**Impact of White Feces Syndrome and its Management practices in the shrimp *Litopenaeus vannamei* in semi-intensive culture systems: Comprehensive understanding review**

**Abstract:**

White Feces Syndrome (WFS), also known as White Gut Disease, is a widespread and economically significant condition affecting the global aquaculture industry that produces Pacific white shrimp (*Litopenaeus vannamei*). This condition is distinguished by the presence of pale or white excrement. In shrimp that have been impacted, there are digestive issues. White gut disease in *L. vannamei* has several contributing factors, but its exact etiology is unknown. The current study reveals that the understanding of the multifactorial illness, involving a combination of environmental stressors, dietary imbalances, infectious agents, and inadequate management techniques would help in developing treatments to prevent the spread of disease and thereby reducing the economic losses of shrimp industry.

**Keywords:** White Feces Syndrome (WFS), white gut disease, shrimp *L.vannamei*, diseases.

1. **Introduction:**

*Litopenaues vannamei* shrimp farming is the world's fastest growing aquaculture industry, and it is widely regarded as the primary source of protein to meet demand and replace depleted natural resources. Due to global seafood demand as it contains a rich source of animal protein, omega-3 fatty acids, and minerals that are essential for human health and development (K.A. Moreno-Sader et al., 2021). Shrimp is one of the most lucrative and profitable aquaculture species, with production up by more than 5.5 million mt in 2017. Furthermore, it is estimated that it will reach 7.28 million mt by 2025 (F. Asche et al. 2021; M.T. El-Saadony et al.,2022 and P. Snega Priya *et.al.,* 2024). The mushrooming of aquafarms in the coastal areas of different shrimp producing countries facing recent dared shrimp disease with high economic losses is white feces syndrome (Priya et al., 2024).

White gut disease (WGD), also known as White Feces Syndrome (WFS) or White Faeces Disease (WFD), is a major health concern in the global *Litopenaeus vannamei* shrimp aquaculture industry (Kumar et al., 2022). This condition has received attention due to its negative impact on shrimp health and the economic losses it causes for shrimp farmers. Infectious etiologies are responsible for the majority of economically significant diseases affecting cultured penaeid shrimp in Asia, the Indo-Pacific region, and the Americas. The most serious infectious diseases of cultivated shrimp are caused by a few viruses (Kooloth Valappil et al., 2021). The penaeid shrimp industry has lost billions of dollars in crops, jobs, and export revenue as a result of the pandemics caused by the penaeid viruses WSSV (White Spot Syndrome Virus) and TSV (Taura Syndrome Virus), as well as, to a lesser extent, IHHNV (Infectious Hypodermal and Hematopoietic Necrosis virus) and YHV (Yellow Head Virus). In countries where shrimp farming is a major industry, the pandemics caused by these pathogens have had a significant social and economic cost.

Shrimp actively seek food by grazing on the substrate found in the water column and culture pond bottom. The gut is a vital organ in a healthy shrimp, serving several functions such as immunity, health regulation, and nutritional absorption. The gut's bacterial metabolism efficiently performs these functions. Shrimp are highly exposed to microflora exchange between the environment and the digestive system. This increases the possibility of the growth of undesirable gut microflora or the microflora becoming unstable, both of which can impair the digestive system's ability to function optimally. This is the primary cause of many intestinal tract illnesses in shrimp. Thus, understanding the function of *L. vannamei's* gut microbiota is critical for improving growth efficiency and overall yield.

Pollution is a major concern in the shrimp culture ponds. The bottom of the culture ponds becomes contaminated due to the fecal matter released by shrimp and dead algae, as well as the organic load of wasted feed from overfeeding (Yew Hu, 1992). The presence of vermiform, gregarine-like bodies in the hepatopancreas (HP) and midgut of cultivated giant tiger shrimp (*P. monodon*) and white leg shrimp *(L. vannamei)* suggests acute hepatopancreatic necrosis disease (AHPND) in shrimp culture. When they are present in sufficient quantities, they cause white feces syndrome (WFS) and white fecal strings (Tang trongpiros.J. 2010). The Aggregated Transformed Microvilli (ATM) that make up these vermiform bodies are formed when the epithelial cells of the shrimp hepatopancreatic tubules slough off. These vermiform bodies accumulate at the hepatopancreas-midgut junction before being expelled via feces. This prevents the villi from absorbing nutrients, resulting in stunted growth. When ATM is widespread, shrimp may develop white fecal strings. White faeces syndrome, or WFS, refers to the condition in which faecal strings float alone or in floating mats in ponds with high stocking densities (Fig.1 (1)). Because white feces contain oil globules from the gut, they appear more buoyant and float on the water's surface. The shrimp's hepatopancreas becomes pale and mushy, and it loses appetite. White Gut Syndrome refers to infected shrimp with a white midgut when exposed to light. ATM is occasionally associated with shrimp hepatopancreatic diseases such as vibriosis, parasitaemia with the microsporidian Enterocytozoon hepatopenaei (EHP), and acute hepatopancreatic necrosis disease (AHPND, Septic Hepatopancreatic Necrosis) (Arisa et al., 2021).

White Feces Syndrome (WFS) is a gastrointestinal disease that affects cultured penaeid prawns around the world. The illness is characterized by the presence of white fecal strings (Fig.1 (3B)) floating on the surface of culture ponds. Infected shrimps (Fig.1 (2)) usually have pale to yellowish midguts(Fig.1 (3A)), slow growth, significant size variation, decreased average daily growth, higher feed conversion ratios (FCR), loose exoskeletons, and occasionally death (Aranguren Caro *et al.,* 2021 and Munkongwongsiri *et al.,* 2022). The intestinal histology revealed a thin intestinal wall, detachment of intestinal epithelial cells, and a decrease or absence of microvilli (Huang et al., 2020). WFS typically occurs between 50 and 60 days of culture (DoC) after seeding the culture ponds. It weakens shrimp and causes chronic mortalities, lowering output yield by up to 60% (Durai *et al.,* 2015 and Huang *et al.,* 2020). White gut disease is a complicated condition that affects the digestive system of the *L. vannamei* shrimp (Kumar et al., 2025). It is distinguished by the presence of white or opaque feces in affected individuals, as well as other clinical symptoms such as lethargy, reduced appetite, slow growth, and poor swimming. While the exact cause of the disease is unknown, it is thought to be viral, bacterial, or parasitic in nature (Kurniawinata et al., 2021). White gut disease is a significant threat to the long-term development of *L. vannamei* shrimp aquaculture worldwide, necessitating a multifaceted prevention and management strategy.

The threat of shrimp diseases remained. Bio-security measures such as bird fencing, crab fencing, and water filtration and disinfection before pumping into the main pond all contributed to limiting disease spread, particularly among pathogen carriers (Tamilarasu et al., 2020). Implementing Better Management Practices (BMP’s) at all stages also contributed to disease containment. High stocking densities, poor pond bottom conditions, high plankton blooms, poor feed management, and climatic conditions, when combined with organic loads that promote the growth and selection of opportunistic pathogens such as bacteria, viruses, fungi, and protozoa, all contribute to an increased risk of WFS (Anjaini et al., 2023). Shrimp that are affected consume less and have a darker color. The hepatopancreas and gut of severely affected shrimp become pale and white. Early disease symptoms appear first on feed trays and at the water's surface, where there is a lot of floating white feces. The impacted shrimp have a loose exoskeleton and a protozoa infestation, which is causing their gills to darken.



**Fig.1. (1). White Fecal strings floating on pond water. (2). WFS infected shrimp (3). WFS infected gut and long white fecal string.**

White fecal syndrome (WFS) in *L.vannamei* is associated with a variety of conditions, including increased stocking numbers, poor water quality, deteriorated pond bottoms, excessive plankton blooms, insufficient feed management, and increased pollutants in pond water. The White Feces Syndrome (WFS) has emerged as a significant issue in the global shrimp aquaculture industry, particularly in the cultivation of *L. vannamei*, in recent years. (Masthan S.A, 2015 and Satish Kumar *et al.,* 2022). Farmers have begun to incorporate antibiotic growth promoters into shrimp feed to address the issue of waterborne fungal infections in culture ponds. However, because of their negative effects, such as the accumulation of residues in fish tissue and the rise of antibiotic-resistant microorganisms, natural substances are more widely accepted by the public.

1. **Signs and symptoms of WFS in shrimp:**

**2.1. Clinical Signs:**

The most noticeable clinical sign of white gut disease is the presence of white or opaque feces in affected shrimp. Healthy shrimp typically excrete feces that are dark or black in color due to the presence of undigested food and pigments. However, shrimp suffering from white gut disease excrete feces that appear white, milky, or opaque in color, hence the name "white feces syndrome." In addition to white feces, affected shrimp may exhibit other clinical signs such as lethargy, reduced appetite, slow growth, and weak swimming (Wang et al., 2020). In severe cases, mortality rates can be significantly high, leading to substantial economic losses for shrimp farmers.

The most noticeable clinical sign of white gut disease in *L. vannamei* shrimp is the presence of white or opaque feces. Healthy shrimp typically excrete feces that are dark or black in color due to the presence of undigested food and pigments. However, shrimp suffering from white gut disease excrete feces that appear white, milky, or opaque. Other clinical signs may include lethargy, reduced appetite, slow growth, and weak swimming. In severe cases, mortality rates can be significantly high, leading to substantial economic losses for shrimp farmers.

**2.2. Etiology of White Gut /White feces Disease:**

White gut disease can be caused by a variety of viral, bacterial, and parasitic agents. Understanding the etiology of the disease is essential for developing effective prevention and control strategies (Mastan, 2015).

White feces disease in shrimp, particularly in *L. vannamei*, can be a result of various factors including viral, bacterial, or parasitic infections, as well as environmental stressors. While the specific signs and symptoms may vary depending on the underlying cause, here are some common indicators associated with white feces disease in *L. vannamei:*

**2.3. White Feces:** The most obvious sign is the presence of white or opaque feces. This can be due to the presence of excess mucus, shed epithelial cells, or undigested food particles.

**2.4. Decreased Appetite:** Infected shrimp may exhibit a reduced appetite or complete anorexia. They may appear uninterested in food or feed less frequently.

**2.5. Reduced Growth:** Growth retardation or stunted growth may be observed in infected shrimp due to the impact of the disease on their metabolism and nutrient absorption.

**2.6. Weakness/Lethargy:** Infected shrimp might become lethargic or weak, spending more time resting at the bottom of the pond or tank and showing reduced swimming activity.

**2.7. Poor Fecundity:** In mature female shrimp, white feces disease can affect reproductive capabilities, leading to reduced fecundity or abnormal reproductive behavior.

**2.8. Shell Abnormalities:** In severe cases, shell abnormalities such as discoloration, softening, or shell deformities may be observed due to the impact of the disease on the shrimp's overall health and immune system.

**2.9. Increased Mortality:** White feces disease can lead to increased mortality rates among affected shrimp, particularly if left untreated or if the underlying cause is a highly virulent pathogen.

It's important to note that while white feces are a common symptom associated with this condition, it's essential to conduct proper diagnostic tests to determine the specific cause of the disease and implement appropriate treatment and management strategies (Hou et al., 2018). Regular monitoring of water quality parameters and environmental conditions can also help prevent the onset of white feces disease in shrimp aquaculture systems.

1. **Factors triggering WFS:**

**3.1. Accumulation of sludge:**

The accumulation of sludge in intensive shrimp ponds is primarily caused by feces, uneaten feed, and dead phytoplankton. Sludge deposits increase biological oxygen demand (BOD), mineralize nutrients from organic matter, and produce toxic metabolites. Sludge is a source of plant nutrients, which can cause unnecessary blooms (Tang et al., 2016). These plankton blooms cause pH fluctuations. Excess blooms can cause artificial eutrophication in culture ponds, where phytoplankton die, resulting in anoxic conditions and the production of toxic gases.

**3.2. Polluted pond bottom and toxic gases:**

Maintaining a clean pond bottom and feeding area is an important management activity in shrimp culture. Poor pond bottom management during culture causes the accumulation of large amounts of organic matter. Adequate aeration is required for the proper development of beneficial bacteria, and improper aerator placement can result in insufficient oxygen for aerobic bacteria to decompose organic matter (Ghouri et al., 2020). Anaerobic bacteria will then take over the decomposition of organic matter, producing byproducts such as ammonia, nitrite, and hydrogen sulphide, which are toxic to shrimp.

**3.3. Over feeding and poor feed quality:**

Overfeeding is a common problem among farmers, and it is typically determined by the amount of feed remaining in the feeding tray. Farmers should actually track their survival rate. When survival is incorrectly estimated as higher when it is actually lower, it leads to overfeeding. The use of low-quality shrimp feed results in poor digestibility and nutrient absorption, leaving a large amount of undigested feed in faeces and check trays, prompting farmers to reduce feeding. This leads to underfeeding, which results in poor growth.

**3.4. Phytoplankton crash:**

High nutrient loads from intensive and super-intensive shrimp ponds have an impact on the dynamics of phytoplankton growth. A crash occurs when phytoplankton grows quickly, turning the water dark and causing pH fluctuations. The accumulation of organic matter at the pond's bottom is caused by phytoplankton crash.

* 1. **Bacterial infections:**

White gut disease (WGD) has been observed in shrimp farms, and Vibriosis is one of the most serious disease agents in aquaculture. Vibriosis is a bacterial disease that causes the death of cultured shrimp worldwide. Vibriosis is caused by gram-negative bacteria from the Vibrionaceae family (Alfiansah et al., 2020). Outbreaks can occur when environmental factors cause the rapid multiplication of bacteria previously tolerated at low levels in shrimp blood, or when bacteria penetrate host barriers. The exoskeleton serves as an effective physical barrier to pathogens attempting to penetrate crustaceans' external surface, as well as the foregut and hindgut.

Several bacterial pathogens have been isolated from shrimp exhibiting clinical signs of white gut disease. These include: Vibrio bacteria have been implicated in the development of white gut disease in *L. vannamei* shrimp. These bacteria can infect the digestive tract, causing inflammation and tissue damage. The diseased shrimp is associated with six Vibrio species, including *V. harveyi, V. parahaemolyticus, V. alginolyticus, V. anguillarum, V. vulnificus, and V. splendidus.* The Aeromonas bacteria have also been associated with white gut disease in *L. vannamei* shrimp. They can colonize the hepatopancreas, leading to the production of white or opaque feces and other clinical signs of the disease.

**3. 6. Viral Infections**

Several viruses have been associated with white gut disease in *L. vannamei* shrimp. These include:

* **White Spot Syndrome Virus (WSSV)**

WSSV is one of the most devastating viruses affecting shrimp aquaculture worldwide. It is known to cause white gut disease in *L. vannamei* shrimp, along with other clinical signs such as white spots on the exoskeleton, lethargy, and high mortality rates.

* **Taura Syndrome Virus (TSV)**

TSV is another virus that has been implicated in the development of white gut disease in *L. vannamei* shrimp. It can cause severe damage to the hepatopancreas, leading to digestive problems and the production of white or opaque feces.

* **Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV)**

IHHNV has also been associated with white gut disease in *L. vannamei* shrimp. It can infect the hepatopancreas, causing tissue damage and disrupting normal digestive function.

* **Hepatopancreatic Parvovirus (HPV)**

HPV infections have been linked to white gut disease in *L. vannamei* shrimp. The virus can cause degenerative changes in the hepatopancreas, leading to the production of white or opaque feces.

**3.7. Parasitic Infections**

Parasites have been found in the hepatopancreas of *L. vannamei* shrimp affected by white gut disease. These include:

**3.8. Microsporidia and ciliates**

Microsporidia are intracellular parasites that have been found in the hepatopancreas of shrimp exhibiting clinical signs of white gut disease. They can cause tissue damage and disrupt normal digestive function. Certain species of ciliates have also been isolated from the hepatopancreas of shrimp with white gut disease. These parasites can infect the digestive tract, leading to the production of white or opaque feces.

**3.9. Climatic changes:**

Climatic changes can cause extreme changes in temperatures and sudden rainfall makes shrimp more susceptible to disease.

1. **Diagnosis of White Gut Disease:**

Diagnosing white gut disease in *L. vannamei* shrimp can be challenging due to the nonspecific nature of its clinical signs and the involvement of multiple causative agents. However, several diagnostic methods can be used to identify the presence of the disease:

**4.1. Histopathological Examination:**

Histopathological examination of the hepatopancreas is one of the most reliable methods for diagnosing white gut disease. Histological changes such as hepatopancreatic tubule degeneration, vacuolization, and the presence of intracellular inclusions can be indicative of viral, bacterial, or parasitic infections.

**4.2. Molecular Techniques**

Polymerase Chain Reaction (PCR) and quantitative PCR (qPCR) can be used to detect the presence of viral, bacterial, and parasitic pathogens in shrimp tissues. These methods allow for the rapid and specific identification of causative agents, aiding in the early diagnosis and management of the WFS disease.

1. **White Faeces Syndrome (WFS) Management:**

**5.1 Biosecurity:**

Prescribed biosecurity systems have to be used as per regulations and policies to prevent and control the spread of WFS diseases. The key elements of biosecurity are a reliable source of stocks, adequate detection and diagnostic methods for excludable diseases, disinfection and pathogen eradication methods, best management practices, and practical & acceptable legislation. Hence, the strict principles and guide lines of biosecurity to be adapted in individual farms and cluster wise in farming areas. PCR screening of brood stock before spawning and PCR screening of larvae (PL) before stocking can help to avoid the entry of pathogens into aquaculture system.

**5.2. Pond water quality management:**

Once White faeces syndrome is identified, water has to be sanitized to reduce microbial load. This is carried out by applying Potassium Monopersulfate or Quaternary Ammonium compounds like Benzalkonium Chloride commercially called as BKC at 1 PPM in pond water. 48 h after sanitization, soil probiotic has to be applied in order to inoculate beneficial microbes to degrade organic loads followed by zeolite to eliminate ammonia nitrate and other toxic gases via cationic exchange as standard procedures followed routinely in farm management. The dosages as advised by the farm technician may be adopted for successful control of WFS.

**5.3. Nutrition and immunostimulation:**

After completion of water treatment, animals need to be treated via feed supplement and functional feeds. Shrimp must be fed supplement with binding gel gut acidifiers like organic acid and lactic acid bacteria to reduce gut pH level, which will reduce the pathogen density level also. Proper usage of the gut probiotics and enzymes will give improve nutrient absorption by gut villi. The application of Vitamin C and chelated minerals improves immunity and reduce the mortality rate of shrimps in culture systems. Thus, probiotics in the culture system reduces the incidence of diseases occurrence thereby improving the immunity. Feeding with immunostimulants improves shrimp immunity to diseases / infection. A number of microbial molecules such as feed additives, probiotics, beta 1,3 glucans, peptidoglycans, polysaccharides have been proven to stimulate the non-specific immune mechanisms in shrimp.

**5.4. Improving environmental conditions**

The environmental parameters can play a significant impact on shrimp health, growth and production. Most disease problems are triggered by deterioration of water and soil quality. Application of probiotic that are capable of oxidizing toxic wastes are useful in improving soil and water quality in shrimp culture ponds. Early detection and diagnosis are crucial factors to well-timed and prompt control. Effective management of the health of shrimp requires consideration of delicate balance between the host, pathogen and environment.

The recommended practices for improved shrimp culture to prevent WFS are listed below

* Sustainable approaches to modulate the gut microflora in farmed shrimps for preventing gut diseases.
* Favouring the development of beneficial bacteria and inhibiting potentially pathogenic micro-organisms in gut
* Specific nutrients promote the development of selected bacterial strains (prebiotics) in gut
* Specific natural compounds (mostly derived from yeast and herbal extracts, so called “phytobiotics”) capable of modulating the microflora towards a favourable composition.
* A suitable central drainage system, with ‘shrimp toilet’ in the pond may be designed for the periodical removal of sludge from culture pond environment.
1. **Other management strategies for control of white gut/white feces disease**

Preventing and managing white gut disease in *L. vannamei* shrimp requires a multifaceted approach that addresses the various factors contributing to its development:

**6.1. Biosecurity Measures**

Implementing strict biosecurity measures is essential for preventing the introduction and spread of pathogens on shrimp farms. This includes controlling water quality, screening and quarantining new stock, and disinfecting equipment and facilities regularly**.**

**6.2. Dietary Management**

Providing a balanced and nutritious diet can help support the immune system of shrimp and reduce their susceptibility to diseases. Feeding high-quality feed with optimal protein and lipid content can promote shrimp health and improve resistance to pathogens.

**6.3. Water qualityManagement**

Maintaining optimal water quality parameters such as temperature, salinity, pH, and dissolved oxygen levels is crucial for minimizing stress and preventing disease outbreaks in shrimp. Regular water exchange and monitoring can help ensure a healthy environment for shrimp growth.

**6.4. Disease Surveillance and Monitoring**

Regular monitoring of shrimp health and behaviour can help detect early signs of disease and prevent its spread. Routine health checks, histopathological examination, and molecular diagnostics can aid in the early detection and management of white gut disease.

**6.5. Therapeutic Treatments**

In cases where white gut disease has already occurred, therapeutic treatments such as antiviral, antibacterial, or antiparasitic agents may be necessary. However, the effectiveness of these treatments may vary depending on the causative agent and the stage of the disease.

**6.6. Prevention and Control Measures**

Preventing and controlling white gut disease requires a coordinated approach that includes both proactive measures to prevent the introduction and spread of pathogens and reactive measures to manage outbreaks:

**6.7. Quarantine and Screening**

Implementing strict quarantine measures for new shrimp stock and screening for pathogens before introduction to the farm can help prevent the introduction and spread of white gut disease.

**6.8. Biosecurity Protocols**

Regular disinfection of equipment and facilities, proper waste management, and restricted access to the farm can help minimize the risk of pathogen introduction and spread.

**6.9. Genetic Selection**

Breeding programs aimed at selecting shrimp with increased resistance to white gut disease can help reduce the prevalence and impact of the disease on shrimp farms.

1. **Future Directions and Research Needs**

Despite significant progress in understanding the etiology, diagnosis, and management of white gut disease, several knowledge gaps still exist. Future research should focus on:

Further elucidating the role of viral, bacterial, and parasitic agents in the development of white gut disease. Developing more sensitive and specific diagnostic techniques for early disease detection. Investigating the effectiveness of novel therapeutic treatments and preventive measures. Exploring the potential impact of environmental factors on disease development and spread.

1. **Conclusion:**

The global sustainable development of *L. vannamei* shrimp aquaculture is seriously threatened by white gut disease frequently. Although the precise cause of the illness is still unknown, it is certain that a variety of agents, including bacteria, viruses, and parasites, play a role in its progression. Effective management techniques, stringent biosecurity protocols, and early diagnosis are critical to stopping the spread of white gut illness on shrimp farms. Continued investigation into the cause, diagnosis, and treatment of the illness is essential to the aquaculture of *L. vannamei* shrimp's long-term viability.

The diseases are serious problems posing threat to sustainability of *L. vannamei* culture in India. The farmers should be vigilant and be sensitised on the knowledge about these diseases and their prevention. If the farmers implement better management practices at every stage of culture, then only the sustainability of *L. vannamei* culture can be achieved. The biosecurity measures like crab fencing, bird fencing and maintaining reservoir ponds are to be maintained for the minimising the diseases during the culture period. The drawn water for culture should be filtered properly and should be disinfected with suitable safe disinfectants. The farmers should purchase the quality seed from the Coastal Aquaculture Authority (CAA) permitted registered hatcheries after proper screening. Once the disease is found in culture ponds, the water should be properly treated, disinfected and then only the water should be released into the creeks . Small farmers can adopt cluster approach to check out the water quality and to control the diseases. By focusing on these areas, the aquaculture industry can work towards more effective management and control of WFS in *L.* *vannamei* shrimp farming, ensuring the long-term sustainability and profitability of the shrimp industry.

**Conflict of Interest**: None

**References:**

1. Aranguren Caro, L. F., Mai, H. N., Cruz-Florez, R., Marcos, F. L. A., Alenton, R. R. R., & Dhar, A. K. (2021). Experimental reproduction of White Feces Syndrome in white leg shrimp, *Penaeus vannamei*. PLOS ONE, 16(12), e0261289. https://doi.org/10.1371/journal.pone.0261289.
2. Durai V, Gunalan B, Johnson PM, Maheswaran ML, Pravinkumar M (2015). Effect on white gut and white feces disease in semi-intensive *Litopenaeus vannamei* shrimp culture system in Sout Indian State of Tamil Nadu. Internationals of Marine Science,5(14):1-5.
3. Huang, Z.; Zeng, S.; Xiong, J.; Hou, D.; Zhou, R.; Xing, C.;Wei, D.; Deng, X.; Yu, L.; Wang, H. (2020). Microecological Koch’s postulates reveal that intestinal microbiota dysbiosis contributes to shrimp white feces syndrome. Microbiome, 8, 32.
4. Mastan S. A. (2015), Incidence of white feces syndrome (WFS) in farm-reared shrimp, *Litopenaeus vannamei*, Andhra Pradesh. Indo American Journal of Pharmaceutical Research, 2015 ISSN No: 2231-6876.
5. Munkongwongsiri, N., Prachumwat, A., Eamsaard, W., Lertsiri, K., Flegel, T.W., Stentiford, G.D., & Sritunyalucksana, K. (2022). Propionigenium and Vibrio species identified as possible component causes of shrimp white feces syndrome (WFS) associated with the microsporidian Enterocytozoon hepatopenaei. Journal of invertebrate pathology, 107784.
6. Sathish Kumar T, P. Ezhil Praveena, T. Sivaramakrishnan, J. Joseph Sahaya Rajan, M. Makesh, K.P. Jithendran (2022), Effect of Enterocytozoon hepatopenaei (EHP) infection on physiology, metabolism, immunity, and growth of *Penaeus vannamei*, Aquaculture, Volume 553. <https://doi.org/10.1016/j.aquaculture.2022.738105>.
7. Tangtrongpiros J (2010) White feces disease in cultured marine shrimp. Document distributed at a public seminar at the Veterinary Medical Aquatic Animal Research Center (VMARC), Faculty of Veterinary Science, Chulalongkorn University, Bangkok, Thailand. 16 pp. (Tanslanted from the Thai language).
8. Yew-Hu, C. (1992). Water quality requirements and management for marine shrimp culture. Proceedings of the special session on shrimp farming world, Boton Rouge, LA U.S.A.
9. [Kariana Andrea Moreno-Sader](https://www.sciencedirect.com/author/57208928630/kariana-moreno-sader), Jairo Martínez-Consuegra , Ángel Darío González-Delgado (2021) [An integrated biorefinery approach via material recycle/reuse networks for the extraction of value-added components from shrimp: computer-aided simulation and environmental assessment](https://www.sciencedirect.com/science/article/pii/S0960308521000663). [Food and Bioproducts Processing](https://www.sciencedirect.com/journal/food-and-bioproducts-processing), [Volume 127](https://www.sciencedirect.com/journal/food-and-bioproducts-processing/vol/127/suppl/C), May 2021, Pages 443-453.
10. Frank Asche,JamesL. Anderson, Robert Botta, Ganesh Kumar, EirikB. Abrahamsen, Ly T. Nguyen, Diego Valderrama (2021) The economics of shrimp disease. [Journal of Invertebrate Pathology](https://www.sciencedirect.com/journal/journal-of-invertebrate-pathology), [Volume 186](https://www.sciencedirect.com/journal/journal-of-invertebrate-pathology/vol/186/suppl/C), November 2021, 107397.
11. MohamedT. ElSaadony, AymanA. Swelum, MahmoudM. AboGhanima, Mustafa Shukry, Amira A. Omar, Ayman E. Taha, Heba M. Salem, Amira M. El-Tahan, Khaled A. El-Tarabily, Mohamed E. Abd El-Hack (2022) Shrimp production, the most important diseases that threaten it, and the role of probiotics in confronting these diseases: A review. [Research in Veterinary Science](https://www.sciencedirect.com/journal/research-in-veterinary-science), [Volume 144](https://www.sciencedirect.com/journal/research-in-veterinary-science/vol/144/suppl/C), May 2022, Pages 126-140.
12. P.Snega Priya, S. Vaishnavi, A.R. Sreekutty, Gokul Sudhakaran, Aziz Arshad, Jesu Arockiaraj (2024) White feces syndrome in shrimp: Comprehensive understanding of immune system responses. [Fish & Shellfish Immunology](https://www.sciencedirect.com/journal/fish-and-shellfish-immunology), [Volume 151](https://www.sciencedirect.com/journal/fish-and-shellfish-immunology/vol/151/suppl/C), August 2024, 109704.
13. Priya, P. S., Vaishnavi, S., Sreekutty, A. R., Sudhakaran, G., Arshad, A., & Arockiaraj, J. (2024). White feces syndrome in shrimp: Comprehensive understanding of immune system responses. *Fish & Shellfish Immunology*, 109704.
14. Kumar, T. S., Makesh, M., Alavandi, S. V., & Vijayan, K. K. (2022). Clinical manifestations of White feces syndrome (WFS), and its association with Enterocytozoon hepatopenaei in Penaeus vannamei grow-out farms: A pathobiological investigation. *Aquaculture*, *547*, 737463.
15. Kooloth Valappil, R., Stentiford, G. D., & Bass, D. (2021). The rise of the syndrome–sub‐optimal growth disorders in farmed shrimp. *Reviews in Aquaculture*, *13*(4), 1888-1906.
16. Kumar, V., Roy, S., Sahu, A. K., & Das, B. K. (2025). Disease in Shrimp Aquaculture: Diagnostic Technique for Sustainable Management. *Laboratory Techniques for Fish Disease Diagnosis*, 147-173.
17. Tamilarasu, A., Nethaji, M., Bharathi, S., Chrispin, C. L., & Lingam, R. S. S. (2020). Review on the emerging white feces syndrome in shrimp industry. *Journal of Entomology and Zoology Studies*, *8*(5), 680-684.
18. Anjaini, J., Simangunsong, T., & Fadjar, M. (2023). Phytoplankton Composition in White Shrimp (Litopenaeus vannamei) Pond Culture Infected White Feces Disease (WFD). *Research Journal of Life Science*, *10*(1), 29-41.
19. Kurniawinata, M. I., Sukenda, S., Wahjuningrum, D., Widanarni, W., & Hidayatullah, D. (2021). White faeces disease and abundance of bacteria and phytoplankton in intensive pacific white shrimp farming. *Aquaculture Research*, *52*(11), 5730-5738.
20. Arisa, I. I., Elmuhtaj, I., Putra, D. F., Dewiyanti, I., & Nurfadillah, N. (2021, February). Study of the spread of white feces disease (WFD) on Litopenaeus vannamei in semi-intensive ponds in Aceh Besar District Aceh Province, Indonesia. In *IOP Conference Series: Earth and Environmental Science* (Vol. 674, No. 1, p. 012015). IOP Publishing.
21. Wang, H., Wan, X., Xie, G., Dong, X., Wang, X., & Huang, J. (2020). Insights into the histopathology and microbiome of Pacific white shrimp, Penaeus vannamei, suffering from white feces syndrome. *Aquaculture*, *527*, 735447.
22. Mastan, S. A. (2015). Incidences of white feces syndrome (WFS) in farm-reared shrimp, Litopenaeus vannamei, Andhra Pradesh. *Indo American journal of pharmaceutical research*, *5*(9), 3044-3047.
23. Hou, D., Huang, Z., Zeng, S., Liu, J., Wei, D., Deng, X., ... & He, J. (2018). Intestinal bacterial signatures of white feces syndrome in shrimp. *Applied microbiology and biotechnology*, *102*, 3701-3709.
24. Tang, K. F., Han, J. E., Aranguren, L. F., White-Noble, B., Schmidt, M. M., Piamsomboon, P., ... & Hanggono, B. (2016). Dense populations of the microsporidian Enterocytozoon hepatopenaei (EHP) in feces of Penaeus vannamei exhibiting white feces syndrome and pathways of their transmission to healthy shrimp. *Journal of invertebrate pathology*, *140*, 1-7.
25. Ghouri, Y. A., Tahan, V., & Shen, B. (2020). Secondary causes of inflammatory bowel diseases. *World journal of gastroenterology*, *26*(28), 3998.
26. Alfiansah, Y. R., Peters, S., Harder, J., Hassenrück, C., & Gärdes, A. (2020). Structure and co-occurrence patterns of bacterial communities associated with white faeces disease outbreaks in Pacific white-leg shrimp Penaeus vannamei aquaculture. *Scientific reports*, *10*(1), 11980.