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A replacement of plant protein sources as an alternative of fish meal ingredient for African catfish, *Clarias gariepinus*: A review

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Abstract

Aquaculture is one of the fastest growing industries in the world. This industry supplies half of the fisheries products consumed annually, and future global demand can only be supplied by increasing aquaculture production, which, in turn, requires more aquafeed. Alternative ingredients must be increasingly used to supply significant proportions of protein and energy in aquafeeds, creating both challenges and opportunities for researchers and industry. Nowadays, there are too many researches on fish disease, growth and health but less in a fish feed especially a replacement of protein from plant sources in the fish feed. One of the alternative ways to optimise the growth and health condition of the fish is provide them a good protein from plant as a replacement in fish meal with the natural source protein instead of giving a good rearing condition and caring of the fish. The present article was constructed to highlight a replacement of plant protein sources as an alternative of fish meal for fish feed in African catfish, *Clarias gariepinus* that has been done by researchers. However, the application of replacement from plant protein sources in fish meal is now gradually gaining importance in commercial aquaculture practices and opened the door for the researchers to expend of this application, thus more detailed studies on molecular basis should be looked as to get the quality and enough nutrient fish feed for good production of aquaculture industry.

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1. INTRODUCTION

Recent years have seen a dramatic expansion of aquaculture feed industry, matched by an intense period of research into the biology of farmed species. The range of species cultured is large and growing. According to National Aquaqlture Sector overview in 2008, African catfish (*Clarias gariepinus*) was first introduced in Malaysia in the early 1980's and it has been reported as the second largest contributor in terms of aquaculture production in Malaysia. The African catfish, is locally known as Ikan Keli belongs to *Clariidae* family, omnivores feeding nature and obligatory air-breathing freshwater fish. African catfish is a most attractive species for aquaculture because of its high degree of hardiness, the ability to feed on variety of feeds, and rapid growth, and survival level in poorly oxygenated water (Pillay, 1990). This species has high economic importance in many countries of the world including Malaysia. Many aqua farming choose this species because the sale price at the market also giving a good promising in profit to the farmer as well as its consumer acceptance and good market in local and global. Nowadays, there are many products produced from African catfish such as fresh and frozen whole-dressed fish, fillets, shank fillets, fillet strips, nuggets, steaks, breaded fillets and nuggets, marinated fillets, and smoked fillets (Silva and Dean, 2001) and make this fish are very valuable and has a high potential to be commercial entrepreneurship development.

Aquaculture is rising because the quickest growing food-producing business within the world due to the increasing demands for fish and seafood. Worldwide, the aquaculture business has vast at a median rate of 8.9% per year since 1970 (FAO, 2016; Huang & Nitin, 2019).

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However, aquaculture industries often suffer serious financial losses that threaten their growth and health standing, in the main cause of the outbreaks of assorted diseases (FAO, 2016). Different types of chemical and drugs are used to control the diseases in aquaculture industry. Those chemicals and medicines now are prohibited by the European Union (EU) and others country because of harmful for human health and environmental contamination.

Plant protein is currently capturing attention throughout the world because of the value of fish meal high price and inconsistency supply in recent years (Shiu, et al., 2013). It used as a replacement of fishmeal for protein and energy source for enhanced fish growth and health status. This plant protein adds further worth to substrates like improvement of organic compound, probiotics inside the gut of fish and improve health performance and additionally to extend economic profits to aquaculture business (Shimeno, et al., 1993; Sun, et al., 2007). The constraints associated with the use of plant proteins in aqua-feed are well reported. The major one is the presence of anti-nutritional factors (ANFs), such as phytate, which is the main storage form of phosphate (P) in plant feedstuff (National Research Council, 2011). The presence of ANFs such as trypsin inhibitors and lectins are known to inhibit digestive enzyme activity (Gemede & Ratta, 2014). Development of bio-processes for bio-remediation and biological detoxification of agro-industrial residues has been the main focus of solid state fermentation (SSF) research to eliminating or reducing by fermentation process. Fermentation is one promising approach for reducing anti nutritional factors and improving nutritional values of plant sources protein of soybean meal and others plant (Shiu et al. 2013; Azarm & Lee, 2014; Jiang et al., 2018). For example in the recent years, several studies have reported on the use of fermented soybean meal in livestock feed (Rahman et al., 2014) and aquaculture (Yamamoto et al., 2010; Azarm & Lee, 2014; Jiang et al., 2018) for replacing fish meal because it is considered as a new protein source with reduced anti nutritional factors such as trypsin inhibitor content, and improved nutritional values such as increased protein, small sized peptide and free amino acids concentrations (Shiu et al. 2013).

2. PRESENT STATUS, TRENDS, PROBLEM AND PROSPECTS IN AFRICAN CATFISH AQUACULTURE INDUSTRY

The world now is occupied with amount of over seven billion people and increasing above nine billion by year 2050. The situation gives us a big challenge to sustain fish stock and feed according to the increasing of the population. Fish is one of the important parts of human diet but when the demands increasing dramatically, resulting the wild fish stock remained static for the past three decades as shown in Figure 1 (FAO, 2016). Therefore, one of the potential industries that can solve the problem with increasing demands for fish is aquaculture industry (Dauda et al., 2013). From that, the production of aquaculture has been increasing dramatically over the past six decades, and the Food and Agricultural Organization (FAO) has classify that aquaculture as the fastest growing food production industry (FAO, 2016; Atanda, 2012).

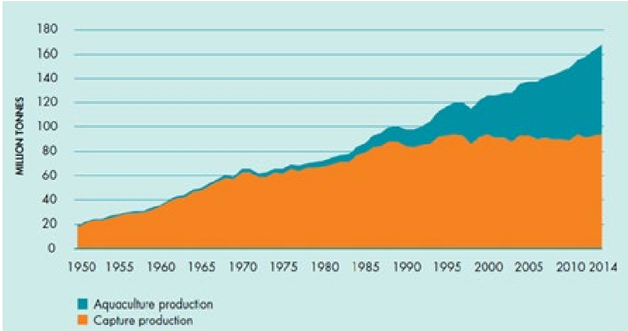

Figure 1: World capture fisheries and aquaculture production

As a chronology, the aquaculture industry's average annual growth rate for 1970 to 2005 is around 8.9 % while the capture fisheries are only 1.2% growth rate. Compared with the terrestrially farm meat production is just only 2.8% with the same time period (Subasinghe, 2005). The new statistic by FAO (2016) reported that from 2009 to 2014 the annual average in aquaculture was increased with 6% compared to the captured fisheries industry that showed reduce trend of 0.71%. In 1974, only 7% of total fish was contributed, but it increased dramatically to 26% in 1994 and 31% after a decade later. Currently, aquaculture industry contributed a total of 44.14% of fish produced all around the world (FAO, 2016).

In a global aquaculture production, China and Asia still the top ranking encompasses all sectors namely finfish, molluscs, aquatic plants, crustaceans, and other aquatic animals including amphibians, in freshwater, brackish and marine environments. According to FAO (2016) reported that 580 species was being farmed and dominated by finfishes by the total of 362 out of 580 species with the famous cultured of finfish are tilapia, carps, salmon and catfish (FAO, 2017). For the catfish, the most cultured and demanded by consumer are Channel catfish (*Ictalurus puncuatus*), Stripped catfish (*Pangasius hypophthalmus*), Amur catfish (*Silurus asotus*) and African catfish (*Clarias gariepinus*) with the percentage of production of 0.53%, 0.52%, 0.62% and 0.33% respectively (FAO, 2017).

The aquaculture sector in Malaysia now consisting of farming both inland and marine fishes, fresh water, crustaceans, molluscs, diadromous fishes and aquatic plants (FAO, 2017 & DOF, 2016). The history of aquaculture industry in Malaysia was started on 1920 with the culture of Chinese carps in mining pools and after that

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in 1950 there was semi-intensive culture of clams and freshwater fish in ponds (Liong et al., 1988; Kechik, 1995). From that, the aquaculture industry has been growing very well with a total production of 506,465.25 tonnes at the end of 2015. Now, aquaculture production in Malaysia lead by aquatic plants (seaweeds) with the value of 51.5% of total aquaculture in 2015 (DOF, 2016). However, more than 30 finfish species are cultured, with the highest percentage from African catfish and lower amounts from sea bass, red (hybrid) tilapia, river catfish (*Pangasius sp.*), and red snapper as shown in Figure 2 (DOF, 2016).

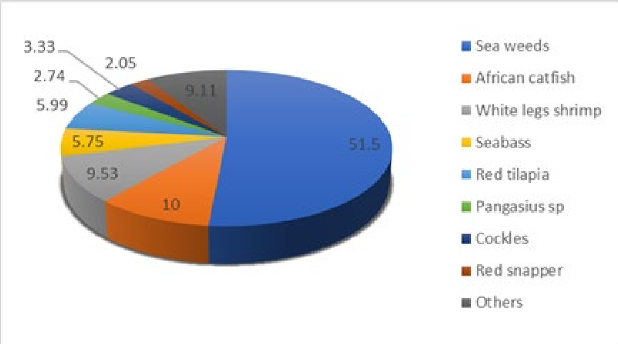

Figure 2: Percentage contribution of major aquaculture species in Malaysia, data sourced from Malaysia, annual fisheries statistics (Department of Fisheries [DOF], 2016).

According to Csavas (1995) reported that aquaculture sector was introduced in Malaysia through the aquaculture industry in Thailand between year of 1986 to 1989. From the reading and file documented, the first cultured for this species in Malaysia was around year 1987 with total production of 6.46 metric tonnes. Currently, Malaysia is one of the importers of fish in the global (FAO, 2016). Therefore, aquaculture industry has a great promise to fill up the gap between supply and demand for fish and automatically can improving food security and creating more jobs for the people. According to Wing-Keong (2009) indicated that until now Malaysia remains as one of the highest consumers of fish per capita in the world and expected to be increase from year to year.

A disease is an abnormal condition that negatively affects the structure or function of organism's part and it is the most economic problem in an aquaculture sector (Grisez & Ollevier, 1995). Nowadays, disease is one of the serious problems occurred many farms because of the several factors. In natural condition, when the fry born, they automatically carry a pathogens and parasites in their body but in a resistance level and it is becoming active when reached a certain size due to the several factors from environment and ecological components. In aquaculture, the cost operational farm will increase when the fish affected by the disease and resulting in profit loss in production. According to Moyle & Cech (2004), the disease in fish is still not understood very well by researchers and need to be explore more detail about their mechanism. To control the disease, it is very crucial to maintain the optimum condition during the growth phase of the fish.

Good nutrition in animal is very important to a healthy and high-quality production. In aquaculture industry, feed represents about 50 – 60% of the production cost in farm. Nowadays, there are too many researches on fish disease, growth performance and health status but less in a fish feed especially a replacement of protein from plant sources in the fish feed. One of the alternative ways to optimise growth and health condition of the fish is by provide them a good protein from plant-based instead of giving a good rearing condition and caring of the fish. A details study on fish feed property can make the unwanted feeds can be minimized, and water quality will be more effective for the any system for the fish to breed and can reduced the cost of the maintenance. Application of chemical in aquaculture industry now is getting common in used among the farmers. According to Faruk et al. (2008) stated that the achievement of aquaculture industry now is depending on the chemicals that has been used in various methods for centuries. The example of chemical and drugs application in aquaculture industry are health management aquatic, soil and water management, pond construction, improvement of the aquatic productivity, reproduction, feed formulation, growth performance and processing proses of the final product (Group of Experts on the Scientific Aspects of Marine Environmental Protection [GESAMP],1997; Subasinghe et al., 1996). In aquaculture industry, some common chemicals used was formalin, sodium chloride, methylene blue, potassium permanganate, malachite green and glutaraldehyde (Plumb, 1992).

According to Ali et al. (2014) stated that the usage of chemical and drugs in aquaculture sometimes lead to several problems for example of lack of knowledge in using the chemical in farm. To solve this problems, policy makers, researchers, academician and scientists should work together in this issue of chemicals used in aquaculture to decrease the negative impacts also very important for the human consumption. Therefore, there is a necessity for better understanding of chemical uses in aquaculture management and initiative should be taken both by the government and private organizations. Instead of using a drug and chemical in aquaculture industry, the others alternative is utilizing a source from plant-based used as an improvement material in aquaculture industries focusing on feed technology. This alternative is very useful in feed formulation and can be used as a supplement and it is safe than using a chemical or drugs.

3. NUTRIENT REQUIREMENTS AND VEGETABLE INGREDIENTS IN AFRICAN CATFISH AQUACULTURE

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Like others living organism, *Clarias gariepinus* also need nutrition for growth and health performance. Nutrition is the series of processes by obtain food substances and use them to provide energy for growth, activities and reproduction. Generally, high quality of nutrient intake in animal production is very crucial to economically produce a healthy and high quality of product (Winfree, 1992). As we all known, *Clarias gariepinus* is an euryphagic animal means it using a wide type of food to consume for survive (Schoonbee, 1969; Richter, 1976; Bruton, 1979; Spataru et al., 1987). African catfish also known as an omnivore feeding nature and consumed a variety of food like insects, plankton, snails, plant matter in the natural water bodies (Bruton, 1979; Uys, 1989). But sometimes it shows propensity toward a carnivorous feeding habit and this make it has a relatively high dietary protein requirement, normally 40–50 % of crude protein on a dry weight basis. The information above revealed that it has an ability to digest plant proteins and utilize carbohydrates as an energy source (Clay, 1979; Van Weerd, 1995). In a farming perspective, euryphagic give an advantages and benefit to the farmers because they can use a variety of feed ingredients including animal and plant-based origin to formulate feeds that will satisfy the fish dietary requirements.

The larvae and early juveniles of this species normally need a protein content around 55 % and 9% of lipid. For the carbohydrates, it used as high as 21 % of the diet. According to Kerdchuen (1992) he suggested that a minimum level of 0.5 – 1 % dietary n-3 fatty acids is recommended for *Heterobranchus longifilis* fry. But, there were still lacking on quantitative information for the *Clarias gariepinus* and the suggestion made by Uys (1989) stated that it will grow better if at least 10 % of the total lipid consists of fish oil and it is recommended that the minimum level also suggested by Kerdchuen (1992) is incorporated into fry feeds. Some work has been done for requirement of the qualitative amino acid of larvae (Conceição et al., 1998), but for the quantitative requirements of larvae, except for methionine (Uys, 1987) are still not clear until now. Similarly, the fatty acid requirements for this species is still unknown, except that a 1:1 ratio of n3 and n6 fatty acids is to be optimal for growth and body condition. Normally, the amino acid requirements of early juveniles and weight more than 10 g onwards is better understood. Uys & Hecht, (1987) studied the pancreatic and foregut amylase activity in *Clarias gariepinus* larvae with consumption of dietary carbohydrate. Their finding was similar with Ali & Jauncey, (2005) found that intestinal amylase activity increased with increasing dietary carbohydrate levels. These findings show that African catfish are capable of digesting carbohydrates from an early stage until they reach a matured stage (Uys, 1989).

In the growing phase, which is the market size, there were some evidence that nutrient composition requirements changed around 5 gram in weight and remain constant after that. At this phase, the basic nutritional needs are range from 40 to 43% of protein, 10 to 12 % of lipid and 15 to 32 % of carbohydrate used in feed. For this species, both animal and plant proteins are well digested and can be used to replace fishmeal and any of them into the diet. According to Van Weerd (1995) reported that protein contain between 35 – 38% can reduce the feed costing and appetite feeding of fish which resulting the increasing of the profitability for the farmers. In other study, by using of fish oil as a source of lipid can negatively affect the growth of the fish (Ng et al., 2003; Ng et al., 2004), indicates that the species has a certain requirement for n-6 fatty acids. However, the lipid source does not affect the whole-body composition or muscle lipid level in catfish, although fatty acid and alpha-tocopherol levels generally reflect the fatty acid profile and alpha-tocopherol concentration of the dietary lipids that are used (Ng et al., 2003).

From the previous study it is concluded that average permissible carbohydrate level for this species is around 27 % and Ali (2001) suggests that this species cannot utilize dietary carbohydrate levels more than 35 % above. On the other hand, Pantazis (2005) found that carbohydrate levels between 26 to 32 % had a significant protein sparing effect (process by which the body derives energy from sources other than protein) and he recommend that carbohydrates level in catfish diet formulation should be more than as usual. Gross and digestible energy requirements needed for this species are around 14 kJ/kg - 19 kJ/kg, respectively, with an average protein to energy ratio value is around 27 mg/kJ. The protein to energy ratio is depend on temperature (Henken et al., 1986) and increases from 25.4 mg/kJ at 24 °C to 34.7 mg/kJ at 29 °C. For the body composition in *Clarias gariepinus*, the study indicated that is not influenced by varying dietary protein to energy (P/E) ratios (Ali & Jauncey, 2005). At a dietary protein content of 40 %, it appears that the optimal lipid and carbohydrate ratio is around 1:2.5.

Until now, the exact amount of vitamin and mineral requirements of *Clarias gariepinus* are poorly understood and some of the farmers just follow their experience or previous knowledge to implement this in the feed manufacturer. According to Wilson & Moreau (1996) reported that the requirement of vitamin and mineral of channel catfish are more than enough for the needs of *Clarias gariepinus.* Under natural conditions, fish normally obtain their nutrient from the environment surrounding. An observation by farmers found that adding vitamin and mineral up to 1% is enough for the growth for this species. Study by Ng et al. (2001) has shown that mineral supplementation of feed containing 27 % fishmeal had no effect on growth of juvenile *Clarias gariepinus.*

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They suggest that it is not necessary to include a mineral mix into diets that contain a high proportion of fishmeal.

4. REGULATION AND SAFETY ASSESSMENT OF THE PLANT PROTEIN USE FOR ANIMAL NUTRITION IN THE GLOBAL

Mostly plant protein source used by the farmers is from by-product and also called as food waste. Until now, many countries including Malaysia do not have a comprehensive food waste management framework although some of the frameworks are underway of planning and in development phases (Thi et al., 2015). In this case, Malaysia could probably adopt a good models of food waste management from other countries such as japan, Taiwan, Thailand and South Korea in efforts of solving the food waste production problems including for the aquaculture purposes. South Korea and Taiwan are countries which have a great demand for animal feeds from food waste. These countries used around 81 % and 72.1 % of food waste in animal feed respectively (Kim et al., 2011). Using a food waste as a feedstock for animal feeding is not suitable in developing countries because the management or handling in the countries not implement very well compared with the developing country. To manage the food waste management, a good standard operating procedure (SOP) is very important to avoid from problem including the environment pollutant, disease spread and also the excessive of the food waste.

In Malaysia, according to Feed Act (Act 698) (law of Malaysia, 2009) described that not all of food waste is suitable to used as animal feed for livestock except for the sources that is commonly practiced. Normally, food waste used for animal feed is mostly comes from bone meal, eggshell, seashells because they are major mineral supplement source of calcium, phosphorus and more. The use of waste materials for fish feed formulation has been practiced for centuries depending on the method that farmer uses but normally it is depending on the eye observation not from the scientific way. To the best of our knowledge, however, food waste is not widely used in the manufacture of feed pellets or any supplements because sometimes the farmer just fed the fish with the raw one especially on the *Clarias gariepinus* species. This situation was different in China where the farmers tend to use a compound pellet feed to maximize the fish growth rather than use a raw food waste (Alice Chiu et al., 2013). The study by Zulhisyam et. al. (2020) revealed that fish pellet coated with plant protein also give a good result of growth performance for *Clarias gariepinus*. Currently, swilling method for fed the pigs is the most popular application of food waste management. According to Menikpura, et al., (2013) stated that the recycling of food waste by swill has been practice by many Asian country, including Korea, Japan and Taiwan and until now there has no safety issues related to the used of food waste for feeding pigs. In addition, Taiwan start recycling food waste in 2001 about 2000 ton of food waste is recycled daily used as pig swill.

Animal feed is an important element by which hazards can enter the human body and the safety of the feed should be confirm very well before feeding the animal. Safety assessments are often multifaceted, and it is very important in any aspect. Consideration by both the safety of animals as the primary of the feed and also safety of human as a consumer is very important because it is related to the content of the feed from the animal origin that consumed by the human. Besides that, the risk of people that working on the feed also should be assessed. To avoid any risk to the consumer, a proper feed safety assessment should be established by providing a guidelines or standard operating procedure used as a reference source. Normally, a good evaluation of safety assessment is conducting on a case-by-case due to the specific characteristics and use of the ingredient which make up a complete feed. This ranges from traditional grains, oilseeds and their by-products (e.g. soybeans and soybean meal), mineral and vitamin supplements (e.g. copper sulphate and vitamin B12), by-products of food processing (e.g. dried bakery residue), viable microbial supplements and fermentation products either purified or not (e.g. *Lactobacillus acidophilus* and dried fermentation soluble), flavouring aids (e.g. aldehyde C-18), colouring agents (e.g. astaxanthin) and to other ingredients used to aid the process of manufacturing the ingredient or the mixed feed (e.g. binding or anti-caking agents).

5. USING A PLANT PROTEIN SOURCES IN AQUACULTURE INDUSTRY

Nowadays, agricultural by-products are considered as an alternative feed for aquaculture industry used as supplement or protein source because of it is easy to get, low price and excellent of functional properties (Harjanti et al., 2012; Rahman et al., 2013; Dong et al., 2005). For example of tofu production in Malaysia, there are a lots of tofu factories located in urban and peri-urban areas. Because of the improper regulation and awareness among the feed manufacture, the soy pulp was thrown away into the river or burn even some portion was used as a feed for animal. Normally, the use of soy waste as animal feed is practicable among the farmers who live near to the soybean factory or processing place. The price of soy pulp in Malaysia still at the low-price range around RM 400 per tonne and sometimes the farmers can get it as a free material because of the excess of the soy waste produced. Generally, there are three common method used of soy waste as an animal feed namely raw soy waste, dry soy waste and ensiled soy waste with other feeds (Amaha et al., 1996). Kim et al. (2012) reported that fed the animal with

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35% of raw soybean curd residue can improved the growth performance of animal without deterioration of meat quality of the animal. In addition, Harjanti et al. (2012) indicated that preparing a feed from soybean curd residue also give a positive effect on nitrogen balance of animal but the feed was formulated similar energy intake with commercial one.

Fishmeal is the most expensive ingredients in commercial feed because it is highly digestible, high content in amino acid and used by many feeds manufactures in aquaculture. According to Amaya et al. (2007) stated that fishmeal now is one of the major dietary protein sources in aquaculture industry because of its characteristic. Nowadays, issue of negative impacts on fishmeal production has been get intention among the scientist and makes them keen on to identify the best ingredient as an alternative to replace the expensive fishmeal for the global aquaculture industry (Peres & Oliva Teles, 2005; Cheng et al., 2013; Goda et al., 2014). There a several scientists did not recommend using a fish meal in the aquaculture feed because of the several factors and issues (De Francesco et al., 2004; Engin & Carter, 2005; Bonaldo et al. 2011; Ramachandran & Ray (2007). As an alternative to replace fish meal, plant protein sources is be the most suitable candidate because of their characteristic as described in previous section and the most important things is it can be used as long as there was no negative effect on the growth performance and health status of animal (Espe et al., 2007; Hansen et al., 2011; Lund et al., 2011; Yun et al., 2012; Daniel, 2017).

The problem involved when using a plant protein in fish feed are well reported by previous researchers. Among the constraints, the major one is the availability of anti-nutritional factors (ANFs) in most of the plant protein sources. According to Soetan & Oyewole (2009) reported that ANFs are the compounds that can reducing the nutrient value of plant products used for both human and animal. The existing of ANFs is very important indicator to determine either the plants can be used as a feed or not. The major compound presence of ANFs in plant such as tannis, phytate, oxalate, saponins, lectins, alkaloids, protease inhibitors and cyanogenic glycosides (Habtamu & Negussie, 2014). According to Habtamu & Negussie (2014) stated that at a low quantity of ANFs it can give a beneficial effect on animal health for example of phytate, lectins, tannins, amylase inhibitors and saponins resulting to reduce the blood glucose and insulin level in the body. In addition, there are also ANFs compound that can reduce the probability of cancer such as phytates, tannins, saponins, protease inhibitors, goetrogens and oxalates. For the others ANFs such as a phytic acid, lectins, tannins, saponins, amylase inhibitors and protease inhibitors, it can reduce the availability of nutrients and cause a growth inhibition. Welker et al. (2016) revealed that ANFs compound sometimes lead to zinc deficiency in fish. In addition, ANFs such as trypsin inhibitors and lectins are also known to inhibit digestive enzyme activity (Gemede & Ratta, 2014).

Development of the agricultural residues get more interest from various scientist regarding to the method to remove or reducing ANFs compound in the plant protein. According to Hamid et. al. (2017) there are several methods used to remove ANFs namely soaking, germination, boiling, autoclaving, fermentation, genetic manipulation and other processing methods without manipulate the nutritional value of food origin. From that, one of the most popular and well-practiced by the aquaculture industries in Malaysia is fermentation process. Until now, fermentative nutrition in aquatic animals is still less understood (Esakkiraj et al., 2009) but for the in vitro processing of plant ingredients by fermentation has been recommended by several authors to decrease anti nutritional factors and increase nutrient availability (Antony & Chandra, 1998; Sahu et al., 2002; Ramachandran & Ray, 2007). However, in Malaysia the biological method of fermentation process is still at the new phase for the detoxification of soybean meal and increase nutrient bio availability because of the action of enzymes produced by the microorganisms itself (Khan & Ghosh, 2012).

6. USE OF PROBIOTICS ASSOCIATED WITH PLANT PROTEIN IN FISH FARMING INDUSTRY

Nowadays, aquaculture industry is the fastest growing food production sector in the world, but diseases especially bacterial infections remain the main problem to the industry to be develop (El-Haroun et al., 2006; Pieters et al., 2008; Abd El-rhman et al., 2009). The infection by microorganism in aquaculture resulting the major problem facing by the farmer and it is a big challenge for the industry to sustain the production (Ringo & Birkbeck, 1999). Because of that, the application on vaccines and antibiotics were used to prevent from disease for decades. The application of an antibiotics and vaccines in aquaculture industry for a long period has creates some problem to the consumers such as the accumulation in the tissue and immune-suppression (Tukmechi et al., 2007; Nayak et al., 2007; El-Haroun et al. 2006) and change of the natural condition at coastal areas due to cultivation of fish and shellfish (Gildberg et al. 1997). Because of that, the concern of using a chemical compound in the aquaculture industry has been increased. The interesting thing that it is not only in aquaculture, it is also related to other field like human medicine and agriculture which also looking for another alternatives method to replace with the chemical compound involvement (Rollo et al., 2006). Besides that, application of antibiotics now is got a less confident among the people because of the several factors

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and it also has been banned in European Union (Angelis et al., 2006).

According to Panigrahi et al. (2010) stated that to avoid the usage of antibiotic and vaccines in aquaculture industry, probiotic now was introduced as one of the alternatives to replace them. Probiotic used as an animal feed started from year 1970 for pig, cattle and poultry but the application in aquaculture industry is still new (Tukmechi et al., 2007). The research of probiotic in aquaculture industry is increasing from year to year ahead because of the demand for environment friendly aquaculture (Abdelhamid et al., 2009) and the use of eco-friendly alternatives of antimicrobials (Merrifield et al., 2010). Probiotics used in aquaculture industry normally available in two types namely dry and liquid form. Dry forms are normally having a longest shelf life compared with the liquid one. For the liquid form of probiotics, it is directly mix with the feed and normally it is recommended in egg hatcheries (Decamp & Moriarty, 2007). In addition, Nageswara & Babu (2006) stated that the liquid forms of probiotics are much better compared with dry form because it has a low-density compound.

Generally, the aquatic probiotics are divided into two categories based on their mode of administration. First category is probiotic bacteria was mix with feed supplements function of enhancement of bacteria in the gut and this category is suitable with plant material used as a medium to send the probiotic into the fish gut. Second category involves the addition of probiotics directly into the water so that the animal can consume nutrients in the water and inhibit the growth of pathogens. All these categories of probiotics were used in finfish and shrimp aquaculture industries (Nageswara & Babu, 2006; Sahu et al., 2008). According to Chauhan & Singh (2019) stated that the sources of probiotics can be isolated from many different sources such as gill, kidney, stomach, gastrointestinal tract, gonads and other internal organs called putative probiotics. Besides that, the probiotics from the commercial sources (non-putative) also available in the market. According to review article by Nwanna (2015) the most famous and frequently used of probiotic in aquaculture industries are *Bacillus, Lactobacillus* and *Bifidobacterium* genus. In addition, there are many species *of Lactobacillus, Bifidobacterium* and *Streptococcus* that has been reported for aquaculture industries as probiotics namely *L. acidophilus, L. casei, L. fermentum, L. gasseri, L. plantarum, L. salivarius, L.rhamnosus, L. johnsonii, L. paracasei, L. reuteri, L. helveticus, L. bugaricus, Bifidobacterium bifidum, Bifidobacterium breve, Bifidobacterium lactis, Bifidobacterium longum, Saccharromyces boulardii, S. thermophilesand* and *S. cremoris* species. Besides that, there are several reports indicated that various aquatic probiotics improve growth performance, increased the immunity system and against bacterial pathogen (Chauhan & Singh, 2019; Barths et al., 2009).

7. SUMMARY OF PREVIOUS STUDY ON THE USAGE A PLANT PROTEIN SOURCES SPECIAL FOCUS ON *Clarias gariepinus*

Nowadays, many studies have been conducted by researchers on the usage a plant protein sources used as a supplement for feed. A lot of modification that has been done to optimum growth performance of animal especially in aquaculture industry. Information regarding the material (plant sources) used for feed need to be documented very well and it is very important as a references source to other researchers. In this literature, special focus on feed used from plant based for *Clarias gariepinus* on previous study was summarized in Table 1.

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Table 1: The study on the usage a plant protein sources special focus on African Catfish, *Clarias gariepinus* by previous researcher.

Main protein source	Summary	References
Freshwater microalgae: *Spirulina Platensis* and *Chlorella vulgaris*	*S. platensis*, and *C. vulgaris* can improve the feed efficiency, as well as the growth performance and health status of African catfish.	Raji et. al. (2019)
Bambaranut Meal	*Clarias gariepinus* does not need high inclusion of fishmeal up to 45% with bambaranut meal substitution for better growth performance and health status.	Uchechukwu & Gift, (2019)
Bambaranut (*Voandzeia subterranea*) meal and Soybean (*Glycine max)* meal	The results suggest that Bambaranut meal can partly substitute fish meal and completely replace soybean meal in the diets of African catfish.	Uchechukwu et al. (2017)
Cashew Kernal Oil, *Anacardium occidentale*	Like other vegetables oils, cashew kernel oil can replace expensive fish oil in fish feed without negatively affecting its growth performances and can reduced fish production cost.	Anvo et. al. (2017)
Mulberry foliage extract	It is concluded that mulberry foliage extract at the concentration of 7 g kg $_{-}^{1}$ DM is potential dietary antioxidant supplements and recommended to improve the quality of fish meat.	Sheikhlar et. al. (2017)
Crickets meal, *Gryllus bimaculatus*	Practical diet containing 100% cricket meals is appropriate for growth and nutrition utilization of fish.	Taufek et. al. (2017)
Soaked *Cajanus cajan* (L.) Millsp.	Soaking *C. cajan* seed for 24 hours improved the nutritional profile of the ingredients to replace 20% of the soybean protein in the diet of *C. gariepinus* with no negative effect on growth and nutrient utilization.	Solomon et al. (2017)
Toasted pigeon pea, *Cajanus cajan* seed	The growth of C. gariepinus was significantly improved by the different inclusion levels of toasted *C. cajan* in the diets; Cost analysis revealed that it was economically cheaper to raise the African catfish using toasted *C.* cajan	Solomon et al. (2017)
Dried Brewer's Yeast *(Saccharomyces cerevisiae)* Slurry	Specific growth rate decreased with increasing substitution while the best feed conversion ratio was obtained in the diet devoid of Dried Brewer's Yeast meal.	Solomon et al. (2017)
Pawpaw (*Carica papaya*) Seed Powder	Fish meal could be replaced up to 80% with pawpaw seed powder meal in the diet of *Clarias gariepinus* fingerlings to encourage growth	Irabor et al. (2016)
Marine Fish Viscera-based-diet	The study indicates that MFV meal can be used up to 30% in formulation fish feed for promotion of *Clariasgariepinus* rearing in rural areas.	Oké et al. (2016)
Green macroalgae, *Ulva lactuca*	Diets of 20% and 30% *U. lactuca* resulted in poor growth and feed utilization compared to control group and 10% of *U. lactuca*	Abdel-Warith et. al. (2016)
Red seaweed, *Gracilaria arcuata*	The results of the experiment revealed that African catfish fed a diet with *G. arcuata* included in 20 %and 30 % levels showed poorer growth and feed utilization than the control group and 10 % of red seaweed extract.	Al-Asgah et. al. (2016)
Cirina butyrospermi caterpillar's meal	The study demonstrates that 50% of fish meal can successfully be replaced with *Cirina butyrospermi* caterpillar meal in *C. gariepinus* fingerlings diet without a negative impact on growth or feed utilization and reduced fish production cost.	Anvo, et. al. (2016)
Fluted pumpkin (*Telfairia occidentalis*) leaf powder	The results suggest that dietary supplementation with *T. occidentalis* leaf powder improved the growth, feed utilization, and survival of *C. gariepinus* fingerlings.	Dada (2015)

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Soybean meal with beniseed (*Sesamum indicum*) meal	The inclusion of sesame seed meal up to 25% is recommended in the diet *of Clarias gariepinus* juvenile, since this inclusion level did not exhibit any negative effect on the fish health.	Ochang et al. (2014)
Sesame seed meal (*Sesamum indicum)* and Bambaranut (*Voandzeia subterranean)* meal	The cost kg^{-1} of diet production increased with inclusion of Sesame seed; Results indicate that Sesame seed and Bambaranut meal alone or in combination are good plant proteins; Inclusions of Sesame seed meal increased body lipid than Bambaranut meal.	Enyidi et al. (2014)
Moringa oleifera leaf meal	Haematological study showed that 10% of *M. oleifera* leaf meal can be substituted in catfish (*C. gariepinus*) diet since it did not have any adverse effect on the blood and serum enzyme	Dienye & Olumuji, (2014)
Agama lizard meat meal, *Agama agama*	Agama lizard meal can be included at any level, but it is recommended that 20% inclusion level be used is the best.	Tiamiyu et al. (2013)
Cooked and mechanically defatted Sesame (*Sesamum indicum*)	Comparable performance in growth nutrient utilization and carcass crude protein deposition in *Clarias gariepinus* fed diets with 25 and 50 % of Sesame cake/meal showed that these meals could be viable means of improving the cost of fish feeding.	Jimoh & Aroyehun (2011)
Groundnut cake	Groundnut cake supplemented with at least 0.45kg each of lysine & methionine per 100kg of feed is suggested for fish feed	Davies & Ezenwa (2010)
Bamboo substrate	The study indicated bamboo poles as substrate for periphyton was a superior alternative to improve catfish production under pond conditions.	Amisah et al. (2008)
Mangosteen (*Garcinia mangostana L.*) extracts	Feeding fish with 0.5 % of mangosteen extracts for 35 days has no adverse effect on growth and enhanced the hematological parameters of African catfish fingerlings.	Soosean et al. (2010).
Soy protein concentrate	Results indicated that 75% of fish meal protein in catfish diets can be replaced with soy protein concentrate for growth performance and health status.	Fagbenro et al. (2004)
Mealworm (*Tenebrio molitor*)	Results indicated that mealworm was an acceptable alternative protein source for the African catfish.	Ng et al. (2001)

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8. CONCLUSION

In fish feed, the nutritive value of fish diet is depending on the quality of the protein ingredients. Protein is the most expensive components in fish feeds and the fish meal is the major source of protein in fish feed. To date, fish meal is not only expensive but also a limited source due to its large demand in animal and fish feed industries. The replacement of plant protein sources in fish meal is growing fast and it has also attracted many nutritionists to explore a new thing to replace the protein sources even from other sources as long as giving a good promising and follow the ethics. In conclusion, the application of protein replacement from plant source in fish meal should be strengthening to obtain a good quality of fish feed and put this industry at a high level.

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