

PAPER • OPEN ACCESS

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

To cite this article: R A Nugroho and F M Nur 2018 *IOP Conf. Ser.: Earth Environ. Sci.* **144** 012002

View the [article online](#) for updates and enhancements.

Related content

- [The Effect of Different Feed and Stocking Densities on Growth And Survival Rate Of Blue Swimming Crablets \(*Portunus pelagicus*\)](#)
R W Ariyati, S Rejeki and R H Bosma
- [Freshwater savings from marine protein consumption](#)
Jessica A Gephart, Michael L Pace and Paolo D'Odorico
- [Climate change and aquaculture development in Nigeria: Experiences and adaptation strategies](#)
Emmanuel Kolawole Ajani



IOP | ebooks™

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the collection - download the first chapter of every title for free.

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

R A Nugroho* and F M Nur

Animal Physiology, Development, and Molecular Laboratory, Department of Biology, Faculty of Mathematics and Natural Sciences Mulawarman University. Samarinda, East Kalimantan, Indonesia.

*Corresponding author: rudyagung.nugroho@fmipa.unmul.ac.id

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%.

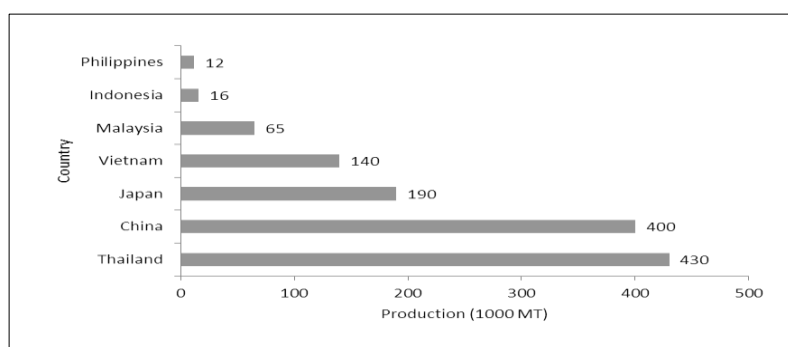


Figure 1. Fish meal production by country [4]

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 <i>Gracilaria arcuate</i>	Better weight gain, specific growth rate, and feed utilization on African catfish, <i>Clarias gariepinus</i>	[6]
2	pea protein concentrate	Amino acid profiles of the diets, body composition, and growth performance of juveniles of tench (<i>Tinca tinca</i> 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 (<i>Lates calcarifer</i> Bloch 1970)	[9]
5	Soybean meal, peas, corn gluten, and wheat	Skeletal muscle growth, flesh texture of <i>Senegalese sole</i>	[10]
6	Canola meal	Growth, feed utilisation, plasma biochemistry, histology of digestive organs and hepatic gene expression of barramundi (Asian sea bass; <i>Lates calcarifer</i>)	[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 (<i>Oreochromis niloticus</i>)	[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, <i>Sparus aurata</i> 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 (<i>Acheta domesticus</i>)	Meal worm (<i>Tenebrio molitor</i>)	Silk worm (<i>Bombyx mori</i>)	Mormon cricket (<i>Anabrus simplex</i>)	Black fly soldier (<i>Hermetia illucens</i>)
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].

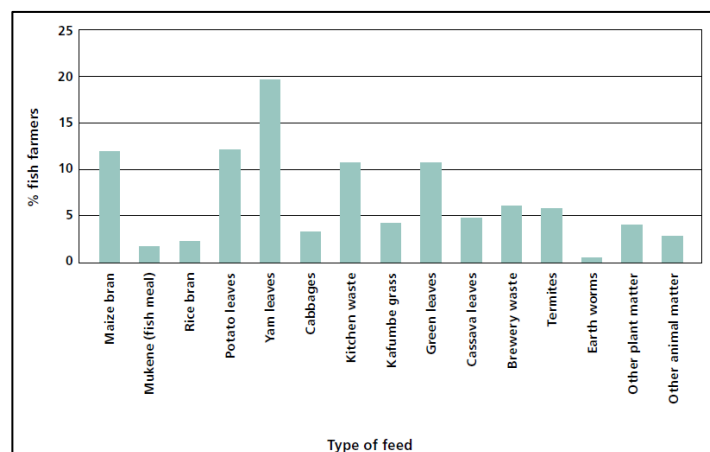


Figure 2. Several of feed types that is used by fish farmer

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	<i>Bombyx mori</i>	Growth, Survival, body composition, hematological parameters of rainbow trout <i>Oncorhynchus mykiss</i>	[31,32]
2	<i>Tenebrio molitor</i>	Growth performance, whole body composition and in vivo apparent digestibility on European sea bass (<i>Dicentrarchus labrax</i> L.) juveniles	[33]
3	<i>Musca domestica</i>	Growth and nutrient utilization indices on African catfish (<i>Clarias gariepinus</i>)	[34]
4	Grasshoppers	Growth of <i>Clarias gariepinus</i> fingerlings	[35]
5	Cricket (<i>Gryllus bimaculatus</i>)	Growth performance, antioxidant enzyme activities, and haematological response of African catfish (<i>Clarias gariepinus</i>)	[36]
6	Black Soldier Fly <i>Hermetia illucens</i> (Linnaeus, 1758) Prepupae	Growth of <i>Clarias gariepinus</i> (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 cover 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.

Acknowledgement

The author grateful to Department of Biology, Faculty of Mathematics and natural Sciences, Mulawarman University for any kinds of support to present this paper.

References

- [1] Caruso G 2015 Use of Plant Products as Candidate Fish Meal Substitutes: An Emerging Issue in Aquaculture Productions *Fisheries and Aquaculture Journal* **6** 1-3
- [2] Miles R and Chapman F 2006 The Benefits of Fish Meal in Aquaculture Diets *IFAS Extension FA122* 1-6
- [3] Tantikitti C, Chookird D and Phongdara A 2016 Effects of Fishmeal Quality on Growth Performance, Protein Digestibility and Trypsin Gene Expression in Pacific White Shrimp (*Litopenaeus vannamei*) *Songklanakar Journal of Science and Technology* **38** 73-82
- [4] USDA 2017 Fish Meal Production by Country in 1000 MT. Index Mundi. <https://www.indexmundi.com/Agriculture/?commodity=fish-meal&graph=production>. accessed July 2017.
- [5] Schipp G 2008 Is the Use of Fishmeal and Fish Oil in Aquaculture Diets Sustainable? *Technote* **124** 2-15
- [6] Al-Asghar N A, Younis E-S M, Abdel-Warith A-W A and Shamlol F S 2016 Evaluation of red seaweed *Gracilaria arcuata* as dietary ingredient in African catfish, *Clarias gariepinus* *Saudi Journal of Biological Sciences* **23** 205-10
- [7] González-Rodríguez Á, Celada J D, Carral J M, Sáez-Royuela M and Fuertes J B 2016 Evaluation of Pea Protein Concentrate as Partial Replacement of Fish Meal in Practical Diets for Juvenile Tench (*Tinca tinca* L.) *Aquaculture Research* **47** 2825-34
- [8] Mo W Y, Lau R S S, Kwok A C K and Wong M H 2016 Use of Soybean Meal and Papain to Partially Replace Animal Protein for Culturing Three Marine Fish Species: Fish Growth and Water Quality *Environmental Pollution In Press: Corrected Proof* 1-6
- [9] Ilham, Fotedar R and Munilkumar S 2016 Effects of Organic Selenium Supplementation on Growth, Glutathione Peroxidase Activity and Histopathology in Juvenile Barramundi (*Lates calcarifer* Bloch 1970) Fed High Lupin Meal-Based Diets *Aquaculture* **457** 15-23
- [10] Valente L M P, Cabral E M, Sousa V, Cunha L M and Fernandes J M O 2016 Plant Protein Blends in Diets for *Senegalese sole* Affect Skeletal Muscle Growth, Flesh Texture and The Expression of Related Genes *Aquaculture* **453** 77-85
- [11] Ngo D T, Wade N M, Pirozzi I and Glencross B D 2016 Effects of canola meal on growth, feed utilisation, plasma biochemistry, histology of digestive organs and hepatic gene expression of barramundi (Asian seabass; *Lates calcarifer*) *Aquaculture* **464** 95-105

- [12] Yu D H, Gong S Y, Lin Y C and Yuan Y C 2014 Partial Replacement of Fish Meal by Several Plant Proteins With or Without Iron and Lysine Supplement in Diets for Juvenile Chinese Sucker, *Myxocyprinus asiaticus* *Aquaculture Nutrition* **20** 205-12
- [13] Khan M S K, Siddique M A M and Zamal H 2013 Replacement of Fish Meal by Plant Protein Sources in Nile Tilapia (*Oreochromis niloticus*) Diet: Growth Performance and Utilization *Iranian Journal of Fisheries Sciences* **12** 864-72
- [14] Kissil G W and Lupatsch I 2004 Successful Replacement of Fishmeal by Plant Proteins in Diets for The Gilthead Seabream, *Sparus aurata* L *The Israeli Journal of Aquaculture* **56** 188-99
- [15] Glencross B, Evans D, Hawkins W and Jones B 2004 Evaluation of Dietary Inclusion of Yellow Lupin (*Lupinus luteus*) Kernel Meal on The Growth, Feed Utilisation and Tissue Histology of Rainbow Trout (*Oncorhynchus mykiss*) *Aquaculture* **235** 411-22
- [16] Francis G, Makkar H P S and Becker K 2001 Antinutritional Factors Present in Plant-Derived Alternate Fish Feed Ingredients and Their Effects in Fish *Aquaculture* **199** 197-227
- [17] Rolland M 2014 Effects of Dietary Methionine on Feed Utilization, Plasma Amino Acid Profiles and Gene Expression in Rainbow Trout (*Oncorhynchus Mykiss*). In: *National Institute of Aquatic Resources*, (Denmark: Technical University of Denmark) p 173
- [18] Chung E 2016 Shift to Plant-Based Fish Feed Could Hurt Health Environment. (Canada: CBCNews Technology and Science)
- [19] Glencross B, Evans D, Rutherford N, Hawkins W, McCafferty P, Dods K, Jones B, Harris D, Morton L and Sweetingham M 2006 The Influence of The Dietary Inclusion of The Alkaloid Gramine, on Rainbow Trout (*Oncorhynchus mykiss*) Growth, Feed Utilisation and Gastrointestinal Histology *Aquaculture* **253** 512-22
- [20] Hemre G, Amlund H, Aursand M, Bakke A M, Olsen R E, Ringø E and Svihus B 2009 *Opinion of the Panel on Animal Feed of The Norwegian Scientific Committee for Food Safety: Criteria for Safe Use of Plant Ingredients in Diets for Aquacultured Fish* vol 7/604 (Norwegia: Norwegian Scientific Committee for Food Safety)
- [21] Laaninen T 2016 Insects – Soon to be A Regulated Food? ed M R Service (Europe: European Parliamentary Research Service) pp 1-2
- [22] Frangoul A 2016 Insects: Food of The Future? (US: CNBC LLC)
- [23] Józefiak D, Józefiak A, Kierończyk B, Rawski M, Świątkiewicz S, Długosz J and Engberg R M 2016 Insects: A Natural Nutrient Source for Poultry—A Review *Annals of Animal Science* **16** 297-313
- [24] Makkar H P, Tran G, Heuzé V and Ankers P 2014 State of The Art on Use of Insects As Animal Feed *Animal Feed Science and Technology* **197** 1-33
- [25] Zhou J and Han D 2006 Proximate, Amino Acid and Mineral Composition of Pupae of The Silkworm *Antheraea pernyi* in China *Journal of Food Composition and Analysis* **19** 850-3
- [26] Stamer A, Wessels S, Neidigk R and Hoerstgen-Schwark G 2014 Black Soldier Fly (*Hermetia illucens*) Larvae-Meal as An Example for A New Feed Ingredients Class in Aquaculture Diets. In: *The 4th ISOFAR Scientific Conference*, ed G Rahman and U Aksoy (Istanbul, Turkey pp 1043-6
- [27] DeFoliart G, Finke M and Sunde M 1982 Potential Value of The Mormon Cricket (Orthoptera: Tettigoniidae) Harvested as A High-Protein Feed for Poultry *Journal of Economic Entomology* **75** 848-52
- [28] Rutaisire J 2007 Analysis of Feeds and Fertilizers for Sustainable Aquaculture Development in Uganda *FAO Fisheries Technical Paper* **497** 471
- [29] Van Huis A, Van Isterbeek J, Klunder H, Mertens E, Halloran A, Muir G and Vantomme P 2013 *Edible Insects: Future Prospects for Food and Feed Security* vol 171 (Rome: FAO)
- [30] Boyd C E 2015 *Feed and Feeding Practices in Aquaculture*, (UK: Woodhead Publishing) p 21
- [31] Shakoori M, Gholipour H and Naseri S 2015 Effect of Replacing Dietary Fish Meal With Silkworm (*Bombyx mori*) Pupae on Hematological Parameters of Rainbow Trout *Oncorhynchus mykiss* *Comparative Clinical Pathology* **24** 139-43

- [32] Shakoori M, Gholipour H, Naseri S and Khara H 2016 Growth, Survival, and Body Composition of Rainbow Trout, *Oncorhynchus mykiss*, when Dietary Fish Meal is Replaced with Silkworm (*Bombyx mori*) pupae *Archives of Polish Fisheries* **24** 53-7
- [33] Gasco L, Henry M, Piccolo G, Marono S, Gai F, Renna M, Lussiana C, Antonopoulou E, Mola P and Chatzifotis S 2016 *Tenebrio molitor* Meal in Diets for European Sea Bass (*Dicentrarchus labrax* L.) Juveniles: Growth Performance, Whole Body Composition and In Vivo Apparent Digestibility *Animal Feed Science and Technology* **220** 34-45
- [34] Aniebo A O, Erondy E S and Owen O J 2009 Replacement of Fish Meal with Maggot Meal in African Catfish (*Clarias gariepinus*) Diets *Revista Cientifica UDO Agricola* **9** 666-71
- [35] Grace O I 2015 Effects of Grasshopper Meal in The Diet of *Clarias Gariepinus* Fingerlings *Journal of Aquaculture Research and Development* **6** 1-3
- [36] Taufek N M, Aspani F, Muin H, Raji A A, Razak S A and Alias Z 2016 The Effect of Dietary Cricket Meal (*Gryllus bimaculatus*) on Growth Performance, Antioxidant Enzyme Activities, and Haematological Response of African Catfish (*Clarias gariepinus*) *Fish Physiology and Biochemistry* **42** 1143-55
- [37] Adeniyi O V and Folorunsho C Y 2015 Performance of *Clarias gariepinus* (Burchell, 1822) Fed Dietary Levels of Black Soldier Fly, *Hermetia illucens* (Linnaeus, 1758) Prepupae Meal as A Protein Supplement *International Journal Fish Aquaculture* **5** 89-93
- [38] Halder P 2012 Evaluation of Nutritional Value of Short-Horn Grasshoppers (Acridids) and Their Farm-Based Mass Production as A Possible Alternative Protein Source for Human and Livestock. In: *Expert Consultation Meeting on Assessing The Potential of Insects as Food and Feed in Assuring Food Security*, (Rome: FAO) pp 23-6
- [39] Fitches E 2014 Why Are Insects Not Allowed in Animal Feed? In: *International Magazine on Animal Nutrition, Processing and Feed Management*, (UK: Reed Business Media) pp 1-9