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Synbiotics and Aquamimicry as alternative microbial-based approaches in intensive shrimp farming and biofloc: novel disruptive techniques or complementary management tools? A scientific-based overview

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Abstract

Globally, aquaculture, especially shrimp farming, plays an important economic role. However, it is known that traditional shrimp farming could negatively create environment impacts (e.g. due to water discharge into coastal areas and marine habitats), if good management practices are not followed. For these problems to be minimized, the industry needs to develop and implement technologies that promote sustainable aquaculture. Among different techniques, the biofloc technology (BFT) system and, more recently, the synbiotics and aquamimicry are considered alternatives microbial-based approaches that address high yields with certain level of biosecurity and better environmental practices. However, different from biofloc, both aquamimicry and synbiotics use fermented carbon sources in their routine practices. The present article aims to bring (i) the current status and research and development (R&D) efforts, (ii) the basics principles around synbiotics and aquamimicry; (iii) compares their key characteristics and (iv) discuss whether these two systems would be considered novel disruptive techniques or more likely management tools. The manuscript evidenced both systems share several operational and microbial similarities, and operate under comparable conditions. Recent bibliometric analysis (Web of Science) showed 578 articles for BFT, and only 20 for synbiotics and 3 for aquamimicry, an evident lack of scientific background highlighting that more science-based R&D efforts are needed in synbiotics and aquamimicry.

Keywords: Aquamimicry, Fermentation, Organic carbon, Synbiotics, Litopenaeus vannamei, Biofloc technology.

1. Introduction

Crustaceans aquaculture has become one of the fastest growing animal food industry in the world with an average growth rate of 2.9% over the past 20 years (FAO, 2020). Such growth has been achieved through horizontal expansion, however, vertical expansion, by means of increased intensification of farming, has gaining traction in the past years (Joffre et al., 2018, Emerenciano et al., 2022). In parallel, shrimp farming in some countries has suffered from environmental issues, leading diseases outbreaks (Liao et al., 2012; Flegel et al., 2012; Abdel-Latif et al., 2022) and nearly collapsed the entire industry. There have also been many other challenges including fish meal and fish oil issues (Cheng et al., 2020), leading to an increase on production costs and market volatility (Engle et al., 2020). In this sense, a growing segment of the shrimp farming industry has opted to use production systems with higher density, biosecurity, and operating control to mitigate the risks posed by diseases. High input practices and intensive farming of *Litopenaeus vannamei* have become more predominant in some regions, which have been driven and enabled by the advancement of front-line technologies and systems tailored to producing shrimp in high density conditions (Emerenciano et al., 2021). Nowadays, different techniques helped to boost and consolidate the intensification of the shrimp industry, including the ones using microbial-based approaches such as biofloc technology (BFT), synbiotics and aquamimicry; however, production costs, skilled staff and bespoke infrastructure have been limiting factors for further expansion (Khanjani et al., 2022a; 2022b; Emerenciano et al., 2022).

In terms of commercial adoption by a broad community, synbiotics and aquamimicry technologies are relatively new (Santhanam et al., 2020; Pimentel et al., 2022; Santos et al., 2022a,b; Khanjani et al., 2022c) compared to BFT (Burford et al 2004; Samocha, 2019; Khanjani et al., 2022c). Over the past 20 years, microbial-based approaches faced multiple challenges for their commercial adoption, and has been extensively adapted and adjusted to different regions, species, salinities, applied to one single-phase (e.g. nursery) or multiple phases, outdoor and indoor conditions, and according to different farm infrastructure, operational and resource limitations (Emerenciano et al., 2021). The accumulated BFT knowledge, mostly science-based and spread worldwide through scientific literatures, seminars and trainings (Ulloa-Walker et al, 2020), contributed as a baseline for the development of other related microbial-based systems. In this sense, this opinion article is based on a scientific overview and has as objectives (i) discuss whether aquamimicry and synbiotics would be considered novel disruptive techniques or more likely a management tool; (ii) understand the basics principles around synbiotics and aquamimicry, and (iii) compares their key characteristics. The comparisons highlighted in the present document are exclusively based on intensive culture conditions with lined ponds or tanks, intensive aeration and water movement, and high grow-out stocking density (≥150 shrimp/m^2) (Figure 1). That means aquamimicry and synbiotics applied to conventional (earthen) shrimp ponds and lower stocking density (e.g. extensive and semi-intensive culture conditions), as well as the use of synbiotics as a feed additive directly in formulated diets, were not considered for the purpose of this article.

2. Synbiotics and Aquamimicry

To date, little scientific information is available for synbiotics and aquamimicry. In addition, there is not a complete consent, especially in the industry, whether they are the same or two different approaches. For the purpose of this article, we will consider as different ones.

According to Romano (2017), the aquamimicry is a shrimp culture system initiated in Thailand in 2013, and is managed in a way to promote biological conditions based on mimicking the natural aquatic environment with algae and zooplankton blooms to feed shrimp and using beneficial bacteria to improve water quality. The core management is the routine application of fermented carbon/grain sources, such as rice bran, soybean meal, and wheat bran, combined with water probiotics (such as *Bacillus* sp.) and other water supplements (Catalani, 2020; Santos, 2022a,b; Nisar et al., 2022; Khanjani et al., 2022b). Microorganisms or enzymes can be used to facilitate the solubility of the carbon source in water and catalyse the nutrient break-down. Bacteria (e.g. *Lactobacillus sp.* and *Bacillus sp.)*, fungi, and yeast (e.g. *Saccharomyces sp.*) have been reported to be involved in the production of hydrolytic enzymes that reduce fibre and carbohydrate contents and increase the protein solubility of carbon sources (Romano et al., 2018; Khanjani et al., 2022b). Water supplements (e.g. sodium bicarbonate) can be used to control the pH in the medium.

This standard procedure, normally carried-out in simple bioreactors placed nearby the ponds, especially in the first weeks of culture, facilitates the entry of nutrients into the system and cause a significant increase in the microbial population in culture ponds (Biesebeke, 2018; Panigrahi et al., 2019; Deepak et al., 2020). When the balance between bacteria, phytoplankton and zooplankton is reached (e.g. microbial community colour index (MCCI) of ~1-1.5; Hargreaves, 2013), creates a synbiotic bond in the system with potential to suppress disease outbreaks (Romano, 2017; Nisar et al., 2022).

Some authors have observed that microbial aggregates, mainly formed by bacteria, may present nutritional deficiencies in their contribution, in particular, essential amino acids and polyunsaturated fatty acids of the ω-3 family (Castro et al., 2021), fundamental for the development of shrimp. The presence of copepods stands out in aquamimicry system. These microcrustaceans are sources of proteins, lipids, amino acids, polyunsaturated fatty acids and other nutrients (Lee et al., 2005; Ajiboye et al., 2011), mainly due to their selective feeding habits, requiring nutritionally adequate algae (Støttrup and Jensen, 1990). In addition, they are the main organisms in the conversion of phytoplankton to higher trophic levels, and are also the main food in the diet of penaeids (Martínez-Córdova and Peña Messina, 2005), which can promote an improvement in the nutritional quality and survival of shrimp (Santhanam et al., 2019). Copepods can also provide direct benefits to the system by creating microhabitats that favour bacterial growth (Møller et al., 2007). In the aquamimicry system, copepods are considered the dominant zooplankton species, usually observed from the second week of cultivation (Romano and Kumar, 2017), likely indicating the maturity of the system (Chakravarty et al., 2018). This technology, also called in some literatures as 'biomimicry' and 'copefloc' (Chakravarty et al., 2018) may also reduce the production costs and the reliance on external formulated feeds due to dense live food (Santhanam et al., 2020; Deepak et al., 2020). The abundance and ratio of nutrients can lead the changes in the dominant planktonic species in the rearing system, according to different stages of cultivation. High C:N ratio increases the heterotrophic microorganisms' loads and decrease the photoautotrophic community (normally observed from the intermediate to later stages of culture). Lower C:N, during early stages, promotes phytoplankton blooms, key food source for zooplankton (Hargreaves, 2013). The inclusion of fermented carbon/nitrogen sources along with probiotics and other water supplements, can provide key macro and micronutrients (e.g. minerals) and assist the balance and diversity of phyto- and zooplankton, and eventually provide a convenient condition for growth and welfare of shrimp (Santos et al 2022). In addition, in aquamimicry systems fluctuations in pH are minimized and the suspended solids are maintained in low concentrations by water exchanges, circulation and/or physical treatment (e.g. settling ponds; Panigrahi et al., 2019; Khanjani et al., 2022b), which is favourable to phytoplankton and improves the amount of dissolved oxygen, reducing the need for intense aeration (Romano, 2017; Nisar et al., 2022).

According to Zeng et al. (2020), several countries have adopted this technique; however, comprehensive scientific studies are scarce in aquamimicry, lacking critical information for management improvements, adjustments to different local conditions or further adoption. The current literature available with *L. vannamei* (not all published in peer-review journals) brings (i) zootechnical performance and microbial composition in a comparison between BFT and aquamimicry (Catalani, 2020), zootechnical and economic performance of shrimp cultivation using the aquamimicry (Albuquerque, 2019), microbial diversity of pond water, shrimp intestine and sediment (Zeng et al., 2020), shrimp farming protocol and some aspects of management (Romano, 2017; Panigrahi et al., 2019), and general system overview (Chakravarty et al., 2018; Santhanam et al., 2020; Deepak et al., 2020; Nisar et al., 2022), use of the system in different stocking densities (Santos, 2020).

In the synbiotics system, the broad concept in animal production, conventionally added into formulated feeds, was early defined in 1995 as "mixtures of probiotics and prebiotics that beneficially affect the host by improving the survival and implantation of live microbial dietary supplements in the gastrointestinal tract, by selectively stimulating the growth and/or by activating the metabolism of one or a limited number of health-promoting bacteria, thus improving host welfare" (Gibson and Roberfroid, 1995; Butt et al., 2021). In shrimp farming, synbiotics has been recently promoted as a new production system (Hussain, 2021), or as a management tool (Kawahigashi, 2018), although similar approaches has been used for years in aquaculture (e.g. 'bokashi'; Ligua-Izquierdo, 2008). The synbiotics concept utilizes a holistic method of balancing the relationship between phytoplankton and other microorganisms (e.g. bacteria and zooplankton), resulting in a 'mature' environment and stable water quality parameters (Kawahigashi, 2018). As per aquamimicry, the core of synbiotics is the routine application of fermented carbon sources including wheat bran and rice bran, but also including fermented protein/nitrogen sources such as soybean meal. However, compared to aquamimicry, the fermentation methods and its comprehension are likely more advanced in synbiotics.

The adoption of different fermentation processes (e.g. anaerobic, aerobic or both) increase the availability of nutrients (protein and lipids) of the raw material sources (Santos et al., 2022a). The final product supplied to the production ponds acts as a fertilizer in the water (Figure 1), but also as a direct food supplement for shrimp (Silva et al., 2022). It is important to mention that if not properly managed (e.g. over doses and/or continuous application without cross-check assessments), continuous fertilization could cause detrimental impact to the water quality, organic matter accumulation with 'dead zones' and proliferation of pathogenic bacteria. There were unsuccessful experiences with synbiotics in Central and South America shrimp farms, especially due to misunderstand, poor management and accumulation of bran and settled solids, leading to vibrio spread.

In terms of the fermentation process, microorganisms cultivated in bioreactors break down complex organic molecules (e.g. fibre and carbohydrates) into simpler molecules, enhancing the bioavailability and solubility of nutrients, as well as supporting the microbial biomass growth (Dawood and Koshio, 2020). In addition, a number of metabolites products including enzymes (amylases, proteases, phytases and lipases), acids (lactic, acetic, formic, propionic, palmitic, pyruvic, malic, formic and butyric), alcohol (ethanol), aldehydes, ketones and bacteriocins, are produced and released (Dawood and Koshio, 2020). Some advantages of enzymes and acids production include, respectively: (i) increase the hydrolysis rate of key nutrients, releasing to the medium soluble vitamins, amino acids and essential fatty acids (Huynh et al., 2017). Also control over phytoplankton blooms due to enzymatic activity breaking down algae cell walls (Wang et al., 2020). And (ii) reduction of pH, altering the balance of the intestinal microbiota and suppressing pathogenic microorganisms (Huynh et al., 2017). The metabolic products generated and the microbial growth can be affected by the composition of the medium (e.g. carbon sources, water hardness, and alkalinity), presence of oxygen, pH and type and concentration of the microbial products applied (Zhang et al., 2021). Usually, the microorganisms involved in the synbiotics production process in shrimp farming include lactic acid bacteria (e.g. *Lactobacillus, Pediococcus; Bifidobacterium,* and *Enterococcus*); gram-positive spore-forming bacteria (e.g. *Bacillus subtillis, B. licheniformis, B. pumilus, B. megaterium, B. amyloliquefaciens, B. clausii,* and *B. megaterium*); and yeasts, mainly represented by *Saccharomyces* species (Bourdichon et al., 2012). Some of those microorganisms (e.g. *Lactobacillus sp.* and *Bacillus sp.)* can be similar to those applied in BFT; however less complexity is involved (normally directly applied in water without a fermentation step).

The effect of *Bacillus subtilis*-fermented rice bran (FRB) with zero water-exchange system was evaluated for *L. vannamei* in microcosm-scale (Abdel-Tawwab et al., 2020). The results showed positive effects on performance, antioxidants levels, immune biomarkers and water quality parameters, with significant increase in the number of *Bacillus* sp. and a decrease in pathogenic bacteria such as vibrio. The mature microbial consortium (bacteria, e.g. *Bacillus sp.,*protozoa, zooplankton, and phytoplankton) compete for space and substrate with pathogens, and bioactive compounds produced (e.g. organic acids, exopolysaccharides, among others) play a key role suppressing e.g. pathogenic bacteria. Liñan-Vidriales et al. (2021) observed that fermented rice bran with *Bacillus* and *Lysinibacillus* sp. has altered the bacterial communities in hepatopancreas and improved the survival and growth rates of *L. vannamei*.

According to Kawahigashi (2018), the commercial adoption of synbiotics in also occurring in multiple countries such as Ecuador, Belize, Brazil, Mexico, Indonesia, Pakistan, Korea and Hawaii. The current scientific literature (as a production system and with *L. vannamei)* is also scarce and limited to general system overview (Kawahigashi, 2018); comparison between BFT and synbiotics in grow-out (Hussain et al., 2021; Santos et al., 2022a); different ionic adjustment strategies in low salinity nursery water (Pimentel et al., 2022; Oliveira et al., 2022a,b); synbiotics as a fertilization strategy and with different salinities (Abdel-Tawwab et al., 2020; Silva et al., 2022); and different synbiotics preparation (anaerobic x aerobic) (Santos et al., 2022b). Table 1 presents recent studies on synbiotics, aquamimicry and FRB systems in shrimp, including few works carried-out with *Macrobrachium rosenbergii*.

Table 1

3. Comparison between systems: more similarities than differences

Classic books and several scientific articles described in detailed the BFT principles, engineering, functionality, key management practices, expected ranges of water quality parameters, and large-scale commercial adoption (for review, refer to Avnimelech, 2015; Samocha, 2019). From first commercial application in the 70's (Sopomer farm, Emerenciano et al., 2013), large-scale adoption in early 2000's (Burford et al., 2004) and currently (Arnold et al., 2020), over more than 30 years of evolution, the BFT system has been extensively improved (Figure 1). The major driver in BFT is the development of a microbial population largely dominated by heterotrophic and chemoautotrophic bacteria/organisms, and the control of algal blooms and excess of suspended solids (Ferreira et al., 2021; Khanjani et al., 2022d). The maintenance of the desirable microbial community is based on stoichiometric adjustment of the C:N ratio (Ebeling et al., 2006; Khanjani and Sharifinia, 2022) and rigorous control of water quality conditions (Samocha, 2019), including the routine application of water supplements (Emerenciano et al., 2022).

Table 2 brings a comparison between BFT, aquamimicry and synbiotics with main characteristics. Both systems share several similarities, and operate under comparable conditions, e.g. (i) pond systems with limited water exchange, high aeration and water movement; (ii) microbial aggregation and 'flocs' particle formation/consumption; and (iii) bacterial-based microbial manipulation. These similarities might explain the results observed by Hussain et al. (2021). The authors compared BFT versus synbiotics and observed no differences on most water quality parameters, and comparable results of shrimp performance. Definitely, the fermentation protocol adopted in synbiotics and aquamimicry (e.g. type of carbon sources and microorganisms selection), doses and frequency might influence the microbial diversity (Zeng et al. 2020), water quality and consequently shrimp performance (Dawood and Koshio, 2020).

However, there are key differences such as (i) the additional *ex-situ* fermentation step in both aquamimicry and synbiotics, adding complexity to the management procedures; (ii) the expected natural productivity in aquamimicry, in large extent formed by zooplankton (e.g., copepods, insect larvae, rotifers, etc.) with major role on shrimp nutrition. Moreover, shrimp performance might vary in different regions due to water quality characteristics, seasonality and endemic zooplankton structure (Johnston et al. 2002), likely impacting the production consistency. In synbiotics, intense zooplankton bloom might not occur, however the fermented material (Figure 1) can be directly ingested by shrimp, playing a major role on feed conversion ratios (Kawahigashi, 2018), though not always the case (Hussain et al 2021); (iii) algae role in aquamimicry to sustain the zooplankton biomass and control over N-compounds. On the other hand, especially in outdoor conditions, high algae concentration might limit the capacity of *in-situ* organic matter degradation; therefore a higher sludge production is expected, likely impacting the water exchange rates.

Table 2

Figure 1

4. Disruptive techniques or management tool?

Considering the research efforts, technology evolution, current level of understanding, development and broad adoption of such techniques, rather than a novel disruptive technique, currently synbiotics and aquamimicry are more likely management tools (Kawahigashi,

2018) or system variations (Figure 2). In terms of future challenges, crucial points to consider are the

complexity and scalability. Compared to BFT, the *ex-situ* fermentation adds more steps, complexity, risks and potential variability to the microbial management, likely making it more difficult to scale-up, especially in large operations. However, for small farms, normally with family-based workforce, such adoption is easier.

Although the fermentation process is a key element, it might impose potential risks with cross-contamination and development of opportunistic microorganisms (e.g. pathogenic vibrio). In such variable conditions, it is difficult to secure a stable microbial composition (within the same production cycle and across multiple cycles) and avoid potential adverse effects. The bacteria selected by the fermentation process are not necessarily the same ones that will adapt, survive and establish in the pond or tank environments (El-Mansi et al., 2018; Dawood and Koshio, 2020). For instance, the presence of high (pathogenic) vibrio loads is not uncommon in some fermented medium elaborated at farm site. The final microbial profile post fermentation can be largely different than those intended and labelled in commercial bacteria/yeasts-based products added initially. In addition, this undesirable microbial population can negatively impact key favourable probiotic-based strains with antagonist vibrio behaviour, causing its reduction or even loss. The routine application of probiotics in culture water is recommended even during synbiotics management (Hostins et al 2019). In this sense, there is no 'silver bullet' to maintain the stability of the microbial community in either aquamimicry, synbiotics and BFT, but a combination of practices & management that will assist to keep the microbial profile stable and predictable over cycles (Martínez-Córdova et al 2015; Samocha, 2019; Catalani, 2020; Oliveira et al. 2022a,b).

Figure 2

5. Conclusion

In future, more science-based research and development (R&D) efforts, academia-private sector collaborations, training and spread of information might help to change the actual scenario. On-site training will be crucial to overcome the lack of knowledge related to these microbial approaches. In addition, examples of research efforts may include (i) better understanding of the microbial dynamics during the fermentation process and after pond/tank application; (ii) impact on pathogen populations (e.g. pathogenic vibrio species) and gut microbiome; (iii) impact of fermented products on feed management and feed costs; (iv) adverse effects on 'traditional' water probiotics management; and (v) suitable stocking densities. Regardless the microbial-based approach selected and adopted, proficient microbial understanding and manipulation are the key to successful operation of shrimp farms and will help to increase biosecurity, overcome disease outbreaks, and enhance sustainability, predictability, and resilience of intensive microbial-based shrimp farming.

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Table 1 Recent studies on synbiotics and aquamimicry systems in crustacean species.

Crustacean s/stagespecie	Topic	Anaerobic/aerobic	Grain substrate	Probiotic strains	pH buffer	Water/substrate ratio	Key production parameters	References
M. rosenbergii nursery	Synbiotics	24 and 24 ;h anaerobic h aerobic	Rice bran	*B. subtilis*, *B. licheniformis* and *Bacillus* sp	Sodium bicarbonate	10x	800 pl m^{-3}; 85 g m^{-3}, 89% survival; 0.12 g final weight; FCR 2.8 commercial feed; rearing period 35 days.	Santos et al. 2022a
M. rosenbergii nursery	Synbiotics	12-24 h anaerobic; and 12-24 h aerobic	Rice bran	*B. subtilis, B. licheniformis, Lactobacillus acidophilus, B. pumilus e Saccharomyces cerevisiae*	Sodium bicarbonate	10x	1,000 pl m^{-3}; 0.14-0.19g m^{-3}, 77-89% survival; 0.17-0.22 g final weight; FCR 2.5-3.5 commercial feed; rearing period 35 days.	Santos et al. 2022b
L. vannamei nursery	Synbiotics	24 and 24 ;h anaerobic aerobic h	Rice bran	*Bacillus subtilis*, *Bacillus licheniformis*, *Bacillus*	Sodium bicarbonate	10x	2,000 pl m^{-3}; 0.69-0.81 kg m^{-3}, 87-82% survival; 0.4-0.49 g final weight; FCR 1.8-1.9 commercial feed; rearing period 35 days.	Pimentel et al. 2022
L. vannamei out-grow	Synbiotics	24 and 24 ;h anaerobic h aerobic	Rice bran	*B. subtilis*, *B. licheniformis* and *Bacillus* sp	Sodium bicarbonate	10x	300 juveniles m^{-3}; 0.6-1.2 kg m^{-3}, 53-81% survival; 3.7-4.7 g final weight; FCR 1.2-1.3 commercial feed; rearing period 56 days.	Oliveira et al. 2022a
L. vannamei nursery	Synbiotics	24 and 24 ;h anaerobic h aerobic	Rice bran	*Bacillus subtilis*, *Bacillus licheniformis*, and *Pseudomonas* sp	Sodium bicarbonate	10x	2,000Pl m^{-3}; 1.7-2.1 kg m^{-3}, 84-94% survival; 1.0-1.1 g final weight; FCR 0.—1.0 commercial feed; rearing period 40 days.	Oliveira et al. 2022b
L. vannamei out-grow	Synbiotics	12 h aerobic	Rice bran	*Bacillus amyloliquefaciens, Bacillus licheniformis, Bacillus pumilus, B. subtilis*	-	10x	125 shrimp m^{-3}; 0.8-1.0 kg m^{-3}, 86-95% survival; 8.5-11 g final weight; FCR 1.0.—1.2 commercial feed; rearing period 56 days.	Hussain et al. 2021;
L. vannamei nursery	Synbiotics	24 h aerobic	Molasses, wheat flour and rice bran	*Bacillus* spp. (9 strains)	-	100x	350 shrimp m^{-3}; 90-91% survival; 0.5-0.6 g final weight; rearing period 28 days	Chakrapani et al. 2021
L. vannamei out-grow	Synbiotics	48 h anaerobic	Rice bran	*B. subtilis*	Sodium bicarbonate	5X	1,000 shrimp m^{-3}; 57-87% survival; 5.3-5.7 g final weight; FCR 2.6-2.8- 50 % basal diets +fermented rice bran with *Bacillus subtilis;* rearing period 60 days.	Moustafa et al. 2020
L. vannamei out-grow	Fermented rice bran (FRB)	24 h aerobicc	Rice bran	*B. subtilis*	Sodium bicarbonate	2x	1000 shrimp m^{-3}; 4.6-5.1 kg m^{-3}, 83-88% survival; 4.1-6.3 g final weight; rearing period 84 days.	Abdel-Tawwab et al. 2020
L. vannamei out-grow	Aquamimicry	24 h aerobicc	Rice bran	*B. subtilis*	Sodium bicarbonate	15x	70 shrimp m^{-3}; 4.0-4.1 t ha^{-1}, 59-61% survival; 9.6-9.7 g final weight; FCR 1.7 commercial feed and fermented	Albuquerque, 2019

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						soya; rearing period 138-148 days.	
L. vannamei grow-out	Aquamimicry	24 h anaerobic	Rice bran	*Bacillus* sp	25X	60 shrimp m^{-2}; 1.44 g initial weight; 53.3% survival; 11.73 g final weight; yield 3.56 ton/ha; rearing period 120 days.	Catalani, 2020

Table 2: Comparison of biofloc, synbiotics and aquamimicry under conditions of high grow-out stocking density (>150 shrimp/m2), and lined ponds or tanks. The information presented below is a general guide only. Specific characteristics may change according to different culture conditions and farm management strategies.

Characteristics	Biofloc	Synbiotics	Aquamimicry
High energy consumption[1]	Yes	Yes	Yes
Indoor or outdoor	Both	Both	Normally outdoor
[2]Stocking densities	Conservative to high	Conservative	Conservative
Water exchange	Minimum	Minimum	Minimum
Sludge removal[3]	Yes	Yes	Yes
Suspended solids management	Yes	Yes	Yes
Polyculture with fish	Not usual	Not usual	Originally yes, not usual currently
External carbon source	Yes	Yes	Yes
Fermented carbon source	No	Yes	Yes
Stoichiometric adjustment of the C:N ratio	Often	No	No
Main carbon sources	Soluble (e.g. molasses) and grain by-products	Grain by-products (wheat bran, rice bran, soybean meal)	Grain by-products (e.g. rice bran)
Water supplements probiotics minerals,) etc.) and feed additives	Yes	Yes	Yes
Natural food source (bioflocs)	Yes	Yes	Yes
Intense zooplakton blooms	Not expected	May not occurs	(Yes (mandatory
Phytoplankton role	Minor	Intermediate-Minor	Major (TAN uptake and sustain (zooplankton blooms
Feed conversion ratio	Reduced	Reduced	Reduced
Skilled work force	Yes	Yes	Yes

[1]Aeration (keep particles in suspension and suitable dissolved oxygen levels), water circulation, draining and/or pumping. [2] Conservatives densities (e.g. 150 to 300 shrimp m^{-2}), and high (e.g. 300 to more than 450 shrimp m^{-2}); [3]Aiming to keep clean the shrimp pond bottom

Figure 1: Preparation of synbiotics: protocols including fermentation of grain during anaerobic (left) and aerobic phases (right)

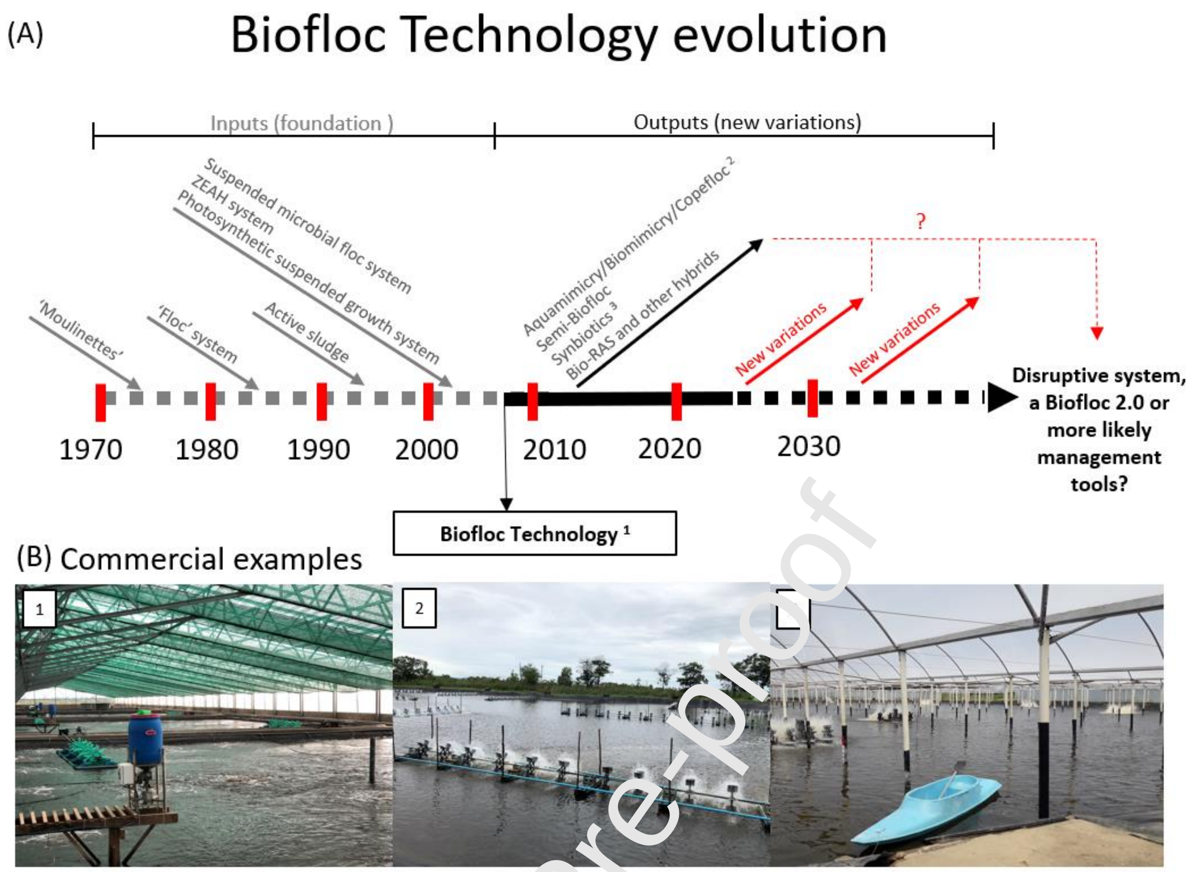

Figure 2: (A) Biofloc Technology evolution and unknown future (adapted from Ulloa-Walker et al. 2020; Emerenciano et al. 2022); (B) Example of commercial farms operating different microbial-based approaches in intensive culture conditions: Biofloc Technology, Vietnam (1), Aquamimicry, Thailand (2) and Synbiotics, Brazil (3).

Subject: **CRediT author statement**

Name of the author and e-mail ID	Types of contribution
Mohammad Hossein Khanjani	(i) Conception and design of study; (ii) Drafting the manuscript; (iii) Revising the manuscript critically for important intellectual content; (iv) Revising the manuscript after reviewers evaluation; (v) Final approval of the version to be published.
Luis Otavio Brito da Silva	(i) Drafting the manuscript; (ii) Revising the manuscript critically for important intellectual content; (iii) Revising the manuscript after reviewers evaluation
Geraldo Kipper Fóes	(i) Drafting the manuscript; (ii) Revising the manuscript critically for important intellectual content; (iii) Revising the manuscript after reviewers evaluation
Felipe do Nascimento Vieira	(i) Drafting the manuscript; (ii) Revising the manuscript critically for important intellectual content; (iii) Revising the manuscript after reviewers evaluation
Moisés A. Poli	(i) Drafting the manuscript; (ii) Revising the manuscript critically for important intellectual content; (iii) Revising the manuscript after reviewers evaluation
Marcos Santos	(i) Drafting the manuscript; (ii) Revising the manuscript critically for important intellectual content; (iii) Revising the manuscript after reviewers evaluation
Mauricio G. C. Emerenciano	(i) Conception and design of study; (ii) Drafting the manuscript; (iii) Revising the manuscript critically for important intellectual content; (iv) Revising the manuscript after reviewers evaluation; (v) Final approval of the version to be published.

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Highlights

1. Aquamimicry and synbiotics comparison with biofloc technology evidenced more similarities than differences, and grow-out farming operated under comparable conditions.
2. In aquamimicry phytoplankton and zooplankton play a key role, less extent in synbiotics and biofloc.
3. From 2009 to date, bibliometric analysis (Web of Science) showed 578 articles for BFT, 20 for synbiotics and 3 for aquamimicry, an evident lack of scientific background.
4. Current research and development (R&D) efforts and scarce science-based literature suggest aquamimicry and synbiotics as additional management tools rather than disruptive systems.