Open Access

© 2023, Centre for Advanced Research in Agricultural Sciences
Research Journal of Agricultural Sciences
Volume 14; Issue 01; pp 178–182

ISSN: 0976-1675 (P)
ISSN: 2249-4538 (E)

Case Study

Development of Dietary Multi-Strain Probiotics on Banana Peel Powder for Sustainable Shrimp Aquaculture in India

Roja B[1], Sasikumar R[2] and Chellapandi P*[3]

[1-3] Industrial Systems Biology Lab, Department of Bioinformatics, School of Life Sciences, Bharathidasan University, Tiruchirappalli - 620 024, Tamil Nadu, India

Abstract

Shrimp production in India has continued to face an increasing challenge in the last two years owing to improper farm and disease management and lack of efficient probiotic availability. India mainly comprises two varieties of shrimp: Pacific white leg shrimp (*Litopenaeus vannamei*) and Indian black tiger shrimp (Penaeus monodon). Generally, shrimps lack an adaptive immune system to combat invading pathogens. Probiotics have been suggested as a substitute strategy to improve immune function and prevent or minimize shrimp disease. A variety of imported single- or multi-strain probiotic formulations and products have been available in markets, but the cell viability and shelf life of the strains in shrimp farms are questionable to date. The current perspective is that new dietary multistrain probiotics must be formulated and immobilized on fruit-based solid matrices for long-term viability and increased shelf life in India. Dried banana peel powder is suggested herein as a food matrix or probiotic carrier because it is a low-cost fruit waste that is readily available and contains more total dietary fiber with antioxidant activity. Hence, dietary multi-strain probiotics could be ideally viable in the pond environment by reducing the bacterial and organic loads, which will fetch larger profits with additional savings in the production costs of shrimp farming.

***Key words*:** Shrimp, Probiotics, Disease control, Immunity, Banana peel

The global production of farmed shrimp in 2017 was estimated between 2.9-3.5 million tons (http://www.fao.org/in-action/globefish/marketreports/resource-detail/es/c/1136583/). The overall export of shrimp during 2016-17 was pegged at 4, 34,484 metric tons worth USD 3,726.36 million. Shrimp exports improved from 2, 56,699 metric tons to 3, 29, 766 metric tons in 2016-17 (28.46% in quantity). The demand for shrimp and shrimp products in international markets has gradually increased (https://mpeda.gov.in/MPEDA/admin/files/PressRelease/PressreleaseFinal2016-17.pdf). Pacific white-leg shrimp (*Litopenaeus vannamei*) and Indian black tiger shrimp (Penaeus monodon) are commonly cultured on Indian farms. India is the second-largest shrimp producer in the world. Andhra Pradesh is India's largest *Litopenaeus vannamei* farming area, it has 974 km of coastline and 175,000 ha of brackish water (http://www.caa.gov.in/uploaded/doc/FAO%20Aqua41-79.pdf). The Indian shrimp industry has gained relative importance globally over the past 10 years. The global export of shrimp rose from 6% in 2009 to 23% in 2018 at a CAGR of 27% from a level of 97 thousand tonnes to 690 thousand tonnes (https://www.televisory.com/blogs/-/blogs/global-shrimp-industry-the-indian-dynamics).

Aquaculture probiotics

Shrimp culture represents a great opportunity for rural development and has a significant economic impact. The feed industry related to shrimp farming is of great economic importance, as it accounts for 60 to 80% of shrimp production costs. Shrimp aquaculture faces several issues and challenges in achieving sustainability related to low feed conversion ratios and microbial diseases. Several infectious disease outbreaks on shrimp farms have resulted in serious mortality and economic losses. Shrimps lack an adaptive immune system, and rely on effective cellular and humoral innate immune responses to combat invading pathogens. Several chemical compounds associated with antibacterial resistance among opportunistic bacteria have been used to treat microbial pathogens in shrimp farming. In addition, continuous antibiotics use antagonists of beneficial gut microbes and suppress the formation of the natural microbiota of shrimp post-larvae. The accumulation of antibiotic residues in animal tissues and the environment is subsequently passed to the consumer. Probiotics in aquaculture

Received: 16 Nov 2022; Revised accepted: 12 Jan 2023; Published online: 23 Jan 2023

Correspondence to: Chellapandi P, Industrial Systems Biology Lab, Department of Bioinformatics, School of Life Sciences, Bharathidasan University, Tiruchirappalli - 620 024, Tamil Nadu, India, Tel: +91 9894109534; E-mail: pchellapandi@gmail.com

Citation: Roja B, Sasikumar R, Chellapandi P. 2023. Development of dietary multi-strain probiotics on banana peel powder for sustainable shrimp aquaculture in India. *Res. Jr. Agril Sci*. 14(1): 178-182.

are an established farm management tool for improving gut health, the immune system, environmental quality, and the prevention of shrimp diseases. The importance of probiotics in aquaculture is increasing because of outbreaks of infectious diseases and environmental problems. This is the biggest constraint on shrimp farming and is a huge challenge for the future. Commercial formulations of aquaculture probiotics include Bacillus spp., lactic acid bacteria, yeast, and nitrifying/denitrifying bacteria. These microorganisms can proliferate and colonize the gastrointestinal tract of shrimps. However, probiotics and other top-dressing chemicals can easily be destroyed by other chemicals, which generally affect their stability and establishment in shrimp culture. This indicates that aquaculture probiotics must be safe, effective, viable, and have a long shelf-life [1].

More than 700 companies produce probiotics that target the aquaculture industry worldwide. The global market for probiotic ingredients, supplements, and food is expected to reach 19.6 billion in 2013 at a CAGR of 4.3%. The Indian probiotics market, valued at $12 million in 2011, is expected to witness a CAGR of 11% by 2016 (https://www.bccresearch.com/market-research/food-and-beverage/probiotics-market-fod035d.html). Farmers apply probiotics directly into pond water (84%) and mix them with aquafeeds (16%) to improve water quality and reduce environmental stress. The cost of probiotic use accounted for 20% of the production. However, this depends on the efficacy of probiotics, viability, and the cost of imported probiotics, which are too burdensome to farmers in India (https://thefishsite.com/articles/the-godfather-of-shrimp-probiotics).

Multi-strain probiotics

Aquaculture probiotics have beneficial effects in enhancing infection resistance, digestive enzyme activity, growth performance, and plankton growth. It induces innate immune responses including transglutaminase, LvTAB2, and syntenin [2-5] for both bacterial and viral infections. Several water-soluble, dietary, and multi-strain probiotics have been investigated and commercialized for use in aquaculture probiotic formulations (Table 1). In addition, *B. licheniformis* [6], *B. subtilis* [7], *B. subtilis* E20 [8], *Bacillus* PC465 [9], mixed *Bacillus spp*. (*B. licheniformis* MAt32, *B. subtilis* MAt43, and *B. subtilis* subsp. subtilis GAtB1) [10] are water-soluble probiotics in shrimp culture. *Vibrio alginolyticus*, *V. gazogenes* [11], *Arthrobacter sp*. CW9 [12], *Ectothiorhodospira shaposhnikovii* [13], *Saccharomyces cerevisiae* [14], *E. arabatum* W-01 [15], *Enterococcus lactis* [16], *Lactobacillus plantarum* [17-18], and *L. lactis* subsp. lactis [19] are dietary probiotics used in shrimp aquaculture.

Table 1 Details of commercial probiotics formulations and dominant bacteria used for shrimp aquaculture

Trade name	Company	Microorganisms	Microbial counts	Packing size
Vibrionix	SRR Aqua	*P. acidolactis, L. acidophilus, L. casei, B. subtilis, B. licheniformis, B. mesentricus, B. polymyxa, B. amyloliquifaciens, C. butyricum,* and *S. faecium*	20 Billion CFU/g	1kg
BIOTAB	New IHC Aqua	*B. subtillis, B. licheniformis, B. megaterium, T. viride, N. europaea, N. winogradskyi, A. oryzae, Rhodococcus, R. rubrum, Cyanobacteria, P. denitrificans,* and *P. oxalaticus*	50 Billion CFU/g	1kg
Profs Power	BIOSTADT	*Bacillus* sp., *Pediococcus* sp., *Nitrosomonas* sp., and *Nitrobacter* sp.	>8 Billion CFU/g	1kg
Environ AC power	BIOSTADT	*Bacillus* sp., *Nitrosomonas* sp., *Nitrobactor* sp., and *Nitrosomonas* sp.	> 5 Billion CFU/g	10kg
UB-SPORE	Unique Biotech	*L. sporogenes*	1.5 Billion CFU/g	500g
UB-Aquaremaid	Unique Biotech	*Bacillus* sp., *Lactobacillus* sp., *Saccharomyces* sp., and *Aspergillus* sp.	NLT 4 Billion CFU/g	500g
UB-Pondcare	Unique Biotech	*Rhodococcus* sp., *Rhodobacter* sp., and *Thiobacillus* sp.	10 Billion CFU/L	1L
Bacimor FP	Hi-Line Aqua	*B. subtillis, B. licheniformis, B. megaterium, B. polymyxa,* and *B. pumilus*	50 Billion CFU/g	100g
Nutrifeast	Waterbase	*B. licheniformis, B. pumilus* and *B. subtilis*	$>1.5x10^{-9}$ CFU/g	500g
BIOSTIM	AABT	*S. cerevisiae, L. sporogenes, L. acidophilus, B. subtilis,* and *B. lechiniformis*	9.5 Million CFU/g	500g
BIO-PROB	AABT	*Lactobacillus, Bacillus, Nitrobacter, Nitrosomonas, Photosynthetic bacteria, Rhodobacter* and Yeast etc.,	150 Billion CFU/g	500g
Fe Clear	SRR Aqua	*Lactobacillus* sp., *Bifidobacteriu* sp., *Streptococcus* sp., and *Clostridium* sp.	2 Billion CFU/ml	100ml
Nitro Con	SRR Aqua	*Denitrifying bacteria (P. denitrificans* and *Lactobacillus* sp.*)*	NLT 5 Billion CFU/ml	5L
Aquasol-PS	SRR Aqua	*Rhodococcus, Rhodobacter, T. denitrificans, Cellulomonas,* and *Bacillus* sp.	3 Billion CFU/ml	5L
AquaPro F	Aquaintech inc.	*B. subtilis, B. licheniformis, B. megaterium, B. pumilus* and *B. polymyxa*	2 Billion CFU/g	1 kg

PrimaLac®, AquaStar®Pond, and AquaStar®Growout are commercial multi-strain probiotic formulations for *L. vannamei* cultures [20]. Multi-strain probiotics have more beneficial effects on multiple health conditions, while boosting the overall gut and immune performance of *L. vannamei* than single-strain probiotics [21]. Mixed dietary multi-strain probiotics can promote growth performance and enhance non-specific immunity [22-23]. Probiotic strains isolated from the

intestinal tract of *L. vannamei* show strong digestive enzyme production activity and antagonistic effects against common bacterial pathogens in shrimp [24]. Additionally, some ammonia-oxidizing bacteria, including Nitrosomonas marina, *Nitrospira moscoviensis*, and *Nitrosopumilus maritimus*, have been used to reduce ammonia in shrimp ponds [25]. The availability of single- and multi-strain probiotics provides insights into the formulation of new multi-strain probiotics with overall health benefits and improved pond environments in India. However, the development of probiotic immobilization matrices could ensure the feasibility of such multi-strain probiotics with the desired benefits.

Table 2 Chemical proximity of dried banana peel powder

Constituents	Concentration
Moisture (% dw)	0.54 ± 0.04
Ash (% dw)	16.07 ± 0.55
Fat (% dw)	7.85 ± 0.34
Protein (% dw)	7.17 ± 0.06
Dietary Fiber (% dw)	42.39 ± 0.80
Carbohydrate (% dw)	25.98 ± 0.76
Calcium (% dw)	34.02 ± 0.01
Sodium (% dw)	3.01 ± 0.01
Vitamin C (% dw)	91.30 ± 0.01
Phenol (mg/g)	1.21 ± 0.02
Flavonoid (mg/g)	1.06 ± 0.23
Solubility (%)	73.71 ± 1.44
Tannin (mg/g)	1.27 ± 1.00
Saponin (mg/g)	0.09 ± 0.01
Water holding capacity (g/g)	5.94 ± 0.29
Oil holding capacity (g/g)	1.04 ± 0.04

Matrix-assisted cell immobilization

Cell immobilization on a solid carrier can be defined as the localization of intact cells via physical adsorption between the carrier and cell membrane. Previously, multi-strain probiotics were immobilized on various solid carriers, such as apple [26], quince [27], cereal [28], bacterial cellulose [29], watermelon rind [30], and pear [31]. Recent studies have shown that total dietary fibers from fruit waste or sugarcane bagasse can be used as food matrices to enhance the viability of multi-strain probiotics [32-33]. This suggests the suitability of fruit waste as a food or solid matrix for increasing the viability and shelf life of multi-strain probiotic formulations. Concerning the commercialization and production cost of probiotics, inexpensive, abundant, and dietary fiber-enriched fruit waste is of great interest for the immobilization of multi-strain probiotics.

Immobilization on banana peel powder

Banana (*Musa acuminate*) is one of the most produced and consumed fruits worldwide, and its by-products (peel, banana fiber/trunk) are discarded in large quantities. Banana peel powder is widely used for the synthesis of nanomaterials, removal of synthetic dyes as absorbents, amelioration of tablet properties as binders, and probiotic carriers. It contains approximately 43–49 g of total dietary fiber, 1 g of inulin, 6 g of fructooligosaccharide, and 10–20 g of pectin per 100 g of dry matter, in addition to significant amounts of α-linolenic acid, essential amino acids, and micronutrients (Table 2) [34-35]. It also contains antioxidant compounds, including polyphenols, catecholamines, and carotenoids [36-38]. The administration of hot-water banana peel extract to diets enhances the resistance of a giant freshwater prawn (*M. rosenbergii*) to pathogenic infections [39-42]. Green banana powder improves the stability of *L. paracasei* LBC 81 enriched fermented milk during storage [43]. Freeze-dried banana powder also serves as a safe probiotic food carrier for microencapsulation of *L. acidophilus* and *L. casei* [44]. Thus, the potential bioactive compounds in banana peel powder are beneficial for human health and aquaculture. The process flow for the development of multi-strain shrimp probiotics using banana peel powder is shown in (Fig 1).

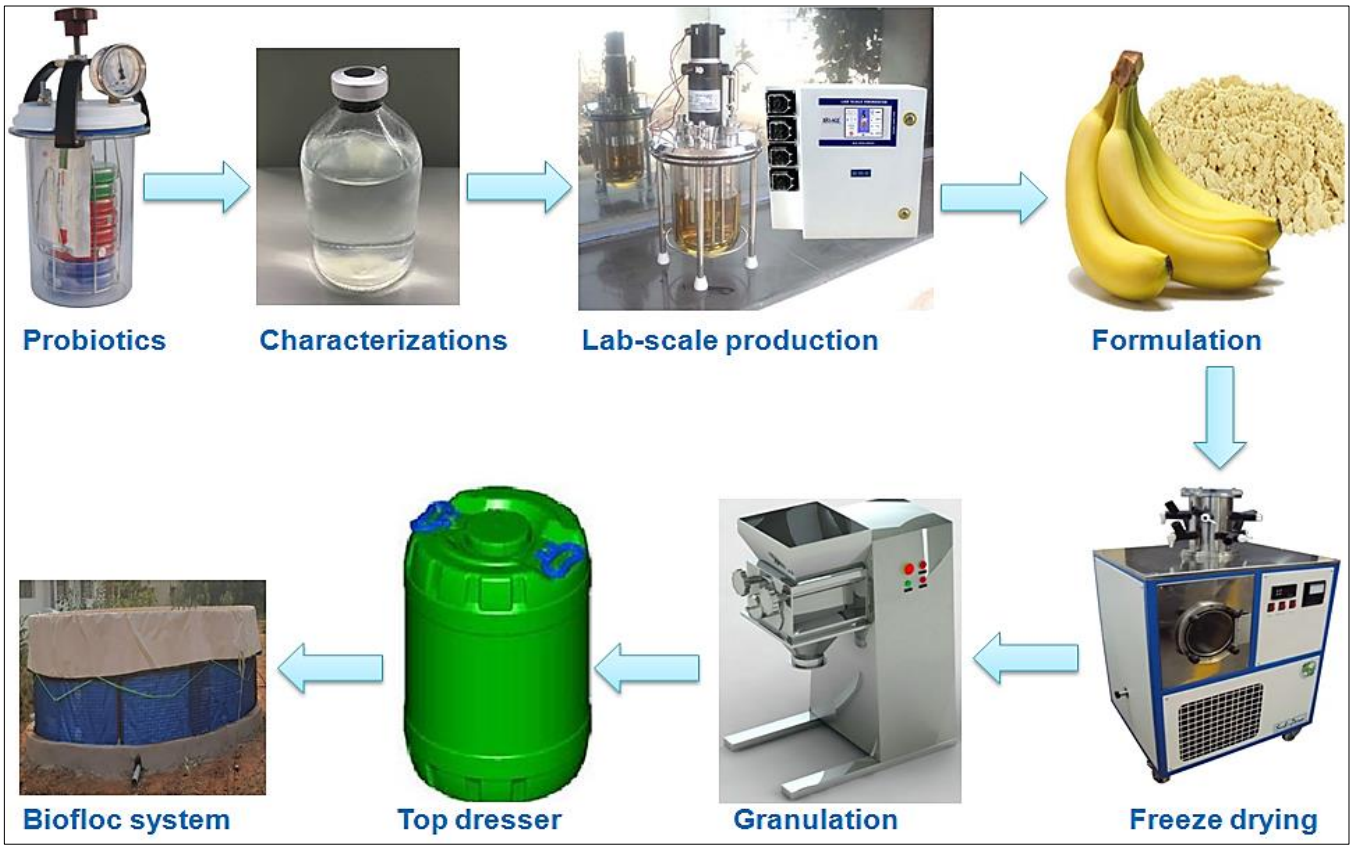

Fig 1 The process flow for the development of multi-strain shrimp probiotics on banana peel powder

Current perspective

Matrix-assisted techniques have been widely used because of their capability to enhance and maintain the viability of multi-strain probiotics during product processing and storage. The functional properties of banana peel powder include water-holding, swelling, gel-forming, bile acid-binding, and cation-exchange capacity. Banana peel powder is a potential agro-based resource that can be exploited as a food/immobilization matrix for the formulation of multi-strain probiotics with prolonged viability and shelf life. Such dietary multi-strain probiotics will gain importance in recycling nutrients, optimizing the food conversion ratio, and conditioning pond environments. The production cost of multi-strain probiotics on banana peel powder is comparatively lower than that of other immobilization matrices. Overexploitation from banana peel (as a probiotic carrier) will signify its scope for entrepreneurs to endeavour to this field of activity, which in turn provides noteworthy revenue to the country.

Acknowledgments

The authors would like to thank the Electronics Systems Development and Application Division, Ministry of Electronics and Information Technology, Government of India (27(1)/2020-ESDA) for financial support.

Declaration

I have no conflict of interest.

LITERATURE CITED

1. Holt CC, Bass D, Stentiford GD, van der Giezen M. 2020. Understanding the role of the shrimp gut microbiome in health and disease. *Jr. Invertebr. Pathology* 107387.
2. Kewcharoen W, Srisapoome P. 2019. Probiotic effects of Bacillus spp. from Pacific white shrimp (*Litopenaeus vannamei*) on water quality and shrimp growth, immune responses, and resistance to *Vibrio parahaemolyticus* (AHPND strains). *Fish Shellfish Immunology* 94: 175-189.
3. Duan Y, Zhang Y, Dong H, Wang Y, Zheng X, Zhang J. 2017. Effect of dietary *Clostridium butyricum* on growth, intestine health status and resistance to ammonia stress in Pacific white shrimp *Litopenaeus vannamei*. *Fish Shellfish Immunology* 65: 25-33.
4. Panigrahi A, Das RR, Sivakumar MR. 2020. Bio-augmentation of heterotrophic bacteria in biofloc system improves growth, survival, and immunity of Indian white shrimp *Penaeus indicus*. *Fish Shellfish Immunology* 98: 477-487.
5. Won S, Hamidoghli A, Choi W. 2020. Evaluation of potential probiotics *Bacillus subtilis* WB60, *Pediococcus pentosaceus*, and *Lactococcus lactis* on growth performance, immune response, gut histology and immune-related genes in white leg shrimp, *Litopenaeus vannamei*. *Microorganisms* 8: 281.
6. Li K, Zheng T, Tian Y. 2007. Beneficial effects of *Bacillus licheniformis* on the intestinal microflora and immunity of the white shrimp, *Litopenaeus vannamei*. *Biotechnology Letters* 29: 525-530.
7. Liu H, Li Z, Tan B, Lao Y, Duan Z, Sun W, Dong X. 2014. Isolation of a putative probiotic strain S12 and its effect on growth performance, non-specific immunity and disease-resistance of white shrimp, *Litopenaeus vannamei*. *Fish Shellfish Immunology* 41: 300-307.
8. Tseng DY, Ho PL, Huang SY, Cheng SC, Shiu YL, Chiu CS, Liu CH. 2009. Enhancement of immunity and disease resistance in the white shrimp, *Litopenaeus vannamei*, by the probiotic, *Bacillus subtilis* E20. *Fish Shellfish Immunology* 26: 339-344.
9. Chai PC, Song XL, Chen GF, Xu H, Huang J. 2016. Dietary supplementation of probiotic *Bacillus* PC465 isolated from the gut of *Fenneropenaeus chinensis* improves the health status and resistance of *Litopenaeus vannamei* against white spot syndrome virus. *Fish Shellfish Immunology* 54: 602-611.
10. Sánchez-Ortiz AC, Angulo C, Luna-González A, Álvarez-Ruiz P, Mazón-Suástegui JM, Campa-Córdova ÁI. 2016. Effect of mixed-*Bacillus spp* isolated from pustulose ark *Anadara tuberculosa* on growth, survival, viral prevalence and immune-related gene expression in shrimp *Litopenaeus vannamei*. *Fish Shellfish Immunology* 59: 95-102.
11. Thompson J, Gregory S, Plummer S, Shields RJ, Rowley AF. 2010. An in vitro and in vivo assessment of the potential of *Vibrio* spp. as probiotics for the Pacific white shrimp, *Litopenaeus vannamei*. *Jr. Appl. Microbiology* 109: 1177-1187.
12. Xia Z, Zhu M, Zhang Y. 2014. Effects of the probiotic *Arthrobacter* sp. CW9 on the survival and immune status of white shrimp (*Penaeus vannamei*). *Lett. Appl. Microbiology* 58: 60-64.
13. Wen CQ, Xue M, Liang HF, Wu Y, Li X. 2015. Beneficial effects of *Ectothiorhodospira shaposhnikovii* WF on larval cultivation of *Litopenaeus vannamei*. *Benef. Microbes* 6: 525-533.
14. Afsharnasab M, Kakoolaki S, Mohammadidost M. 2016. Immunity enhancement with administration of *Gracilaria corticata* and *Saccharomyces cerevisiae* compared to gamma irradiation in expose to WSSV in shrimp, in juvenile *Litopenaeus vannamei*: A comparative study. *Fish Shellfish Immunology* 56: 21-33.
15. Wang S, Li H, Chen Y, Wei H, Gao GF, Liu H, Huang S, Chen JL. 2012. Transport of influenza virus neuraminidase (NA) to host cell surface is regulated by ARHGAP21 and Cdc42 proteins. *Jr. Biol. Chemistry* 287: 9804-9816.
16. Ben Braïek O, Ghomrassi H, Cremonesi P, Morandi S, Fleury Y, Le Chevalier P, Hani K, Bel Hadj O, Ghrairi T. 2017. Isolation and characterization of an enterocin P-producing *Enterococcus lactis* strain from a fresh shrimp (*Penaeus vannamei*). *Antonie Van Leeuwenhoek* 110: 771-786.
17. Chiu CH, Guu YK, Liu CH, Pan TM, Cheng W. 2007. Immune responses and gene expression in white shrimp, *Litopenaeus vannamei*, induced by Lactobacillus plantarum. *Fish Shellfish Immunology* 23: 364-377.
18. Zheng X, Duan Y, Dong H, Zhang J. 2017. Effects of dietary *Lactobacillus plantarum* in different treatments on growth performance and immune gene expression of white shrimp *Litopenaeus vannamei* under normal condition and stress of acute low salinity. *Fish Shellfish Immunology* 62: 195-201.
19. Adel M, El-Sayed AM, Yeganeh S, Dadar M, Giri SS. 2017. Effect of potential probiotic *Lactococcus lactis* subsp. lactis on growth performance, intestinal microbiota, digestive enzyme activities, and disease resistance of *Litopenaeus vannamei*. *Probiotics Antimicrob Proteins* 9: 150-156.

20. Zokaeifar H, Balcázar JL, Saad CR, Kamarudin MS, Sijam K, Arshad A, Nejat N. 2012. Effects of *Bacillus subtilis* on the growth performance, digestive enzymes, immune gene expression and disease resistance of white shrimp, *Litopenaeus vannamei*. *Fish Shellfish Immunology* 33: 683-689.
21. Wang YC, Hu SY, Chiu CS, Liu CH. 2019. Multiple-strain probiotics appear to be more effective in improving the growth performance and health status of white shrimp, *Litopenaeus vannamei*, than single probiotic strains. *Fish Shellfish Immunology* 84: 1050-1058.
22. Amoah K, Huang QC, Tan BP. 2019. Dietary supplementation of probiotic *Bacillus coagulans* ATCC 7050, improves the growth performance, intestinal morphology, microflora, immune response, and disease confrontation of Pacific white shrimp, *Litopenaeus vannamei*. *Fish Shellfish Immunology* 87: 796-808.
23. Xie JJ, Liu QQ, Liao S. 2019. Effects of dietary mixed probiotics on growth, non-specific immunity, intestinal morphology and microbiota of juvenile pacific white shrimp, *Litopenaeus vannamei*. *Fish Shellfish Immunology* 90: 456-465.
24. Zuo ZH, Shang BJ, Shao YC, Li WY, Sun JS. 2019. Screening of intestinal probiotics and the effects of feeding probiotics on the growth, immune, digestive enzyme activity and intestinal flora of *Litopenaeus vannamei*. *Fish Shellfish Immunology* 86: 160-168.
25. Ramachandran K, Elayaperumal G, Mishra S, Ramalingam K, Vanitha MC. 2016. Beneficial microbes as probiotics on aquaculture to bring sustainability in blue revolution. *Int. Jr. Recent Sci. Res*. 7: 14606-14612.
26. Kourkoutas Y, Xolias V, Kallis M, Bezirtzoglou E, Kanellaki M. 2005. *Lactobacillus casei* cell immobilization on fruit pieces for probiotic additive, fermented milk and lactic acid production. *Process Biochemistry* 40: 411-416.
27. Corbo MR, Bevilacqua A, Gallo M, Speranza B, Sinigaglia M. 2013. Immobilization and microencapsulation of *Lactobacillus plantarum*: Performances and in vivo applications. *Innovative Food Sci. Emerg. Technology* 18: 196-201.
28. Michida HS, Tamalampudi SS. Pandiella C, Webb H, Kondo A. 2006. Effect of cereal extracts and cereal fiber on viability of *Lactobacillus plantarum* under gastrointestinal tract conditions. *Biochem. Eng Journal* 28: 73-78.
29. Jagannath A, Raju PS, Bawa AS. 2010. Comparative evaluation of bacterial cellulose (nata) as a cryoprotectant and carrier support during the freeze-drying process of probiotic lactic acid bacteria. *Food Sci Technology* 43: 1197-1203.
30 Reddy LV, Reddy YHK, Reddy LPA, Reddy OVS. 2008. Wine production by novel yeast biocatalyst prepared by immobilization on watermelon (*Citrullus vulgaris*) rind pieces and characterization of volatile compounds. *Process Biochem*. 43: 748-752.
31. Kourkoutas Y, Bosnea L, Taboukos S, Baras C, Lambrou D, Kanellaki M. 2006. Probiotic cheese production using *Lactobacillus casei* cells immobilized on fruit pieces. *Jr. Dairy Science* 89: 1439-1451.
32. Ribeiro C, Freixo R, Silva J, Gibbs P, Morais A, Teixeira P. 2014. Dried fruit matrices incorporated with a probiotic strain of *Lactobacillus plantarum*. *Int. Jr. Food Studies* 3: 69-73
33. Shaharuddin S, Muhamad I. 2015. Microencapsulation of alginate-immobilized bagasse with *Lactobacillus rhamnosus* NRRL 442: enhancement of survivability and thermotolerance. *Carbohydr Polym*. 119: 173-181.
34. Emaga TH, Andrianaivo RH, Wathelet B, Tchango JT, Paquot M. 2007. Effects of the stage of maturation and varieties on the chemical composition of banana and plantain peels. *Food Chemistry* 103: 590-600.
35. Mohapatra D, Mishra S, Sutar N. 2010. Banana and its by-product utilization: An overview. *Jr. Sci. Ind. Research* 69: 323-329.
36. Gonzalez-Montelongo R, Gloria, Lobo M, Gonzalez M. 2010. Antioxidant activity in banana peel extracts: Testing extraction conditions and related bioactive compounds. *Food Chemistry* 119: 1030-1039.
37. Zokaeifar H, Babaei N, Saad CR, Kamarudin MS, Sijam K, Balcazar JL. 2014. Administration of *Bacillus subtilis* strains in the rearing water enhances the water quality, growth performance, immune response, and resistance against *Vibrio harveyi* infection in juvenile white shrimp, *Litopenaeus vannamei*. *Fish Shellfish Immunology* 36: 68-74.
38. Martins ANA, Pasquali MAB, Schnorr CE, Martins JJA, de Araújo GT, Rocha APT. 2019. Development and characterization of blends formulated with banana peel and banana pulp for the production of blends powders rich in antioxidant properties. *Jr. Food Sci. Technology* 56: 5289-5297.
39. Rattanavichai W, Chen YN, Chang CC, Cheng W. 2015. The effect of banana (*Musa acuminata*) peels hot-water extract on the immunity and resistance of giant freshwater prawn, *Macrobrachium rosenbergii* via dietary administration for a long term: Activity and gene transcription. *Fish Shellfish Immunology* 46: 378-386.
40. Rattanavichai W, Cheng W. 2014. Effects of hot-water extract of banana (*Musa acuminata*) fruit's peel on the antibacterial activity, and anti-hypothermal stress, immune responses and disease resistance of the giant freshwater prawn, *Macrobrachium rosenbergii*. *Fish Shellfish Immunology* 39: 326-335.
41. Rattanavichai W, Cheng W. 2015. Dietary supplement of banana (*Musa acuminata*) peels hot-water extract to enhance the growth, anti-hypothermal stress, immunity and disease resistance of the giant freshwater prawn, *Macrobrachium rosenbergii*. *Fish Shellfish Immunology* 43: 415-426.
42. Rattanavichai W, Cheng W, Chang CC. 2017. Simplified processing method of banana (*Musa acuminata*) peels possess the improvement in immunological responses of *Macrobrachium rosenbergii*. *Aqua Res.* 48: 5202-5213.
43. Vogado CO, Leandro EDS, Zandonadi RP. 2018. Enrichment of probiotic fermented milk with green banana pulp: Characterization, microbiological, physicochemical and sensory. *Nutrients* 10: 427.
44. Massounga Bora AF, Li X, Zhu Y, Du L. 2019. Improved viability of microencapsulated probiotics in a freeze-dried banana powder during storage and under simulated gastrointestinal tract. *Probiotics Antimicrob. Proteins* 11: 1330-1339.