Review Article

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Journal of Environmental Biology

JEB™ p-ISSN: 0254-8704
e-ISSN: 2394-0379
CODEN: JEBIDP

DOI : http://doi.org/10.22438/jeb/41/5(SI)/MS_16

A review on the improvement of cladocera (*Moina*) nutrition as live food for aquaculture: Using valuable plankton fisheries resources

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Paper received: 13.01.2020 *Revised received*: 07.04.2020 *Accepted*: 14.08.2020

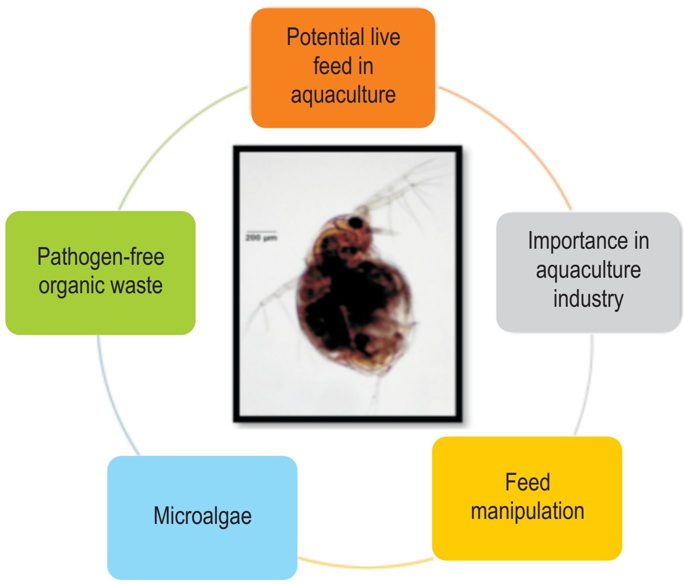
Abstract

This review focuses on the potential of *Moina* sp. as a promising live feed in aquaculture, as well as on low-cost enrichment methods, which can improve nutrition levels available from this live feed species.

Since formulated feed for this purpose has not yet been established effectively, the features of live feeds in the performance of marine and freshwater larval rearing is essential. Hence, to succor growth productivity and to introduce newly livestock species into aquaculture industry, support for the stage of larval rearing must be improved and, better nutritional options must be applied. Furthermore, the natural feeding habits of fish needs live food rich in protein for improved growth, enhanced reproduction as well as survival. Common enrichment protocols, such as oil emulsion, are relatively expensive and consequently, increase overall production cost in hatcheries. The above factors have moved scientists to focus more on development of low-cost, live feed substitutions to ensure success of larval feeding in aquaculture. Larval feed performance depends directly on improvements in finding a better low-cost live feed technology for a better zooplankton and phytoplankton production.

Cladocerans like *Moina* sp. have recently been explored as a potential live feed alternative to boost fish and shrimp larval cultivation in hatcheries. The increase in demand for fish as a source of protein for human consumption requires advancement in the development of aquaculture technologies and, emphasis is well placed on improving supply of live food organisms to assist in the larval development process.

The continuous production of live food organisms is prerequisite to fish and shrimp larval growth and survival in hatcheries.



Key words: Aquaculture live feed, Low-cost, *Moina*, Nutrition, Zooplankton

How to cite : Rasdi, N.W., A. Arshad, Mhd. Ikhwanuddin, A. Hagiwara, F. Md. Yusoff and N. Azani: A review on the improvement of cladocera (*Moina*) nutrition as live food for aquaculture: Using valuable plankton fisheries resources. *J. Environ. Biol.*, **41**, 1239-1248 (2020).

Introduction

The continuous production of larvae in aquaculture systems depends on the planktons that have been enclosed with important nutrients (Budhin *et al.,* 2016). Availability of suitable live feed for feeding finfish and shellfish larvae has led to successful propagation of hatchery-reared species (Pronob *et al.,* 2012). Supplying adequate live food for fish larvae is important and the nutritional quality of living food species can be improved by enriching the nutrients (Rasdi and Qin, 2016a; Rasdi and Qin*.,* 2018b). Live feed species in larvae and early post-larvae stages of various fish are more beneficial than artificial feed and shellfish species, since zooplankton are known to be an important food for animals in natural aquatic habitats where they pass on the organic matter to higher trophic levels from phytoplankton and detritus (Das *et al.,* 2007; Parakrama *et al.,* 2012; Abbas *et a.l*, 2015). Larvae consumption of zooplankton constitutes major part of their nutritional intake with zooplankton also playing a major role in recycling nutrients and sources of energy within their respective food web (Kar *et al., 2017;* Miah *et al.,* 2013).

The diet of larval fish in aquaculture primarily depends on the use of brine shrimp (*Artemia* spp.), especially for starter feed in the larval rearing of most fish and crustaceans . Nevertheless, brine shrimp price is the major restraint for poor-resource farmers in the developed countries but required to continuously use this species in feeding hatchery-reared larvae (Ngupula *et al.,* 2014). The live food species are the most important resource for aquaculture in an aquatic environment and most fish larvae and shellfish in nature directly feed on small zooplanktonic species (Pronob *et al.,* 2012). Live food organisms are commonly referred to as "living nutritional capsules" because they contain natural essential nutrients and energy sources such as proteins, lipids, carbohydrates, vitamins, minerals, fatty acids and amino acids that are needed in aquaculture for the growth and maintenance of majority of cultivated species (Mona *et al.*, 2017).

The major management aspect in farming of both finfish and shellfish is proper management of feeding. In order to minimize larval production cost and, maximize the overall production level in hatcheries, good larval feed is important for the rapid growth of young fish and prawns (Rimmer *et al.,* 2011). Major factors such as availability, nutritional requirement of larval fish and shellfish, size of feed that fits the mouth gape of larval fish and, high nutritional value complement selecting zooplankton as live feed for larvae (Budhin *et al.,* 2016). Since no artificial larval diet can fully satisfy larval nutritional requirements, good rearing still depends on a suitable supply of best quality plankton, usually in the common form of rotifers *Brachionus plicatilis* and brine shrimp *Artemia salina*. Consequently, the development of live feed is mostly restricted to *Artemia* nauplii, which is matured after incubating dry eggs (cysts) (Parisi *et al*., 2014). Moreover, live prey feeding typically takes 40–50 days, depending on the temperature of water and the procedure for rearing before fish are transferred to an artificial diet (weaning). In recent years, the timing of first dry food source has been continually pushed to an earlier date by the use of new, more complex artificial foods that also include antioxidants and immunostimulants and better meet the larval requirements in terms of structure, size, buoyancy and taste (Villamizar *et al*., 2009). However, fish larvae had showed poor response towards artificial diet due to inadequate growth of their digestive system during early feeding cycle with low digestive enzyme production (Akbary *et al*., 2010). Furthermore, zooplankton provides good digestive enzymes of trypsin and pepsin that is vital to fish larvae during early stages of development (Ronnestead *et al*., 2013).

In most hatcheries, feeding regimes for early larval stages are often dependent on rotifers and *Artemia* followed by artificial pelleted diets. Rotifers are common larval live feeds used in both marine and freshwater hatcheries due to their small size that can be accommodated by the mouth gape of fish larvae (Velasco *et al*., 2011). However, mass culture of rotifers often carry risks of sudden mortality which may result from contamination of populations by ciliates or, pathogenic bacteria . Therefore, there is a need to develop other reliable continuous cultures of potential zooplankton species with high nutritional value to assist larval feeding in hatcheries). Even though many live food organisms commonly used in larviculture own a nutritional value higher than that of formulated diets, certain live food zooplanktons are selected as a food source in larviculture depending on qualities including purity, acceptability, nutrient indicators (digestibility and nutrients / organism energy), ease of availability, reliable and quick reproduction and, economically viable. Cladoceran culture offers the possibility of obtaining several living food organisms throughout short period of time when developed under optimum temperature, air, and water quality conditions. Furthermore, the cladocerans, *Moina* sp. and *Daphnia* sp. are both valuable sources of protein, inexpensive to produce and, can serve as an option to *Artemia*. Both species have high reproduction rates, wide environmental tolerance, and an ability to feed phytoplankton and organic waste medium (Samir *et al.,* 2015).

Cladocerans display remarkable tolerance to abrupt increase in salinity as in several species of *Daphnia exilis*, *Bosmina coregoni* and *Daphnia longispina* (Heine-Fuster *et al*., 2010; Zorina-Sakharova *et al.,* 2014 and Leitao *et al.,* 2013). Most fish larvae show a preference for cladocerans because of their whimsical movement, that make them more obvious to their prey (Mayer *et al.*, 1997; Budhin *et al.,* 2016). *Moina* are suitable for fry of freshwater fish and, most freshwater fish species can digest little *Moina* as their first meal (Rottman *et al.,* 2014). *Moina* is ideal for use in aquaculture because of easy handling, fast reproduction, non-selective filter feeding of bacteria in solution, high nutritional value, and suitable for a large variety of conditions (Oh *et al.,* 2012; Samuel, 2014). Since the use of *Artemia is* costly, *Moina* can be a suitable candidate to replace them for feeding fry. It is also highly recommended to use live *Moina* in the hatchery as a replacement to *Artemia* since it can be easily grown in fresh water and can be easily digested by frying (Okunsebor *et al.,* 2010).

This review article discusses enrichment of *Moina* by using different media for improving dietary composition of *Moina* to make them fit for larval feeding. This review focuses on the biology of feeding and the media culture of *Moina*, the basic principles of nutritional requirements, and application of *Moina* to fish and shrimp larval feeding in hatchery. Specifically, the current study discusses the application of *Moina* in aquaculture as live feed, evaluates nutritional composition of *Moina,* reviews current live food enrichment methods for *Moina culture* and demonstrates the current culture practices applied to *Moina.*

***Moina*: Among the richest species diversity:** The genus *Moina* is known to dominate North and South American, Australia, China, tropical Asia as well as Eurasia waters, where the number of moinid species in these areas are comparable to that in *Daphnia*, which further indicates that *Moina* is one of the largest genera of Cladocera in these regions (Bekker *et al.,* 2016; Wang *et al.,* 2009; Alonso *et al.,* 2019). Due to the virtue of high reproduction rates, moinids are utilized as one of the potential foods for fish larvae in commercial aquaculture (Dumont *et al.*, 2013). *Moina* is a small freshwater microcrustacean and is one of the most commonly found freshwater zooplankton in Malaysia (Sinef and Yusoff, 2018). Cladocerans are one of the microcrustaceans, these are considered major secondary consumers in their natural surroundings, as the highest filtration rate among freshwater zooplankton in the ecosystem exists (Dumont *et al*., 2013; Lim *et al.,*1984). *Moina* also demonstrates a broad range of ability to adapt to various environmental parameters (Rizo *et al.,* 2016). Moinids are narrow to average zooplankton species that are usual in tropical waters and along with daphniids, and are generally recognized in limnetic water bodies (Fernando, 2002; Rizo *et al.*, 2017). One of the cladoceran species of *Moina micrura* has been recorded in diverse environments, from freshwater to brackish hyper-eutrophic estuary (Paranhos *et al*., 2013, Moreno *et al.,* 2019).

Use of *Moina* as live feed in shrimp, fish, shellfish and ornamental fish aquaculture : Fish larvae and shellfish diet requires adequate amount of carbohydrates, lipids, vitamins and minerals (Watanabe *et al.*, 1994; Kanazawa *et al.,* 2003; Budhin *et al.,* 2016). Deficiency of any required nutrient may lead to poor growth, anemia, high mortality and / or low feed efficiency in rearing fish larvae and shellfish (Karlsen *et al.,* 2015; Olivotto *et al.*, 2003; Budhin *et al.,* 2016). In aquatic trophic systems, cladocerans occupy the primary consumer level of extensive zooplankton commonly found in freshwater bodies. In recent years, cladocerans such as *Moina and Daphnia* have received much attention in the aquaculture industry (Saini *et al.,* 2013). As filter feeders, cladocerans ingest nanoplankton, phytoplankton, detritus, bacteria and particles of different sizes. Furthermore, cladocerans are then devoured as an important naturally available component of fish diets (Nandini *et al.,* 2013; Qin *et al.,* 1996; Suresh *et al.,* 2000; Srivastava *et al.,* 2006; Hudson *et al.,* 1999; Li *et al*., 2017).

Cladocerans are preferred by most fish larvae and successfully used as food in the fish farming industry for fish larvae (Taghavi *et al.,*2013; Armin *et al.,* 2014). Cladocerans are considered palatable and attractive food for many ornamental fish and prawn seed (Saini *et al.,* 2013). This specie contain a high protein as well as digestive enzymes, such as peptidases, proteinases, lipases and amylases in their intestines, which can act as exoenzymes in the gut of fish larvae (Miah *et al*., 2013). *Moina* is effectively used throughout inland aquaculture as larval live feed (Qin *et al,* 1996; Budhin *et al,* 2016), and used as a replacement live feed for *Artemia* (Alam *et al.,* 1993; Armin *et al.,* 2014; Kotani *et al.,* 2016). It was proposed that the use of *Moina* enhances condition of different fish both young and adult stages (FRSS 2005; Kushniryk *et al.,* 2015).

Moina is suitable for use in the aquaculture applications because it is simple to handle, reproduces easily, is a non-selective filter feeder for solution bacteria, has high nutrient value and is adaptable to different environmental conditions (Ricardo, 1981; Samuel, 2014). *Moina* species may also be considered a promising species for feeding fish larvae and fingerlings as they have a short lifespan, abundant energy storage, small size, and short embryonic stage (Sipauba-Tavares *et al*., 2014; Samuel, 2014). *Moina* macroocopa is a cladoceran mostly found in water bodies and plays a role in food chains in the aquatic environment (Iannacone and Alvarino, 2000; Vignatti *et al.*, 2013) and, has economic importance arising from its use in aquaculture as live food for fish larval stages (Vignatti *et al*., 2013; Rasdi *et al*., 2019). Tawaratmanikul (1988) reported that *Clarius batrachus, Ompok bimaculatus, Lates calcarifer* and *Channa striatus* fish larvae show improved growth and survival for cladorans as live feed (Amornsakun *et al.,* 2001; Budhin *et al.,* 2016). Since the used of *Artemia is* costly, *Moina* can replace them as a suitable candidate for feeding fry. Thorough use of *Moina* in the hatchery is strongly recommended as a substitute of *Artemia*, since it is readily cultivated in fresh water (Okunsebor *et al.,* 2010).

The nutritional value of *Moina's* depends on the stage of life cycle and the form of food obtained (Budhin *et al.,* 2016). The average protein content of *Moina* is 50% dry and adults typically have higher fat content (20-27%), then juveniles (4-6%) (War *et al.,* 2011; Rottman *et al.,* 2014). When cultured in different media, fatty acid contents vary in *Moina* (Bouchnak *et al.,* 2014; Loh *et al.,* 2012; Gama-Flores *et al.,* 2015). Like other live feeds, *Moina* does not fully satisfy the demands of heavily unsaturated fatty acids (HUFA) of larvae fish and crustaceans (Kamrunnahar *et al.,* 2019). Hence, enrichment of *Moina* is important to improve the nutritional content of *Moina* for fish growth.

Feeding *Moina* to fish fry as a mono diet can generally give comparatively better results than feeding a mixed diet or feeding other live feeds, although results are dependent on the specific requirements of fish cultured. Okunsebor *et al.* (2010) showed best performance of *Heteroclarias* fry (African catfish) when fed on *Moina alone* when compared with a mixed diet (*Moina* and *Artemia*). In fact, the best mean weight gain of goldfish fry (*Carassius auratus*) was recorded for fry fed with *Moina* in comparison to other diets tested (Okunsebor and Ofojekwu, 2003; Samuel, 2014). However, *Moina* can be used alone or, in combination with *Artemia* when fed to *Macrobrachium rosenbergii* without any adverse effect on production (Alam *et al.,* 1991; Rahman *et al.,* 2003).

Although Artemia being the most frequently used for larval feeding, the seasonal variation and expensive cost often limit their use in aquaculture hatcheries, and hence it is a requisite to develop low cost live feed organisms which are easy to culture like *Moina in order* to minimize risk to aquaculture practice during early larval development stages (Singh *et al.,* 2012). Moreover, the use of *Moina* as fish larval feed has yielded commendable results with indigenous species in various regions of the world (Bryant and Marty, 1980; Adeyemo *et al.,* 1994; Samuel, 2014). *Moina* has been utilized as an ideal food organism for carp, shrimp and catfish larvae (Singh *et al.,* 2019; Islam *et al.,* 2017). In India and Thailand, *Moina* has also been used in shrimp hatcheries (Rahman *et al.,* 2003).

Nutritional value comparison of live food organisms: *Artemia* is famous as solitary live feed for commercially cultured larvae fish for several decades, and their amino acid profile has been well approved (Watanabe *et al.*, 1978, 1983; Solomon *et al.,* 2006; Dararat *et al.,* 2012). On the other hand, the amino acid profile of freshwater zooplankton has been poorly documented, although these species are increasingly relevant as larvae feeds in hatcheries for freshwater fish (Solomon *et al.,* 2006). The nutritional value of *Moina* differs according to the culture media used and life- cycle. Adult *Moina* usually have higher protein composition than juveniles. However, *Moina* has a higher nutritional value when compared with *Artemia* and, furthermore both species breed and grow faster (Mubarak *et al.,* 2017) making *Moina* comparable to that of *Artemia* (Mubarak *et al.,* 2017). As compared to other live foods, the cladocerans are high in protein as well as other nutrients (Alam *et al.,* 1993; Altaff *et al.,* 2010; Loh *et al.,* 2012).

The moisture content of *Moina* species, approximately 87.9 - 89.0%, is similar to other live foods such as *Daphnia* (88.1 - 89.3%), *Branchionus plicatilis* (86.4 - 91.8%) and *Tigriopus japonica* (86.0 - 87.3%) (Watanabe, 1978, 1983; Solomon *et al.,* 2006). With respect to crude protein content, *Moina* (59.95 - 62.6%) had the highest protein content when compared with *Daphnia* (62.6%) and *B. plicatilis* (52.15 - 60.57%) (Watanabe, 1983; Solomon *et al.,* 2006). Bogut *et al.* (2010) claimed that *D. magna* contained 39.24% and 33% which is relatively lower than *Moina* in fresh and dry weight, which is lower than the equivalent values determined for *Moina*. Solomon *et al.* (2006) stated that the moisture content of *M. micrura* was around 89%, while crude protein was 52.4% of dry weight. *M. micrura* recorded higher amino acid concentrations than *Diaphanosoma excisum* and *B. calyciflorus*, except for alanine, tyrosine, threonine, proline and serine amino acids (Solomon *et al.,* 2006). The main amino acid identified for *M. micrura* was lysine, and glutamine is the main non-essential amino acid (Solomon *et al.,* 2006).

Amino acid levels in the profile of *Moina were* higher than for *Artemia except for* alanine, glycine, proline, serine, and tyrosine (Watanabe *et al.,* 1983; Solomon *et al.,* 2006). *M. micrura was reported to* contain sufficient crude protein and amino acid concentration to provide basic requirements of larvae and post-larvae feed that are essential to the survival and growth of fry and larval cultivated species (Solomon *et al.*, 2006). Meanwhile, *M. mongolica* had most essential amino acids less than *Artemia* and *B. plicatilis*, but, methionine content in *M. mongolica* (1.5%) was greater than *Artemia* (0.9%) and *B. plicatilis* (0.8%) (Tong *et al.,* 1988; Budhin *et al.*, 2016; Khudyi *et al.,* 2018). Therefore, *M. mongolica* can serve as a supply medium in terms of methionine levels for fish larvae. For unsaturated fatty acids, *M. mongolica* recorded high eicosapentaenoic acid levels (EPA) (12.7%) of total fatty acids, while in *Artemia* and *B. plicatilis* EPA level was recorded low, *i.e.,* 2.1% and 1.9%, respectively (Tong *et al.,* 1988; Budhin *et al.,* 2016; Singh *et al.,* 2019).

It can be summarized that the nutritional content of *Moina* was higher as other live foods and can be a reliable and affordable replacement for costly marine *Artemia*. In fact, Lavens and Sorgeloos (1996) believed that *Artemia cysts* are less nutritious than other zooplanktons (Solomon *et al.,* 2006).

Enrichment of *Moina* species : Cladocerans tend to grow aggressively in water suspended organic microscopic particles (phytoplankton, bacteria, protozoans and fungi). (Rodolfo *et al.,* 1980; Balayla *et al.,* 2004; Kim *et al.,* 2008; Budhin *et al.,* 2016). *Moina* can feed on bacteria, algae and organic detritus (Samir *et al.,* 2015). *Moina* culture density can also be enhanced by fecundity optimization and somatic development which can be achieved through regulation of quality and quantity of feed (Mubarak *et al.,* 2017). Several feeds, including algae and artificial diets can be fed to *Moina* in order to enrich their nutritional value (Rasdi and Qin, 2018d). Enhancement of nutrition of cladoceran through enrichment of feed appears to be a good practice (Parakrama *et al.,* 2012).

Similar to other live feeds, *Moina does not really provide enough nutrients necessary for larval growth* (Das *et al.,* 2007; Parakrama *et al.,* 2012). The dietary content of *Moina* is actually not favorable for small fish and shellfish, hence *Moina* must be supplemented with algae and / or artificial feed to improve its nutrition to that specific cultivation of a particular larval species. Live food enrichment strategies improve the importance and ability of live food to contribute as larval aquatic species in captive conditions are rising (Pronob *et al.,* 2012; Rasdi and Qin, 2018a). As demonstrated for *Artemia* nauplii and rotifers, the nutritional value of *Moina* can be enhanced by enrichment through provision of various culture media (Watanabe *et al.*, 1993; Das *et al.*, 2007; Loh *et al.*, 2016).

Microalgae : In aquaculture, microalgae fill an important role of enriching zooplankton before they are fed to fish or other larvae wherein microalgae nutrients are shifted through zooplankton intermediates to higher trophic levels (Brown *et al.,* 1997; Guedes *et al.,* 2015). Algae are the most important and common sources influencing feed value of herbivorous zooplankton such as cladocerans and rotifers (Hypolite *et al.*, 2014). They provide key nutrients like vitamins, PUFA, pigment, and sterols in addition to providing protein (essential amino acid) as energy sources for zooplankton organisms. The levels of protein (12 - 35%), lipids (7.2 - 23%), and carbohydrates (4.6 - 23%) recorded for algae species varies depending on differences between species and methods of production (Guedes *et al.,* 2015). Microalgae species that are most widely used in aquaculture are *Isochrysis* sp., *Chlorella* sp., *Tetraselmis* sp., *Nannochloropsis* sp., *Thalassiosira* sp., *Chaetoceros sp.* and *Pavlova sp.* (Guedes *et al.,* 2015; Rasdi and Qin, 2015).

Microalgae, including microalgae paste can be used to enrich live food organisms to directly improve the fatty acid composition in live food such as *Moina* (Mendez-Martinez *et al.*, 2018). As reported in prior research, the important nutrients in larvae enrichment including critical Polyunsaturate Fatty Acid (PUFAs of EPA and DHA) and most microalgae composition are rich either in one or both fatty acids (Rasdi and Qin*.,* 2016a, b; Ahmad *et al.,* 2018). The specific growth rate of *Moina macrocopa* and *Moina micrura* increased when fed on three different algae, namely *Pseudokirchneriella subcapitta, Monoraphidium minutum* and *Desmodesmus armatus*, and carbon content of these algal species varied between 42.05 and 49.3% dry weight, phosphorus content ranged between 0.04% and 0.20% and nitrogen content ranged between 6.7% and 7.7% (Bouchnak *et al.*, 2014) such that these algae can provide improved nutrition for *Moina* water flea species.

Studies by Nandini *et al.* (2004) proved that production of *Moina* offspring was frequent and fecundity was high when fed on microalgae diet of *Chlorella* with lipid accumulation of up to 85% of biomass (Blazencic, 2007; Kumar *et al.*, 2017). *Chlorella* contains proteins, polysaccharides, minerals, antioxidants, carotenoids, lipids, immune stimulator compounds as well as vitamins (Sharma *et al.,* 2012; Maliwat 2017). While microalgae provide good nutrition for cladocerans, other research has shown that application of vitamin to the cultivation of algae used as food for zooplankton has contributed to a major rise in the production of zooplankton species for instance in *Moina micrura* where faster growth was achieved when fed on algae with vitamin (B vitamin complex) additives (Sipauba *et al.*, 2002).

Other than microalgae, artificial diets including rice bran, yeast, oil emulsion, chicken and cow manures have been used to enrich cladoceran culture media. Rice bran and cassava bran is an artificial diet that has been directly used in *Moina f*eeding, typically processed into a suspension of small particles (Mubarak *et al.,* 2017). Rice bran is a suitable feed for *Moina* as it provides multiple nutrients and sources of energy, such as protein (12-13%), lipid (16-205), linoleic acid (6.35-6.85%), acid α- linolenate (0.2-0.27%), vitamin B and minerals (6 - 9%) (Faria *et al.,* 2012; Murtaza *et al.,* 2011; Mubarak *et al.,* 2017). Cassava bran (*Manihot utilisima*) also contain nutrients including carbohydrates (56 - 94%), Vitamin B1 (*thiamin*) (2.16-48 $\mu g\ g^{-1}$) and Vitamin C (50-510 $\mu g\ g^{-1}$), with low protein content (1.5 - 4.7%0, lipid (0.3 - 3.2%) and lower mineral content as compared to rice bran (Salvador *et al.,* 2014; Faria *et al.,* 2012; Mubarak *et al.,* 2017). Enrichment of live food culture media with rice bran showed higher levels of RNA, DNA, amino acid and protein such as in cultured *Moina* than with cassava bran enrichment (Mubarak *et al. ,* 2017).

Oil emulsions from canola oil, squid oil, etc., are also using to boost composition of fatty acids of *Moina* while essential fatty acids also foster other cladoceran development (Muller-Navarra, 1995; Loh *et al.,* 2013). Loh *et al.*, (2012) demonstrate low essential fatty acids in unenriched *Moina* (DHA, AA, EPA) and the lipid level improved when culture media was enriched with canola and squid oil (. Enrichment of *Moina* with carotenogenic yeast improved carotenoid content and it has been concluded that the enriched *Moina* can be supplied to cultured fish, as fish cannot synthesize carotenoids like other animals (Kushniryk *et al.,* 2015).

Since this cladocerans species can tolerate poor water conditions, both organic and inorganic manures can be used for culturing *Moina*. Previous study by Golder *et al.* (2007) reported human urine, animal urine, chicken manure, poultry droppings, and cattle dung may all be used to produce zooplankton due to their indirect roles as organic fertilizers. The use of organic fertilizers or manure in aquaculture is an efficient and economical means of increasing production in aquaculture ponds (Rahman *et al.,* 2003). A study by Loh *et al.* (2009), demonstrated that *Moina macrocopa*, fed with fish feces resulted in higher reproductive rates within shorter generation times such that a greater number of neonates could be produced. *Moina micrura* showed a high intrinsic increase when cultured in poultry droppings, and the results showed positive effects of organic fertilization in providing a nourishing quality of water which improved production of zooplankton (Hyppolite *et al.*, 2014). When cultured on poultry manure, *Moina* may have acquired a high amount of n-3 HUFA directly from the manure or, indirectly, from algae and other fertilizer-induced microorganisms (Alam *et al.,* 1993; Rahman *et al.,* 2003). Large production of cladocerans resulted from culture in chicken manure fertilizer medium. Indeed, *Moina* cultured with fish waste materials also contained higher nutritional value including HUFA levels and, it was concluded that the available nutrients could provide better growth performance of shrimp and fish larvae at early stages (Loh *et al.*, 2016).

Pathogen-free organic waste product as feed for rearing cladocerans : *Moina* can generally adapt to poor water quality (Rottman *et al.,* 2014) which is of significant characteristic. Under varying conditions, they can be cultivated quickly, even in conditions with low oxygen and heavy ammonium content as reported by Sarma *et al.* (2003). The characteristics of superior adaptable to environmental conditions, their survival in a deficient oxygen environment has been enhanced by *Moina* ability to synthesize haemoglobin (Samuel, 2014). Being hardy in quite extreme condition, *Moina have* also been used in toxicity testing (Mangas-Ramirez *et al.,* 2002; Nandini *et al.,* 2004). Beside extreme parameters, it is recognized that the cladoceran grows optimally at 25 - 30°C (Lampert and Sommer, 1997; Nandini *et al.*, 2004) with pH ranging between 6.5 - 9.5 (Rahman *et al.*, 2003). Being a microscopic and filter feeder; bacteria, yeast, phytoplankton and detritus (decaying organic matter) *Moina* are known to feed on different species. Due to this advantage, *Moina* can be cultured on animal, agricultural and food industry waste as feed (Patil *et al.,* 2010; Mubarak *et al.,* 2017). Cow dung, fish faces, horse manure, rice bran, chicken dropping and mineral fertilizers were found to support successful mass culture of cladocerans (Punia *et al.,* 1988; Rottman *et al.,* 2014; Loh *et al.,* 2009; Okunsebor *et al.,* 2012; Budhin *et al.,* 2016; Rasdi *et al.*, 2018c). As cladocerans are considered for many fish and shrimp larvae as live feed, they have been mass cultured successfully by many researchers, who have been able to use a variety of cheap feed, organic and waste products (Golder *et al.,* 2007; Shrivastava *et al*., 2006; Sivakumar, 2005; Suresh Kumar, 2000; Kareem *et al.,* 2010). The density of *Moina's* also increases quickly as there are sufficient number of yeast, bacteria and phytoplankton (Rottman *et al.,* 2014). Hence, finding an appropriate feed in large amount is required to ensure continuous production of *Moina* for sustainable aquaculture production all year round. The use of pathogen-free poultry waste is of considerable importance to avoid potential transmission of pathogens to planktons, as well as to humans by microbially infected poultry services fed by fish (Adewunmi *et al.*, 2011). The organic fumes were treated to ensure their hygienic state by steam cooking, cooked-oven drying, sun-dried and roasted dried methods before application in aquaculture to ensure pathogen-free fish and shellfish production (Nwabueze, 2011).

Improving *Moina* cultivation by feed manipulation: *Moina* can be developed from affordable, restorative waste products (Loh *et al.*, 2013). In Singapore, *Moina micrura has been* grown in ponds fertilized with chicken and pig manures as the means of feeding (Rottman *et al.,* 2014). In India, *Moina* has been successfully cultivated by the application of both organic manures and inorganic fertilizers as culture media (Iyiola, 2018). However, the availability of *Moina* in natural environment is seasonal and therefore, it is always necessary to develop culture technology for *Moina* in order to maintain their availability (Armin *et al.,* 2014).

By manipulating the quality and quantity of feed, *Moina* population density can be increased by increasing its fecundity and, by decreasing the reproductive period (Hakima *et al.,* 2013; Mubarak *et al.,* 2017). Previous study showed an increase in density of *Moina* to 15,000- 20,000 individual l^{-1} when fed on *Chlorella* (1.0x 10^4 cell ml^{-1}), as compared with density resulting from enrichment with animal waste; fowl and cow manure (1,301 individual l^{-1}). Nutritional content of *Moina* feed also plays an essential role in maintaining sustainable development and survival of the continuous culture for generations[redacted]rotein, fatty acids and amino acids concentrations of feed directly affects the population growth and fecundity of *Moina* (Mubarak *et al.,* 2017). The endocrine system and reproduction of *Moina were* also affected by amino acid and arginine levels in media provided for their growth and development (Jobgen *et al.,* 2006; Mubarak *et al.,* 2017). It was identified that arginine and histidine can increase population growth rate, induce resting egg production and enhance reproduction rate (Koch *et al.,* 2011; Fink *et al.*, 2011; Bouchnak *et al.,* 2014). Moreover, glycine, tyrosine, phenylalanine and lysine levels were seen to affect the speed of embryo development in the incubating cavity (Li *et al.,* 2008; Mubarak *et al.,* 2017).

Moina can be cultured by mass culture, semi-continuous culture or batch culture method. Batch culture method permits control of daily production of *Moina* and is particularly applicable when a specific amount of *Moina* is needed (Rottman *et al.,* 2014). *Moina* is collected fully from 5 to 10 days after inoculation, and the colony is restarted again. The batch process is useful for preserving Moina's pure cultures, since there are limited risks that the sample may get tainted with contaminants (Rottman *et al.*, 2014). Semi-continuous cultivation with partial daily harvest of produced *Moina* can be sustained for two months. Exchange of water and daily feeding will hold the population in a state of rapid increase and development in *Moina* (Rottman *et al.,* 2014).

This review highlights the importance of using *Moina* as live feed organisms in the aquaculture industry and that the enrichment of *Moina* is required in order to meet the adequate nutrient supply for fish and shrimp larvae to enhance their growth performance. It has been concluded that *Moina* meets the requirement of a suitable candidate for live feed applications. *Moina* was selected as live feed sources for larval crops due to their nutritional value and low production costs as feeding medium. High protein levels, essential and non- amino acids and

HUFAs have been recorded in *Moina*. Moreover, *Moina* can be easily maintained through mass culture as they can tolerate poor water quality. Also, *Moina* has been successfully enriched for improved nutritional value by various feeding methods. Thus, this review reflects that *Moina* has strong potential as a live feed organism for larvae and shrimp production.

Acknowledgment

The writing of this review article was supported by the Fundamental Research Grant Scheme (FRGS) provided by Ministry of Higher Education Malaysia under grant Vote No. 59530, in order to generate new ideas and methodology for the development of live food nutrition in Malaysian aquaculture industry. Contribution to the reviews by researchers from other institutions are greatly appreciated.

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