Asian Journal of Research in Zoology

Volume 6, Issue 4, Page 10-17, 2023; Article no.AJRIZ.103043
ISSN: 2582-466X

A Review on Herb Utilization in Vannamei Shrimp Cultivation

Yuli Andriani [a*] and Rusky I. Pratama [a]

[a] Department of Fisheries, Faculty of Fisheries and Marine Science, Universitas Padjadjaran, Sumedang Regency, West Java, Indonesia.

Authors' contributions

This work was carried out in collaboration between both authors. Author YA designed the study, wrote the protocol, and wrote the first draft of the manuscript, and managed the analyses of the study. Author RIP managed the literature searches and writing. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJRIZ/2023/v6i4117

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/103043

Review Article

Received: 08/05/2023
Accepted: 12/07/2023
Published: 17/07/2023

ABSTRACT

Aquaculture activities play a crucial role in boosting fishery production. Among the various commodities, Vannamei shrimp (*Litopenaeus vannamei*) stands out as a leading choice due to its competitive pricing and the ability to conduct mass production with high stocking densities. However, shrimp farming has encountered challenges, particularly the occurrence of diseases that often lead to reduced production levels. These diseases typically arise from the shrimp's weakened condition and suboptimal rearing conditions. To address this issue, incorporating several herbal plants, such as noni fruit, ginger, and garlic, into the feed has emerged as an alternative to enhance shrimp immunity. Through an extensive literature search, optimal doses for these herbal additives were identified. Noni fruit demonstrated the best performance at a 6% dose, resulting in a feed conversion ratio (FCR) of 1.1 and a survival rate of 95%. Garlic performed well at a 5% dose, achieving an FCR of 1 and a survival rate of 98%. Similarly, ginger showed promising results at a 3% dose, with an FCR of 1.18 and a survival rate of 98%. The findings of this study emphasize that incorporating herbs into the feed can serve as a viable solution to enhance productivity in Vannamei shrimp farming.

**Corresponding author: Email: yuli.andriani@unpad.ac.id;*

Keywords: Vannamei shrimp; Litopenaeus vannamei; herbs; shrimp disease; feed conversion; survival.

1. INTRODUCTION

Vannamei shrimp (*Litopenaeus vannamei*) stands as a prominent commodity in aquaculture. Its competitive pricing and suitability for mass production with high stocking densities make it highly sought after [1]. Vannamei shrimp enjoys significant demand in both local and international markets due to its exceptional nutritional value and strong economic worth, driving its rapid cultivation [2]. The species boasts various advantages, including ease of cultivation, resilience against bacterial and viral diseases, and adaptability to low salinity environments [3]. Vannamei shrimp culture technology continues to evolve, embracing intensive and supra-intensive techniques that achieve high stocking densities ranging from 100-400 individuals/m^2 [4].

However, shrimp farming encounters challenges, particularly the emergence of diseases that adversely impact production levels. Shrimp diseases primarily arise from shrimp vulnerability caused by factors such as inadequate handling, excessive feeding, and unfavourable environmental conditions. One effective preventive measure involves the administration of immunostimulants. Immunostimulants encompass chemicals, drugs, stressors, or actions that enhance non-specific or innate immune responses by directly interacting with immune cells [5]. Natural antibiotics, such as a mixture of noni simplicia, turmeric, ginger, garlic, and worm water extract, can be employed as preventive measures to mitigate the risks associated with shrimp diseases.

2. METHODOLOGY

This research employed a literature review methodology, which involves the examination of academic articles, books, and other relevant materials to provide a description, summary, and critical evaluation of the existing works on a specific subject, field of study, or theory. Various sources, including scientific articles, organizational and government websites, published surveys, reports, and research papers, were analyzed to assess the research methodologies and instruments used in the utilization of different herbs in shrimp culture. The search process involved structured keyword searches in databases such as Elsevier Science Direct, Google Scholar, and various university repositories, focusing on publications between 1987 and 2022. Source selection criteria included scientific research, research articles, theses, and publications in both Indonesian and English. The findings were then categorized into distinct groups, including Vannamei shrimp biology, shrimp culture diseases, mechanisms of herbal action on shrimp immune systems, and the application of herbs in shrimp culture.

3. VANNAMEI SHRIMP (*Litopenaeus vannamei*)

Vannamei shrimp (*Litopenaeus vannamei*) is native to the subtropical regions along the west coast of America, ranging from the Gulf of California in northern Mexico to the west coast of Guatemala, El Salvador, Nicaragua, Costa Rica in Central America, and Peru in South America. The entry of Vannamei shrimp into Indonesia was authorized by the Decree of the Minister of Maritime Affairs and Fisheries of the Republic of Indonesia No.41/2001, as tiger prawn production had declined since 1996 due to diseases and environmental degradation. Vannamei shrimp has a transparent white body, earning it the nickname "white shrimp," although some individuals may display a bluish hue due to the dominance of blue chromatophores. They can reach a body length of up to 23 cm, with the body divided into two parts: the head (thorax) and abdomen (abdomen). The Vannamei shrimp head consists of antenulae, antennae, mandibles, and two pairs of maxillae [6].

Image of Vannamei shrimp: One of the primary challenges in vaname shrimp cultivation is the occurrence of bacterial and viral attacks, which have been the leading cause of crop failures to date. Once Vannamei shrimp are infected with a virus, there is no cure available, making prevention the key approach. Boosting the shrimp's defence system is an essential preventive measure, and this can be achieved through the use of immunostimulants, vitamins, and hormones. Enhancing shrimp immunity involves the use of chemicals, drugs, or other substances to stimulate specific and non-specific response mechanisms in fish [7].

The aim of increasing immunity in Vannamei shrimp is to enable them to withstand virus or bacterial attacks that can jeopardize crop yields for shrimp cultivators. Immunity refers to the resistance or resilience to diseases, particularly infections. The immune system involves the coordination of cells, molecules, and tissues that work together to combat infections. Administering immunostimulants aims to activate non-specific immune system cells, such as hemocytes in invertebrates. However, when administering immunostimulants, it is crucial to consider the optimal dosage, as it directly influences the enhancement of the immune response in shrimp [7]. Hemocytes, or shrimp blood cells, consist of three types: granulocyte cells, agranulocyte cells, and hyaline cells. Although the composition and function of hemocytes are not fully understood, monitoring their numbers, types, and microbial activity can be useful in assessing shrimp health. The characteristics and activity of the shrimp defence system, represented by hemocytes, serve as indicators of shrimp health. Among hemolymph parameters, total hemocytes are the most sensitive and consistent under stress conditions in *Farfantepenaeus paulensis* shrimp culture [8].

Changes in the number of hemocytes often correspond to alterations in cell differentiation composition [8]. Hemocytes can be employed as a quantitative parameter to measure stress responses in shrimp. The host's ability to combat foreign substances and respond to infections is influenced by total hemocytes, as low levels of hemocytes can lead to susceptibility to pathogen attacks. An increase in total hemocytes enhances the organism's overall health status by facilitating the formation of phagocytic cells, which play a crucial role in defending against microbial invasions [9].

4. SHRIMP DISEASES

Shrimp diseases pose a significant threat to production, including the cultivation of Vannamei shrimp. Viral and bacterial infections are the primary causes of mass mortality in both hatchery and rearing stages. However, comprehensive scientific information regarding the transmission mechanisms of these pathogens in the culture systems of tiger shrimp and Vannamei shrimp (*Litopenaeus vannamei*) is currently limited.

In Indonesia, viral infections, including White Spot Syndrome Virus (WSSV), Taura Syndrome Virus (TSV), Yellowhead Virus (YHV), Infectious Myonecrosis Virus (IMNV), and Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV), are the most dangerous and result in substantial losses for shrimp farmers. WSSV, in particular, is a highly virulent viral disease that commonly affects both tiger and Vannamei shrimp.

Vannamei shrimp are susceptible to viral diseases such as Taura Syndrome Virus (TSV), also known as red tail disease. The systemic nature of TSV was first discovered in ponds near the Taura River in Ecuador. Clinical symptoms of Vannamei shrimp affected by vibriosis include brownish-red hepatopancreas, red spots on the body, thin and reddish-brown tail [10]. Observed that Vannamei shrimp affected by vibriosis exhibited red discoloration on the pleopod and abdomen, which appeared luminescent at night. Acute and chronic symptoms of vibriosis in Vannamei shrimp are clearly visible, such as blackish back, red spots at the base of the fins, erect scales, slow movement, disturbed balance, decreased appetite, exophthalmia (protruding eyes), fluid-filled abdomen, and hemorrhagic gills, mouth, body, intestines, and internal organs. Peeling skin, sores, necrosis, and ulcers may also develop at advanced stages.

5. HERBAL ACTION MECHANISM ON THE SHRIMP IMMUNE SYSTEM

The mechanism of herbal action on the shrimp immune system aims to enhance shrimp immunity without the negative impacts associated with chemical treatments, such as bacterial resistance. To overcome these drawbacks, an alternative approach is to utilize local ingredients with medicinal properties, specifically herbal mixtures. Herbal supplementation has been found to be effective in increasing the body's resistance of Vannamei shrimp. Preventing bacterial infections that can jeopardize the harvest's success is crucial for enhancing the productivity of Vannamei shrimp.

Several studies have demonstrated the immunostimulatory effects of herbal components on shrimp immunity. For instance, [11] successfully developed an immunostimulant from noni (*Morinda citrifolia*), which reduced the infection of White Spot Syndrome Virus (WSSV) in shrimp and provided protection. The use of this immunostimulant resulted in survival rates increasing from 26% to 83%. In another study, [12] conducted a trial involving immunized Vannamei shrimp cultivated in ponds, which effectively enhanced their defences and reduced *Zoothamnium penaei* infestations.

6. IMPROVING SHRIMP HEALTH STATUS WITH HERBAL APPLICATIONS

6.1 Noni

Noni plants are perennial plants with small stems and broad leaves. They consist of roots, stems, leaves, fruits, and seeds. The root of the noni plant has a taproot structure that penetrates the soil deeply, with root branches and root hairs growing in all directions. Noni fruit (*Morinda citrifolia* L.) is believed to contain phytochemical and antibacterial substances such as scopoletin, anthraquinone, acubin, and alizarin. Ethanol extraction of noni fruit has been shown to inhibit and kill *Aeromonas hydrophila* bacteria. To ensure the production of non-toxic fishery products, the use of natural ingredients such as noni fruit extract is necessary. Table 1 shows several studies on the use of noni as a feed mixture in shrimp farming.

Improved growth performance in aquaculture species through feed supplementation has been previously reported, showing benefits in terms of cost and profitability. The use of plant compounds to enhance the growth performance of fish species has been well documented [15], indicating that supplementing shrimp with plant extracts or beneficial nutrients often leads to improved growth. In this study, the growth performance of *L. vannamei* PL was increased by supplementing with *M. citrifolia* fruit extract. Enhancing the growth of aquaculture organisms through food supplementation typically results in improved productivity, quality, and resistance to pathogen invasion [15].

The hepatopancreas, located in the posterior part of the cephalothorax, is the largest organ in prawns. It consists of a network of channels and tubules that play crucial roles in digestion, nutrition, absorption, storage, and waste disposal [16], similar to the functions of the liver and pancreas in mammals. Additionally, the hepatopancreas is involved in other physiological functions of shrimp, including immune response and ion transport. The preference for using plant-derived products as immunostimulants has increased as an alternative to antibiotics or drugs due to their cost-effectiveness and environmental friendliness [17]. Previous studies have reported the potential of plant extracts to enhance the immunity of various aquaculture species, including fish and shrimp. Improved growth and immunity in aquatic organisms have been associated with increased activity of digestive enzymes [17]. Although the involvement of antioxidant enzymes in enhancing the defence mechanisms and growth of shrimp is not fully documented, the hepatopancreas is known as the metabolic centre for digestion and detoxification in shrimp. Crustaceans rely on cellular and humoral immune responses to eliminate infectious pathogens, which often induce oxidative stress. Therefore, the antioxidant system plays an important role in protecting cells from oxidative stress caused by immune responses and reactive oxygen species (ROS) [18]. The accompanying image shows the hepatopancreas of shrimp supplemented with noni fruit.

The nutritional state of crustaceans is determined by the presence of R cells in the hepatopancreas. R cells are storage cells where nutrients are stored in the form of lipids and/or glycogen droplets [19]. The results of this study demonstrated an increase in the number of R cells with increasing concentrations of *M. citrifolia* fruit extract during the feeding trial period. Previous studies have revealed that nutrients stored in R cells are crucial for decapod physiology during periods of starvation, molting, and reproduction [20]. B cells, derived from F cells, are the most abundant cells in the hepatopancreas [16]. These highly vacuolated cells appear in different sizes and shapes at various functional stages, enabling them to be involved in intracellular digestion and absorption of nutrients through protein synthesis and digestive enzymes [20]. Nutrients are stored in vacuoles before being released, along with remaining enzymes, into the lumen for reabsorption by R cells. Based on this evidence, the current research suggests that supplementing *L. vannamei* PL with *M. citrifolia* fruit extract has the potential to increase the conversion of F cells to B cells, leading to enhanced intracellular digestion, absorption of nutrients, and ultimately, animal growth. E cells are actively dividing cells and play a crucial role in cell renewal, facilitating optimal tubular growth and maintaining hepatopancreatic health [16]. The increase in the number of E cells observed in this study indicates an increase in mitotic cell division [21], suggesting that supplementation of shrimp with M. citrifolia fruit extract promotes cell renewal and growth in the hepatopancreas of *L. vannamei* PL.

Table 1. Studies on the use of noni in shrimp farming

Dosage (%)	Survival Rate (%)	Average Weight Gain (% daily)	Feed Conversion Ratio	Reference
0.5	96	1.4	1.4	[11]
0.6	95	1.8	1.1	[13]
0.5	93	1.6	1.13	[14]

6.2 Garlic

Garlic contains bioactive compounds including organosulfur, phenolic components, and flavonoids, which possess antioxidant properties. When shrimp are exposed to air, enzymatic oxidation occurs, and the phenolic group-containing amino acid tyrosine is oxidized by the enzyme polyphenol oxidase.

The growth rate of fish refers to the increase in weight or length over a specific period of time and is influenced by both external and internal factors within the fish's body. Among the external factors, food plays a significant role in promoting growth. Protein is an essential component in this process as it serves as the main source of energy, facilitates tissue formation and maintenance, aids in the replacement of damaged tissue, and supports metabolic processes.

In an experimental study, it was found that the optimal specific growth rate in tilapia was achieved by supplementing the feed with 2% coconut husk oil extract, outperforming other treatments. These results suggest that the addition of 2% coconut husk oil extract is an appropriate dosage that is well-tolerated by fish and promotes the digestion and utilization of nutrients from the feed, leading to good-quality feed and enhanced growth. These results emphasized that improved nutrient digestibility enables better utilization and intake of nutrients from high-quality feed, resulting in superior growth performance. Previous research has also indicated that the inclusion of medium-chain fatty acid distillates from coconut oil can increase food intake in fish, thereby promoting weight gain. Furthermore, it is reported that the addition of coconut oil to the feed enhances the activity of the lipase enzyme in tilapia, which is associated with increased feed and protein utilization.

Fasting and subsequent re-feeding lead to higher growth compared to fish fed daily. During fasting, fish tend to utilize fat stores in the body as a source of metabolic energy, resulting in increased levels of blood plasma fat and triglycerides, and decreased insulin levels. Upon re-feeding, insulin levels increase while fat and triglyceride levels decrease. This indicates that fasting stimulates the utilization of stored fat as an energy source, while re-feeding promotes the utilization of carbohydrates. The utilization of energy from fat during fasting and carbohydrate energy during re-feeding allows protein energy to be utilized for body tissue formation and repair, ultimately promoting maximum growth. The stored protein in the body serves as the raw material for building body tissues, supporting weight gain.

Under fasting conditions, the activity of the amylase enzyme tends to decrease and then increases upon re-feeding [22]. Found that fasting treatment in *Sepia phaonis* fish leads to decreased activity of digestive enzymes such as amylase, lipase, pepsin, and trypsin. Upon re-feeding after fasting, amylase and lipase enzyme activity increases and becomes comparable to fish fed daily. In contrast, the activity of pepsin and trypsin decreases after fasting. The increased post-fasting activity of amylase suggests that carbohydrates are utilized as energy for tissue repair during fasting. Table 2 shows several studies regarding the use of garlic in shrimp farming and its effect on survival rate, weight gain and feed conversion ratio.

Table 2. Studies on the use of garlic in shrimp farming

Dosage (%)	Survival Rate (%)	Weight Gain Average (% daily)	Feed Conversion Ratio	Reference
4	97	1.01	1.35	[23]
5	98	1.33	1	[24]
6	96	1.23	1.12	[22]
2	77 – 88	1.03	1.13	[25]

Table 3. Studies on the use of ginger in shrimp farming

Dosage (%)	Survival Rate (%)	Average Weight Gain (% daily)	Feed Conversion Ratio	Reference
3	98	1.9	1.18	[27]
4	94	1.56	1.32	[28]
3	95	1.87	1.17	[29]
5	92	1.78	1.19	[20]

6.3 Ginger

Ginger, a common spice and seasoning, has natural antibiotic properties. Various studies have demonstrated that ginger contains substances that can reduce inflammation in the body and eliminate infection-causing germs. Ginger has been found to be effective against bacteria such as *E. coli, Staphylococcus*, and *Streptococcus*, which can cause skin infections, diarrhea, and pneumonia. Considering the inhibitory effects of substances or compounds found in plants such as ginger, garlic, and honey on bacterial growth, it is important to investigate their effects on *Vibrio sp.* bacteria, which often infect shrimp. These herbal remedies could serve as alternative methods for shrimp farmers to control the population of *Vibrio sp*. bacteria in the rearing water media [26].

Zingiber officinale, commonly known as ginger, is a globally recognized medicinal plant that contains sesquiterpenes and phenolic compounds, including gingerol and shogaol. Ginger consists of various bioactive components such as alkamides, caffeic acid derivatives, polysaccharides, flavonoids (quercetin, kaempherol, isorhamnetin), and free phenolic acids (p-coumaric, phydroxybenzoic, and protocatechuic acids). These compounds contribute to the diverse therapeutic properties of ginger.

Research conducted by [26] demonstrated that ginger extract significantly increased the activity of important enzymes such as superoxide dismutase (SOD), glutathione peroxidase (GPx), phenoloxidase (PO), and catalase (CAT), leading to excellent shrimp growth. Ginger plant extracts have been recognized for their various beneficial effects in aquaculture, including promoting growth, stimulating appetite, boosting immune function, and exhibiting anti-pathogenic and anti-stress properties in shrimp and fish. Several studies have reported that incorporating *Z. officinale* into the diet positively impacts the growth performance and feed utilization of aquatic animals and shrimp. Table 3 summarizes many studies on the application of ginger in shrimp farming, as well as its impact on survival rate, increase in weight, and feed conversion ratio [30].

7. CONCLUSIONS

After analyzing the results from various studies which focused to Vanamei shrimp, it can be inferred that the optimal dosage for noni fruit extract is 6%, yielding a feed conversion ratio (FCR) of 1.1 and a survival rate of 95%. Garlic extract shows the best performance at a dosage of 5%, resulting in an FCR of 1 and a survival rate of 98%. Similarly, ginger extract exhibits its highest efficacy at a dosage of 3%, achieving an FCR of 1.18 and a survival rate of 98%. In general, it can be concluded that the utilization of herbal ingredients, either individually or in combination, in shrimp cultivation, leads to an increase in the survival rate and growth of Vannamei shrimp.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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https://www.sdiarticle5.com/review-history/103043