UNIVERSITI PUTRA MALAYSIA

IMPROVEMENT OF BIOFLOC SYSTEM FOR POST LARVAL REARING OF GIANT FRESHWATER PRAWN (Macrobrachium rosenbergii de Man, 1879)

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By

MD. EILIOUS HOSAIN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

August 2021

DEDICATIONS

To

My Parents
My Siblings
My late and alive Grandparents
My late elder brother Md. Shahadat Hosain

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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August 2021

Chairperson : Associate Professor S M Nurul Amin Harmuj Ali Sarker, PhD
Faculty : Agriculture

Giant freshwater prawn, *Macrobrachium rosenbergii,* is a commercially important crustacean, which is being cultured throughout the South-East Asia. The production of *M. rosenbergii* has been declined owing to lack of adequate post larvae (PL) production, non-effective farming system and diseases that cause high economic losses. Biofloc technology (BFT) can be an alternative culture system as it has been proven a viable culture system that improves water quality, provides live feeds and health care of culture species as well as increases the production of many fishes, prawns and shrimps. Little report is published on prawn productive performance in biofloc technology system (BFT) so far. This study was conducted to investigate the growth, survival and proximate composition of *M. rosenbergii* PL in BFT. Therefore, five experiments were conducted on nursery phase of *M. rosenbergii* PL to identify the suitable carbon source, C-N ratio, salinity and floc volume, and influence of copepod addition in BFT under completely randomized design of each treatment with triplicate. The first experiment tested five carbon sources *i.e.,* wheat bran, rice flour, maize starch, molasses and palm kernel cake for biofloc. The PL growth was similar ($P > 0.05$) among five carbon sources. PLs survival (88.66%) was higher ($P < 0.05$) in maize starch and followed by rice flour (73.0%), molasses (68.33%), wheat bran (61.0%) and palm kernel cake (56.33%) treatments. The better FCR (2.21) and the highest lipid content (1.98% dry weight) were obtained in maize starch bioflocs than other four carbon sources. The water quality parameters *viz.* temperature, pH, dissolved oxygen and ammonia did not differ ($P > 0.05$) among five different carbon treatments. The second experiment examined the effects of four C-N ratios of 10, 15, 20, 25 and clear water system as control. Specific growth rate (SGR) was similar between the control (9.29% d^{-1}) and the CN-20 (9.47% d^{-1}) and CN-25 (9.34% d^{-1}) treatments which were significantly higher than that in the C-N10 treatment (8.03% d^{-1}). A higher survival (87.34%) was obtained in the C-N ratio 20 when compared to control (80.33%) and other C-N ratios groups, but no significant differences among five treatments were observed. The best FCR (2.65) was observed in the C-N ratio 20 treatment. Biofloc crude protein content was higher in the C-N ratio 20 than C-N ratio 10, 15 and 25 groups. The third experiment was conducted to compare the

performance of BFT under four different salinities (0, 5, 10 and 15‰). Better growth of PLs were found in 10‰ and 15‰ saline water biofloc system. A higher survival (85.66%) of *M. rosenbergii* PL was obtained in 15‰ biofloc system and followed by10‰, 5‰ and freshwater BFT. The best FCR was found in 15‰ and 10‰ salinity groups. Ciliate and rotifer abundances were higher in 15 ‰ saline water biofloc system than 10‰, 5‰ and freshwater biofloc system. A lower density of *Vibrio* spp. remained in 15‰ biofloc system than in 10‰ system. The fourth experiment investigated the effects of different floc volume of 2-5, 7-10 and 12-15 ml L^{-1} as well as zero-exchange BFT (control). A higher ($P < 0.05$) prawn survival (82.33%) was obtained in 2-5 ml L^{-1} floc treatment and followed by 7-10, 12-15 ml L^{-1} and zero-exchange BFT treatments. *Vibrio* spp. density was lower ($P < 0.05$) in 2-5 ml L^{-1} floc treatment than 12-15 ml L^{-1} and zero-exchange BFT. The fifth experiment was conducted to evaluate the effects of copepod addition in BFT under three treatments *i.e.,* clear water system as control, BFT with or without copepods addition. A higher final weight (117.23 mg), weight gain (107.82 mg), SGR (8.40 % d^{-1}), and survival (94.46%) of PLs were found in BFT with copepod addition treatment ($P < 0.05$) than BFT without copepod and control. The best FCR (1.08) and crude protein content (66.91%) in PLs were significantly higher ($P < 0.05$) in the copepod addition BFT than without copepod addition BFT and control. Significantly lower ammonia was found in two BFT groups than control. Overall, the study suggested that maize starch as carbon source; C-N ratio of 20, salinity range of 10-15 ‰, floc volume 2-5 ml L^{-1} and addition of copepod for the better growth and survival of *M. rosenbergii* PL in the nursery phase using BFT. Thus, the biofloc based nursery system could be implemented in commercial venture of *M. rosenbergii* industry to enhance the productivity and profit.

Keywords: Giant freshwater prawn, post larvae, biofloc system, carbon source, C-N ratio, biofloc volume, nursery operation

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENAMBAH-BAIKAN SISTEM TEKNOLOGI BIOFLOK UNTUK PENTERNAKAN PASCA-REGA UDANG GALAH (*Macrobrachium rosenbergii* de Man, 1879)

Oleh

MD. EILIOUS HOSAIN

Ogos 2021

Pengerusi : Profesor Madya S M Nurul Amin Harmuj Ali Sarker, PhD
Fakulti : Pertanian

Udang galah, *Macrobrachium rosenbergii,* adalah krustasea komersial penting yang dikultur di serata Asia Tenggara. Pengeluaran *M. rosenbergii* telah berkurangan disebabkan pengeluaran pasca-rega (PL) yang tidak mencukupi, sistem penternakan yang efektif serta penyakit yang menyebabkan kerugian besar. Teknologi bioflok (BFT) boleh menjadi sistem kultur alternatif setelah terbukti sebagai sistem penternakan yang berdaya maju yang meningkatkan kualiti air, menyediakan makanan hidup dan penjagaan kesihatan spesies yang dikultur serta meningkatkan pengeluaran ikan dan udang. Setakat ini hanya sedikit laporan yang diterbitkan mengenai prestasi pengeluaran udang dalam teknologi bioflok (BFT). Kajian ini dijalankan untuk menyelidik pertumbuhan, kemandirian dan komposisi proksimat bagi PL *M. rosenbergii* dalam sistem BFT. Oleh yang demikian, lima eksperimen telah dijalankan pada fasa nurseri PL udang untuk mengenal pasti sumber karbon, nisbah C-N, kemasinan, isipadu flok yang sesuai, dan pengaruh pertambahan kopepod dalam BFT di bawah susun atur rawak sepenuhnya bagi setiap rawatan dengan tiga replikat. Eksperimen pertama menguji lima sumber karbon iaitu dedak gandum, tepung beras, kanji jagung, molas and kek isirong sawit. Pertumbuhan PL udang adalah sama ($P > 0.05$) di antara lima sumber karbon. Kemandirian PL (88.66%) adalah lebih tinggi ($P < 0.05$) pada rawatan kanji jagung diikuti tepung beras (73.0%), molas (68.33%), dedak gandum (61.0%) dan kek isirong sawit (56.33%). FCR yang lebih baik (2.21) dan kandungan lipid tertinggi (1.98% berat kering) telah diperolehi pada bioflok kanji jagung berbanding dari empat sumber karbon yang lain. Parameter kualiti air seperti suhu, pH, oksigen terlarut dan amonia tidak berbeza ($P > 0.05$) di antara lima rawatan karbon yang berlainan. Eksperimen kedua mengjkaji kesan empat nisbah C-N iaitu 10, 15, 20, 25 dengan sistem air jernih sebagai kawalan. Kadar pertumbuhan spesifik (SGR) adalah sama di antara kawalan (9.29% d^{-1}) dan rawatan CN-20 (9.47% d^{-1}) dan rawatan CN-25 (9.34% d^{-1}) serta ketara lebih tinggi dari rawatan C-N10 (8.03% d^{-1}). Kemandirian yang lebih tinggi (87.34%) telah diperolehi pada C-N nisbah 20 berbanding dengan kawalan (80.33%) dan kumpulan C-N yang lain tetapi tiada perbezaan ketara di antara kelima-lima rawatan. FCR terbaik

(2.65) telah dikesan pada rawatan C-N nisbah 20. Kandungan protin kasar bioflok adalah lebih tinggi pada C-N nisbah 20 berbanding kumpulan C-N nisbah 10, 15 and 25. Eksperimen ketiga telah dijalankan untuk membandingkan prestasi BFT pada empat kemasinan berbeza (0, 5, 10 dan 15‰). Pertumbuhan PL yang lebih baik telah didapati pada sistem bioflok air payau 10‰ dan 15‰. Kemandirian yang lebih tinggi (85.66%) bagi PL *M. rosenbergii* telah diperolehi pada sistem bioflok 15‰ diikuti oleh system BFT 10‰, 5‰ dan air tawar. FCR terbaik telah berlaku pada kemasinan 15‰ dan 10‰. Penyahan amonia yang dikeluarkan lebih tinggi pada sistem bioflok 10 dan 15‰ kemasinan. Kepadatan siliat dan rotifer adalah lebih tinggi pada sistem biofloc 15‰ berbanding sistem bioflok 10‰, 5‰ dan air tawar. Ketumpatan *Vibrio* spp. yang lebih rendah didapati dalam sistem bioflok 15‰ berbanding sistem 10‰. Eksperimen keempat mengkaji kesan isipadu flok yang berlainan bagi 2-5, 7-10, dan 12-15 ml L^{-1} serta BFT penukaran sifar (kawalan). Kemandirian udang (82.33%) yang lebih tinggi ($P < 0.05$) telah didapati pada 2-5 ml L^{-1} rawatan flok dan diikuti oleh 7-10, 12-15 ml L^{-1} dan rawatan BFT penukaran sifar. Ketumpatan *Vibrio* spp. ($P < 0.05$) adalah lebih rendah pada rawatan flok 2-5 ml L^{-1} berbanding 12-15 ml L^{-1} dan BFT penukaran sifar. Eksperimen kelima telah dijalankan untuk menilai kesan penambahan kopepod pada BFT dalam tiga rawatan iaitu sistem air jernih sebagai kawalan, BFT dengan atau tanpa penambahan kopepod. Berat akhir yang lebih tinggi (117.23 mg), penambahan berat (107.82 mg), SGR (8.40% d^{-1}), dan kemandirian (94.46%) bagi PL telah didapati pada BFT dengan rawatan penambahan kopepod berbanding BFT tanpa kopepod dan kawalan. FCR terbaik (1.08) dan kandungan protein kasar (66.91%) pada PL adalah ketara lebih tinggi ($P < 0.05$) dengan penambahan kopepod berbanding tanpa penambahan kopepod BFT dan kawalan. Amonia yang ketara lebih rendah telah dikesan dalam kumpulan dua BFT berbanding kawalan. Keseluruhannya, kajian ini mengesyorkan kanji jagung sebagai sumber karbon, nisbah C-N 20; tahap kemasinan 10-15‰, isipadu flok 2-5 ml L^{-1} dan penambahan kopepod adalah disarankan bagi pertumbuhan dan kemandirian yang lebih baik bagi fasa nurseri PL *M. rosenbergii* menggunakan BFT. Jadi, sistem nurseri udang menggunakan bioflok boleh diterap dalam pelaburan komersial industri udang galah untuk meningkatkan produktiviti dan keuntungan.

Kata kunci: Udang galah, pasca rega, sistem bioflok, sumber karbon, nisbah C-N, isipadu bioflok, operasi nurseri

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This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

Ammonia-N	Ammonia-Nitrogen
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
BF	Biofloc
BFT	Biofloc technology
BFT-C	Biofloc technology with copepods
BFZ	Zero exchange biofloc system
BOD	Biological oxygen demand
CFU	Colony forming unit
CHO	Carbohydrate
C-N	Cabon to nitrogen
COD	Chemical oxygen demand
CON	Control
CS	Culture system
DO	Dissolved oxygen
DIN	Dissolved Inorganic Nitrogen
DW	Dry weight
FAO	Food and agriculture organigation
FCR	Food conversion ratio
FW	Final weight
IBSrs	Integrated biofloc system of *L. venameii* and red seaweed
I-AQUAS	International Institute of Aquaculture and Aquatic Sciences
IW	Initial weight

RF	Rice flour
MO	Molassess
MRS	De Man, rogosa and sharpe agar
min	Minutes
Nitrite-N	Nitrite-nitrogen
Nitrate-N	Nitrate-nitrogen
MS	Maize strach
P	Period
PKE	Palm kernel Expelar
RAS	Recirculating aquaculture system
SD	Stocking density
SE	Standard error
SR	Survival rate
Sal	Salinity
SGR	Specific growth rate
SVI	Sluudge volume index
TB	Total bacteria
TCBS	Thiosulphate citrate bile salt sucrose
TSA	Tryptone soya agar
TSS	Total suspended solid
UPM	Universiti Putra Malaysia
USA	United State of America
VSS	Volitile suspended solid
WB	Wheat bran

WG	Weight gain
YSI	Yellow Spring Instruments
g	Gram
m	Meter
L	Liter
ml	milileter
mg	Miligram
ppm	Parts per million
ºC	Degree celsius
%	The percent sign
<	The less than sign
>	The greater than sign

CHAPTER 1

INTRODUCTION

1.1 Background

The giant freshwater prawn, *Macrobrachium rosenbergii* (de Man, 1879), is a commercially important crustacean freshwater aquaculture species in tropical and subtropical countries (New, 2002). It lives in freshwater environment which is linked to brackish waters, because of larval survival, development and metamorphos is require the brackish waters (10-12‰) in natural environment or in commercial hatcheries (David *et al.,* 2016; New, 2010). The *M. rosenbergii* shows a wide range of distribution worldwide and inhabiting in estuaries, rivers, lakes, ponds and ditches also native to Southeast Asia, South Pacific countries, northern Oceania, and western Pacific islands (De Grave *et al.*, 2008; FAO, 2019; New, 1990, 1995; New and Nair, 2012).

In Malaysia, *M. rosenbergii* is commonly known as udang galah and annual production was 619.0 and 414.92 tonnes in 2010 and 2019, respectively (Anon, 2019; Banu and Christianus, 2016; Farook *et al*., 2019). The global production of *M. rosenbergii* in 2016 and one decade ago were 0.23 and 0.22 million tonnes showing sloth increment production. The *M. rosenbergii* is famous for lean protein, healthy fat include omega-3 fatty acids, many vitamins and minerals, low in calories and beneficial for human health though some high in cholesterols (Bhavan *et al.*, 2010; Cavalli *et al.*, 2001; De Silva, 2016; Muralisankar *et al.*, 2017). Therefore, prawn aquaculture industries require sustainable development to boost up production for the food security of growing populations.

Currently, biofloc technology (BFT) has recognized an alternative successful aquaculture system for finfishes and crustaceans culture, which minimize water usages and pollutants emission (Ballester *et al.*, 2017; Luo *et al.*, 2014; Dauda, 2019). BFT is an environment friendly, zero to minimal water exchange aquaculture system. This system proliferates heterotrophic organisms and requires organic carbon source supplementation to maintain carbon nitrogen ratio. This technology removes hazardous nitrogenous compound, provides on station live feeds, augment productivity and enhances performance in terms of growth, survival, feed conversion ratio, and protein efficiency ratio (Ahmad *et al.*, 2017; Dauda *et al.*, 2018). The BFT also increases the immunity and robustness to pathogens (Ahmad *et al.*, 2017). It ensures beneficial nutritional compounds such as protein, lipid, carbohydrate, vitamins, minerals as well as some bioactive and derivative compounds, such as organic acids, polyhydroxy acetate and polyhydroxy butyrate to many culture animal during nursery phase, grow-out and broodstock rearing (Ahmad *et al.*, 2017; Cardona *et al.*, 2016; Crab *et al.*, 2010; Dauda *et al.*, 2018).

1.2 Problem statement

The production of *M. rosenbergii* has not been increased in last decade when compared to white leg shrimp (FAO, 2019). Some studies have been identified the reasons of declining the prawn production, which are inadequate post larvae (PL) or advanced PL production in hatcheries, diseases, lack of effective culture system, climate change and natural disasters (Schwantes *et al.*, 2009; Sin and Shapawi, 2017; Sultana *et al.*, 2017; Farook *et al*., 2019). For example, the lack of stable PL nursery techniques, unavailability of PL as well as feeds are the main obstacle for prawn farming in several countries such as Bangladesh, India, Malaysia, Thailand, Philippines etc. (Schwantes *et al.*, 2009; Banu and Christianus; 2016; Tambalque lII *et al.*, 2015; Ghosh *et al.*, 2017; Sultana *et al.*, 2017; Jayasankar, 2018).

There are several types of nursery operation system for *M. rosenbergii* that include earthen ponds, cages/hapas, flow through, recirculation aquaculture system (RAS) and green water static systems (Lober and Zeng, 2009; Coyle *et al.*, 2010). Each of these have different drawbacks. For example, flow through system is often cheaper than RAS, however, it requires a greater amount of high quantity of water (Forster and Slaski, 2010; Losordo *et al.*, 2004). There has been succeed of PLs production with using green water culture where microalgae enrich zooplankton and maintains water quality (Lober and Zheng, 2009), but require to maintain live microalgae. An alternative system could be biofloc technology, which can be reduced water usages and economically viable as well as it is recognized as an environment-friendly aquaculture system which can potentially increase fish and crustacean production (Taw, 2010; Dauda, 2019). The novelty of the present study is to find out suitable carbon source, C-N ratio, salinity preference, optimum floc volume and impact of copepod addition in BFT for culturing of *M. rosenbergii* in nursery phase.

1.3 Objectives and hypotheses of the study

1. To investigate the effect of different carbon sources and carbon to nitrogen ratios on water quality, floc volume; growth, survival and proximate composition of *M. rosenbergii* post larvae in biofloc system

Null hypothesis (*Ho*): Different carbon sources and C-N ratios do not have any influence on nursery culture of *M. rosenbergii* post larvae in BFT system.

Alternative hypothesis (*Ha*): Nursery culture of *M. rosenbergii* post larvae will be influenced by different carbon sources and C-N ratios in BFT system.

2. To compare the effect of different salinities on growth, survival and proximate composition of *M. rosenbergii* post larvae in biofloc system

Null hypothesis (*Ho*): Four different salinity at 0‰, 5‰, 10‰ and 15‰ will not impact on the nursery culture of *M. rosenbergii* post larvae in BFT system.

Alternative hypothesis (*Ha*): Nursery culture of *M. rosenbergii* post larvae will be impacted by different salinity in BFT system.

3. To determine the effect of different floc volume on growth and survival of *M. rosenbergii* post larvae in biofloc system

Null hypothesis (*Ho*): Different floc volumes level based biofloc systems will not influence on nursery culture of giant freshwater prawn post larvae.

Alternative hypothesis (*Ha*): Nursery culture of *M. rosenbergii* post larvae will be influenced by different floc volumes level based biofloc systems.

4. To evaluate the effect of copepod addition on survival, growth and biochemical composition of *M. rosenbergii* post larvae in biofloc system.

Null hypothesis (*Ho*): Periodical copepod addition will not impact on nursery culture of giant freshwater prawn post larvae BFT system.

Alternative hypothesis (*Ha*): Nursery culture of *M. rosenbergii* post larvae will be influenced by periodical copepod addition in BFT system.

1.4 Overall hypothesis of the study

Null hypothesis (*Ho*): There is no effect of biofloc technology system on culture of *M. rosenbergii* during nursery phase.

Alternative hypothesis (*Ha*): Culture of *M. resenbergii* will be influenced in biofloc technology system during nursery phase.

REFERENCES

Abreu, J.L., Brito, L.O., Lima, P.C.M., Silva, S.M.B.C.D., Severi, W. & Gálvez, A.O. (2019). Effects of addition of *Navicula* sp. (diatom) in different densities to postlarvae of shrimp *Litopenaeus vannamei* reared in a BFT system: Growth, survival, productivity and fatty acid profile. *Aquaculture Research, 50*, 2231-2239.

Ahmed, N. & Thompson, S. (2019). The blue dimensions of aquaculture: a global synthesis. *Science of the Total Environment, 652*, 851-861.

Ahmed, N., Thompson, S., & Glaser, M. (2018). Transforming organic prawn farming in Bangladesh: Potentials and challenges. *Journal of Cleaner Production, 172*, 3806–3816.

Ahmad, H, I., Verma, A. K., Babitha Rani, A. M., Rathore, G., Saharan, N., & Gora, A. H. (2016). Growth, non-specific immunity and disease resistance of *Labeo rohita* against *Aeromonas hydrophila* in biofloc systems using different carbon sources. *Aquaculture*, *457*, 61–67.

Ahmad, I., Rani, A. M. B., & Verma, A. K. (2017). Biofloc technology : an emerging avenue in aquatic animal healthcare and nutrition. *Aquaculture International*, *25*, 1215–1226.

Ahmed, N., & Garnett, S. T. (2010). Sustainability of freshwater prawn farming in rice fields in southwest Bangladesh. *Journal of Sustainable Agriculture*, *34*, 659–679.

Ahmed, N., Ahammed, F., & Brakel, M.V. (2008). An economic analysis of freshwater prawn, *Macrobrachium rosenbergii*, farming in Mymensingh , Bangladesh. *Journal of the World Aquaculture Society*, *39*, 37–50.

Ahmmed, F., Ahmmed, M. K., Khushi, S. S., Sumon, M. S., Karamcheti, S. S., & Sarower, M. G. (2020). Host gut-derived probiotic *Lactobacillus* sp. improves resistance of giant freshwater prawn *Macrobrachium rosenbergii* against *Vibrio harveyi*. *Aquaculture International*, *28*, 1709–1724.

Ajadi, A., Sabri, M. Y., Atata, J. A., Daodu, O. B., & Emikpe, B. O. (2019). Pathology and immunohistochemical evaluation of *Vibrio alginolyticus* infection in *Macrobrachium rosenbergii*. *Comparative Clinical Pathology*, *28* 359–368.

Alam, M. J., Ang, K. J., & Begum, M. (1995). Use of egg custard augmented with cod liver oil and *Moina micrura* on production of freshwater prawn postlarvae. *Aquaculture International*, *3*, 249–259.

Alfiansah, Y. R., Hassenrück, C., Kunzmann, A., Taslihan, A., Harder, J., & Gärdes, A. (2018). Bacterial abundance and community composition in pond water from shrimp aquaculture systems with different stocking densities. *Frontiers in*

Microbiology, *9*, 1–15.

Ali, H., Rahman, M. M., Rico, A., Jaman, A., Basak, S. K., Islam, M. M., Khan, N., Keus, H. J., & Mohan, C. V. (2018). An assessment of health management practices and occupational health hazards in tiger shrimp (*Penaeus monodon*) and freshwater prawn (*Macrobrachium rosenbergii*) aquaculture in Bangladesh. *Veterinary and Animal Science*, *5*, 10–19.

Anand, P.S., Kohli, M.P.S., Kumar, Su., Sundaray, J. K., Roy, S. D., Venkateshwarlu, G., Sinha, A., & Pailan, G. H. (2014). Effect of dietary supplementation of periphyton on growth, immune response and metabolic enzyme activities in *Penaeus monodon*. *Aquaculture Research*, *418–419*, 108–115.

Anh, N. T. N., Hien, T. T. T., Mathieu, W., Hoa, N. Van, & Sorgeloos, P. (2009). Effect of fishmeal replacement with *Artemia* biomass as a protein source in practical diets for the giant freshwater prawn *Macrobrachium rosenbergii*. *Aquaculture Research*, *40*, 669–680.

Anon (2015) Annual Fisheries Statistics, Department of Fisheries, Ministry of Agriculture, Malaysia.p.23.https://www.dof.gov.my/dof2/resources/user_29/Documents/Perangkaan%20Perikanan/2015/6._Jadual_Perikanan_Darat_.pdf

Anon (2016) Annual Fisheries Statistics, Department of Fisheries, Ministry of Agriculture, Malaysia.p34.https://www.dof.gov.my/dof2/resources/user_29/Documents/Perangkaan%20Perikanan/2016/Perairan_Umum.pdf

Anon (2019) Annual Fisheries Statistics, Department of Fisheries, Ministry of Agriculture, Malaysia.Table33.2.https://www.dof.gov.my/dof2/resources/user_29/Documents/Perangkaan%20Perikanan/2019/Perairan_Umum.pdf

AOAC. (1990). *Official Methods of Analysis of the Association of Official Analytical Chemists, 15th edn. Association of official analytical chemists, INC.* Suite 400, 2200 Wilson Boulevard Arlington, Virginia 22201 USA.

Arantes, R., Schveitzer, R., Magnotti, C., Lapa, K. R., & Vinatea, L. (2017). A comparison between water exchange and settling tank as a method for suspended solids management in intensive biofloc technology systems: effects on shrimp (*Litopenaeus vannamei*) performance, water quality and water use. *Aquaculture Research*, *48*, 1478–1490.

Asaduzzaman, M., Rahman, M. M., Azim, M. E., Islam, M. A., Wahab, M. A., Verdegem, M. C. J., & Verreth, J. A. J. (2010). Effects of C/N ratio and substrate addition on natural food communities in freshwater prawn monoculture ponds. *Aquaculture*, *306*, 127–136.

Asaduzzaman, M., Salam, M. A., Wahab, M. A., Kunda, M., & Rahman, M. B. (2006). Effects of control of C/N ratio by low-cost carbohydrate addition on water quality and pond ecology in freshwater prawn *Macrobrachium rosenbergii* post-larvae nursing system. *Bangladesh Journal of Fisheries Research*, *10*, 121–130.

Asaduzzaman, M., Wahab, M. A., Verdegem, M. C. J., Huque, S., Salam, M. A., & Azim, M. E. (2008). C/N ratio control and substrate addition for periphyton development jointly enhance freshwater prawn *Macrobrachium rosenbergii* production in ponds. *Aquaculture*, *280*, 117–123.

Avnimelech, Y. (1999). Carbon/nitrogen ratio as a control element in aquaculture systems. *Aquaculture*, *176*, 227–235.

Avnimelech, Y. (2006). Bio-filters: The need for an new comprehensive approach. *Aquacultural Engineering*, *34*, 172–178.

Avnimelech, Y. (2007). Feeding with microbial flocs by tilapia in minimal discharge bio-flocs technology ponds. *Aquaculture*, *264*, 140–147.

Avnimelech, Y. (2009). *Biofloc technology – A Practical guide book*. The World Aquaculture Society, Baton Rouge, LA.

Avnimelech, Y. (2015). *Biofloc Technology – A Practical Guide Book*, 3rd ed. The World Aquaculture Society, Baton Rouge, Louisiana, USA, pp. 21–73.

Ayazo-Genes, J., Pertúz-Buelvas, V., Jiménez-Velásquez, C., Espinosa-Araujo, J., Atencio-García, V., & Prieto-Guevara, M. (2019). Describing the planktonic and bacterial communities associated with bocachico *Prochilodus magdalenae* fish culture with biofloc technology. *Revista MVZ Cordoba*, *24*, 7209–7217.

Azim, M. E., Little, D. C., & Bron, J. E. (2008). Microbial protein production in activated suspension tanks manipulating C:N ratio in feed and the implications for fish culture. *Bioresource Technology*, *99*, 3590–3599.

Bakar, A. N. S., Mohd Nasir, N., Lananan, F., Abdul Hamid, S. H., Lam, S. S., & Jusoh, A. (2015). Optimization of C/N ratios for nutrient removal in aquaculture system culturing African catfish, (*Clarias gariepinus*) utilizing bioflocs technology. *International Biodeterioration and Biodegradation*, *102*, 100–106.

Bakhsh, H. K., & Chopin, T. (2011). Water quality and nutrient aspects in recirculating aquaponic production of the freshwater prawn, *Macrobrachium rosenbergii* and the lettuce, *Lactuca sativa*. *International Journal of Recirculating Aquaculture*, *12*, 13–33.

Bakhshi, F., Najdegerami, E. H., Manaffar, R., Tukmechi, A., & Farah, K. R. (2018). Use of different carbon sources for the biofloc system during the grow-out culture of common carp (*Cyprinus carpio* L.) fingerlings. *Aquaculture*, *484*, 259–267.

Ballester, E. L. C., Abreu, P. C., Cavalli, R. O., Emerenciano, M., de Abreu, L., & Wasielesky, W. (2010). Effect of practical diets with different protein levels on the performance of *Farfantepenaeus paulensis* juveniles nursed in a zero exchange suspended microbial flocs intensive system. *Aquaculture Nutrition*, *16*, 163–172.

Ballester, Eduardo L C, & Cavalli, R. O. (2011). Effect of biofloc technology (BFT) on the early postlarval stage of pink shrimp *Farfantepenaeus paulensis* : growth performance , floc composition and salinity stress. *Aquaculture International*, *19*, 891–901.

Ballester, E. L. C., Marzarotto, S. A., Silva de Castro, C., Frozza, A., Pastore, I., & Abreu, P. C. (2017). Productive performance of juvenile freshwater prawns *Macrobrachium rosenbergii* in biofloc system. *Aquaculture Research*, *48*, 4748–4755.

Banu, R., & Christianus, A. (2016). Giant freshwater prawn *Macrobrachium rosenbergii* farming: A review on its current status and prospective in Malaysia. *Journal of Aquaculture Research & Development*, *7*, 1–5.

Bassin, J. P., Kleerebezem, R., Muyzer, G., Rosado, A. S., Van Loosdrecht, M. C. M., & Dezotti, M. (2012). Effect of different salt adaptation strategies on the microbial diversity, activity, and settling of nitrifying sludge in sequencing batch reactors. *Applied Microbiology and Biotechnology*, *93*, 1281–1294.

Bauer, W., Prentice-Hernandez, C., Tesser, M. B., Wasielesky, W., & Poersch, L. H. S. (2012). Substitution of fishmeal with microbial floc meal and soy protein concentrate in diets for the pacific white shrimp *Litopenaeus vannamei*. *Aquaculture*, *342–343*, 112–116.

Becerril-Cortés, D., Monroy-Dosta, M. del C., Coelho-Emerenciano, M. G., Castro-Mejía, G., Cienfuegos-Martínez, K., & de Lara-Andrade, R. (2017). Nutritional importance for aquaculture and ecological function of microorganisms that make up biofloc, a review. *Int. J. of Aquatic Science*, *8*, 69–77.

Bhavan, P. S., Radhakrishnan, S., Seenivasan, C., Shanthi, R., Poongodi, R., & Kannan, S. (2010). Proximate composition and profiles of amino acids and fatty acids in the muscle of adult males and females of commercially viable prawn species *Macrobrachium rosenbergii* collected from natural culture environments. *International Journal of Biology*, *2*, 107–119.

Bonami, J. R., & Sri Widada, J. (2011). Viral diseases of the giant fresh water prawn *Macrobrachium rosenbergii*: A review. *Journal of Invertebrate Pathology*, *106*, 131–142.

Boyd, C.E., (2014). Nitrite toxicity affected by species susceptibility, environmental conditions. *Global Aquaculture Advocate 17*, 34–37.

Bregnballe, J. (2015). A Guide to Recirculation Aquaculture. In *FAO and Eurofish*

Report. Food and Agriculture Organization of the United Nations (FAO) and EUROFISH International Organisation. Pp-100.

Brito, L. O., Chagas, A. M., da Silva, E. P., Soares, R. B., Severi, W., & Gálvez, A. O. (2016a). Water quality, *Vibrio* density and growth of Pacific white shrimp *Litopenaeus vannamei* (Boone) in an integrated biofloc system with red seaweed *Gracilaria birdiae* (Greville). *Aquaculture Research*, *47*, 940–950.

Brito, L. O., dos Santos, I. G. S., de Abreu, J. L., de Araújo, M. T., Severi, W., & Gàlvez, A. O. (2016). Effect of the addition of diatoms (*Navicula* spp.) and rotifers (*Brachionus plicatilis*) on water quality and growth of the *Litopenaeus vannamei* postlarvae reared in a biofloc system. *Aquaculture Research*, *47*, 3990–3997.

Brown, J. H., New, M. B., & Ismael, D. (2010). Biology. In M. N. K. M. B. New, W. C. Valenti, J. H. Tidwell, L. R. D'Abramo (Ed.), *Freshwater Prawns Biology and Farming* (p. 570). Wiley-Blackwell, A John Wiley & Sons, Ltd., Publication.

Cardona, E., Gueguen, Y., Magré, K., Lorgeoux, B., Piquemal, D., Pierrat, F., Noguier, F., & Saulnier, D. (2016). Bacterial community characterization of water and intestine of the shrimp *Litopenaeus stylirostris* in a biofloc system. *BMC Microbiology*, 1–9.

Cardona, E., Lorgeoux, B., Chim, L., Goguenheim, J., Le Delliou, H., & Cahu, C. (2016). Biofloc contribution to antioxidant defence status, lipid nutrition and reproductive performance of broodstock of the shrimp *Litopenaeus stylirostris*: Consequences for the quality of eggs and larvae. *Aquaculture*, *452*, 252–262.

Cardona, E., Lorgeoux, B., Geffroy, C., Richard, P., Saulnier, D., Gueguen, Y., Guillou, & G., Chim, L. (2015). Relative contribution of natural productivity and compound feed to tissue growth in blue shrimp (*Litopenaeus stylirostris*) reared in biofloc: Assessment by C and N stable isotope ratios and effect on key digestive enzymes. *Aquaculture 448*, 288–297.

Castro, G. M., Castro, J. M., Ramírez, J. M., & Castro, C. A. E. (2018). Zooplankton growth in a Biofloc system with different carbon sources in a *Cyprinus carpio* culture. *International Journal of Fisheries and Aquatic Studies*, *6*, 253–258

Cavalli, R. O., Tamtin, M., Lavens, P., & Sorgeloos, P. (2001). Variations in lipid classes and fatty acid content in tissues of wild *Macrobrachium rosenbergii* (de Man) females during maturation. *Aquaculture*, *193*, 311–324.

Chakraborty, D., Gopikrishna, M., & Altaff, K. (2001). Study on the growth of post larvae of *Macrobrachium rosenbergii* (de Man) on a copepod and a cladoceran livefood. *Journal of Aquatic Biology*, *16*, 81–85.

Chand, B. K., Trivedi, R. K., Dubey, S. K., Rout, S. K., Beg, M. M., & Das, U. K. (2015). Effect of salinity on survival and growth of giant freshwater prawn *Macrobrachium rosenbergii* (de Man). *Aquaculture Reports*, *2*, 26–33.

Chen, J. C., & Chen, S. F. (1992a). Effects of nitrite on growth and molting of *Penaeus monodon* juveniles. *Comparative Biochemistry and Physiology. Part C, Comparative*, *101*, 453–458.

Chen, J. C., & Kou, Y. Z. (1992b). Effects of ammonia on growth and molting of *Penaeus japonicus* juveniles. *Aquaculture*, *104*, 249–260.

Chen, S. M., & Chen, J. C. (2003). Effects of pH on survival, growth, molting and feeding of giant freshwater prawn *Macrobrachium rosenbergii*. *Aquaculture*, *218*, 613–623.

Chen, J., Ren, Y., Li, Y., & Xia, B. (2018). Regulation of growth, intestinal microbiota, non-specific immune response and disease resistance of sea cucumber *Apostichopus japonicus* (Selenka) in biofloc systems. *Fish and Shellfish Immunology*, *77*, 175–186.

Chen, K. F., Tan, W. S., Ong, L. K., Zainal Abidin, S. A., Othman, I., Tey, B. T., & Lee, R. F. S. (2021). The *Macrobrachium rosenbergii* nodavirus: a detailed review of structure, infectivity, host immunity, diagnosis and prevention. *Reviews in Aquaculture*, *13*, 2117–2141.

Cheng, W. & Chen, J. (2002). Effects of environmental factors on the immune responses of freshwater prawn *Macrobrachium rosenbergii* and other decapod crustaceans. *J. Fish. Soc. Taiwan*, *29*, 1–19.

Cheng, W., & Chen, J. C. (1998). *Enterococcus*-like infections in *Macrobrachium rosenbergii* are exacerbated by high pH and temperature but reduced by low salinity. *Diseases of Aquatic Organisms*, *34*, 103–108.

Chowdhury, M.A.K., Goda, A.M.A.S., El-Haroun, E.R., Wafa, M.A., El-Din, S.A.S., 2008. Effect of dietary protein and feeding time on growth performance and feed utilization of post larval freshwater prawn *Macrobrachium rosenbergii* (de Man 1879). J. Fish. Aquat. Sci. 3, 1–11.

Correia, E. S., Wilkenfeld, J. S., Morris, T. C., Wei, L., Prangnell, D. I., & Samocha, T. M. (2014). Intensive nursery production of the Pacific white shrimp *Litopenaeus vannamei* using two commercial feeds with high and low protein content in a biofloc-dominated system. *Aquacultural Engineering*, *59*, 48–54.

Cortés-Lorenzo, C., González-Martínez, A., Smidt, H., González-López, J., & Rodelas, B. (2016). Influence of salinity on fungal communities in a submerged fixed bed bioreactor for wastewater treatment. *Chemical Engineering Journal*, *285*, 562–572.

Coyle, S., Dasgupta, S., Tidwell, J. H., Van Arnum, A., & Bright, L. A. (2003). Effects of stocking density on nursery production and economics of the freshwater prawn, *Macrobrachium rosenbergii*. *Journal of Applied Aquaculture*, *14*, 137–148.

Coyle, S.D., Dallas E. Alston, & Sampaio, C.M.S. (2010). Nursery systems and management. In M. N. K. M. B. New, W. C. Valenti, J. H. Tidwell, L. R. D'Abramo (Ed.), *Freshwater Prawns Biology and Farming* (p. 570). Wiley-Blackwell, A John Wiley & Sons, Ltd., Publication.

Crab, R., Chielens, B., Wille, M., Bossier, P., & Verstraete, W. (2010). The effect of different carbon sources on the nutritional value of biofloc, a feed for *Macrobrachium rosenbergii* postlarvae. *Aquaculture Research*, *41*, 559–567.

Crab, R., Defoirdt, T., Bossier, P., & Verstraete, W. (2012). Biofloc technology in aquaculture: Beneficial effects and future challenges. *Aquaculture*, *356–357*, 351–356.

Crab, R., Kochva, M., Verstraete, W., & Avnimelech, Y. (2009). Bio-flocs technology application in over-wintering of tilapia. *Aquacultural Engineering*, *40*, 105–112.

Craig, S., Kuhn, D., & Schwarz, M. (2017). Understanding fish nutrition, feeds, and feeding. *Virginia Cooperative Extention* 1–6.

Cuvin-Aralar, M. L. A., Aralar, E. V., Laron, M., & Rosario, W. (2007). Culture of *Macrobrachium rosenbergii* (De Man 1879) in experimental cages in a freshwater eutrophic lake at different stocking densities. *Aquaculture Research*, *38*, 288–294.

D'Abramo, L., Daniels, W., Fondren, M., & Brunson, M. (1995). *Management practices for culture of freshwater prawns in temperate climates*. *Mississippi Agricultural & Forestry Experiment Station* (Vol. Bulletin 1). Mississippi State.

D`Abramo L.R., Cortney L. Ohs, Mack W. Fondren, J. A. S. (2003). *Culture of freshwater prawns in temperate climates: Management practices and econonices*. Agricultural Communications, a unit of the Division of Agriculture, Forestry, and Veterinary Medicine at Mississippi State University.

da Silva, J. L. S., Cavalcante, D. D. H., de Carvalho, F. C. T., Vieira, R. H. S. D. F., e Sá, M. V. D. C., & de Sousa, O. V. (2016). Aquatic microbiota diversity in the culture of Nile tilapia (*Oreochromis niloticus*) using bioflocs or periphyton: virulence factors and bioflim formation. *Acta Scientiarum - Animal Sciences*, *38*, 233–241.

Daniel, N., & Nageswari, P. (2017). Exogenous probiotics on biofloc based aquaculture : A review. *Current Agriculture Research Journal*, *5*, 88–107.

Das, S. K., Tiwari, V. K., Venkateshwarlu, G., Reddy, A. K., Parhi, J., Sharma, P., & Chettri, J. K. (2007). Growth, survival and fatty acid composition of *Macrobrachium rosenbergii* (de Man, 1879) post larvae fed HUFA-enriched *Moina micrura*. *Aquaculture*, *269*, 464–475.

Dash, G., Prakash, R., Prasad, K. P., Makesh, M., Pradeep, M. A., & Sen, S. (2014). Evaluation of *Lactobacillus plantarum* as feed supplement on host associated microflora , growth, feed efficiency, carcass biochemical composition and immune response of giant freshwater prawn, *Macrobrachium rosenbergii* (de Man, 1879). *Aquaculture*, *432*, 225–236.

Dauda, A. B. (2019). Biofloc technology: a review on the microbial interactions, operational parameters and implications to disease and health management of cultured aquatic animals. *Reviews in Aquaculture*, 1–18.

Dauda, A. B., Romano, N., Ebrahimi, M., Karim, M., Natrah, I., Kamarudin, M. S., & Ekasari, J. (2017). Different carbon sources affects biofloc volume, water quality and the survival and physiology of African catfish *Clarias gariepinus* fingerlings reared in an intensive biofloc technology system. *Fisheries Science*, *83*, 1037–1048.

Dauda, A. B., Romano, N., Ebrahimi, M., Teh, J. C., Ajadi, A., Chong, C. M., Karim, M., Natrah, I., & Kamarudin, M. S. (2018). Influence of carbon/nitrogen ratios on biofloc production and biochemical composition and subsequent effects on the growth, physiological status and disease resistance of African catfish (*Clarias gariepinus*) cultured in glycerol-based biofloc systems. *Aquaculture*, *483*, 120–130.

David, F.S., Cohen, F.P.A., & Valenti, W.C. (2016). Intensification of the giant river prawn *Macrobrachium rosenbergii* hatchery production. *Aquaculture Research 47*, 3747–3752.

David, F. S., Fonseca, T., Wolff Bueno, G., & Valenti, W. C. (2018). Economic feasibility of intensification of *Macrobrachium rosenbergii* hatchery. *Aquaculture Research*, *49*, 3769–3776.

Day, S. B., Salie, K., & Stander, H. B. (2016). A growth comparison among three commercial tilapia species in a biofloc system. *Aquaculture International*, *24*, 1309–1322.

da Silva, A. E. M., Brito, L. O., da Silva, D. A., de Lima, P. C. M., Farias, R. S., Gálvez, A. O., & da Silva, S. M. B. C. (2021). Effect of *Brachionus plicatilis* and *Navicula* sp. on Pacific white shrimp growth performance, *Vibrio*, immunological responses and resistance to white spot virus (WSSV) in nursery biofloc system. *Aquaculture, 535*, 736335.

de Alvarenga, É. R., Alves, G. F. de O., Fernandes, A. F. A., Costa, G. R., da Silva, M. A., Teixeira, E. de A., & Turra, E. M. (2018). Moderate salinities enhance growth performance of Nile tilapia (*Oreochromis niloticus*) fingerlings in the biofloc system. *Aquaculture Research*.49, 2919-2926

De Grave, S., Cai, Y., & Anker, A. (2008). Global diversity of shrimps (Crustacea: Decapoda: Caridea) in freshwater. *Hydrobiologia*, *595*, 287–293.

De Schryver, P., Crab, R., Defoirdt, T., Boon, N., & Verstraete, W. (2008). The basics of bio-flocs technology: The added value for aquaculture. *Aquaculture*, *277*, 125–137.

De Silva, S. S. (2016). Culture based fisheries in Asia are a strategy to augment food security. *Food Security*, *8*, 585–596.

de Souza, D. M., Borges, V. D., Furtado, P., Romano, L. A., Wasielesky, W., Monserrat, J. M., & de Oliveira Garcia, L. (2016). Antioxidant enzyme activities and immunological system analysis of *Litopenaeus vannamei* reared in biofloc technology (BFT) at different water temperatures. *Aquaculture*, *451*, 436–443.

de Souza, D. M., Suita, S. M., Romano, L. A., Wasielesky, W., & Ballester, E. L. C. (2014). Use of molasses as a carbon source during the nursery rearing of *Farfantepenaeus brasiliensis* (Latreille, 1817) in a Biofloc technology system. *Aquaculture Research*, *45*, 270–277.

Decamp, O., Cody, J., Conquest, L., Delanoy, G., & Tacon, A. G. J. (2003). Effect of salinity on natural community and production of *Litopenaeus vannamei* (Boone), within experimental zero-water exchange culture systems. *Aquaculture Research*, *34*, 345–355.

Deng, M., Chen, J., Gou, J., Hou, J., Li, D., & He, X. (2018). The effect of different carbon sources on water quality, microbial community and structure of biofloc systems. *Aquaculture*, *482*, 103–110.

Dexter, D. M. (1993). Salinity tolerance of the copepod *Apocyclops dengizicus* (Lepeschkin, 1900), a key food chain organism in the Salton Sea, California. *Hydrobiologia*, *267*, 203–209.

Dou, L., Chen, W., Pan, L., & Huang, F. (2021). Characterization of *Vibrio* sp. strain AB15 and *Pseudomonas fluorescens* strain NB14 from the biofloc of shrimp culture ponds capable of high ammonia and nitrite removal efficiency. *Journal of the World Aquaculture Society*, *52*, 843–858.

Drillet, G., Frouël, S., Sichlau, M. H., Jepsen, P. M., Højgaard, J. K., Joardeer, A. K., & Hansen, B. W. (2011). Status and recommendations on marine copepod cultivation for use as live feed. *Aquaculture*, *315*, 155–166.

Du, X., Almeida, D., Song, D., Zhao, Z., Luo, L., Wang, C., Li, J., Wang, L., Ji, F., & Xu, Q. (2018). Effects of organic carbon addition on water quality and phytoplankton assemblages in biofloc technology ponds. *Aquaculture*, *497*, 155–163.

Ebeling, J. M., Timmons, M. B., & Bisogni, J. J. (2006). Engineering analysis of the stoichiometry of photoautotrophic, autotrophic, and heterotrophic removal of ammonia-nitrogen in aquaculture systems. *Aquaculture*, *257*, 346–358.

Eli, D. A., Dandu, R. V. S. N., Verghese, J. T., Rao, N., Samraj, T. Y. C., Ovadia, O., & Sagi, A. (2014). Neo-females production and all-male progeny of a cross between two Indian strains of prawn (*Macrobrachium rosenbergii*): Population structure and growth performance under different harvest strategies. *Aquaculture*, *429*, 7–15.

Ekasari, J., Crab, R., & Verstraete, W. (2010). Primary nutritional content of bio-flocs cultured with different organic carbon sources and salinity. *HAYATI Journal of Biosciences*, *17*, 125–130.

Ekasari, J., Hanif Azhar, M., Surawidjaja, E. H., Nuryati, S., De Schryver, P., & Bossier, P. (2014). Immune response and disease resistance of shrimp fed biofloc grown on different carbon sources. *Fish and Shellfish Immunology*, *41*(2), 332–339.

Ekasari, J., Rivandi, D. R., Firdausi, A. P., Surawidjaja, E. H., Zairin, M., Bossier, P., & De Schryver, P. (2015). Biofloc technology positively affects Nile tilapia (*Oreochromis niloticus*) larvae performance. *Aquaculture*, *441*, 72–77.

Ekasari, J., Suprayudi, M. A., Wiyoto, W., Hazanah, R. F., Lenggara, G. S., Sulistiani, R., Alkahfi, M., & Zairin, M. (2016). Biofloc technology application in African catfish fingerling production: The effects on the reproductive performance of broodstock and the quality of eggs and larvae. *Aquaculture*, *464*, 349–356.

El-Husseiny, O. M., Goda, A. M. A. E., Mabroke, R. S., & Soaudy, M. (2018). Complexity of carbon sources and the impact on biofloc integrity and quality in tilapia (*Oreochromis niloticus*) tanks. *AACL Bioflux*, *11*, 846–855.

El-Sayed, A.F. (1997). Growth rates and feed efficiency of the freshwater prawn *Macrobrachium rosenbergii* fed varying protein and energy levels. *Bulletin of the National Institute of Oceanography and Fisheries 23,* 439–448.

Emerenciano, M., Ballester, E. L. C., Cavalli, R. O., & Wasielesky, W. (2011). Effect of biofloc technology (BFT) on the early postlarval stage of pink shrimp *Farfantepenaeus paulensis*: growth performance, floc composition and salinity stress tolerance. *Aquaculture International*, *19*, 891–901.

Emerenciano, M., Ballester, E. L. C., Cavalli, R. O., & Wasielesky, W. (2012). Biofloc technology application as a food source in a limited water exchange nursery system for pink shrimp *Farfantepenaeus brasiliensis* (Latreille, 1817). *Aquaculture Research*, *43*, 447–457.

Emerenciano, M., Cuzon, G., Arévalo, M., & Gaxiola, G. (2014). Biofloc technology in intensive broodstock farming of the pink shrimp *Farfantepenaeus duorarum*: Spawning performance, biochemical composition and fatty acid profile of eggs. *Aquaculture Research*, *45*, 1713–1726.

Emerenciano, M., Cuzon, G., Arévalo, M., Mascaró Miquelajauregui, M., & Gaxiola, G. (2013a). Effect of short-term fresh food supplementation on reproductive performance, biochemical composition, and fatty acid profile of *Litopenaeus*

vannamei (Boone) reared under biofloc conditions. *Aquaculture International*, *21*, 987–1007.

Emerenciano, M., Cuzon, G., Goguenheim, J., & Gaxiola, G. (2012). Floc contribution on spawning performance of blue shrimp *Litopenaeus stylirostris*. *Aquaculture Research*, *44*, 75–85.

Emerenciano, M., Cuzon, G., Paredes, A., & Gaxiola, G. (2013b). Evaluation of biofloc technology in pink shrimp *Farfantepenaeus duorarum* culture: Growth performance, water quality, microorganisms profile and proximate analysis of biofloc. *Aquaculture International*, *21*, 1381–1394.

Emerenciano, M. G. C., Martínez-Porchas, L. R. M.-C. M., & Miranda-Baeza, A. (2017). *Biofloc technology (BFT): A Tool for water quality management in aquaculture*. *Intech*. https://doi.org/http://dx.doi.org/10.5772/66416

Emerenciano, M., Gaxiola, G., & Cuzo, G. (2013c). Biofloc Technology (BFT): A Review for Aquaculture Application and Animal Food Industry. In *Biomass Now - Cultivation and Utilization* (pp. 300–328). https://doi.org/10.5772/53902

ESS (Environmental Sciences Section), Inorganic Chemistry Unit, Wisconsin State Lab of Hygiene, 1993. *ESS Method 340.2: Total Suspended Solids, Mass Balance (Dried at 103–105 °C) Volatile Suspended Solids (Ignited at 550 °C)*. Wisconsin State Lab of Hygiene, Madison, WI, USA.

FAO. (2018). *The State of World Fisheries and Aquaculture 2018- Meeting the sustainable development goals*. Food and Agriculture Organization of the United Nations, Rome.

FAO (2019). *Cultured Aquatic Species Information Programme. Macrobrachium rosenbergii. Cultured Aquatic Species Information Programme*. Text by New, M. B. In: FAO Fisheries and Aquaculture Department. Rome.

Farhadian, O., Md Yusoff, F., & Arshad, A. (2014). Effects of salinity, temperature, light intensity and light regimes on production, growth and reproductive parameters of *Apocyclops dengizicus*. *Iranian Journal of Fisheries Sciences*, *13*, 30–46.

Farhadian, Omidvar, Yusoff, F. M. D., & Arshad, A. (2008). Population growth and production of *Apocyclops dengizicus* (Copepoda: Cyclopoida) fed on different diets. *Journal of the World Aquaculture Society*, *39*, 384–396.

Farhadian, Omidvar, Yusoff, F. M. D., Mohamed, S., & Saad, C. R. (2009a). Use of cyclopoid copepod *Apocyclops dengizicus* as live feed for *Penaeus monodon* postlarvae. *Journal of the World Aquaculture Society*, *40*, 22–32.

Farhadian, Omidvar, Yusoff, F. M., & Mohamed, S. (2009b). Nutritional values of *Apocyclops dengizicus* (Copepoda: Cyclopoida) fed *Chaetocerous calcitrans* and *Tetraselmis tetrathele*. *Aquaculture Research*, *40*, 74–82.

Fadhilah, N., Estim, A., & Fatihah, S. N. (2019). Water quality and growth performance of giant freshwater prawn , *Macrobrachium rosenbergii* and green Bean, *Phaseolus vulgaris* in aquaponics system at different flow rates. *Transactions on Science and Technology*, *6*, 1–8.

Farook, M. A., Mohamed, H. S. M., Tariq, N. P. M. M., Shariq, K. M., & Ahmed, I. A. (2019). Giant freshwater prawn, *Macrobrachium rosenbergii* (de man 1879): A review. *International Journal of Research and Analytical Reveiws*, *6*, 571–584.

Fauji, H., Budiardi, T., & Ekasari, J. (2018). Growth performance and robustness of african catfish *Clarias gariepinus* (Burchell) in biofloc-based nursery production with different stocking densities. *Aquaculture Research*, *49*, 1339–1346.

Ferreira, G. S., Bolívar, N. C., Pereira, S. A., Guertler, C., Vieira, F. do N., Mouriño, J. L. P., & Seiffert, W. Q. (2015). Microbial biofloc as source of probiotic bacteria for the culture of *Litopenaeus vannamei*. *Aquaculture*, *448*, 273–279.

Fischer, H., Romano, N., Renukdas, N., Egnew, N., Sinha, A.K., & Ray, A.J. (2020). The potential for rearing juveniles of bluegill, *Lepomis macrochirus,* in a biofloc system. *Aqaculture Reports. 17,* 100398.

Forster, J., & Slaski, R. (2010). Lessons from unsuccessful farms, in: Chadwick, E.M.P., Parsons, G.J., Sayavong, B. (Eds.), *Evaluation of Closed-Containment Technologies for Saltwater Salmon Aquaculture*. NRC Research Press Ottawa, pp. 21.

Furtado, P. S., Campos, B. R., Serra, F. P., Klosterhoff, M., Romano, L. A., & Wasielesky, W. (2014). Effects of nitrate toxicity in the Pacific white shrimp, *Litopenaeus vannamei*, reared with biofloc technology (BFT). *Aquaculture International*, *23*, 315–327.

Furtado, P. S., Poersch, L. H., & Wasielesky, W. (2011). Effect of calcium hydroxide, carbonate and sodium bicarbonate on water quality and zootechnical performance of shrimp *Litopenaeus vannamei* reared in bio-flocs technology (BFT) systems. *Aquaculture*, *321*, 130–135.

Gallardo-Collí, A., Pérez-Rostro, C. I., & Hernández-Vergara, M. P. (2019). Reuse of water from biofloc technology for intensive culture of Nile tilapia (*Oreochromis niloticus*): effects on productive performance, organosomatic indices and body composition. *International Aquatic Research*, *11*, 43–55.

Gallardo-Collí, A., Pérez-Rostro, C. I., Hernández-Vergara, M. P., & Pérez-Legaspi, I. A. (2019). Microeukaryote community and the nutritional composition of the biofloc during Nile tilapia culture in water-reusing biofloc systems. *Aquaculture International*, *27*, 381–398.

Gao, F., Liao, S., Liu, S., Bai, H., Wang, A., & Ye, J. (2019). The combination use of *Candida tropicalis* HH8 and *Pseudomonas stutzeri* LZX301 on nitrogen

removal, biofloc formation and microbial communities in aquaculture. *Aquaculture*, *500*, 50–56.

Gao, X., Zhou, Y., Zhu, X., Tang, H., Li, X., Jiang, Q., Wei, W., & Zhang, X. (2021). *Enterobacter cloacae*: A probable etiological agent associated with slow growth in the giant freshwater prawn *Macrobrachium rosenbergii*. *Aquaculture*, *530*, 735826.

Gaona, C. A. P., de Almeida, M. S., Viau, V., Poersch, L. H., & Wasielesky, W. (2017). Effect of different total suspended solids levels on a *Litopenaeus vannamei* (Boone, 1931) BFT culture system during biofloc formation. *Aquaculture Research*, *48*, 1070–1079.

Ghosh, S., Manna, S., Sahu, N. C., Dutta, A., & Goswami, R. (2017). Social, economic and production characteristics of freshwater prawn, *Macrobrachium rosenbergii* (De Man, 1879) culture in West Bengal, India. *Aquaculture International*, *25*, 1935–1957.

Goda, A. M. A. S. (2008). Effect of dietary protein and lipid levels and protein-energy ratio on growth indices, feed utilization and body composition of freshwater prawn, *Macrobrachium rosenbergii* (de Man 1879) post larvae. *Aquaculture Research*, *39*, 891–901.

Gopal, S., Otta, S.K., Kumar, S., Karunasagar, Indrani, Nishibuchi, M., & Karunasagar, I. (2005). The occurrence of *Vibrio* species in tropical shrimp culture environments; implications for food safety. *International Journal of Food Microbiology, 102*, 151–159.

Green, B. W., Rawles, S. D., Webster, C. D., & McEntire, M. E. (2018). Effect of stocking rate on growing juvenile Sunshine Bass, *Morone chrysops* × *M. saxatilis*, in an outdoor biofloc production system. *Journal of the World Aquaculture Society*, *49*, 827–836.

Gupta, A., & Dhawan, A. (2013). Probiotic based diets for freshwater prawn *Macrobrachium rosenbergii*. *Indian Journal of Fisheries*, *60*, 103–109.

Gutiérrez, S. M., Monroy, C., Partida, H., Mejía, J. C., & Rodríguez, G. A. (2016). Effect of two carbon sources in microbial abundance in a Biofloc culture system with *Oreochromis niloticus* (Linnaeus, 1758). *International Journal of Fisheries and Aquatic Studies*, *4*, 421–427.

Hai, T. N., Phuong, N. T., Huong, D. T. T., Viet, L. Q., & H.K. Huong. (2017). Giant freshwater prawn (*Macrobrachium rosenbergii* de Man, 1879) farming in brackish water areas of the Mekong Delta, Vietnam. *Can Tho University Journal of Science*, *7*, 82-90.

Hapsari, F. (2016). The effect of fermented and non fermented biofloc inoculated with bacterium *Bacillus cereus* for catfish (*Clarias gariepinus*) juveniles. *AACL Bioflux*, *9*, 334–339.

Hargreaves, J. A. (2006). Photosynthetic suspended-growth systems in aquaculture. *Aquacultural Engineering*, *34*, 344–363.

Hargreaves, J. A. (2013). Biofloc Production Systems for Aquaculture Southern regional aquaculture center. *SRAC Publication*, (4503), 1–12.

Hari, B., & Kurup, B.M. (2003). Comparative evaluation of dietary protein levels and plant-animal protein ratios in *Macrobrachium rosenbergii* (de Man). *Aquaculture Nutrition 9*, 131–137.

Harikrishnan, R., Balasundaram, C., Jawahar, S., & Heo, M. S. (2012). Immunomodulatory effect of *Withania somnifera* supplementation diet in the giant freshwater prawn *Macrobrachium rosenbergii* (de Man) against *Aeromonas hydrophila*. *Fish and Shellfish Immunology*, *32*, 94–100.

Hasnita, C. H., A, M. D. A. N., Yusrina, A., R, N. D., Khairiyah, M., A, F. A., & Shazani, S. (2015). Constraint analysis in the farming of giant freshwater prawn (*Macrobrachium rosenbergii*) in peninsular Malaysia. *Advances in Environmental Biology*, *9*, 182–186.

Hayawin, Z.N., Astimar, A.A., Ibrahim, M.H., Abdul Khalil, H.P.S., Syirat, Z.B., & Menon, N.R. (2014). The growth and reproduction of *Eisenia fetida* and *Eudrilus eugeniae* in mixtures of empty fruit bunch and palm oil mill effluent. *Compost Science & Utilization 22*, 40–46.

He, H., Chen, Y., Li, X., Cheng, Y., Yang, C., & Zeng, G. (2017). Influence of salinity on microorganisms in activated sludge processes: A review. *International Biodeterioration and Biodegradation*, *119*, 520–527.

Hilton, J. W., Harrison, K. E., & Slinger, S. J. (1984). A semi-purified test diet for *Macrobrachium rosenbergii* and the lack of need for supplemental lecithin. *Aquaculture*, *37*, 209–215.

Hisano, H., Barbosa, P. T. L., Hayd, L. A., & Mattioli, C. C. (2019). Evaluation of Nile tilapia in monoculture and polyculture with giant freshwater prawn in biofloc technology system and in recirculation aquaculture system. *International Aquatic Research*, *11*, 335–346.

Hongtuo, F., Sufei, J., & Yiwei, X. (2012). Current status and prospects of farming the giant river prawn (*Macrobrachium rosenbergii*) and the oriental river prawn (*Macrobrachium nipponense*) in China. *Aquaculture Research*, *43*, 993–998.

Hooper, C., Debnath, P. P., Biswas, S., van Aerle, R., Bateman, K. S., Basak, S. K., Rahman, M. M., Mohan, C. V., Rakibul Islam, H. M., Ross, S., Stentiford, G. D., Currie, D., & Bass, D. (2020). A novel RNA virus, *Macrobrachium rosenbergii* golda virus (MrGV), linked to mass mortalities of the larval giant freshwater prawn in Bangladesh. *Viruses*, *12*, 1–18.

Hosain, M. E., Amin, S. M. N., Arshad, A., Kamarudin, M. S., & Karim, M. (2021). Effects of carbon sources on the culture of giant river prawn in biofloc system during nursery phase. *Aquaculture Reports*, *19*, 100607.

Hosain, M. E., Amin, S. M. N., Kamarudin, M. S., Arshad, A., Karim, M., & Romano, N. (2021a). Effect of salinity on growth, survival, and proximate composition of *Macrobrachium rosenbergii* post larvae as well as zooplankton composition reared in a maize starch based biofloc system. *Aquaculture*, *533*, 736235.

Hosain, M. E., Amin, S. M. N., Kamarudin, M. S., Arshad, A., & Romano, N. (2021b) Effects of C-N ratio on growth, survival and proximate composition of *Macrobrachium rosenbergii* post larvae reared under a corn starch based zero-exchange brackish water biofloc system. *Aquaculture Research*. https://doi.org/10.1111/are.15146

Hossain, M. A., & Islam, M. S. (2006). Optimization of stocking density of freshwater prawn *Macrobrachium rosenbergii* (de Man) in carp polyculture in Bangladesh. *Aquaculture Research*, *37*, 994–1000.

Hostins, B., Braga, A., Lopes, D. L. A., Wasielesky, W., & Poersch, L. H. (2015). Effect of temperature on nursery and compensatory growth of pink shrimp *Farfantepenaeus brasiliensis* reared in a super-intensive biofloc system. *Aquacultural Engineering*, *66*, 62–67.

Hostins, B., Lara, G., Decamp, O., Cesar, D. E., & Wasielesky, W. (2017). Efficacy and variations in bacterial density in the gut of *Litopenaeus vannamei* reared in a BFT system and in clear water supplemented with a commercial probiotic mixture. *Aquaculture*, *480*, 58–64.

Hostins, Barbara, Wasielesky, W., Decamp, O., Bossier, P., & De Schryver, P. (2019). Managing input C/N ratio to reduce the risk of Acute Hepatopancreatic Necrosis Disease (AHPND) outbreaks in biofloc systems- A laboratory study. *Aquaculture*, *508*, 60–65.

Huong, D. T. T., Wang, T., Bayley, M., & Phuong, N. T. (2010). Osmoregulation, growth and moulting cycles of the giant freshwater prawn (*Macrobrachium rosenbergii*) at different salinities. *Aquaculture Research*, *41*, e135–e143.

Iketani, G., Pimentel, L., Silva-Oliveira, G., Maciel, C., Valenti, W., Schneider, H., & Sampaio, I. (2011). The history of the introduction of the giant river prawn, *Macrobrachium cf. rosenbergii* (Decapoda, Palaemonidae), in Brazil: New insights from molecular data. *Genetics and Molecular Biology*, *34*, 142–151.

Indulkar, S. T., & Belsare, S. G. (2004). Live and inert foods for postlarvae of the giant freshwater prawn *Macrobrachium rosenbergii*. *Israeli Journal of Aquaculture - Bamidgeh*, *56*, 45–50.

Jayasankar, P. (2018). Present status of freshwater aquaculture in india - A review. *Indian Journal of Fisheries*, *65*, 157–165.

Jespersen, K. S., Kelling, I., Ponte, S., & Kruijssen, F. (2014). What shapes food value chains? Lessons from aquaculture in Asia. *Food Policy*, *49*, 228–240.

Jiang, W., Ren, W., Li, L., Dong, S., & Tian, X. (2020). Light and carbon sources addition alter microbial community in biofloc-based *Litopenaeus vannamei* culture systems. *Aquaculture*, *515*. 734572.

Ju, Z. Y., Forster, I., Conquest, L., Dominy, W., Kuo, W. C., & David Horgen, F. (2008). Determination of microbial community structures of shrimp floc cultures by biomarkers and analysis of floc amino acid profiles. *Aquaculture Research*, *39*, 118–133.

Juneta-Nor, A. S., Noordin, N. M., Ma, H., Azra, M. N., & Ikhwanuddin, M. (2020). Molt cycle related changes on the feed intake and biochemical composition of Giant freshwater prawn, *Macrobrachium rosenbergii*. *Aquaculture Reports*, *18*, 100444.

Jung, J. Y., Damusaru, J. H., Park, Y., Kim, K., Seong, M., Je, H. W., Kim, S., & Bai, S. C. (2017). Autotrophic biofloc technology system (ABFT) using *Chlorella vulgaris* and *Scenedesmus obliquus* positively affects performance of Nile tilapia (*Oreochromis niloticus*). *Algal Research*, *27*, 259–264.

Kalaiselvi, V., Bhavan P, S., R, K., G, R., & T, S. (2018). *Phyllanthus amarus* enriched *Artemia* nauplii enhanced survival, growth and nutritional quality of early post-larvae of the prawn *Macrobrachium rosenbergii*. *Clinical Nutrition and Metabolism*, *1*, 1–15.

Kamarudin, M. S., Jones, D. A., le Vay, L., & Abidin, A. Z. (1994). Ontogenetic change in digestive enzyme activity during larval development of *Macrobrachium rosenbergii*. *Aquaculture*, *123*, 323–333.

Kawamura, G., Bagarinao, T., Seok, A., Yong, K., Chen, C. Y., & Mat, S. N. (2015). Low pH affects survival , growth , size distribution , and carapace quality of the postlarvae and early juveniles of the freshwater prawn *Macrobrachium rosenbergii* de Man. *Ocen Science Journal*, *50*, 371–379.

Keysami, M. A., & Mohammadpour, M. (2013). Effect of *Bacillus subtilis* on *Aeromonas hydrophila* infection resistance in juvenile freshwater prawn, *Macrobrachium rosenbergii* (de Man). *Aquaculture International*, *21*, 553–562.

Khanjani, M. H., Sajjadi, M. M., Alizadeh, M., & Sourinejad, I. (2017). Nursery performance of Pacific white shrimp (*Litopenaeus vannamei* Boone, 1931) cultivated in a biofloc system: the effect of adding different carbon sources. *Aquaculture Research*, *48*, 1491–1501.

Khatoon, H., Banerjee, S., Guan Yuan, G. T., Haris, N., Ikhwanuddin, M., Ambak, M. A., & Endut, A. (2016). Biofloc as a potential natural feed for shrimp postlarvae. *International Biodeterioration and Biodegradation*, *113*, 304–309.

Khemundu, G. R., & Banerjee, K. (2019). Culture of *Macrobrachium rosenbergii* using indigenous floral extract in the hilly terrains of Koraput district of Odisha , India. *Heliyon*, *5*, e02312.

Kim, Y. C., Romano, N., Lee, K. S., Teoh, C.Y., & Ng, W. K. (2013). Effects of replacing dietary fish oil and squid liver oil with vegetable oils on the growth, tissue fatty acid profile and total carotenoids of the giant freshwater prawn, *Macrobrachium rosenbergii***.** *Aquaculture Research* 44, 1731-1740.

Kim, S. K., Pang, Z., Seo, H. C., Cho, Y. R., Samocha, T., & Jang, I. K. (2014). Effect of bioflocs on growth and immune activity of Pacific white shrimp, *Litopenaeus vannamei* postlarvae. *Aquaculture Research*, *45*, 362–371.

Koshio, S., Kanazawa, A., & Teshima, S. (1992). Nutritional evaluation freshwater of dietary prawn soybean protein for juvenile *Macrobrachium rosenbergii*. N*ippon Suisan Gakkaishi 58,* 965–970.

Krishna, C., & Van Loosdrecht, M. C. M. (1999). Effect of temperature on storage polymers and settleability of activated sludge. *Water Research*, *33*, 2374–2382.

Kumar, B. P., Sahu, N. P., Saharan, N., Reddy, A. K., & Kumar, S. (2006). Effect of dietary source and level of chitin on growth and survival of post-larvae *Macrobrachium rosenbergii*. *Journal of Applied Ichthyology*, *22*, 1–6.

Kumar, S., Anand, P. S. S., De, D., Deo, A. D., Ghoshal, T. K., Sundaray, J. K., Punniah, A.G., Jithendran, K.P., Raja, R.A., Biwas, G., Lalitha, N. (2017). Effects of biofloc under different carbon sources and protein levels on water quality, growth performance and immune responses in black tiger shrimp *Penaeus monodon* (Fabricius, 1978). *Aquaculture Research*, *48*, 1168–1182.

Kumar, V., Wille, M., Lourenço, T. M., & Bossier, P. (2020). Biofloc-based enhanced survival of *Litopenaeus vannamei* upon AHPND-causing *Vibrio parahaemolyticus* challenge is partially mediated by reduced expression of its virulence genes. *Frontiers in Microbiology*, *11*, 1–12.

Kumaresan, V., Palanisamy, R., Pasupuleti, M., & Arockiaraj, J. (2017). Impacts of environmental and biological stressors on immune system of *Macrobrachium rosenbergii*. *Reviews in Aquaculture*, *9*, 283–307.

Kuris, A. M., Ra'anan, Z., Sagi, A., & Cohen, D. (1987). Morphotypic differentiation of male Malaysian giant prawns, *Macrobrachium rosenbergii*. *Journal of Crustacean Biology*, *7*, 219–237.

Langer, S., Karlopia, S. K., & Bakhtiyar, Y. (2009). Effect of different feeds on the growth and survival of post larvae of fresh water prawn *Macrobrachium rosenbergii* in Jammu. *National Journal of Life Sciences*, *6*, 187–192.

Lee, C., Kim, S., Lim, S. J., & Lee, K. J. (2017). Supplemental effects of biofloc powder on growth performance, innate immunity, and disease resistance of Pacific

white shrimp *Litopenaeus vannamei*. *Fisheries and Aquatic Sciences*, *20*, 1–7.

Lemos, D., & Weissman, D. (2021). Moulting in the grow-out of farmed shrimp: a review. *Reviews in Aquaculture*, *13*, 5–17.

Li, H. D., Han, D., Zhu, X. M., Yang, Y. X., Jin, J. Y., Xie, S. Q., & Liu, H. K. (2018). Effect of biofloc technology on water quality and feed utilization in the cultivation of gibel carp (*Carassius auratus gibelio* var. CAS III). *Aquaculture Research*, *49*, 2852–2860.

Li, J., Li, J., Li, W., Sun, Y., Liu, X., Liu, M., & Cheng, Y. (2019). Juvenile *Procambarus clarkii* farmed using biofloc technology or commercial feed in zero-water exchange indoor tanks: A comparison of growth performance, enzyme activity and proximate composition. *Aquaculture Research*, *50*, 1834–1843.

Li, X., Zhou, Y., Jiang, Q., Yang, H., Pi, D., Liu, X., Gao, X., Chen, N., & Zhang, X. (2019). Virulence properties of *Vibrio vulnificus* isolated from diseased zoea of freshness shrimp *Macrobrachium rosenbergii*. *Microbial Pathogenesis*, *127*, 166–171.

Lim, P.N., Wu, T.Y., Clarke, C., & Nik Daud, N.N. (2015). A potential bioconversion of empty fruit bunches into organic fertilizer using *Eudrilus eugeniae*. *Internationa Journal of Environment Science and Technology 12*, 2533–2544.

Ling, S. W. & Costello, T.J. (1979). The culture of freshwater prawns: a review. In *Advances in Aquaculture. Papers presented at the FAO Technical Conference on Aquaculture, 26May–2 June 1976, Kyoto*, (Ed. by T.V.R. Pillay & W.A. Dill), pp. 299–304. Fishing News Books, Blackwell Science, Oxford.

Liu, G., Ye, Z., Liu, D., Zhao, J., Sivaramasamy, E., Deng, Y., & Zhu, S. (2018). Influence of stocking density on growth, digestive enzyme activities, immune responses, antioxidant of *Oreochromis niloticus* fingerlings in biofloc systems. *Fish and Shellfish Immunology*, *81*, 416–422.

Liu, L., Hu, Z., Dai, X., & Avnimelech, Y. (2014). Effects of addition of maize starch on the yield , water quality and formation of bioflocs in an integrated shrimp culture system Effects of addition of maize starch on the yield , water quality and formation of bioflocs in an integrated shrimp culture. *Aquaculture*, *418–419*, 79–86.

Liu, W., Luo, G., Zhang, N., Yu, Y., Chen, W., Tan, H., & Wu, S. (2018). Effect of no carbohydrate addition on water quality, growth performance and microbial community in water-reusing biofloc systems for tilapia production under high-density cultivation. *Aquaculture Research*, *49*, 2446–2454.

Liu, G., Zhu, S., Liu, D., Guo, X., & Ye, Z. (2017). Effects of stocking density of the white shrimp *Litopenaeus vannamei* (Boone) on immunities, antioxidant status, and resistance against *Vibrio harveyi* in a biofloc system. *Fish and Shellfish Immunology*, *67*, 19–26.

Lobato, O.S.C., de Azevedo Silva Ribeiro, F., Miranda-Baeza, A., & Emerenciano, M.G.C. (2019. Production performance of *Litopenaeus vannamei* (Boone, 1931) fed with different dietary levels of tilapia processing waste silage reared in biofloc system using two carbon sources. *Aquaculture 501,* 515–518.

Llario, F., Falco, S., Sebastiá-Frasquet, M. T., Escrivá, J., Rodilla, M., & Poersch, L. H. (2019). The role of *Bacillus amyloliquefaciens* on *Litopenaeus vannamei* during the maturation of a biofloc system. *Journal of Marine Science and Engineering*, *7*, 1–17.

Lober, M. & Zeng, C. (2009). Effect of microalgae concentrations on larval survival, development and growth of an Australian strain of giant freshwater prawn *Macrobrachium rosenbergii*. *Aquaculture 289,* 95-100.

Long, L., Yang, J., Li, Y., Guan, C., & Wu, F. (2015). Effect of biofloc technology on growth, digestive enzyme activity, hematology, and immune response of genetically improved farmed tilapia (*Oreochromis niloticus*). *Aquaculture*, *448*, 135–141.

Losordo, T.M., Ray, L.E., & DeLong, D.P. (2004). Flow-through and recirculating systems, in: *Biology and Culture of Channel Catfish*. pp. 545–560.

Loureiro, C.K., Wasielesky Jr, W., & Abreu, P.C. (2012). the use of protozoan, rotifers and nematodes as live food for shrimp raised in BFT system. *Atlântica 34*, 5–12.

Luis-Villaseñor, I. E., Voltolina, D., Audelo-Naranjo, J. M., Pacheco-Marges, M. R., Herrera-Espericueta, V. E., & Romero-Beltrán, E. (2015). Effects of biofloc promotion on water quality, growth, biomass yield and heterotrophic community in *Litopenaeus vannamei* (Boone, 1931) experimental intensive culture. *Italian Journal of Animal Science*, *14*, 332–337.

Luo, G., Gao, Q., Wang, C., Liu, W., Sun, D., Li, L., & Tan, H. (2014). Growth, digestive activity, welfare, and partial cost-effectiveness of genetically improved farmed tilapia (*Oreochromis niloticus*) cultured in a recirculating aquaculture system and an indoor biofloc system. *Aquaculture, 422–423*, 1–7.

Luo, G., Li, W., Tan, H., & Chen, X. (2017). Comparing salinities of 0, 10 and 20 in biofloc genetically improved farmed tilapia (*Oreochromis niloticus*) production systems. *Aquaculture and Fisheries*, *2*, 220–226.

Ma, C.W., Cho, Y.S., & Oh, K.H. (2009). Removal of pathogenic bacteria and nitrogens by *Lactobacillus* spp. JK-8 and JK-11. *Aquaculture, 287*, 266–270.

Magondu, E. W., Charo-Karisa, H., & Verdegem, M. C. J. (2013). Effect of C/N ratio levels and stocking density of *Labeo victorianus* on pond environmental quality using maize flour as a carbon source. *Aquaculture*, *410–411*, 157–163.

Maica, P. F., Borba, M. R. De, & Jr, W. W. (2012). Effect of low salinity on microbial floc composition and performance of *Litopenaeus vannamei* (Boone) juveniles reared in a zero-water-exchange super-intensive system. *Aquaculture Research*, *43*, 361–370.

Maliwat, G. C., Velasquez, S., Robil, J. L., Chan, M., Traifalgar, R. F., Tayamen, M., & Ragaza, J. A. (2017). Growth and immune response of giant freshwater prawn *Macrobrachium rosenbergii* (De Man) postlarvae fed diets containing Chlorella vulgaris (Beijerinck). *Aquaculture Research*, *48*, 1666–1676.

Mallasen, M., Valenti, W. C., & Ismael, D. (2004). Effects of nitrate concentration on larval development of the giant river prawn, *Macrobrachium rosenbergii*. *Journal of Applied Aquaculture 14,* 55-69.

Mamun, M., Hossain, M., Hossain, M., & Ali, M. (2010). Effects of different types of artificial substrates on nursery production of freshwater prawn, *Macrobrachium rosenbergii* (de Man) in recirculatory system. *Journal of the Bangladesh Agricultural University*, *8*, 333–340.

Manan, H., Moh, J. H. Z., Kasan, N. A., Suratman, S., & Ikhwanuddin, M. (2017). Identification of biofloc microscopic composition as the natural bioremediation in zero water exchange of pacific white shrimp, *Penaeus vannamei*, culture in closed hatchery system. *Applied Water Science*, *7*, 2437–2446.

Manickam, N., Bhavan, P.S., Santhanam, P., Muralisankar, T., 2020. Influence of wild mixed zooplankton on growth and muscle biochemical composition of the freshwater prawn Macrobrachium *rosenbergii* post larvae. Aquaculture 522, 735110.

Mansour, A.T., & Esteban, M.Á. (2017). Effects of carbon sources and plant protein levels in a biofloc system on growth performance, and the immune and antioxidant status of Nile tilapia (*Oreochromis niloticus*). *Fish & Shellfish Immunology 64*, 202–209.

Marinho, Y. F., Brito, L. O., Silva Campos, C. V. F. da, Severi, W., Andrade, H. A., & Galvez, A. O. (2017). Effect of the addition of *Chaetoceros calcitrans*, *Navicula* sp. and *Phaeodactylum tricornutum* (Diatoms) on phytoplankton composition and growth of *Litopenaeus vannamei* (Boone) postlarvae reared in a biofloc system. *Aquaculture Research*, *48*, 4155–4164.

Marques, H. L. D. A., & Moraes-valenti, P. M. C. (2012). Current status and prospects of farming the giant river prawn (*Macrobrachium rosenbergii* (De Man 1879) and the Amazon river prawn *Macrobrachium amazonicum* (Heller 1862) in Brazil. *Aquaculture Research*, *43*, 984–992.

Marques, H. L. A., New, M. B., Boock, M. V., Barros, H. P., Mallasen, M., & Valenti, W. C. (2016). Integrated freshwater prawn farming: State-of-the-art and future potential. *Reviews in Fisheries Science and Aquaculture*, *24*, 264–293.

Marques, H. L. de A., Lombardi, J. V., & Boock, M. V. (2000). Stocking densities for nursery phase culture of the freshwater prawn *Macrobrachium rosenbergii* in cages. *Aquaculture*, *187*, 127–132.

Martinez-Cordova, L. (2011). Effect of supplying four copepod densities (*Acartia* sp. and *Calanus pacificus*) on the productive response of *Litopenaeus vannamei* pregrown intensively at microcosm level. *Ciencias Marinas*, *37*, 415–423.

Martins, T. G., Odebrecht, C., Jensen, L. V., D'Oca, M. G., & Wasielesky, W. (2016). The contribution of diatoms to bioflocs lipid content and the performance of juvenile *Litopenaeus vannamei* (Boone, 1931) in a BFT culture system. *Aquaculture Research*, *47*, 1315–1326.

Megahed, M. E. (2010). The effect of microbial biofloc on water quality , survival and growth of the green tiger shrimp (*Penaeus Semisulcatus*) fed with different crude protein levels 1: Sustainable solution to the dependency on fish oil, fishmeal and environmental problems. *Journal of the Arabian Aquaculture Society*, *5*, 119–141.

Mendez-Martínez, Y., García-Guerrero, M.U., Arcos-Ortega, F.G., Martínez-Cordova, L.R., Yamasaki-Granados, S., Perez-Rodríguez, J.C., & Cortes-Jacinto, E. (2018). Effect of different ratios of dietary protein-energy on growth, body proximal composition, digestive enzyme activity, and hepatopancreas histology in *Macrobrachium americanum* (Bate, 1868) prawn juveniles. *Aquaculture 485*, 1–11.

Miao, S., Sun, L., Bu, H., Zhu, J., & Chen, G. (2017a). Effect of molasses addition at C:N ratio of 20:1 on the water quality and growth performance of giant freshwater prawn (*Macrobrachium rosenbergii*). *Aquaculture International 25*, 1409–1425.

Miao, S., Zhu, J., Zhao, C., Sun, L., Zhang, X., & Chen, G. (2017b). Effects of C/N ratio control combined with probiotics on the immune response, disease resistance, intestinal microbiota and morphology of giant freshwater prawn (*Macrobrachium rosenbergii*). *Aquaculture*, *476*, 125–133.

Miao, S., Hu, J., Wan, W., Han, B., Zhou, Y., Xin, Z., & Sun, L. (2020). Biofloc technology with addition of different carbon sources altered the antibacterial and antioxidant response in *Macrobrachium rosenbergii* to acute stress. *Aquaculture 525*, 735280.

Ming, B. Y., & Fujiang, D. (2018). Culture of giant freshwater prawns in China. *Global Aquaculture Advocate*, *June 2016*.

Monroy, C. M., Montes, A. R., Oca, D., Castro, J., Castro, G., & Becerril, D. (2015). Importance and function of microbial communities in aquaculture systems with no water exchange. *Journal of Animal Science*, *4*, 103–110.

Moon, B. H., Seo, G. T., Lee, T. S., Kim, S. S., & Yoon, C. H. (2003). Effects of salt concentration on floc characteristics and pollutants removal efficiencies in treatment of seafood wastewater by SBR. *Water Science and Technology*, *47*, 65–70.

Moussa, M. S., Sumanasekera, D. U., Ibrahim, S. H., Lubberding, H. J., Hooijmans, C. M., Gijzen, H. J., & Van Loosdrecht, M. C. M. (2006). Long term effects of salt on activity, population structure and floc characteristics in enriched bacterial cultures of nitrifiers. *Water Research*, *40*, 1377–1388.

Muralisankar, T., Bhavan, P. S., Radhakrishnan, S., Santhanam, P., & Jayakumar, R. (2017). Growth performance, muscle biochemical constituents, amino acid and fatty acid compositions of the giant freshwater prawn, *Macrobrachium rosenbergii*, fed with herb-incorporated diet. *Aquaculture Nutrition*, *23*, 766–776.

Nair, C. M., & Salin, K. R. (2012). Current status and prospects of farming the giant river prawn *Macrobrachium rosenbergii* (De Man) and the monsoon river prawn *Macrobrachium malcolmsonii* (H. M. Edwards) in India. *Aquaculture Research*, *43*, 999–1014.

Nandal S., & Pickering, T. (2005). *Freshwater prawn Macrobrachium rosenbergii farming in Pacific Island countries* (Vol. One). Hatchery operation. Noumea, New Caledonia: Secretariat of the Pacific Community.

NaveenKumar, S., Shekar, M., Karunasagar, I., & Karunasagar, I. (2013). Genetic analysis of RNA1 and RNA2 of *Macrobrachium rosenbergii nodavirus* (MrNV) isolated from India. *Virus Research*, *173*, 377–385.

Naqvi, A. A., Adhikari, S., Pillai, B. R., & Sarangi, N. (2007). Effect of ammonia-N on growth and feeding of juvenile *Macrobrachium rosenbergii* (De Man). *Aquaculture Research*, *38*, 847–851.

Negrini, C., de Castro, C. S., Bittencourt-Guimarães, A. T., Frozza, A., Ortiz-Kracizy, R., & Cupertino-Ballester, E. L. (2017). Stocking density for freshwater prawn *Macrobrachium rosenbergii* (Decapoda, Palaemonidae) in biofloc system. *Latin American Journal of Aquatic Research*, *45*, 891–899.

Nery, R. C., Costa, C. B., Rodrigues, F., Soares, R., Bezerra, R. de S., & Peixoto, S. (2019). Effect of feeding frequency on growth and digestive enzyme activity in *Litopenaeus vannamei* during the grow-out phase in biofloc system. *Aquaculture Nutrition*, *25*, 577–584.

New, M. B. (1995). Status of freshwater prawn farming: a review. *Aquaculture Research*, *26*, 1–54.

New, M. B. (2002). *Farming freshwater prawns: a manual for the culture of giant river prawn (Macrobrachium rosenbergii). FAO fisheries technical paper 428*. Food and Agriculture Organization of the United Nations Rome.

New, M. B. (2010). History and global status of freshwater prawn farming. In M. N. K. M. B. New, W. C. Valenti, J. H. Tidwell, L. R. D'Abramo (Ed.), *Freshwater Prawns Biology and Farming* (p. 570). Wiley-Blackwell, A John Wiley & Sons, Ltd., Publication.

New, M. B., & Nair, C. M. (2012). Global scale of freshwater prawn farming. *Aquaculture Research*, *43*, 960–969.

Nguyen, N.H.Y., Trinh, L.T., Chau, D.T., Baruah, K., Lundh, T., & Kiessling, A. (2019). Spent brewer's yeast as a replacement for fishmeal in diets for giant freshwater prawn (*Macrobrachium rosenbergii*), reared in either clear water or a biofloc environment. *Aquaculture Nutrition 25,* 970–979.

Nootong, K., Pavasant, P., & Powtongsook, S. (2011). Effects of organic carbon addition in controlling inorganic nitrogen concentrations in a biofloc system. *Journal of the World Aquaculture Society*, *42*, 339–346.

Okwute, O.L., & Isu, N.R. (2007). Impact analysis of palm oil mill effluent on the aerobic bacterial density and ammonium oxidizers in a dumpsite in Anyigba, Kogi State. *African Journal of Biotechnology 6,* 116–119.

Pacheco-Vega, J. M., Cadena-Roa, M. A., Leyva-Flores, J. A., Zavala-Leal, O. I., Pérez-Bravo, E., & Ruiz-Velazco, J. M. J. (2018). Effect of isolated bacteria and microalgae on the biofloc characteristics in the Pacific white shrimp culture. *Aquaculture Reports*, *11*, 24–30.

Pande, G. S. J., Scheie, A. A., Benneche, T., Wille, M., Sorgeloos, P., Bossier, P., & Defoirdt, T. (2013). Quorum sensing-disrupting compounds protect larvae of the giant freshwater prawn *Macrobrachium rosenbergii* from *vibrio harveyi* infection. *Aquaculture*, *406–407*, 121–124.

Panigrahi, A., Das, R. R., Sivakumar, M. R., Saravanan, A., Saranya, C., Sudheer, N. S., Kumaraguru Vasagam, K. P., Mahalakshmi, P., Kannappan, S., & Gopikrishna, G. (2020). Bio-augmentation of heterotrophic bacteria in biofloc system improves growth, survival, and immunity of Indian white shrimp *Penaeus indicus*. *Fish and Shellfish Immunology*, *98*, 477–487.

Panigrahi, A., Saranya, C., Sundaram, M., Vinoth Kannan, S. R., Das, R. R., Satish Kumar, R., Rajesh, P., & Otta, S. K. (2018). Carbon: Nitrogen (C:N) ratio level variation influences microbial community of the system and growth as well as immunity of shrimp (*Litopenaeus vannamei*) in biofloc based culture system. *Fish and Shellfish Immunology*, *81*, 329–337.

Panigrahi, A., Sundaram, M., Chakrapani, S., Rajasekar, S., Syama Dayal, J., & Chavali, G. (2019). Effect of carbon and nitrogen ratio (C:N) manipulation on the production performance and immunity of Pacific white shrimp *Litopenaeus vannamei* (Boone, 1931) in a biofloc-based rearing system. *Aquaculture Research*, *50*, 29–41.

Panigrahi, A., Sundaram, M., Saranya, C., Swain, S., Dash, R. R., & Dayal, J. S. (2019). Carbohydrate sources deferentially influence growth performances, microbial dynamics and immunomodulation in Pacific white shrimp (*Litopenaeus vannamei*) under biofloc system. *Fish and Shellfish Immunology*, *86*, 1207–1216.

Panjaitan, P. (2010). Shrimp culture of Penaeus monodon with zero water exchange model (ZWEM) using molasses. *Journal of Coastal Development*, *14*, 35–44.

Pasco M, J. J., Carvalho Filho, J. W., de Espirito Santo, C. M., & Vinatea, L. (2018). Production of Nile tilapia *Oreochromis niloticus* grown in BFT using two aeration systems. *Aquaculture Research*, *49*, 222–231.

Paul, P., Rahman, A., Hossain, M., Islam, S., Mondal, S., & Haq, M. (2016). Effect of stocking density on the growth and production of freshwater prawn (*Macrobrachium rosenbergii*). *International Journal of Fisheries and Aquaculture*, *6*, 77–86.

Peixoto, S., Silva, E., Costa, C. B., Nery, R. C., Rodrigues, F., Silva, J. F., Bezerra, R., & Soares, R. (2018). Effect of feeding frequency on growth and enzymatic activity of *Litopenaeus vannamei* during nursery phase in biofloc system. *Aquaculture Nutrition*, *24*, 579–585.

Pérez-Fuentes, J. A., Pérez-Rostro, C. I., & Hernández-Vergara, M. P. (2013). Pond-reared Malaysian prawn *Macrobrachium rosenbergii* with the biofloc system. *Aquaculture*, *400–401*, 105–110.

Pérez-Fuentes J. A, Hernández-Vergara, M. P., Pérez-Rostro, C. I., & Fogel, I. (2016). C:N ratios affect nitrogen removal and production of Nile tilapia *Oreochromis niloticus* raised in a biofloc system under high density cultivation. *Aquaculture*, *452*, 247–251.

Perry, W.B., Lindsay, E., Payne, C.J., Brodie, C., Kazlauskaite, R., 2020. The role of the gut microbiome in sustainable teleost aquaculture. *Proceedings of the Royal Society B: Biological Sciences, 287*. 20200184. http://dx.doi.org/10.1098/rspb.2020.0184

Piedrahita, R.H. (2003). Reducing the potential environmental impact of tank aquaculture effluents through intensification and recirculation. *Aquaculture 226*, 35–44.

Poli, M. A., Legarda, E. C., de Lorenzo, M. A., Martins, M. A., & do Nascimento Vieira, F. (2019). Pacific white shrimp and Nile tilapia integrated in a biofloc system under different fish-stocking densities. *Aquaculture*, *498*, 83–89.

Poli, M. A., Schveitzer, R., & de Oliveira Nuñer, A. P. (2015). The use of biofloc technology in a South American catfish (*Rhamdia quelen*) hatchery: Effect of suspended solids in the performance of larvae. *Aquacultural Engineering*, *66*, 17–21.

Pillai, D., & Bonami, J. R. (2012). A review on the diseases of freshwater prawns with special focus on white tail disease of *Macrobrachium rosenbergii*. *Aquaculture Research*, 43, 1029–1037.

Ponce-Palafox, J. T., Pavia, Á. A., Mendoza López, D. G., Arredondo-Figueroa, J. L., Lango-Reynoso, F., Castañeda-Chávez, M. del R., Esparza-Leald, H., Ruiz-Lunae, A., Páez-Ozunaf, F., Castillo-Vargasmachucaa, S.G., Peraza-Gómez, V. (2019). Response surface analysis of temperature-salinity interaction effects on water quality, growth and survival of shrimp *Penaeus vannamei* postlarvae raised in biofloc intensive nursery production. *Aquaculture*, *503*, 312–321.

Ponte, S., Kelling, I., Jespersen, K. S., & Kruijssen, F. (2014). The blue revolution in asia: Upgrading and governance in aquaculture value chains. *World Development*, *64*, 52–64.

Prasad, L., Nayak, B. B., Srivastava, P. P., Reddy, A. K., & Kohli, M. P. S. (2013). Use of brewer's yeast *Saccharomyces cerevisiae* as growth promoter in giant freshwater prawn (*Macrobrachium rosenbergii* de man) post larvae. *Turkish Journal of Fisheries and Aquatic Sciences*, *13*, 447–452.

Pronk, M., Bassin, J. P., De Kreuk, M. K., Kleerebezem, R., & Van Loosdrecht, M. C. M. (2014). Evaluating the main and side effects of high salinity on aerobic granular sludge. *Applied Microbiology and Biotechnology*, *98*, 1339–1348.

Putra, I., Rusliadi, R., Muhammad, F., Tang, U. M., & Muchlisin, Z. A. (2017). Growth performance and feed utilization of African catfish *Clarias gariepinus* fed a commercial diet and reared in the biofloc system enhanced with probiotic. *F1000Research*, *6*, 1–9.

Querijero, B. V. L., Teshima, S. I., Koshio, S., & Ishikawa, M. (1997). Effects of dietary stearic acid and protein levels on the utilization of stearic acid by freshwater prawn *Macrobrachium rosenbergii* juveniles. *Fisheries Science*, *63*, 1035–1041.

Rajkumar, M., Pandey, P. K., Aravind, R., Vennila, A., Bharti, V., & Purushothaman, C. S. (2016). Effect of different biofloc system on water quality, biofloc composition and growth performance in *Litopenaeus vannamei* (Boone, 1931). *Aquaculture Research*, *47*, 3432–3444.

Rao, R., Bing Zhu, Y., Alinejad, T., Tiruvayipati, S., Lin Thong, K., Wang, J., & Bhassu, S. (2015). RNA-seq analysis of *Macrobrachium rosenbergii* hepatopancreas in response to *Vibrio parahaemolyticus* infection. *Gut Pathogens*, *7*, 1–16.

Rasdi, N. W., & Qin, J. G. (2016). Improvement of copepod nutritional quality as live food for aquaculture: A review. *Aquaculture Research*, *47*, 1–20.

Ravi Kumar, A., Venkateswara Rao, G., & Sambasiva Rao, K. R. S. (2004). Appendage deformity syndrome - A nutritional disease of *Macrobrachium rosenbergii*. *Diseases of Aquatic Organisms*, *59*, 75–78.

Ray, A. J., Dillon, K. S., & Lotz, J. M. (2011). Water quality dynamics and shrimp (*Litopenaeus vannamei*) production in intensive, mesohaline culture systems with two levels of biofloc management. *Aquacultural Engineering*, *45*, 127–136.

Ray, A. J., Lewis, B. L., Browdy, C. L., & Leffler, J. W. (2010a). Suspended solids removal to improve shrimp (*Litopenaeus vannamei*) production and an evaluation of a plant-based feed in minimal-exchange, superintensive culture systems. *Aquaculture*, *299*, 89–98.

Ray, A. J., & Lotz, J. M. (2014). Comparing a chemoautotrophic-based biofloc system and three heterotrophic-based systems receiving different carbohydrate sources. *Aquacultural Engineering*, *63*, 54–61.

Ray, A.J., Lotz, J.M., 2017. Shrimp (*Litopenaeus vannamei*) production and stable isotope dynamics in clear-water recirculating aquaculture systems versus biofloc systems. *Aquaculture Research*, *48*, 4390–4398.

Ray, A. J., Seaborn, G., Browdy, C. L., & Leffler, J. W. (2012). Effects of biofloc reduction on microbial dynamics in minimal-exchange, superintensive shrimp, *Litopenaeus vannamei*, culture systems. *Journal of the World Aquaculture Society*, *43*, 790–801.

Ray, A. J., Seaborn, G., Leffler, J. W., Wilde, S. B., Lawson, A., & Browdy, C. L. (2010b). Characterization of microbial communities in minimal-exchange, intensive aquaculture systems and the effects of suspended solids management. *Aquaculture*, *310*, 130–138.

Ray, A. J., Vencro, J. A., Browdy, C. L., & Leffler, J. W. (2010). Simple settling chambers aid solids management in biofloc system. *Global Aquaculture Advocate*, 28–30.

Reedy, B. S., & Reddy, K. V. S. (2014). Proximate composition of the fresh water prawn *Macrobrachium rosenbergii* in cultured and frozen stage from Nellore Coast, India. *International Food Research Journal*, *21*, 1707–1710.

Reinoso, S., Muñoz, D., Cedeño, R., Tirado, J. O., Bangeppagari, M., & S.I., M. (2019). Adaptation of "biofloc" aquatic system for polyculture with tilapia (*Oreochromis* Sp.) and river prawn (*Macrobrachium* Sp.). *Journal of Microbiology, Biotechnology and Food Sciences*, *8*, 1130–1134.

Ringø, E., Van Doan, H., Lee, S.H., Soltani, M., Hoseinifar, S.H., Harikrishnan, R., & Song, S.K. (2020). Probiotics, lactic acid bacteria and bacilli: interesting supplementation for aquaculture. *Journal of Applied Microbiology, 129*, 116–136.

Romano, N. (2017). Aquamimicry : A revolutionary concept for shrimp farming. *The Global Aquaculture Advocate*, 1–5.

Romano, N., & Zeng, C. (2013). Toxic effects of ammonia, nitrite, and nitrate to decapod crustaceans: A Review on factors influencing their toxicity, physiological consequences, and coping mechanisms. *Reviews in Fisheries Science 21,* 1–21.

Romano, N. & Zeng, C. (2017). Cannibalism of decapod crustaceans and implications for their aquaculture: A review of its prevalence, influencing factors, and mitigating methods. *Reviews in Fisheries Science and Aquaculture* 25, 42-69.

Romano, N., Dauda, A. B., Ikhsan, N., Karim, M., & Kamarudin, M. S. (2018). Fermenting rice bran as a carbon source for biofloc technology improved the water quality , growth , feeding efficiencies, and biochemical composition of African catfish *Clarias gariepinus* juveniles. *Aquaculture Research, 49*, 3691–3701.

Romano, N., Surratt, A., Renukdas, N., Monico, J., Egnew, N. & Sinha, A. K. (2020). Assessing the feasibility of biofloc technology to largemouth bass *Micropterus salmoides* juveniles: insights into their welfare and physiology. *Aquaculture 520,* 735008.

Roustaian, P., Kamarudin, M. S., Omar, H., Saad, C. R., & Ahmad, M. H. (1999). Changes in fatty acid profile during larval development of freshwater prawn *Macrobrachium rosenbergii* (de Man). *Aquaculture Research*, *30*, 815–824.

Saad, S., Habashy, M., & Sharshar, M. (2009). Growth response of the freshwater prawn, *Macrobrachium rosenbergii* (De Man), to diets having different levels of Biogen®. *World Applied Sciences Journal*, *6*, 550–556.

Sace, C. F., & Fitzsimmons, K. M. (2013). Vegetable production in a recirculating aquaponic system using Nile tilapia (*Oreochromis niloticus*) with and without freshwater prawn (*Macrobrachium rosenbergii*). *Academia Journal of Agricultural Research*, *1*, 236–250.

Sagar, V., Sahu, N.P., Pal, A.K., Jain, K.K., & Venugopal, G. (2009). Growth and digestive enzymes of *Macrobrachium rosenbergii* juveniles: effect of different stocktypes and dietary protein levels under a similar culture environment. *Aquaculture Research 40*, 1383–1393.

Sahul Hameed, A. S., Charles, M. X., & Anilkumar, M. (2000). Tolerance of *Macrobrachium rosenbergii* to white spot syndrome virus. *Aquaculture*, *183*, 207–213.

Samocha, T. M., Patnaik, S., Speed, M., Ali, A. M., Burger, J. M., Almeida, R. V., Ayub, Z., Harisanto, M., Horowiti, A., & Brock, D. L. (2007). Use of molasses as carbon source in limited discharge nursery and grow-out systems for *Litopenaeus vannamei*. *Aquacultural Engineering*, *36*, 184–191.

Sampaio, C. M. S., & Valenti, W. C. (1996). Growth curves for *Macrobrachium rosenbergii* in semi-intensive culture in Brazil. *Journal of the World Aquaculture Society*, *27*, 353–358.

Sandifer, P. A., Hopkins, J. S., & Smith, T. I. J. (1975). Observations on salinity tolerance and osmoregulation in laboratory-reared *Macrobrachium rosenbergii* post-larvae (Crustacea: Caridea). *Aquaculture*, *6*, 103–114.

Sandoval-Vargas, L. Y., Jiménez-Amaya, M. N., Rodríguez-Pulido, J., Guaje-Ramírez, D. N., Ramírez-Merlano, J. A., & Medina-Robles, V. M. (2020). Applying biofloc technology in the culture of juvenile of *Piaractus brachypomus* (Cuvier, 1818): Effects on zootechnical performance and water quality. *Aquaculture Research*, *51*, 3865–3878.

Santhanam, P., Begum, A., & Perumal, P. (2019). *Basic and applied zooplankton biology*. Springer.

Saurabh, S., & Sahoo, P. K. (2008). Major diseases and the defence mechanism in giant freshwater prawn, *Macrobrachium rosenbergii* (de Man). *Proceedings of the National Academy of Sciences India Section B - Biological Sciences*, *78*, 103–121.

Schveitzer, R., Arantes, R., Costódio, P. F. S., do Espírito Santo, C. M., Arana, L. V., Seiffert, W. Q., & Andreatta, E. R. (2013). Effect of different biofloc levels on microbial activity, water quality and performance of *Litopenaeus vannamei* in a tank system operated with no water exchange. *Aquacultural Engineering*, *56*, 59–70.

Schveitzer, R., Arantes, R., Francisco, M., Fóes, P., Costódio, S., Vinatea, L., Seiffert, W.Q., & Roberto, E. (2013). Use of artificial substrates in the culture of *Litopenaeus vannamei* (Biofloc System) at different stocking densities : Effects on microbial activity , water quality and production rates. *Aquacultural Engineering*, *54*, 93–103.

Schwantes, V. S., Diana, J. S., & Yi, Y. (2009). Social, economic, and production characteristics of giant river prawn *Macrobrachium rosenbergii* culture in Thailand. *Aquaculture*, *287*, 120–127.

Seenivasan, C., Bhavan, P. S., Radhakrishnan, S., & Muralisankar, T. (2012). Effects of probiotics on survival , growth and biochemical constituents of freshwater prawn *Macrobrachium rosenbergii* post larvae, *338*, 331–338.

Seenivasan, C., Saravana Bhavan, P., Radhakrishnan, S., & Muralisankar, T. (2012). Effects of probiotics on survival, growth and biochemical constituents of freshwater prawn *Macrobrachium rosenbergii* post larvae. *Turkish Journal of Fisheries and Aquatic Sciences*, *12*, 19.

Serra, F. P., Gaona, C. A. P., Furtado, P. S., Poersch, L. H., & Wasielesky, W. (2015). Use of different carbon sources for the biofloc system adopted during the nursery and grow-out culture of *Litopenaeus vannamei*. *Aquaculture International*, *23*, 1325–1339.

Sharma, A., Siingh, R., Sangotra, R., Bandhana, & Sharma, K. K. (2017). Effect of temperature on the production of bioflocs. *International Journal of Recent Scientific Research*, *8*, 20217–20221.

Sheen, S. S., & D'Abramo, L. R. (1991). Response of juvenile freshwater prawn, *Macrobrachium rosenbergii*, to different levels of a cod liver oil/corn oil mixture in a semi-purified diet. *Aquaculture*, *93*, 121–134.

Shi, S., Li, J., Guan, W., & Blersch, D. (2018). Nutrient value of fish manure waste on lactic acid fermentation by *Lactobacillus pentosus*. *RSC Advances*, *8*, 31267–31274.

Shil, J., Ghosh, A.K., & Rahaman, S.M.B. (2013). Abundance and diversity of zooplankton in semi intensive prawn (*Macrobrachium rosenbergii*) farm. *SpringerPlus*, *2*, 1-8.

Silva, E., Silva, J., Ferreira, F., Soares, M., Soares, R., & Peixoto, S. (2015). Influence of stocking density on the zootechnical performance of *Litopenaeus vannamei* during the nursery phase in a biofloc system. *Boletim Do Instituto de Pesca*, *41*, 777–783.

Silva-Oliveira, G. C., Ready, J. S., Iketani, G., Bastos, S., Gomes, G., Sampaio, I., & Maciel, C. (2011). The invasive status of *Macrobrachium rosenbergii* (De Man, 1879) in Northern Brazil, with an estimation of areas at risk globally. *Aquatic Invasions*, *6*, 319–328.

Sin, N., Nurhusna, N., & Shapawi, R. (2017). Innovative egg custard formulation reduced rearing period and improved survival of giant freshwater prawn, *Macrobrachium rosenbergii*, larvae. *Journal of the World Aquaculture Society*, *48*, 751–759.

Smith, D .G. (2001). *Pennak's Freshwater Invertebrates of the United States* (4th Edition, Protozoa to Crustacea). John Wiley & Sons, Inc.

Soedibya, P. H. T., Pramono, T. B., & Listiowati, E. (2017). Growth performance of African catfish *Clarias gariepinus* cultured in biofloc system at high stocking density. *Jurnal Akuakultur Indonesia*, *16*, 255.

Sriputhorn, K., & Sanoamuang, L. (2011). Fairy shrimp (*Streptocephalus sirindhornae*) as live feed improve growth and carotenoid contents of giant freshwater prawn *Macrobrachium rosenbergii*. *International Journal of Zoological Research*, *7*, 138–146.

Srisala, J., Pukmee, R., McIntosh, R., Choosuk, S., Itsathitphaisarn, O., Flegel, T. W., Sritunyalucksana, K., & Vanichviriyakit, R. (2018). Distinctive histopathology of *Spiroplasma eriocheiris* infection in the giant river prawn Macrobrachium rosenbergii. *Aquaculture*, *493*, 93–99.

Straus, D. L., Randall Robinette, H., & Heinen, J. M. (1991). Toxicity of un-ionized ammonia and high pH to Post-larval and juvenile freshwater shrimp *Macrobrachium rosenbergii*. *Journal of the World Aquaculture Society*, *22*, 128–133.

Sullivan, T.J., & Neigel, J.E. (2018). Effects of temperature and salinity on prevalence and intensity of infection of blue crabs, *Callinectes sapidus* by *Vibrio cholerae*, *V. parahemolyticus*, and *V. vulnificus* in Louisiana. *Journal of Invertebrate Pathology, 151*, 82–90.

Sultana, T., Rahman, M., & Hossain, A. (2017). Present status and sustainability of prawn (*Macrobrachium rosenbergii*) farming in Noakhali district. *Journal of Noakhali Science and Technology University*, *1*, 51–57.

Syamala, K., Lakra, W. S., Chadha, N. K., Sahu, N. P., & Prasad, K. P. (2017). Effect of de-oiled oil palm kernel meal based biofloc system on growth and digestive enzyme activity of pacific white shrimp, *Litopenaeus Vannamei*. *International Journal of Current Microbiology and Applied Sciences*, *6*, 1806–1816.

Tambalque lII, H.G., Perez, M.L., Nieves, P.M., Corre, V.L., Duarte, J.A., Pulido, A.N., Dejarme, H.E., Tanay, D.D., & Garces, L. R. (2015). Challenges and opportunities for giant freshwater prawn culture through participatory learning and fish farmer engagements. *Asian Journal of Agriculture and Development*, *12*, 35–52.

Taw, N. (2010). Biofloc technology expanding at white shrimp farms. *Global Aquaculture Advocate*, (June), 20–22.

Teh, J.C., Kamarudin, M.S., Romano, N., Arshad, A., & Wong, N.L.W.S. (2018). Dietary effects of rotifers, brine shrimps and cultured copepods on survival and growth of newborn seahorse (Bleeker 1852). *Journal of Environmental Biology, 39*, 923-930.

Thompson, F. L., Abreu, P. C., & Wasielesky, W. (2002). Importance of biofilm for water quality and nourishment in intensive shrimp culture. *Aquaculture*, *203*, 263–278.

Tidwell, J., & Coyle, S. (2008). Impact of substrate physical characteristics on grow out of freshwater prawn, *Macrobrachium rosenbergii*, in ponds and pond microcosm tanks. *Journal of the World Aquaculture Society*, *39*, 406–413.

Tidwell, J. H. (2012). Current status and prospects of farming the giant river prawn (*Macrobrachium rosenbergii* De Man 1879) in the United States. *Aquaculture Research*, *43*, 1023–1028.

Tidwell James H., S., C., Aaron, V., Anne, B. L., & McCathy, M. (2001). The effect of photoperiod on growth and survival of juvenile freshwater prawn, *Macrobrachium rosenbergii*, in nursery tanks. *Journal of Applied Aquaculture*, *11*, 41–47.

Tomasso, J.R. (1994). Toxicity of nitrogenous wastes to aquaculture animals. *Reviews in Fisheries Science 2*, 291–314.

Van Doan, H., Hoseinifar, S.H., Ringø, E., Ángeles Esteban, M., Dadar, M., Dawood, M.A.O., & Faggio, C. (2020). Host-Associated Probiotics: A Key Factor in Sustainable Aquaculture. *Reviews in Fisheries Science & Aquaculture, 28*, 16–42.

Velu, C. S., & Munuswamy, N. (2008). Evaluation of *Streptocephalus dichotomus* nauplii as a larval diet for freshwater prawm *Macrobrachium rosenbergii*. *Aquaculture Nutrition*, *14*, 331–340.

Vilani, F.G., Schveitzer, R., Da Fonseca Arantes, R., Do Nascimento Vieira, F., Manoel do Espírito Santo, C., & Quadros Seiffert, W. (2016). Strategies for water preparation in a biofloc system: Effects of carbon source and fertilization dose on water quality and shrimp performance. *Aquaculture Engeneering 74*, 70–75.

Vinatea, L., Gálvez, A. O., Browdy, C. L., Stokes, A., Venero, J., Haveman, J., Lewis, B. L., Lawson, A., Shuler, A., & Leffler, J. W. (2010). Photosynthesis, water respiration and growth performance of *Litopenaeus vannamei* in a super-intensive raceway culture with zero water exchange: Interaction of water quality variables. *Aquacultural Engineering*, *42*, 17–24.

Wahab, A., Ahmad-al-nahid, S., Ahmed, N., & Haque, M. M. (2012). Current status and prospects of farming the giant river prawn *Macrobrachium rosenbergii* (De Man) in Bangladesh. *Aquaculture Research*, *43*, 970–983.

Wang, G., Yu, E., Xie, J., Yu, D., Li, Z., Luo, W., Qiu, L., & Zheng, Z. (2015). Effect of C/N ratio on water quality in zero-water exchange tanks and the biofloc supplementation in feed on the growth performance of crucian carp, *Carassius auratus*. *Aquaculture*, *443*, 98–104.

Wankanapol, A., & Chaibu, P. (2017). Evaluation of different carbon sources for polyculture of hybrid catfish (*Clarias gariepinus* x *Clarias macrocephalus*) and nile tilapia (*Oreochromis niloticus*) under biofloc technology. *International Journal of Agricultural Technology*, *13*, 1005–1014.

Wei, Y., Liao, S., & Wang, A. (2016). The effect of different carbon sources on the nutritional composition, microbial community and structure of bioflocs. *Aquaculture*, *465*, 88–93.

Whangchai, N., Ungsethaphand, T., & Chitmanat, C. (2007). Performance of giant freshwater prawn (*Macrobrachium rosenbergii* de Man) reared in earthen ponds beneath plastic film shelters. *Chiang Mai Journal of Sciences*, *34*, 89–96.

Wilkie, M. P. (2002). Ammonia excretion and urea handling by fish gills: Present understanding and future research challenges. *Journal of Experimental Zoology*, *293*, 284–301.

Wong, Y.Y., Lee, C.W., Bong, C.W., Lim, J.H., Narayannan, K., & Sim, E.U.H. (2019). Environmental control of *Vibrio* spp. abundance and community structure in tropical waters. *FEMS Microbiology Ecology 95,* fiz176.

Xu, W. J., Morris, T. C., & Samocha, T. M. (2016). Effects of C/N ratio on biofloc development, water quality, and performance of *Litopenaeus vannamei* juveniles in a biofloc-based, high-density, zero-exchange, outdoor tank system. *Aquaculture*, *453*, 169–175.

Xu, W. J., Morris, T. C., & Samocha, T. M. (2018). Effects of two commercial feeds for semi-intensive and hyper-intensive culture and four C/N ratios on water quality and performance of *Litopenaeus vannamei* juveniles at high density in biofloc-based, zero-exchange outdoor tanks. *Aquaculture*, *490*, 194–202.

Xu, W. J., & Pan, L. Q. (2012). Effects of bioflocs on growth performance, digestive enzyme activity and body composition of juvenile *Litopenaeus vannamei* in zero-water exchange tanks manipulating C/N ratio in feed. *Aquaculture*, *356–357*, 147–152.

Xu, W. J., & Pan, L. Q. (2013). Enhancement of immune response and antioxidant status of *Litopenaeus vannamei* juvenile in biofloc-based culture tanks manipulating high C/N ratio of feed input. *Aquaculture*, *412–413*, 117–124.

Xu, W. J., & Pan, L. Q. (2014). Evaluation of dietary protein level on selected parameters of immune and antioxidant systems, and growth performance of juvenile *Litopenaeus vannamei* reared in zero-water exchange biofloc-based culture tanks. *Aquaculture*, *426–427*, 181–188.

Yan, J., Gao, Q., Cui, Z., Yang, G., & Long, Y. (2018). Molecular characterization of the giant freshwater prawn (*Macrobrachium rosenbergii*) beta-actin gene promoter. *PeerJ*, *6:e5701.*

Yang, G., Frinsko, M., Chen, X., Wang, J., Hu, G., & Gao, Q. (2012). Current status of the giant freshwater prawn (*Macrobrachium rosenbergii*) industry in China, with special reference to live transportation. *Aquaculture Research*, *43*, 1049–1055.

Yogev, U., & Gross, A. (2019). Reducing environmental impact of recirculating aquaculture systems by introducing a novel microaerophilic assimilation reactor: Modeling and proof of concept. *Journal of Cleaner Production*, *226*, 1042–1050.

Zacarias, S., Schveitzer, R., Arantes, R., Galasso, H., Pinheiro, I., Espirito Santo, C., & Vinatea, L. (2019). Effect of different concentrations of potassium and magnesium on performance of *Litopenaeus vannamei* postlarvae reared in low-salinity water and a biofloc system. *Journal of Applied Aquaculture*, *31*, 85–96.

Zhang, W., Murray, F. J., Liu, L., & Little, D. C. (2017). A comparative analysis of four internationally traded farmed seafood commodities in China : domestic and international markets as key drivers. *Reviews in Aquaculture*, *2009*, 157–178

Zhang, K., Pan, L., Chen, W., & Wang, C. (2017). Effect of using sodium bicarbonate to adjust the pH to different levels on water quality, the growth and the immune response of shrimp *Litopenaeus vannamei* reared in zero-water exchange biofloc-based culture tanks. *Aquaculture Research*, *48*, 1194–1208.

Zhao, P., Huang, J., Wang, X. H., Song, X. L., Yang, C. H., Zhang, X. G., & Wang, G. C. (2012). The application of bioflocs technology in high-intensive, zero exchange farming systems of *Marsupenaeus japonicus*. *Aquaculture*, *354–355*, 97–106.

Zhao, Z., Xu, Q., Luo, L., Wang, C., Li, J., & Wang, L. (2014). Effect of feed C/N ratio promoted bioflocs on water quality and production performance of bottom and filter feeder carp in minimum-water exchanged pond polyculture system. *Aquaculture*, *434*, 442–448.

Zidni, I., Buwono, I. D., & Mahargyani, B. P. (2019). Water Quality in the Cultivation of Catfish (*Clarias gariepinus*) and Nile Tilapia (*Oreochromis niloticus)* in the Aquaponic Biofloc System, *Asian Journal of Fisheries and Aquatic Research*, *4*, 1–6.