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Insect-based protein: future promising protein source for fish cultured

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Abstract. As one of the vital component feed used in fisheries, fishmeal (FM) is generally added to the fish diet to enhance fish growth, digestive performance and absorption of nutrients. This addition contributes significantly to the variable production cost in the aquaculture industry. Expanded production of carnivorous species requiring high protein, high-energy feeds will further tax global fish meal. Thus, research based on the low-cost budget for feed operating cost should be strategized to assist aquaculturists in enhancing fish productivity. Moreover, suitable alternative feed ingredients will have to be utilized to provide the essential nutrients and energy needed to fuel the growth of aquaculture production. To this effect, the use of insect-based protein sources to replace FM that often scarce, expensive, limited availability, and leads to high fish production costs is alternative ways and has been gaining momentum. Currently, Insects have been proposed as one of the potential future protein sources of protein because of the production of insects is highly sustainable. Farming insects is characterized by higher food conversion efficiencies, lower environmental impact, and higher potential to be grown on waste streams.

1. Introduction

As fish demand continues to grow, the strategies to increase fish productivity need to be developed. The research based on eco-friendly and sustainable commercial aims should also be strategized to assist aquaculturists in increasing fish productivity. To this effect, the use of fish meal in the fish diet in production systems to improve productivity has been gaining momentum. Fish meal plays an important role ingredient for fish feed [1] . Fish meal is a prime protein source and known as a high-quality, very digestible feed ingredient [2, 3]. Fish meal has large unit energy per unit weight which contains protein, lipids (oils), minerals, and vitamins. However, there is a limit amount of carbohydrate in fishmeal.

Fish meal is a generic term for a nutrient-rich feed ingredient used primarily in diets for domestic animals, sometimes used as a high-quality organic fertilizer. Fish meal can be made from almost any type of seafood but is generally manufactured from wild-caught, small marine fish that contain a high percentage of bones and oil, and usually deemed not suitable for direct human consumption. These fishes are considered 'industrial' since most of them are caught for the sole purpose of fishmeal and fish oil production. A small percentage of fishmeal is rendered from the by-catch of other fisheries, and by-products or trimmings created during processing (e.g., fish filleting and cannery operations) of various seafood products destined for direct human consumption.

The fish meal is one of the few major animal industries existing today that still relies greatly on a "hunting-and-gathering" technique. Most fish rendered into a meal is captured at sea. Millions of tons of fishmeal are produced worldwide. Contrary to recent that beneficial to increase weight gain, specific growth rate, feed conversion ratio, protein utilization efficiency, and carcass enhancement, more than tons of fish are used to produce fish meal.

According to United States Department of Agriculture [4], Thailand has the highest production of fish meal in Asian region, reaching up to 430.000 metric tons while Japan around 190.000 metric tons and Indonesia about 16.000 metric tons (figure 1). In 2016, it is estimated that the production annual growth rate of fish meal is up to 3.70% in Vietnam, followed by Japan 2.70%.

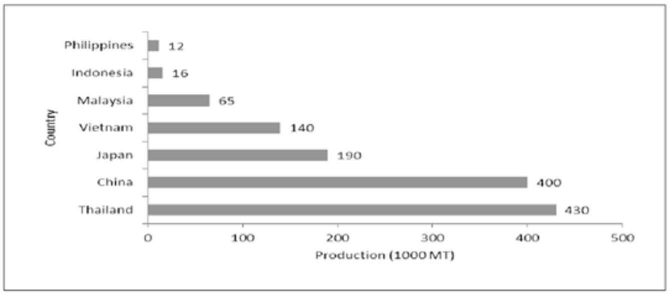

Figure 1. Fish meal production by country [4]

On the other hand, there is a reducing of fish production in related to the fish meal. The use of fish from nature to produce fish meal is a competition with human needs. Further, the decrease in the availability, sustainability, and the increase in the prices of the fish meal have stimulated the search for sustainable alternatives for aquaculture feeds. It is also stated that feeding fish to fish is useless and wasteful that because more than 6 kg of wild fish is taken up to produce 1 kg of farmed fish [5]. To this regard, the use of protein-based plant is an alternative way to satisfy the increasing demands of the aquaculture feed industry, to partially or totally replace of fish meal in fish diet.

Some attempts have been made to explore the possibilities on the use of plant-based protein to replace total or partial replacement of fish meal. Previous research stated that many protein-based plants have a good nutritional value including protein content that beneficial to fish growth and physiology (table 1).

Table 1. The use of plant-based protein and its effects on the growth and physiology of fish

No	Plant-based Protein	Effects	References
1	seaweed *Gracilaria arcuate*	Better weight gain, specific growth rate, and feed utilization on African catfish, *Clarias gariepinus*	[6]
2	pea protein concentrate	Amino acid profiles of the diets, body composition, and growth performance of juveniles of tench (*Tinca tinca* L.)	[7]
3	Soybean meal	Increase marine fish growth	[8]
4	Lupin	Better apparent digestibility and coefficient of protein (ADC-P) on the Juvenile barramundi (*Lates calcarifer* Bloch 1970)	[9]
5	Soybean meal, peas, corn gluten, and wheat	Skeletal muscle growth, flesh texture of *Senegalese sole*	[10]
6	Canola meal	Growth, feed utilisation, plasma biochemistry, histology of digestive organs and hepatic gene expression of barramundi (Asian sea bass; *Lates calcarifer*)	[11]
7	Cotton Seed Meal without lysine supplementation	Growth performance, body composition and digestive enzyme activities.	[12]

No	Plant-based Protein	Effects	References
8	Rice polish	Growth performance of Nile tilapia (*Oreochromis niloticus*)	[13]
9	Wheat gluten	Growth in the range of 40-130 g was superior to the fishmeal control with the diet containing wheat gluten gilthead seabream, *Sparus aurata* L	[14]

Due to the reason mentioned above, fishmeal is still quite commonly used in animal feed diets. Nevertheless, overfishing, the low availability and the increase in the prices of fish meal which is reflected by increasing market prices over the last decades have stimulated the search for environmentally friendly and eco-sustainable alternatives for animal feeds. Alternative protein sources of comparable value are therefore urgently needed. Thus, the potential of insect-based protein in animal feed diets has attracted much attention

2. Why insect?

It is predicted by Food and Agricultural Organization (FAO) the world need to enhance food production by 70% by 2050 that would be given to whole population in the world which cover 9 billion people. Almost 80% of the world's agricultural land is occupied for grazing and feeding farm animals. Meanwhile, global meat consumption, especially in relation to fish production is expected to rise by 50% above 2006 levels to meet expected demand by 2050 [21].

In order to balance that situation above, a comparable value of alternative protein sources is urgently needed to produce protein source production. Currently, the potential of insect-based protein has attracted much attention not only farmer but also researcher. It seems there are few reasons that can consider in related to the use of insect.

The insects such as crickets, caterpillars and silkworms could be the good source of food in the future. Insects, an edible food that contains protein, vitamins and important amino acids are efficient to be reared. Insects only need six times less feed than cattle and can be cultivated by using organic waste. As consequences, insects produce fewer greenhouse gasses emission (100-1000x) [22]. The others reasons that could be used as consideration are insects has high feed conversion rate (FCR), low use of water and energy, and nutritious as source of essential protein as well as amino acids for animal feed (table 2). However, to ensure the less cost production of insect-based protein, the insect must be able to reproduce in short time [23].

Table 2. Examples of nutrient contents of some insects

Nutrients	House Cricket (*Acheta domesticus*)	Meal worm (*Tenebrio molitor*)	Silk worm (*Bombyx mori*)	Mormon cricket (*Anabrus simplex*)	Black fly soldier (*Hermetia illucens*)
Crude protein*	55-67	47-60	52-71	60.3^	42++
Fats*)	10-22	31-43	6-37	12.9^	35++
Methionine+	1.4	1.5	46**	1.4	2.1
Cysteine+	0.8	0.8	14**	0.1	0.1
Lysine+	5.4	5.4	75**	5.9	6.6

Source: *Crude protein and ether extracts of fats (% of dry matter) in house cricket, silkworm and mealworm. +Amino acid content (g/16 g N) in insects produced as animal feed [24] **Amino acid composition of pupae of the silkworm (mg/g crude protein) [25]. ++protein and fats content [26]. ^Proximate analysis (percent, dry weight) of adult Mormon crickets [27].

3. Insect-based protein in aquaculture

Traditionally, the application of insect in aquaculture fields has been seen in a recent decade. In Uganda, a research regarding on the use of ingredient such as vegetables, grass, cereals, cereal brands, oil seed cakes, industrial and kitchen wastes fishmeal and insects by fish farmer was reported by Rutaisire [28] (Figure 2). Unfortunately, the availability of most of these ingredients is seasonal. In addition, termites for feeding fish that used by fish farmer up to 5% has been collected directly or purchased from collectors at a cost of US$0.27/kg – only at certain month, March to April and from August to

September. The availability of insect is also depending on the number and size of termite hills on the farm, moonlight intensity and termite species. Meanwhile in Southeast Asia region, fluorescent light commonly used as an insect attractant that place above fish ponds. The insect that attracted by light falls into the pond and can be eaten by fish. Wingless grasshoppers and crickets, another example of insect which cannot float, are also made as fish bait [29].

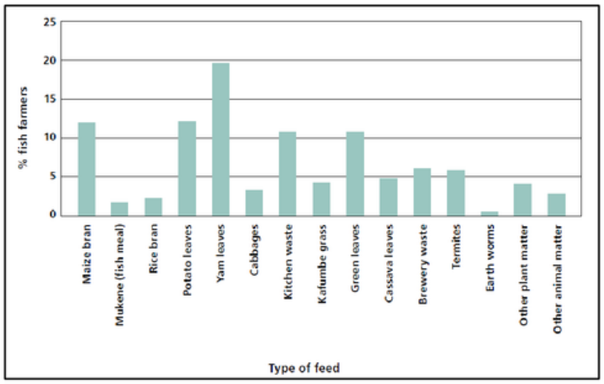

Figure 2. Several of feed types that is used by fish farmer

In current year, fish meal is very popular in aquaculture. Almost 63% of the fish meal is used in aquaculture field [30] . However, due to the low availability and the increase in the prices of fish meal have stimulated the search for environmentally friendly and eco-sustainable alternatives for aquaculture feeds [1]. To this concern, the research to find out new ingredients to replace fish meal has gained a momentum and growth importance specifically in aquaculture field. Recently, the aquaculture field has shown a significant improve and in future the amount of global productions is a key point to provide a pivotal point in supply of seafood to satisfy the growing consumers demand.

Table 3. Insect-based meal and its effect on the growth and physiological of fish

No	Insect-based Protein	Effects	References
1	*Bombyx mori*	Growth, Survival, body composition, hematological parameters of rainbow trout *Oncorhynchus mykiss*	[31,32]
2	*Tenebrio molitor*	Growth performance, whole body composition and in vivo apparent digestibility on European sea bass (*Dicentrarchus labrax* L.) juveniles	[33]
3	*Musca domestica*	Growth and nutrient utilization indices on African catfish (*Clarias gariepinus*)	[34]
4	Grasshoppers	Growth of *Clarias gariepinus* fingerlings	[35]
5	Cricket (*Gryllus bimaculatus*)	Growth performance, antioxidant enzyme activities, and haematological response of African catfish (*Clarias gariepinus*)	[36]
6	Black Soldier Fly *Hermetia illucens* (Linnaeus, 1758) Prepupae	Growth of *Clarias gariepinus* (Burchell, 1822)	[37]

Previous research stated that, feeding trials on several fish using ratio 25:50 % of fish meal was replaced with acridid (a genus of grasshoppers) meal produced results similar to the control diet, containing 100 percent fish meal. In addition, growth parameters measured for the selected fish found significantly higher fish fed acridid meal than for fish fed commercial diets. This finding indicates that acridids can be successfully implemented as fish meal replacement [38]. Another successful implementation research of insect as fish meal replacement can be seen in Table 3 above.

Though insect based protein has many advantages in animal feed specifically aquaculture fields, there are other reasons that need to be considered as the disadvantage of insect meal. Some opponent stated that the production costs for insect-based meal are still relatively high; the effects of insect nutrients on the health of animal still need to be further investigated. The legislation will also need to be paid to cove the safe use of substrates such as vegetable and domestic waste and manure that usually is economically made as insect's substrate [39].

4. Conclusion

The fish meal will stay as a pivotal point in future diets of fish. However, the concerns about the sustainability of these ingredients and the increasing price on the global market are boosting the fish farmer to use a more efficient of fish meal and find alternative feed sources such as insect-based meal. Next research needs to be conducted in order to determine the further effects on the use of insect-based meal on the physiology, immunology, and molecular basis of the animal.

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