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The Application of Microalgae Feeding Regime on Whiteleg Shrimp Culture in Each Stage: A Mini Review

(Aplikasi Rejim Pemakanan Mikroalga pada Kultur Udang *Whiteleg* dalam Setiap Peringkat: Suatu Ulasan Mini)

Sulastri Arsad[1], Rubina Melini Siallagan[2], Evellin Dewi Lusiana[1], Muhammad Musa[1], Mohammad Mahmudi[1], Luthfiana Aprilianita Sari[3,*], Fiddy Semba Prasetiya[4] & Nadirah Musa[5]

[1]*Study Program of Aquatic Resources Management, Faculty of Fisheries and Marine Science, Universitas Brawijaya, Jl. Veteran Malang 65145, Indonesia*
[2]*Undergraduate Student at the Faculty of Fisheries and Marine Science, Universitas Brawijaya, Jl. Veteran Malang 65145, Indonesia*
[3]*Department of Aquaculture, Faculty of Fisheries and Marine Universitas Airlangga, Surabaya 60115, Indonesia*
[4]*Research Center for Biosystematics and Evolution, Research Organization for Life Sciences and Environment, National Research and Innovation Agency (BRIN), Jalan Raya Bogor Km 46, Cibinong, West Java 16911, Indonesia*
[5]*Department of Fisheries and Aquaculture, Faculty of Agrotechnology and Food Science, Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu Darul Iman, Malaysia*

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ABSTRACT

Feed management in shrimp culture aims to improve the quality of shrimp organisms. The application of the feeding regime in shrimp culture has been developed to determine the best formulation of diet in order to maximize growth rate and survival rate of shrimp by increasing feed efficiency and minimizing waste. The application of the feeding regime is closely related to the understanding of the physiological and morphological aspects of shrimp from the larval stage to the adult stage. The success of the application of feed management with the application of the feeding regime will be a solution to the problem of the high costs of feed needed in shrimp culture. The best formulation of diet in shrimp culture in the N6-P3 stage is microalgae, at the M1-PL10 stage is zooplankton, and in the juvenile-adult shrimp stage is artificial feed. Microalgae can significantly increase the survival rate and growth rate of shrimp at the hatchery stage. This article aimed to examine the effect of the application of feeding regime using different diet formulations to produce the highest growth performance of shrimp in shrimp culture based on the morphological and physiological aspects of shrimp.

Keywords: Green consumption; microalgae; shrimp feed; shrimp growth; sustainable food

ABSTRAK

Pengurusan makanan dalam kultur udang bertujuan untuk meningkatkan kualiti organisma udang. Aplikasi rejim pemakanan dalam kultur udang telah dibangunkan untuk menentukan formulasi diet terbaik bagi memaksimumkan kadar pertumbuhan dan kadar kemandirian udang dengan meningkatkan kecekapan makanan dan meminimumkan sisa. Aplikasi rejim pemberian makanan berkait rapat dengan pemahaman aspek fisiologi dan morfologi udang daripada peringkat larva hingga peringkat dewasa. Kejayaan penerapan pengurusan makanan ternakan dengan penerapan rejim pemberian makanan akan menjadi penyelesaian kepada masalah kos makanan yang tinggi yang diperlukan dalam kultur udang. Formulasi diet terbaik dalam kultur udang pada peringkat N6-P3 ialah mikroalga, pada peringkat M1-PL10 ialah zooplankton dan pada peringkat remaja-dewasa adalah makanan tiruan. Mikroalga boleh meningkatkan kadar kemandirian dan kadar pertumbuhan udang dengan ketara pada peringkat penetasan. Artikel ini bertujuan untuk mengkaji kesan aplikasi rejim pemakanan menggunakan formulasi diet yang berbeza untuk menghasilkan prestasi pertumbuhan tertinggi udang dalam kultur udang berdasarkan aspek morfologi dan fisiologi udang.

Kata kunci: Makanan lestari; makanan udang; mikroalga; penggunaan hijau; pertumbuhan udang

Introduction

Giant tiger prawn (*Penaeus monodon*) and whiteleg shrimp (*Litopenaeus vannamei*) are types of shrimp, which is widely cultivated in Indonesia (Tran et al. 2017). These two types of shrimp are one of the fishery commodities, which have promising prospects and profits (Babu & Mude 2014). In order to produce quality shrimp commodities in aquaculture activities, the maintenance-change to farming must pay attention to internal aspects, which include the quality and type of seeds, and external aspects, which include water quality, feed and technology used. One of the important aspects, which affects the growth of shrimp is feeding (Arsad et al. 2017).

In aquaculture activities, feeding is a very crucial factor as it dominates 60-70% of the total operational costs (Ulumiah et al. 2020) and inappropriate feeding and feed management can therefore be detrimental. Inappropriate diets may affect the homeostatic equilibrium causing growth inhibition and increased stress and mortality. Due to increased catabolism processes during molting period the production of radical oxygen species (ROS) in the hepatopancreas is increasing. Inappropriate diets also cause delay metamorphosis thus shrimp took longer time for their growth (Mastoraki et al. 2020). Intensive shrimp culture with improper management leads to eutrophication of water due to the high load of nutrients and accumulation of nitrogen metabolites that cause lethal for shrimp (Tawwab et al. 2020). Feeding in the culture process will influence shrimp growth performance and survival. The type, size, amount and feeding frequency given must be done correctly. The degree of the influence of feed causes the need for good feeding management to support the success of shrimp culture (Hasan, Bilbas & Dutta 2020).

One of feed management aspects in aquaculture is the feeding regime. The design of feeding regime aims to predict the appropriate type of feed used, feeding rates and feeding frequencies to produce shrimp production that has better shrimp quality (Nofiyanti, Subandiyono & Suminto 2014). The composition of feed given to shrimp is adjusted to age, dose, mouth opening and type of nutrition (Wang et al. 2020). During the application of the feeding regime, it is important to observe the average growth rate of shrimp after being given a combination of feeds. The better the growth of shrimp, the better the feeding regime applied (Gamboa-Delgado et al. 2011). This article aimed to examine the best type of dietary formula based on the application of feeding regime with different diets to obtain growth performance, development and survival of whiteleg shrimp culture.

GIANT TIGER SHRIMP (*Penaeus monodon*) AND WHITELEG SHRIMP (*Litopenaeus vannamei*)

Windu shrimp (*Penaeus monodon*) is a type of shrimp, which is widely distributed in the waters of the Indo-West Pacific and is found in most Asian countries (Fuller et al. 2014). The giant tiger prawn (*Penaeus monodon*) is widely distributed in the Indo-western Pacific Ocean with the most diverse population in Indonesia. Since the 1990s giant tiger prawns have been cultivated in Indonesia, but in 1993 their production experienced a decline due to the infection with white spot syndrome virus (WSSV). The emergence of this virus infection caused mass mortality in giant tiger prawns, and since then, it has been difficult to produce quality tiger shrimp brood stock so tiger shrimp culture has continued to decline (Koesharyani et al. 2019).

Whiteleg shrimp (*Litopenaeus vannamei*) is an introduced species originating from the Pacific coast of Mexico and South America. However, the seed production was not successful due to the presence of pathogen infection (Sugama, Novita & Koesharyani 2006). Whiteleg shrimp were first imported from Hawaii to Bali and East Java at the end of 1999, and starting in 2000 whiteleg shrimp began to be cultivated in semi-line ponds with a floc system. The demand for whiteleg shrimp continues to incline and they are widely cultivated, so whiteleg shrimp become a superior type of shrimp to replace giant tiger prawn (Taukhid & Nur'aini 2008).

The cultivation of giant tiger prawns and whiteleg shrimp in Indonesia has spread to several islands to increase the production of aquaculture products (Tran et al. 2017). There are several areas in Indonesia which become the centers of shrimp culture (Figure 1).

GROWTH PHASE

The process of embryogenesis takes about 16 hours. The growth phase of shrimp larvae before stocking consists of 4 phases (Table 1) namely nauplius, protozoea, mysis and post larvae (Crisp et al. 2016).

FEEDING HABIT

Whiteleg shrimp are classified as omnivorous shrimp while tiger shrimp are classified as carnivores (Nofiyanti, Subandiyono & Suminto 2014). At each transition of shrimp growth, eating habits will also change. This is due to the development of the digestive system in shrimp (Crisp et al. 2017). Shrimp's feeding habits also change with their morphological development such as sensory

FIGURE 1. Shrimp culture location in Indonesia

organ development (Kawamura, Bagarinao & Yong 2017) (Table 1). This is supported by Ibrahim, Alqurashi and Hashimi (2019) which stated that changes in feeding habits in shrimp are due to adaptation changes in the digestive system. Changes in the digestive system are related to enzyme activity, which is thought to be the main factor in the change of feeding habits. Changes in enzyme activity occur in hepatopancreatic tissue (Queiroz, Abrunhosa & Maciel 2011).

Trypsin is considered as a very important enzyme in shrimp digestion. This enzyme is responsible for over 60% in digesting protein (Le Vay et al. 2001). Related to the enzyme, Córdova-Murueta et al. (2004) stated that Penaeid shrimp have the ability to adapt biochemically to feeding habits and biological processes to avoid self-destruction by increasing or decreasing trypsin in the digestive system. Trypsin enzyme activity in the protozoa stage is high and reaches its peak in the protozoa stage III, and afterwards the enzyme activity decreases at the beginning of the mysis stage before increasing again at the beginning of the post larval stage (Kumlu & Jones 1995). This stage might also cause shrimp to experience changes in feeding habits, which will impact on different nutritional needs and feed requirements (Crisp et al. 2016).

NATURAL FEED REQUIREMENTS FOR SHRIMP

Natural feed is given to shrimp larvae because it is in accordance with the characteristics of shrimp larvae and has a high nutritional content (Rukmana et al. 2017). This is also supported by Aftab et al. (2021), who stated that natural feeding on shrimp larvae not only increases growth and survival, but also increases the success of metamorphosis, provides natural color and increases antibiotic activity in shrimp larvae.

Natural feeds, which are usually applied to shrimp culture are in the form of microalgae and zooplankton. Microalgae are given to shrimp larvae as initial feed for nauplius VI stage to protozoea stage, while zooplankton are given as initial feed for mysis to post larval stages (Seychelles et al. 2018). Natural feeding of shrimp larvae is based on differences in characteristics and behavior of shrimp larvae (Knuckey et al. 2002). This is also supported by Pronob et al. (2012), who stated that the natural feed given to shrimp must meet some requirements (Table 2), such as being small in size, being fitted to the shrimp's mouth opening, having high nutrition according to the needs of shrimp larvae, easy to digest, having a striking color as well as moving and stimulating the shrimp to eat the feed.

TABLE 1. Morphology and sensory system development in shrimp

Stage	Structure development	Reference	Sensory system	Reference
Nauplius	The shrimp body has a shape like a water flea, and there are 3 pairs of antennae.	Romero-Carvajal, Turnbull & Baeza (2018)	The sensory system is only in the form of chemoreceptors on the antennae as a sense of smell. Shrimp flick their antennae to release chemoreceptors to detect food. The visual sensory system does not function because the eyes have not yet formed. Shrimp are filter feeders.	Bardera et al. (2018)
Protozoea - 1	The shrimp body forms 2 parts, which are anterior and posterior. There is a formation of the thorax and abdomen that is segmented and the eyes begin to form cones	Ruiz et al. (2020) Lage et al. (2017) Crisp et al. (2017)	The development of the visual sensory system in the eyes so that the shrimp can detect food particles from a distance of 10 -20 cm during the day. Shrimp still cannot detect food at night because they cannot focus light so they rely on the chemoreceptor system. Shrimp are filter feeders.	Kawamura, Bagarinao & Yong (2017)
Protozoea – 2	The development of the organ of vision and the formation of the rostrum. The abdomen forms 6 segments			
Protozoea - 3	The development of uropods but not yet perfect and the formation of swimming legs			
Mysis - 1	The development of the uropods is perfect, and there is a telson in the middle of the uropod. Moreover, 5 pairs of walking legs have developed	Lage et al. (2017) Ibrahim, Alqurashi & Hashimi (2019)	The development of chemoreceptor sensory system cells in the locomotor and mouth so that shrimp can detect food through their walking legs, swimming legs, maxilla and mandible. In the visual sensory organ, there is a rhabdom, which functions as a light guiding structure formed by retinular cells so that shrimp can adapt to light and dark colors. There was a change in feeding habits from a filter feeder to taking food directly using the maxilla and mandible	Bardera et al. (2018)
Mysis – 2	The body size is longer than M-1, the development of a pleopod that is segmented in each segment of the abdomen, and the development of swimming legs to form one segment			
Mysis – 3	The swimming legs have developed into 2 segments, the telson is clearly visible on the uropod, and the spine has developed on the dorsal and rostrum			
Post Larva	Complete development of walking legs, swimming legs, uropods and other systems	(Lage et al. 2017)	Compound eyes are formed, which is followed by the development of the visual sensory system. In the visual sensory organs, there are identical visual units called Ommatidia. Each Ommatidium consists of an optical structure of the cornea, lens and crystalline cone. Shrimp have adapted perfectly to light and dark colours	Sanudin, Tuzan & Yong (2014)

Juvenile	The gill system is perfect, the sexes can be distinguished because of increasing hormones	Ibrahim, Alqurashi & Hashimi (2019)	The chemoreceptors and visual sensory systems are fully developed. Shrimp catch all food without hesitation and the depicted coloujr does not affect shrimp in taking food.	Eap et al. (2020)
Adult Shrimp	The organs of movement, the organs of vision, the respiratory system, the digestive system, and the reproductive system are perfect	Queiroz, Abrunhosa & Maciel (2011)	The chemoreceptor and visual sensory systems have been perfected. Shrimp are perfectly adapted to light and smell	Eap et al. (2020)

TABLE 2. Natural feed requirements for shrimp culture

Shrimp larval stages	Types of natural feed	Shrimp body size (mm)	Feed size	Protein needs (%)	Shrimp movement	Digestibility	Reference
Nauplius VI	*Chaetoceros Skeletonema Isochrysis*	0.5 - 0.21	2 – 4 µm	45	Planktonic	Can be digested	Abdel, Azek & Aha (2006) Karthik et al. (2016)
Protozoea -I	*Chaetoceros Skeletonema Isochrysis*	0.26-0.32	3 – 5 µm	45	Planktonic	Can be digested	Abdel, Azek & Aha (2006) Lim (1998) Karthik et al. (2016) Pérez- Morales et al. (2016) Kiatmetha et al. (2011)
Protozoea - II	*Chaetoceros Skeletonema Tetraselmis Isochrysis*	0.42 – 0.58	7 – 12 µm				
Protozoea - III	*Chaetoceros Skeletonema Tetraselmis Thalassiosira*	1.05 – 2.30	15 > 20 µm				
Mysis - I	*Brachionus Artemia naupli*	2.60 – 2.91	50 – 200 µm	40	Planktonic	Can be digested	Abdel, Azek & Aha (2006) Karthik et al. (2016) Nofiyanti, Subandiyono & Suminto (2014)
Mysis - II	*Brachionus Artemia nauplii*	3.08 – 3.48	300 – 500 µm				
Mysis – III	*Brachionus Artemia nauplii*	4.07 – 4.60	> 500 µm				
Post Larvae	*Zooplankton Artificial feed*	5.11 – 5.80	< 0,5 mm	35-38	Walking legs and swimming legs	Can be digested	Abdel, Azek & Aha (2006) Karthik et al. (2016)
Juvenile (Sub – adult)	*Artificial feed*	8.5 – 9.0 cm	> 0,5 mm	30	Walking legs and swimming legs	Can be digested	Xue et al. (2021)
Adult Shrimp	*Artificial feed*	>15 cm	3 – 4 cm	30	Walking legs and swimming legs	Can be digested	Xue et al. (2021)

MICROALGAE AS NATURAL FEED

In aquaculture activities, microalgae have a very essential role in supporting the success of cultivation. The integrity of microalgae in aquaculture brings not only technical advantages but also economic benefits (Han et al. 2019). This is also supported by Aftab et al. (2021), who stated that microalgae are used in commercial business of marine biota cultivation as natural feed, among others, at the larval growth stage of several species of shrimp, mollusks and fish.

The importance of the role of microalgae as feed in aquaculture is related to the fact that in general protein, is the largest component contained in microalgae, followed by fat and carbohydrates. The average range of protein content in microalgae is around 12-35%; the average range of fat is around 7.5-23%; and the average range of carbohydrates is around 4.6-23% (Noerdjito 2019). Microalgae with long chain polyunsaturated fatty acids (LC-PUFA) are important nutrients for marine biota, particularly at the time of larvae. The nutritional content contained in microalgae varies, depending on the species (Adams et al. 2013). Microalgae have different nutritional contents in each species (Table 3).

Protein is a source of essential amino acids and energy, which is needed by larvae. Protein is also one of the compositions of feed. which requires the greatest cost compared to other nutrients that are also contained in feed (Piña et al. 2005). This is also supported by Roy and Pal (2015), who explained that almost 40% of the cost of feed is spent to meet the protein needs of shrimp larvae, followed by carbohydrates and fats. The large need for protein nutrition causes the need for alternative feeds, which have high protein and can reduce the cost of feed that will be spent. Microalgae are known as a source of protein that is not easily leached and can reduce feed costs (Araújo et al. 2020). Moreover, Rajeswari and Balasubramanian (2014) also explained that the selection of microalgae with the highest protein content will help producers reduce feed prices with a combination of other feed sources while maintaining digestibility to ensure shrimp growth.

In cultivation activities, not all types of microalgae can be used as feed to support shrimp growth and survival. Several types of microalgae are selected as feed according to the nutritional needs and developmental stages of shrimp (Noerdjito 2019).

TABLE 3. Nutritional content of microalgae

Types of microalgae	Protein (%)	Carbohydrate (%)	Fat (%)	Reference
Chlorella vulgaris	51-58	12-17	14-22	Renaud, Thinh & Parry (1999); Liu et al. (2012)
Dunaliella salina	47-55	29-32	6	Colusse et al. (2020); Gouveia et al. (2006)
Tetraselmis maculata	49-52	15	3	Roy & Pal (2015) Sintra et al. (2021)
Spirulina maxima	55-68	16	7	Roy & Pal (2015); Tibbetts, Milley & Lall (2015)
Euglena gracilis	40-61	14-18	20	Sintra et al. (2021); Hemaiswarya et al. (2011)
Pavlova Iutheri	32	9	12	Guedes, Sousa-Pinto & Malcata (2015); Knuckey et al. (2002)
Chaetoceros mulleri	50	17	5	Chae, Hwang & Shin (2006); Tossavainen et al. (2019)
Skeletonema costatum	32	19-22	8	Shah et al. 2018); Widiastuti, Hutabarat & Herawati (2012)
Anabaena cylindrica	43-56	19	5	Roy & Pal (2015); Sintra et al. (2021)

Zooplankton as Natural Feed

The use of zooplankton in shrimp culture has been widely proposed as an alternative natural feed with high nutritional content (Campaña-Torres et al. 2010). The improvement of the nutritional quality of feed must be continuously conducted in order to maximize shrimp production (Ayisi et al. 2017). This is related to the nutritional needs of shrimp, which are increasing along with the shrimp growth (Kandathil Radhakrishnan et al. 2020). Feeding zooplankton is considered not sufficient for the nutritional needs of shrimp larvae because it does not contain essential nutrients, so it is necessary to improve the nutritional quality of feed by enriching zooplankton using microalgae (Samat, Yuso & Rasdi 2020). The type of zooplankton that can be given as shrimp feed to support their growth are *Artemia* sp., *Brachionus* sp., *Moina* sp., and *Dhapnia* sp. (Brito et al. 2004).

Artificial Feed as Shrimp Feed

Artificial feed in shrimp culture is usually applied from the juvenile stage to adult shrimp stage. Artificial feed is useful in reducing problems and risks in the provision of live feed and in meeting the feed size requirements of predators. It is also considered more effective (Lavens et al. 1999). This is also supported by Labrador, Guiñares and Hontiveros (2016), who stated that the provision of artificial feed can improve general physiological conditions and increase disease resistance. Artificial feed in shrimp culture is divided into 3 stages, which are starter, grower and finisher. The feed which is given at each stage has different purposes.

MECHANISM OF THE APPLICATION OF FEEDING REGIME IN SHRIMP CULTURE

Shrimp as experimental animals are usually studied at the nauplius VI stage to the adult shrimp stage (Nunez et al. 2002). This is also supported by Hernandez-Cortes et al. (2017), who stated that at the nauplius I - V stages, shrimp larvae still have food reserves in their bodies in the form of egg yolks which meet their nutritional content for 36-60 hours, so shrimp do not need to be fed from outside. In the nauplius stage (Figure 2), shrimp will be fed with very small microalgae as initial feed (Seychelles et al. 2018).

The protozoea stage is a very critical transitional stage in the growth of shrimp larvae. In the protozoea stage II, there is a special condition commonly known as zoea syndrome or weak zoea. This syndrome results in a decrease in the shrimp's immune system, which can inhibit the molting process and increase mortality. In the protozoa stage, shrimp require high nutrition so the feed given is in the form of microalgae, which have high nutritional value, have size and shape according to the shrimp's mouth opening, can be digested well and have chemical nutritional components that support the shrimp immune system (Piña et al. 2005).

In the mysis stage, the type of feed given changes from microalgae to zooplankton (Nofiyanti, Subandiyono & Suminto 2014). This is also supported by Hernandez-Cortes et al. (2017), who stated that changes in feeding habits of shrimp larvae in the mysis stage are influenced by changes in behavior and development of body organs (movement organs, vision and digestion). In the nauplius stage to mysis stage shrimp have a level of planktonic behavior. However, in the mysis stage, movement, organs, vision and digestion have developed so the type of good food given is the type of small zooplankton as initial feed in the mysis stage. Microalgae feed is still given at this stage, but microalgae feeding aims at adding nutrients to zooplankton (Sintra et al. 2021). This is also supported by Gagneux-Moreaux et al. (2007), who explained that when zooplankton prey on microalgae, the pigments contained in microalgae will be contained in zooplankton, which will contribute to the nutritional value of zooplankton.

The post larval stage will also be followed by changes in behavior and type of feed. The type of feed that is usually given in the early stages of the post larval stage is zooplankton (Purba 2012). This is also supported by Adams et al. (2013), who stated that based on their feeding habits, shrimp larvae in the post larval stage prefer zooplankton because it is easily digested by shrimp.

The development of shrimp from post larval stage to juvenile will result in the change of the osmoregulation system in the shrimp body. This is because at the juvenile stage, shrimp will adapt to an environment that has higher salinity. The change in salinity causes the need for nutrients to increase. This is supported by Cuzon et al. (2004), who explained that when shrimp adapt to an environment with higher salinity, shrimp will utilize protein as a source of amino acids to defend themselves from osmotic pressure and partly for growth to meet the nutritional needs of shrimp. At this stage, artificial feed needs to be given to support their nutritional needs.

In the sub-adult stage to adult shrimp, the type of feed given is artificial feed. Changes in the type of feed are influenced by the digestive system, which is getting more perfect at this stage. Shrimp at this stage have been able to utilize nutrients, especially carbohydrates and fats efficiently for metabolism without disturbing the portion of protein used (Hukama, Djokosetiyanto & Affandi 2011). The provision of artificial feed at this stage will lead to an increase in shrimp weight before harvest, an increase in the value of feed efficiency and an increase in the ability of shrimp in the reproductive process (Soeharmanto et al. 2019).

The application of the feeding regime in shrimp culture includes determining the type, density, frequency of feeding, feeding techniques and feeding levels (Darodes et al. 2021). The critical point in feed management in shrimp culture starts from rearing shrimp larvae from the protozoea stage to the post larval stage (Purba 2012). This is also supported by Boonyawiwat et al. (2017), who stated that the low quality of seeds due to poor application of feed management and poor production technology will influence the rearing stage in shrimp culture, so that the application of feed management at the larval stage will highly determine the success of cultivation.

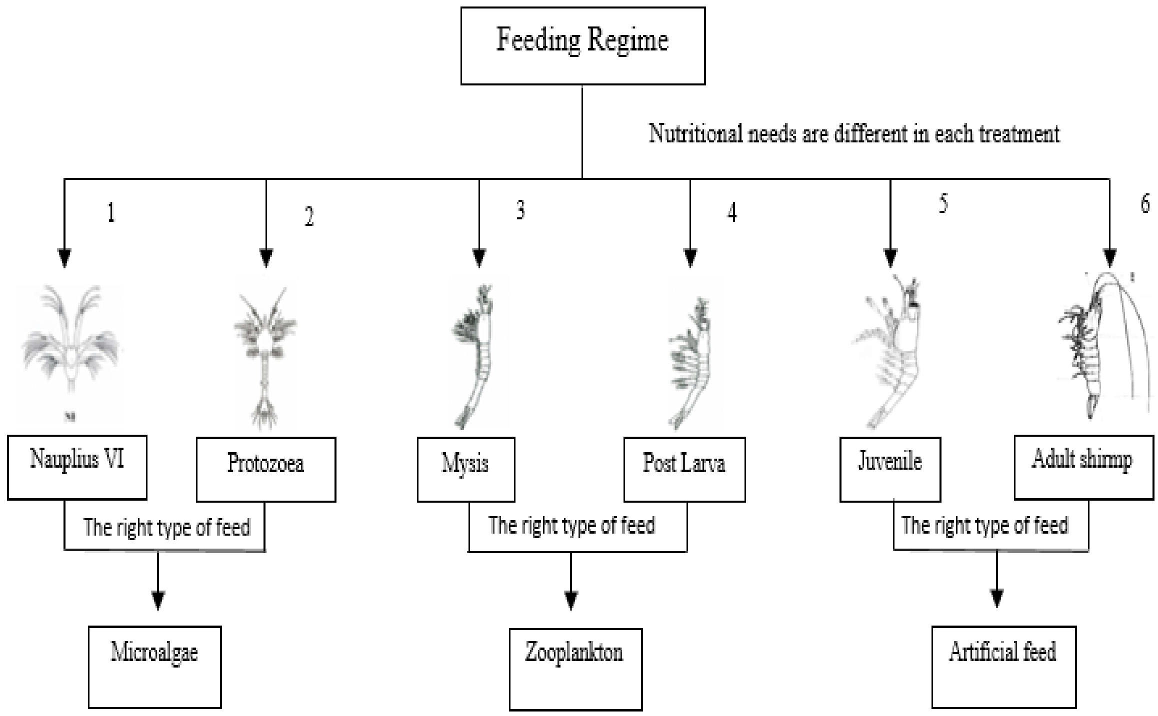

FIGURE 2. Mechanism of the application of feeding regime in shrimp culture
Figure [1,2,3,4] (Crisp et al. 2016); Figure [5,6] (Farchan & Mulyono 2011)

COMPARISON OF THE APPLICATION OF FEEDING REGIME IN SHRIMP CULTURE

The application of the feeding regime has been widely known to affect the growth, survival, and physiological conditions of cultured organisms. In the experimental application of the feeding regime in several studies, the type of feed applied to shrimp culture from the larval stage to the adult shrimp was different. The comparison of the application of the feeding regime in shrimp culture will be observed by comparing the survival rate and growth rate in the length of shrimp with the provision of different types of feed. The comparison of the application of the feeding regime is observed from the development of shrimp at the nauplius stage to adult shrimp. The observed feed formulations including microalgae, zooplankton, and artificial feed are presented in Tables 4 - 5. In general, based on Tables 4-5, the best formulation of diet in shrimp culture in the N6-P3 stage is microalgae, at the M1-PL10 stage is zooplankton, and in the juvenile-adult shrimp stage is artificial feed.

Based on the results of the comparison of the application of the feeding regime at the nauplius IV to Protozoea III stages (Table 4), it was found that the type of microalgae feed produces a higher survival rate, growth rate and body weight compared to artificial feeding. This is because the type of microalgae feed has high nutrition and can be digested easily in the shrimp digestive system. This is supported by Iba, Rice and Wikfors (2014), who stated that the nutritional content of microalgae is very good in meeting the needs of shrimp, especially at the larval stage. Microalgae contain essential amino acids comparable to other foods. Furthermore, microalgae have single cells that make it easier for shrimp to digest feed, so the performance of shrimp growth increases (Skrede et al. 2011).

The low survival rate, growth rate and body weight of shrimp with the provision of artificial feeding is thought to be caused by the fact that in the nauplius stage to the protozoea stage, the digestive system in shrimp has not been able to digest the nutritional content in artificial feed (Novriadi 2013). This is supported by Piña et al. (2005), who stated that artificial feeding at the larval stage is thought to be inappropriate. The nutritional content of artificial feed tends to be more easily leached, especially protein, so the percentage of protein decreases, which results in low shrimp growth performance (Sudaryono 2001).

Based on the results of the comparison of the application of the feeding regime at the mysis to post larval stage-10 (Table 4), it is found that the zooplankton feed type results in a higher survival rate, growth rate and body weight compared to artificial feeding (Sudaryono 2001). At the mysis stage up to post larval stage-10, shrimp prefer zooplankton to microalgae feed (De et al. 2015). This is also supported by Brito et al. (2001), who stated that larval development is closely related to changes in morphology and digestive physiology, especially in the early stages of mysis. In the mysis stage, the shrimp undergoes a change in feeding into carnivores, so in this stage the shrimp will have predatory properties.

The low value of survival rate, growth rate and body weight of shrimp with artificial feeding occurs because the digestibility of shrimp from the mysis stage to post larval stage -10 is low, so the survival rate of shrimp decreases (Lemos & Weissman 2021). This is supported by Evangelista et al. (2005), who stated that the digestive system in the mysis stage to post larval stage is not perfect yet because it only consists of a small intestine and pancreas and a less functional stomach, which causes low digestibility of shrimp in digesting artificial feed.

Based on the results of the comparison of the application of the feeding regime in the juvenile stage to the adult shrimp stage (Table 5), the study conducted by Soeharmanto et al. (2019) found that artificial feeding resulted in the highest survival rate, growth rate, and feed efficiency compared to natural feeding. The high yield of survival rate, growth rate and feed efficiency are due to the type of feed and the suitability of nutrients, which are in accordance with the shrimp stage so as to increase the survival rate and growth rate of shrimp. This is also supported by Hukama, Djokosetiyanto and Affandi (2011), who stated that in the post-larval stage-25, the digestive system in shrimp is almost perfect so that shrimp can utilize synthetic amino acids and other nutrients. The provision of natural feed is thought to be less effective at this stage because the nutrients contained in natural feed do not meet the nutritional needs of shrimp in the juvenile to adult shrimp stage (Porchas-Cornejo et al. 2012).

The provision of natural feed in the juvenile stage to adult shrimp stage has several drawbacks, which include high feed prices, fluctuating feed availability, inconsistent nutritional values and the high possibility of pathogen contamination (Davis & Arnold 2000). Artificial feeding in the juvenile stage to adult shrimp stage is the most logical choice to solve this problem (Vaghei et al. 2017). Artificial feed has a stable cost, controlled nutritional value, long shelf life of feed, easy application, and low possibility of contamination (Wouters et al. 2002).

Artificial feed in shrimp culture has various types. Based on research conducted by Evangelista et al. (2005) on the analysis of the type of artificial feed that produced the best growth performance of shrimp, it was found that the provision of mixed artificial feed resulted in high survival rate and growth rate as well as low FCR values. The high survival rate and high growth rate with mixed artificial feeds are due to the more diverse nutritional content of the feed, assumed to be a factor in the high rates obtained (Wouters et al. 2001). This is supported by Ayisi et al. (2017), who stated that by giving mixed artificial feed, the nutrients contained in feed will be more fulfilled, thereby increasing the growth performance of shrimp.

TABLE 4. Comparison of the application feeding regime of whiteleg shrimp in the Nauplius – post larva stage-10

Types of feed	Density (cell)	Amount of feed (g)	Frequency	GR (g/head/ day)	SR (%)	Final weight	Research period (day)	Number of organisms (ind / liter)	Research media	Reference
Comparison of feeding regime in the Nauplius – protozoea stage										
C. muelleri and *I. galbana*	105	-	4	0.23	90	2.5	30	100	Aquarium	Sangha et al. (2000)
Frippak	-	0.020	4	0.24	75	2.1	30	100	Aquarium	
CAR	-	0.020	4	0.10	25	1.5	30	100	Aquarium	
Frippak + CAR	-	0.040	4	0.27	76	2.3	30	100	Aquarium	
C. muelleri	105	-	4	0,29	85	6.5	30	100	Tank	Robinson et al. (2005)
Liqualife	-	0.050	4	0.15	30	3.9	30	100	Tank	
Epifeed	-	0.070	4	0.13	28	3.5	30	100	Tank	
Z-plus	-	0.086	4	0.14	30	4.1	30	100	Tank	
Comparison of feeding regime in the Mysis – post larva stage										
Frozen *A. salina*	-	21,25	6	0.33	72	5.6	30	100	Tank	Nunez et al. (2002)
Frippak	-	21,25	6	0.21	53	3.6	30	100	Tank	
EZ liquid	-	21,25	6	0.88	67	4.3	30	100	Tank	
Fresh *A. salina*	25	-	6	0.88	65	11.7	30	50	Tank	Hoseinifar & Zare (2013)
Bern Aqua	-	-	6	0.54	50	6.7	30	50	Tank	
A. salina		20	4	50	86	3	10	50	Aquarium	Perdana et al. (2021)
A. salina and *C. calcitrans*		20	4	90	86	5,45	10	50	Aquarium	

ADVANTAGES OF FEEDING REGIME OF MICROALGAE IN SHRIMP CULTURE

In general, the application of the feeding regime can increase the survival rate and growth rate of shrimp through feed formulated at each growth stage. In addition to increasing the survival and growth rate of shrimp, the application of the feeding regime can affect the economic aspects of shrimp culture (Syafaat et al. 2019).

TABLE 5. Comparison of the application feeding regime of whiteleg shrimp in the juvenile – adult shrimp stage

Types of feed	Frequency	Growth rate (%)	SR (%)	Feed efficiency (%)	FCR	Research period (day)	Number of organisms	Research media	Reference
Frozen *C. muelleri*	4	6.87	81	5.86	-	30	20	Aquarium	
Commercial Feed of Shrimp	4	12.10	90	13.77	-	30	20	Aquarium	
Fish feed	4	16	82	-	2.1	56	50	Tank	
Shellfish Feed	4	19	91	-	1.8	56	50	Tank	Sivanandavel, Soundarapandian & Kannuoandi (2007)
Soybean Feed	4	16	85	-	1.9	56	50	Tank	
Mixed Feed	4	22	97	-	1.8	56	50	Tank	

This statement is also supported by Henuk and Dingle (2002), who stated that shrimp farmers are very focused on changing shrimp feed as quickly and efficiently as possible in order to produce maximum shrimp production that can reduce feed costs. Through the application of the feeding regime, the value of feed efficiency can be increased so that the incurred cost of feed can be reduced (Amaya, Davis & Rouse 2007). The comparison of feed efficiency is presented in Table 6. In addition, the use of microalgae in shrimp farming can minimize feed waste in a sustainable manner and improve the water quality of aquaculture (Han et al. 2019). The mechanism is that microalgae convert organic matter in eutrophic waste into biomass and accelerate carbon dioxide fixation, thereby increasing oxygen production in cultivated media. Generally, microalgae utilize ammonium and nitrate as well as carbon during the photosynthesis process to be synthesized to produce amino acids and oxygen (Sanz et al. 2015).

TABLE 6. Comparison of feed efficiency

Types of Feed	Stage	SR (%)	FCR	SGR (%)	Reference
Zooplankton without enrichment	Mysis – Post larvae	74	1.6	5	Zelaya, Davis & Rouse (2007)
Zooplankton with microalgae enrichment	Mysis – Post larvae	87	1.2	8	
Commercial feed	Juvenile	50	1.36	12	Sharawy et al. (2020)
Commercial feed with *Thalassiosira weissflogi* supplement	Juvenile	90	0.99	18	
Pellets	Adult Shrimp	69	1.04	12	Bojórquez-Mascareño & Soto-Jiménez (2013)
Pellets with *Tetraselmis suecica* supplements	Adult Shrimp	90	0.9	16	

Conclusions

Feed management in shrimp culture plays a crucial role in aquaculture activities. The application of different feeding regimes in shrimp culture provides information regarding the best diet formulation in shrimp culture. Microalgae is one of the best dietary formulations needed for every shrimp growth, especially at the hatchery stage. This review concludes that microalgae play an important role as complementary nutrition so that feeding can be given effectively and efficiently as efforts to increase the performance of shrimp growth and to minimize feed costs in shrimp culture. The best formulation of diet in shrimp culture in the N6-P3 stage is microalgae, at the M1-PL10 stage is zooplankton, and in the juvenile-adult shrimp stage is artificial feed. The importance of the role of microalgae in increasing survival, growth performance and minimizing waste in shrimp farming, the development of the application of microalgae feeding regime applications will make a major contribution to the sustainability of aquaculture and global sustainability.

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*Corresponding author; email: luthfianaas@fpk.unair.ac.id