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Current status of the global production chain of giant river prawn (*Macrobrachium rosenbergii*)

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ABSTRACT

Objective: To determine the current state of the global production chain of *Macrobrachium rosenbergii*, identifying its links and the characteristics of the techniques used.

Design/Methodology/Approach: Studies over a period of 20 years (2001-2022) about the production chain of *M. rosenbergii* were reviewed and analyzed. The information was synthesized in tables and the most relevant production and farming data are offered as an output.

Results: The following links of the production chain were identified: production, processing, and commercialization. The *Macrobrachium rosenbergii* farming and the main technologies used to improve its production are described.

Study Limitations/Implications: There is limited systemic information about the *M. rosenbergii* production chain. The topics addressed the specifics of production, processing, and marketing.

Findings/Conclusions: To improve the *M. rosenbergii* production chain, the following aspects must be guaranteed: the supply of post-larvae (PL) specimens, the development of better monoculture practices, and its integration with other species of commercial importance. The organization of the production chain must also be reviewed, considering its direct and indirect participants.

Keywords: farming, crustaceans, production.

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INTRODUCTION

Macrobrachium rosenbergii is a species of freshwater crustacean, native to the Indo-Pacific region. It is commercially important and is farmed in various countries around the world (New and Valenti, 2000). According to the Food and Agriculture Organization (FAO) of the United Nations, it has been introduced as an aquaculture product in at least 40 countries (FAO, 2022a). The global production of *M. rosenbergii* in 2020 was 294,000 tons, representing 2.6% of the total crustacean production (FAO, 2022b). Modern farming of this species started around 1960. In 1978, the first major FAO project designed to expand the farming of this species in Thailand began (New, 2009). Since then, it has been developed on all continents, particularly in Asia and the Americas (FAO, 2022a). In view

Image by Kreingkrai Luangchaipreeda at Pixabay of the increase in global prawn demand, guaranteeing a responsible production process throughout the entire production chain is an essential measure; this chain is composed of a set of linked elements that constitute a complex network with various multidisciplinary characteristics (Valenti and Tidwell, 2006). In particular, the farming of *M. rosenbergii* has a low environmental impact and offers opportunities for the socioeconomic development of developing countries, becoming a market alternative that contributes to job generation. Therefore, the objective of this work was to determine the current state of the global production chain of *Macrobrachium rosenbergii*, identifying its links and the characteristics of the techniques used.

MATERIALS AND METHODS

The Web of Science, EBSCO, Scopus, Scielo, Redalyc, Dimensions, and Google Scholar databases were consulted, using the keywords "*Macrobrachium rosenbergii*," "productive chain," and "freshwater prawn," in the 2001-2022 period. The resulting information was analyzed according to the production chain links (production, processing, and commercialization) proposed by Valenti and Tidwell (2006). Relevant information is provided in the description of each of them.

RESULTS AND DISCUSSION

Production

Production is divided into three stages: post-larvae (PL) production, nursery, and grow out. Obtaining PL in commercial hatcheries —whether they are private or governmental— depends on access to economic resources, brackish water, technology, and infrastructure. Its success is mainly based on location, design, and management, as well as on its proximity to the PL market of nursery and grow-out producers (Valenti *et al.*, 2010).

Post-larva production

The production of post-larvae meets the appropriate conditions of the reproducer management, embryonic process, and larval process.

Commercial hatcheries usually obtain prawn breeders from grow-out ponds, although they also frequently acquire them from the natural environment in the countries of

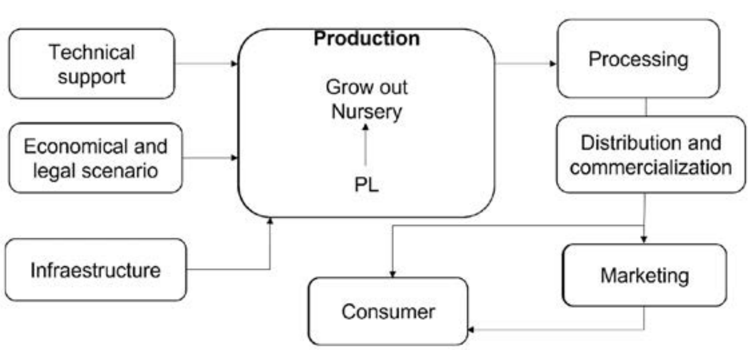

Figure 1. Production chain of *M. rosenbergii*, modified from the original model proposed by Valenti and Tidwell (2006).

origin (Daniels *et al.*, 2000). After the reproduction process, female prawns (commonly known as ovigerous females) carry the eggs attached to their abdomen (Valenti Daniels *et al.*, 2010). The embryonic process begins with the selection of ovigerous females and their introduction to aquaculture systems (tubs with aeration), using brackish water at 5 ppt, keeping the temperature within a 25-30 °C range, and preferably with a pH of 7.0 to 7.2, until the eggs hatch (New, 2002). According to Wei *et al.* (2021), *M. rosenbergii* larvae record a better growth and survival rate at a salinity level of 13 ppt. The larval development of *M. rosenbergii* has eleven stages that occur in brackish water, before their metamorphosis into PL, and eventual migration to freshwater in the wild (Brown *et al.*, 2010). Overall, the reproduction and incubation period of the larvae of this species lasts from 20 to 25 days (Wei *et al.*, 2021).

The larval process of *M. rosenbergii* is carried out in raceways systems and recirculating aquaculture systems (RAS), using clear water (Valenti *et al.*, 2010). The first system is based on the regular exchange of water, which reduces the accumulation of the toxic substances that originate from the metabolism of the larvae, from the *Artemia* nauplius offered as live food, and from the bacterial decomposition of food waste, feces, and dead organisms (New and Valenti, 2000). The second system uses the continuous or semi-continuous processing of water to reduce nitrogen and solid waste, as well as disinfection to control diseases (Valenti *et al.*, 2010). These systems enable high densities of larvae in ponds; the maximization of the use of space, water, supplies, and natural resources generates commercial and environmental benefits (Piedrahita, 2003).

The diet of growing *Macrobrachium rosenbergii* larvae basically consists of newly hatched *Artemia* nauplius, supplemented with inert food (Valenti and Daniels, 2000).

Table 1 shows suitable farming conditions for larval production.

The survival rate in PL production in experimental and commercial hatcheries varies between 40% and 50% in continuous flow systems and 60% to 80% in RAS (Valenti *et al.*, 2010).

In addition to salinity, another major environmental factor is the photoperiod, which has a positive impact with continuous light conditions, improving the survival of *M. rosenbergii* larvae (Wei *et al.*, 2021).

The production of both female and male monosex post-larvae has likewise been evaluated. Although the farming of males is in demand, some authors favor monosex female

Table 1. Optimal conditions for farming *M. rosenbergii* larvae.

Conditions for the larval rearing	Contribution	Reference
Salinity	Salinity level of 13 ppt.	(Wei *et al.*, 2021)
Density	100 larvae L^{-1}.	(David *et al.*, 2016, 2018)
Photoperiod and light spectrum	24 hours continues of light, green or white.	(Wei *et al.*, 2021)
Feed	They concluded to feed during daylight with *Artemia* nauplii up to 5 not exceeding 10 mL^{-1}.	(Aviz *et al.*, 2018)
	They evaluated of semi-moist product with squid	(Santos-Gutiérrez *et al.*, 2011)

production (Levy *et al.*, 2017; Malecha, 2012), given the feasibility with which they can be managed at high densities and homogeneous sizes. Some commercial hatcheries (such as the prawn biotechnology company Enzootic) have developed high-density monosex female technology for selective breeding. This RAS vertical hatchery in Thailand has been designed to produce 450 million PL per year (Shechter and Sagi, 2021).

Nursery

The nursery phase of *M. rosenbergii* is an intermediate stage between the recent metamorphosis to PL and grow-out, when it is grown at high densities, until they reach advanced sizes (Coyle *et al.*, 2009). PL (with a <0.01 g average weight) achieve an average weight ≥ 0.3 g in 30-60 days (Tidwell *et al.*, 2005). Once the nursery phase is over, PL are generally called "juveniles." Juveniles are more resistant than PL to predation, cannibalism, and environmental fluctuations (New, 2002). The duration of the nursery phase and the optimal size of juveniles shows geographical differences, depending on the climatic conditions of temperate and tropical zones (Coyle *et al.*, 2009).

Table 2 shows the nursery phase conditions: the stocking density is the number of post-larvae that can be stocked in the pond to guarantee a greater survival.

The use of artificial substrate or shelters in ponds —such as bamboo sheets, polypropylene nets, fine nylon material (Apud *et al.*, 1983), or waste PVC pipes (Asiain-Hoyos *et al.*, 2014)— provides prawns with a three-dimensional contact surface (D'Abramo *et al.*, 2006), increasing survival and production (D'Abramo *et al.*, 2000).

The intensification of *M. rosenbergii* farming implies a greater use of resources (*e.g.*, water and feed) than in traditional farming systems. Therefore, other alternative systems (Table 3), such as Biofloc technology (BFT) and synbiotics have been studied (Santos *et al.*, 2022). BFT allows the recycling of nitrogenous waste as microbial proteins, which subsequently are fed to the prawns (Ballester *et al.*, 2010).

Symbiotic systems use a holistic approach to balance the relationship between phytoplankton and other microorganisms (such as bacteria and zooplankton), resulting in a "mature" environment and stable water quality parameters (Kawahigashi, 2018).

Grow-out

The *Macrobrachium rosenbergii* species has been farmed under monoculture (Table 4) and polyculture systems, until the specimens reach commercial size in both in commercial

Table 2. Nursery phase conditions of *M. rosenbergii* post-larvae.

Nursery	Contribution	Reference
Stocking density	860 PL/m^2 produced a greater number of nursed juveniles (5.5/L and 527/m^2) in 56 days.	(Coyle *et al.*, 2003)
Photoperiod	24 hours continues of light.	(Tidwell *et al.*, 2001)
Artificial substrate	Preference for dark shelters.	(Kawamura *et al.*, 2017)
	They increased the substrate surface area in cages by 75%, improving growth and survival rate.	(Thapa *et al.*, 2021)

Table 3. Alternative farming systems for *M. rosenbergii*.

Systems	Contribution	Reference
Biofloc technology (BFT)	BFT can be used for the nursery phase.	(Ballester *et al.*, 2017)
	They used BFT with a salinity of 15 ppt for the nursery phase.	(Hosain *et al.*, 2021)
	Higher protein and lipid content due to the nutritional contribution of the biofloc material.	(Pérez-Fuentes *et al.*, 2013)
Symbiotic	A symbiotic diet was evaluated in postlarvae.	(Chen *et al.*, 2017)
	Longer time of symbiotic preparation may promote better performance.	(Santos *et al.*, 2022)

hatcheries and in research centers. These types of systems are classified according to their stocking density: extensive (1-4/m^2), semi-intensive (4-20/m^2), and intensive (>20/m^2). They have also been grown in brackish water, cages, and pens; however, this species is usually farmed in earthen ponds fed with fresh water, at a wide range of temperatures (Valenti *et al.*, 2010).

Prawns can play an important role in the success of commercial polyculture and integrated aquaculture, which are already carried out in some countries (particularly in Bangladesh, Brazil, China, India, and Vietnam) and are the subject of experiments in many others (Zimmermann *et al.*, 2009). According to Marques *et al.* (2016) integrated aquaculture (Table 5) of *M. rosenbergii* includes various farming systems, such as fish-prawns (New and Valenti, 2017), rice-prawns (Ahmed *et al.*, 2008; Ahmed and Garnett, 2010), aquaponics (Ma *et al.*, 2020; Tong *et al.*, 2021), and the integration with terrestrial animals and plant crops.

Processing

Market sells frozen and peeled prawns, frozen spots, and headless prawns. Meanwhile, the gourmet market particularly prefers whole prawns, given the distinctive characteristics of the chelae and the head.

In addition to these presentations, Freeman *et al.* (2016) examined consumer willingness to pay for prawns with and without added value, using sensory analysis and experimental

Table 4. Grow-out conditions of *M. rosenbergii* in monoculture.

Monoculture	Contribution	Reference
Phased cultivation	Separating prawns several times by size showed compensatory growth.	(Valverde, 2021)
Density	They evaluated two densities (2.5 and 6 /m^2, was more rentable the lower density.	(Valverde y Varela, 2020)
Probióticos	The daily addition of probiotics (*Bacillus subtilis* and *Bacillus licheniformis*), even at low concentrations, influences greater survival.	(Frozza *et al.*, 2021)
Artificial substrate	Growth and survival of juvenile prawns improved in the presence of artificial substrate.	(Tuly *et al.*, 2014)

Table 5. Grow-out conditions of *M. rosenbergii* in integrated aquaculture.

Integrate aquaculture	Contribution	Reference
Biofloc technology (BFT) and polyculture	They evaluated the BFT and clear water in an aquaponic system with *M. rosenbergii* and *O. niloticus*, BFT increased content of fat in the fillets of Nile tilapia and the control of the nitrates production.	(Barbosa *et al.*, 2022)
	They evaluate BFT and RAS in polyculture y monoculture with *M. rosenbergii* and *O. niloticus*. The BFT provides better growth responses in monoculture for *O. niloticus* and in polyculture with *M. rosenbergii* compared to RAS.	(Hisano *et al.*, 2019)
Aquaponic	They evaluated the feasibility of producing romaine lettuce (*Lactuca sativa* L. var. Longifolia) in a semi-intensive aquaponic system of *O. niloticus* and *M. rosenbergii*.	(Calderón-García *et al.*, 2019)
Polyculture	They evaluated the feasibility of polyculture with *Litopenaeus vannamei* and *M. rosenbergii*.	(Ni *et al.*, 2021)

auction. They confirmed that the willingness to pay per consumer increased significantly with two alternative salting processes: salt acclimatization (live prawns acclimatized in salt before harvest) and marinating (peeled prawns marinated in salt for 18 hours).

Dasgupta and Williams (2008) evaluated the operations of two representative processing facilities: a site-built plant and a processing trailer. The latter option provided mobile and convenient services for multiple producers.

Karim (2008) noted that prawn farming, processing, and exportation are an important economic activity in Bangladesh. However, importing countries and economic zones (including the United States and the European Union) are imposing harsher food safety measures; consequently, exporting countries (such as Bangladesh) must guarantee that all the levels of their aquaculture activities meet the conditions of international trade, if they are to survive the tough global competition (Karim 2008). According to Ahmed (2008), around 35 plants were engaged in the processing and exportation of prawns in southwestern Bangladesh, between November 2007 and February 2008.

Freshwater prawn is different from marine shrimp and its favorable culinary characteristics should be promoted. Ongoing research and a more efficient promotion of better breeding and processing technology is necessary to exploit the opportunities for expansion of the aquaculture production sector (Banu and Christianus, 2016).

Commercialization

Commercialization is carried out in domestic and international markets, with the main exporters being China, Thailand, India, and Bangladesh. The latter exports to the United States, the United Kingdom, Belgium, Germany, and Japan (Rabiul Islam *et al.*, 2017). Commercialization is also carried out through gastronomic festivals in Brazil and the United States; these strategies promote local consumption (Dasgupta *et al.*, 2007; Marques and Moraes-Valenti, 2012). In other countries, PL, live prawn, and processed products are marketed through internet pages or social networks.

Dasgupta *et al.* (2007) described the current situation of prawn commercialization in Kentucky, which is largely based on niche marketing, in which fresh prawn is supplied to a specific sector of consumers who are willing to pay a premium for a quality product.

For their part, Ahmed *et al.* (2007) evaluated prawn commercialization in Mymensingh, Bangladesh, and found that several intermediaries are part of the commercialization chain that connects producers and consumers. They also identified that 60% of prawn production is exported, particularly to the United States, Japan, and Europe, while the rest (40%) is sold in local markets.

Ahmed *et al.* (2016) also evaluated the prawn commercialization chain in the southeastern region of Bangladesh, before and after the implementation of a project funded by Denmark. Before the project was implemented, several intermediaries were part of a more extensive commercialization chain and they used to share a considerable amount of the marketing margin. However, after the implementation of the project, both the commercialization chain and the intermediaries were reduced, which facilitated the direct sale of prawn to processing plants.

CONCLUSIONS

The review of the current state of the *M. rosenbergii* production chain detected relevant information about the species and the technologies used to farm it. There is plenty data about farming and production issues, unlike the other links (*e.g.*, processing and commercialization). This situation opens an opportunity area to develop new research and generate more information.

In order to improve the production chain of *M. rosenbergii*, the supply of PL must be guaranteed, better monoculture practices must be developed, farming must be integrated with other species of commercial importance, and the organization of the production chain should be restructured —according to the direct and indirect participants. The trend towards innovative and alternative farming systems is undeniable; however, its application will depend on the characteristics of the region and its resources.

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