of the herbal plants commonly used in Chinese aquaculture are listed in Table 1 above (see Figures 4, 5 and 6).

In summary, feed additives and water treatment reagents being used by the aquaculture industry are important and growing areas of applied research, dealing with animal health and welfare, environmental protection and food safety.

Figure 6. A plant of Areca catechu *(betel nut palm)*

All photos J. Chen, FAO

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[1] Joint FAO/WHO Working Group Report on Drafting Guidelines for the Evaluation of Probiotics in Food, London, Ontario, Canada, April 30 and May 1, 2002. Available at: ftp://ftp.fao.org/es/esn/food/wgreport2.pdf.

[2] *Haematococcus pluvialis* is a freshwater species of Chlorophyta from the Haematococcaceae family. This species is well known for its high content of the strong antioxidant astaxanthin used in aquaculture and various pharmaceutical and cosmetic products. The high amount of astaxanthin is present in the resting cells, which are rapidly produced and accumulated when the environmental conditions becomes unfavorable for normal cell growth (e.g. strong light, high salinity levels).

[3] *Spirulina* are multicellular and filamentous blue-green microalgae belonging to two separate genera *Spirulina* and *Arthrospira* and consists of about 15 species. Of these, *Arthrospira platensis* is the most common and widely available *Spirulina*.

[4] See also: Habib, M.A.B., Parvin, M., Huntington, T.C., & Hasan, M.R. 2008. A review on culture, production and use of *Spirulina* as food for humans and feeds for domestic animals and fish. *FAO Fisheries and Aquaculture Circular*. No. 1034. Rome, FAO. 2008. 33p.

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