Colegio de Postgraduados

Characterization of the Production and Commercialization Process of Tilapia Aquaculturists from Laguna de Tres Palos, Acapulco, Guerrero

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ABSTRACT

Objective: To characterize the production process and commercialization channels of tilapia (*Oreochromis niloticus*) farmed in floating cages by producers from the Laguna de Tres Palos, Acapulco, Guerrero and to propose a marketing strategy.

Design/Methodology/Approach: The design consisted of a quantitative and qualitative approach and included a descriptive and cross-sectional scope. In addition, a non-probability convenience sampling and a semi-structured questionnaire with closed and open-ended questions were used. The questionnaire included overall producer and commercialization data. The SPSS software and the coding method were used to analyze the information.

Results: Producers have a low organization level which, consequently, favors buyers in the tilapia sale negotiation. Likewise, tilapia aquaculturists use a traditional commercialization approach, which the producers believe to be an acceptable income.

Study Limitations/Implications: The non-probabilistic convenience sampling design used means that the results of this study are exclusive to the analyzed sample. Consequently, the results of this study cannot be applied to all aquaculture producers in Laguna de Tres Palos. Probabilistic sampling should be used in future research to confirm these results at a population level.

Findings/Conclusions: A better integration of the different stages of the process could improve tilapia production and commercialization. In addition, including advertising and awareness-raising campaigns about tilapia consumption is recommended.

Keywords: Aquaculture, cages, cultivation, sustainable fishing.

INTRODUCTION

The consumption of fish and aquaculture products provides essential proteins and nutrients to the most unprotected population. In 2023, the Mexican fish production

reached 1,947,601 t of landed catch. Out of total domestic production, 1,720,599 t (88.3%) came from the Pacific Ocean coastline, 217,090 t from the Gulf and Caribbean areas, and 9,912 t from areas without coastline (CONAPESCA, 2023). Meanwhile, the total production of tilapia (*Oreochromis* spp.) in Mexico recorded 75,573 t of landed catch —3.9% of the domestic fish production. Guerrero accounted for 1.9% (1,454 t) of the domestic tilapia production (CONAPESCA 2023). The contribution of aquaculture accounts for 78% (60,377 t out of a total of 77,687 t of live weight) of the domestic tilapia production. In this regard, tilapia aquaculture in Guerrero produces 95.5% (1,205 t) of live fish weight (CONAPESCA, 2023). Consequently, tilapia aquaculture is fundamental for fish production in Guerrero. In addition, the production of tilapia in floating cages ranks first in Guerrero, followed by catfish production. Fish production is carried out in La Villita dam, between Guerrero and Michoacán; however, this activity also takes place in Laguna de Tres Palos (SADREG, 2018). Consequently, tilapia is farmed more than other fresh water fish species in Guerrero. This state has 334 fattening tilapia, trout, catfish, and white shrimp farms, with different technification degrees and development of their production processes, in floating cages and concrete and mud ponds (Gobierno del estado de Guerrero, 2024). Out of this total, 227 production units farm tilapia. Forty-five of these production units are mainly located in Laguna de Tres Palos and use 1,320 floating cages.

Research about the characterization of the production process and commercialization of tilapia is scarce. Nevertheless, Lango-Reynoso *et al.* (2015) concluded that live tilapia commercialization is a strategy of market differentiation. In addition, the freshness of the product plays a key role, guiding the decision-making process of consumers. González *et al.* (2017) pointed out that producers use a traditional commercialization route —*i.e.*, producers sell directly to final consumers. However, both in the domestic and international markets, tilapia is sold in a wide array of presentations, including whole tilapia (fresh, frozen) and tilapia filets (fresh, frozen, and in affordable packages) (Lango-Reynoso *et al.*, 2015). These authors also mentioned that the commercialization channels are "producer-retailer-final consumer" and "producer-final consumer." Likewise, Ahmed *et al.* (2012) and Hsiao *et al.* (2025) indicated that the commercialization chains from the producers to the final consumers are "producer-final consumers" and "producer-wholesaler-retailer-final consumer". These commercialization chains are also a system, with different degrees of traditional commercialization. Consequently, the objective of this study was to characterize the production process and the commercialization channels of tilapia farmed in floating cages by producers from Laguna de Tres Palos, Acapulco, Guerrero. The ultimate aim was to propose sustainable commercialization strategies.

MATERIALS AND METHODS

Study Area

The research was conducted in the localities of San Pedro de las Playas, Plan de los Amates, El Arenal, and Laguna de Tres Palos, Acapulco, Guerrero, Mexico. Tilapia is mainly farmed in floating cages in these production areas (Figure 1).

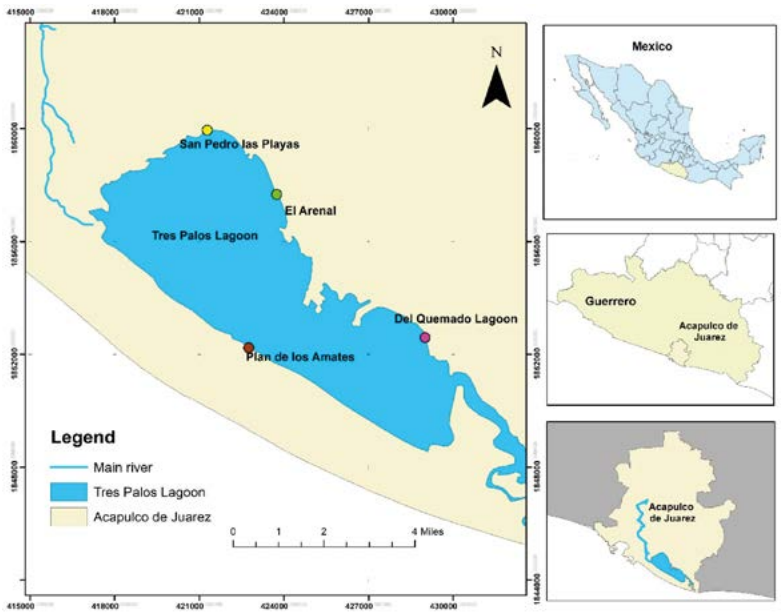

Figure 1. Location of Laguna de Tres Palos and the study areas, Acapulco, Guerrero.

Research Design

The design had a quantitative and qualitative approach, with a descriptive, cross-sectional, and non-experimental scope (Hernández-Sampieri and Mendoza, 2018; Müggenburg-Rodríguez and Pérez-Cabrera, 2018). A questionnaire was applied from November 2024 to April 2025 to determine the tilapia commercialization channels. The sampling population was made up of aquaculturists, wholesalers, retailers, and female sellers that buy fishes in the localities of San Pedro las Playas, Plan de los Amates, El Arenal, and Laguna del Quemado. In addition, a non-probability convenience sampling and a semi-structured questionnaire with closed and open-ended questions were used to gather overall data about the tilapia producers and the commercialization process. A previous pilot test with aquaculturists was conducted. Subsequently, the questions were adjusted to improve understanding and accuracy. In addition, the reliability degree of the open-ended questions of the tool was determined (Cronbach's Alpha=0.71). The appropriate reliability level validated the questionnaire (Bojórquez *et al.*, 2013).

Eighty-one individuals (50 producers and 31 buyers, divided into 4 wholesalers and 27 retailers) were interviewed. In addition to the interviews and direct monitoring, four work meetings were carried out with a focus group of producers that included leaders and chairpersons of fishing cooperatives. The aim was to find out their opinion about production processes and commercialization.

Data Analysis

The data obtained were analyzed using the SPSS v. 22.0 (Nel, 2014) software. Meanwhile, Excel was used to conduct the descriptive statistical analysis and to develop graphs. The Kruskal Wallis test was also used to differentiate the answers of the questionnaire by locality. The quantitative and qualitative data from the interviews and meetings with producers were triangulated. Matching and different answers were compared in order to validate the findings. Subsequently, the categorization and codification process proposed by Rincón (2014) was used to analyze textual data. Only the traditional content analysis was used.

RESULTS AND DISCUSSION

Identification of Participants in the Tilapia Production Chain

Field information was used to identify the participants in the production, harvest, and commercialization processes of tilapia farming in Laguna de Tres Palos, Acapulco, Guerrero (Figure 2).

Aquaculturists, wholesalers and retailers, final consumers were identified as direct participants, while net, fingerling, and food providers were identified as indirect participants.

Production Link

The first link of the tilapia production chain in Laguna de Tres Palos includes the main social actors (aquaculturists) of the four localities showed in Figure 3. In this activity, men have a higher participation than women (Figure 3b). The average age of the producers is 50 (Figure 3c). Producers pointed out that they mainly started farming tilapia in floating cages due to the decrease of capture fishery (Figure 3d). In addition, they mentioned that they invested their own resources when they first engaged in this primary economic activity (Figure 3e).

The interviewees indicated that they did not have the permit granted by Comisión Nacional del Agua (CONAGUA). Nevertheless, they were enrolled in the National Fisheries Register and, when the questionnaire was applied, they were also using floating cages in their operations (Figure 3f).

Producers require net, food, and fingerling providers in order to farm tilapia in floating cages. The chairpersons of the cooperatives or leaders of the work groups interviewed were Argenie Morales Martínez, Benito Morales, Norberto Castillo Victorio, Jorge Nájera de la Paz, and Pedro Gómez Alonso. They mentioned that approximately 80% of the

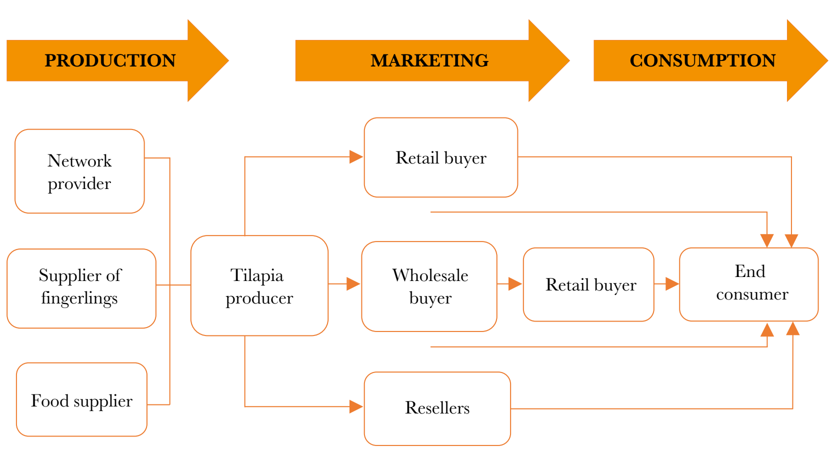

Figure 2. Value chain diagram of tilapia farmed in floating cages in Laguna de Tres Palos, Acapulco, Guerrero.

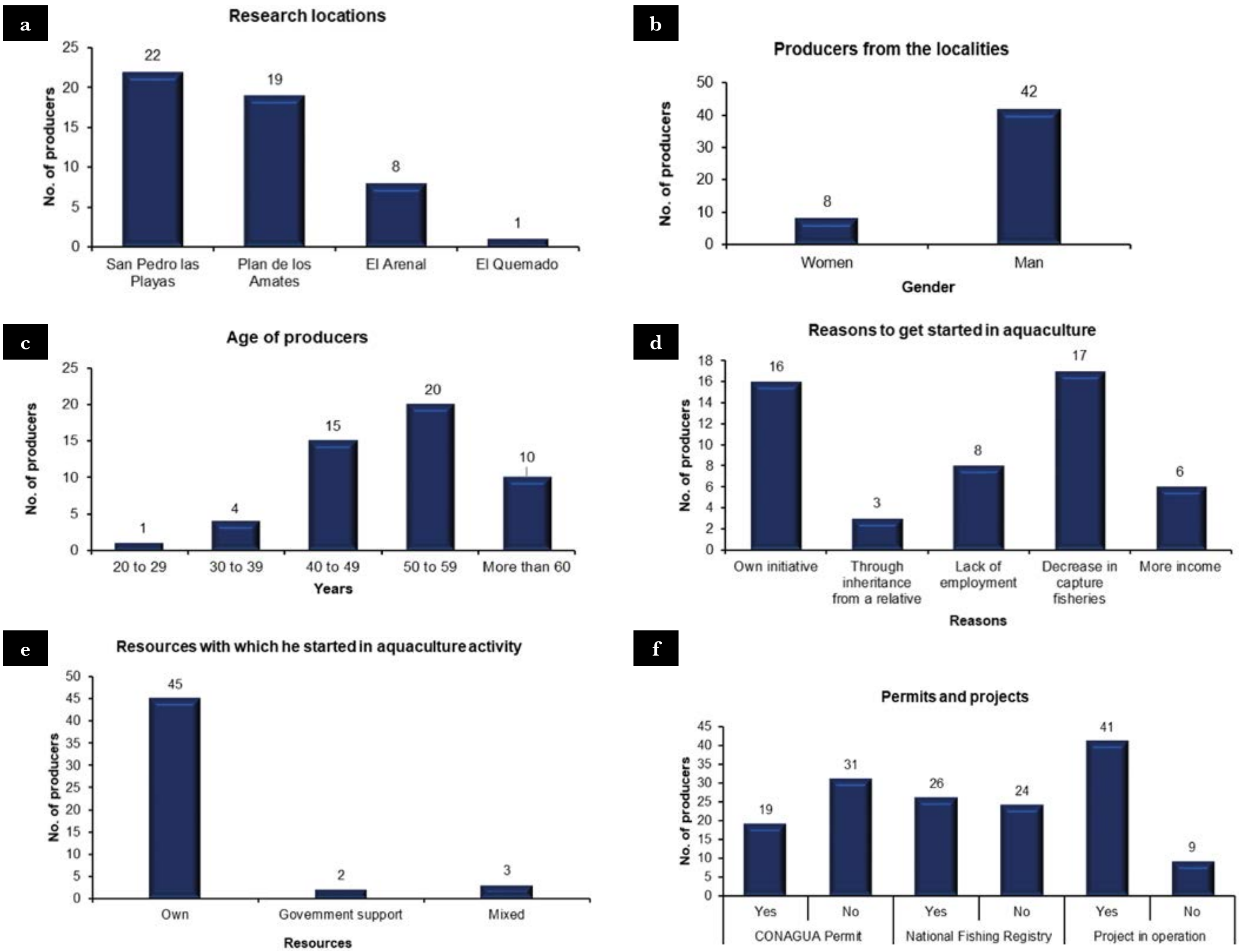

Figure 3. a) Localities. b) Gender. c) Age. d) Reasons to start aquaculture. e) Origin of the resources. f) Permits and operation projects.

aquaculturists purchase their main materials —including 9×1” tarred nylon fishing net, 16” nylon rope, #12 silk thread, and mosquito net —from providers in Guadalajara, while the remaining 20% buy their materials from local providers in Acapulco. In addition, 90% of aquaculturists purchase food for tilapias from a provider located in the Llano Largo locality, Municipality of Acapulco, Guerrero.

Construction of the Nurseries

A nursery is an area or infrastructure designed to handle and look after fingerlings (youngsters), providing them an optimal environment for their initial growth and development, before they can be moved to larger fattening cages. Nurseries are built with 10 m long × 5 m wide × 1.80 m high mosquito nets. Fingerlings are deposited in these nurseries for 30 days. The most common nurseries measured 5 m × 5 m × 1.50 m, 6 m × 6 m × 1.50 m, 3 m × 3 m × 1.50 m, and 4 m × 4 m × 1.50 m (Figure 4b).

Table 1. Characteristics of the Production Units (N=50).

Statistics/Item	Juvenile fish density per cycle	Fish density (fattening, cage)	Number of cycles per year	Production per cycle (t)	Weight (g) of harvested fish	Mortality reported per cycle	Number of cages at the time of interview
Average	22,020.00	2,520.00	1.48	1.98	496.00	144.00	3.18
Standard deviation	18,874.98	952.76	0.54	0.84	92.49	73.290	1.935
Minimum	1,000.00	1,000.00	1.00	1.00	400.00	100	0
Maximum	80,000.00	6,000.00	3.00	4.00	1,000.00	400	10

Where: t, tons; g, grams.

Construction of Fattening Cages

A 1-inch mesh size tarred nylon fishing net is used to build the fattening cages. Measures are taken with a tape measure and then the net is cut by hand. Afterwards, a plastic weaver and silk thread (No. 12) are used to sow the net to a nylon rope. Subsequently, the bottom and upper parts are sown together, creating 9 m long × 6 m wide × 1.50 m high rectangular cages. The cages are then anchored and nailed with mangrove branches by their four corners. In addition, a 0.30-m mosquito net is placed around the cage to prevent food spilling. According to the interviewees, square (58%) and rectangular cages (40%) are the most common shapes. The usual measures such as 5 m × 5 m × 1.50 m, 6 m × 6 m × 1.50 m, 3 m × 3 m × 1.50 m, and 4 m × 4 m × 1.50 m. In this regard, at the moment of the interviews, most of the producers had 1 to 3 floating cages (72%) (Figure 4a, b).

Production Process

In order to farm tilapia in floating cages, the leaders and chairpersons of aquaculture cooperatives pointed out in a work meeting that they stock an average of 80-100 fishes/m^3; however, the results of the questionnaire indicated that producers stock an average of 45-60 fishes/m^3 (Table1). Tilapia farming in floating cages requires various labors for the appropriate development of the fishes. The following labors are carried out during different stages of the process:

1. Stocking of tilapia fingerlings. Tilapia fingerlings (≈1 g) are introduced to nursery cages of different sizes (5 m × 5 m × 1.5 m, 6 m × 6 m × 1.5 m, 3 m × 3 m × 1.5 m, and 4 m × 4 m × 1.5 m). This process lasts approximately 30 days.
2. Moving tilapia to fattening cages. Fishes are moved from the nurseries to floating cages of different sizes built with 1-inch mesh size tarred nylon fishing nets.
3. Feeding. Depending on their development stage, fishes are fed with different rations of balanced feed. The portion should be 1% to 3% of the body mass of the fish per day, divided into two rations to prevent waste and to guarantee a good development.
4. Monitoring and management. This process includes measurements of water quality, daily check of fish health, net cleaning, and monitoring.
5. Harvest. Once the fishes have reached a 400-500 g body weight, they can be harvested (≈6 months). Aquaculturists harvest fishes in the small hours, between

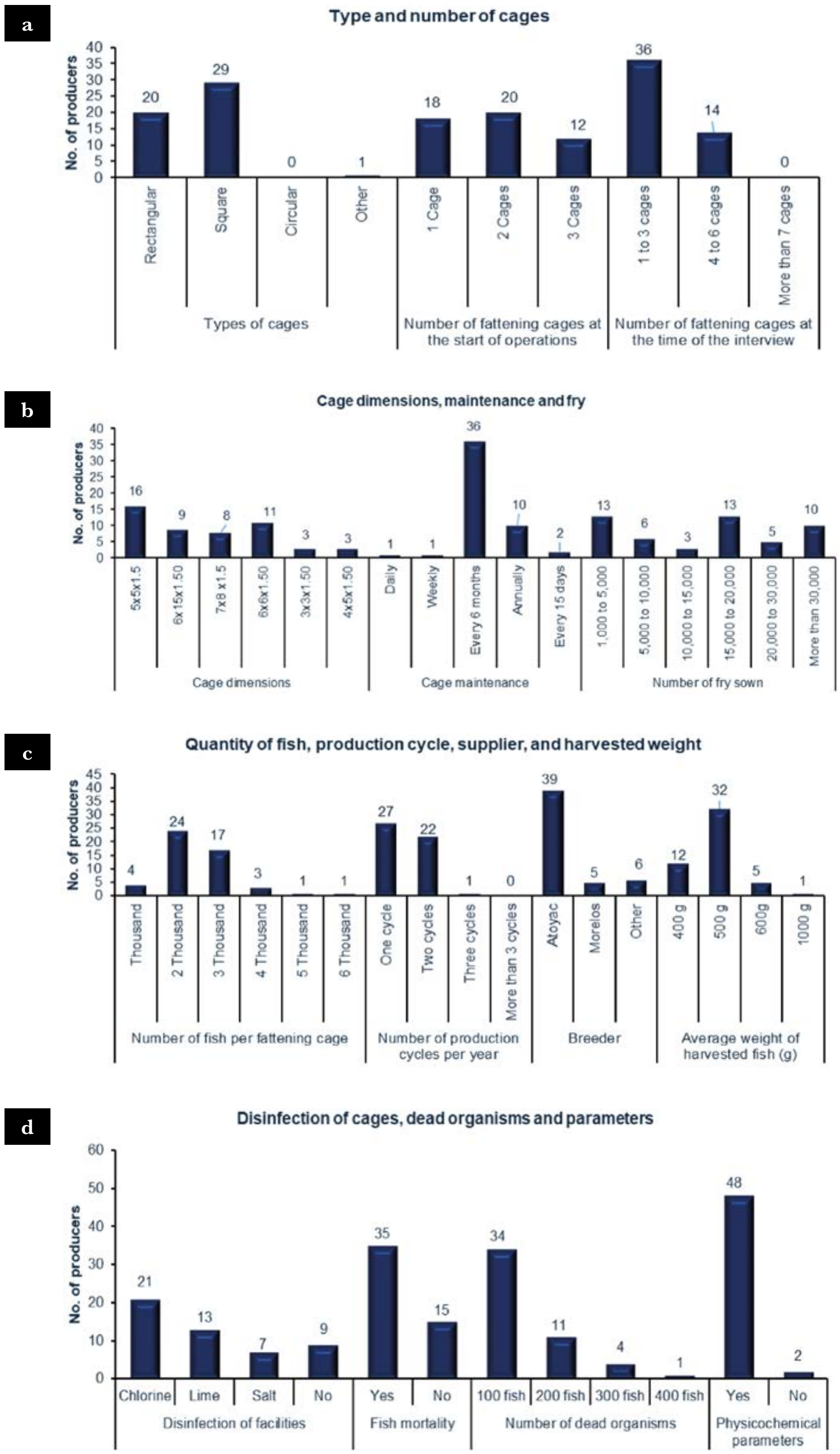

Figure 4. a) Types and number of cages. b) Measures and maintenance of the cages and number of stocked fingerlings. c) Number of stocked fishes, number of cycles, and providers. d) Disinfection, mortality, and physicochemical parameters.

3:00 am and 5:00 am. Afterwards, the catch is moved in rowboats and motorboats to the shore of the lagoon, where the producers sell it to wholesalers, retailers, or final consumers.

The results of this study indicated that 26, 26, 20, 12, 10, and 6% of the producers stocked their nurseries with 1,000-5,000, 15,000-20,000, >30,000, 5,000-10,000, 20,000-30,000, and 10,000-50,000 tilapia fingerlings per cycle, respectively (Figure 4b, Table 1). These tilapia fingerlings are purchased from the reproduction center located in Atoyac de Álvarez, Guerrero (Figure 4c). Meanwhile, during the moving stage, 48, 34, 8, 6, 2, and 2% of the producers moved 2,000, 3,000, 1,000, 4,000, 5,000, and 6,000 tilapias per fattening cage, respectively. Regarding the culture cycles, most of the producers (54%) carried out fattening in one cycle, while the rest (44%) implement a two-cycle fattening (Figure 4c, Table 1).

Although none of the aquaculturists monitor the physicochemical parameters of the water, 96% of them believe that the said measurements are crucial for a good tilapia production (Figure 4d). Nevertheless, as their main management practice, 82% of the producers disinfect their cages and materials with chlorine, lime, and/or salt, mainly at the end of the farming cycle. However, 70% of the producers also report fish mortality cases during the cycle. Most of the cases involve 100 to 200 deaths (Figure 4d, Table 1). Finally, most producers (72%) carry out maintenance of the cages every six months, while 20, 4, and 2% repair their cages every year, every fifteen days, and every week, respectively (Figure 4b).

Producers harvest 1 to 2 t per cycle, depending on the number of fingerlings and operating cages (Table 1). The average weight of six-month tilapia ranges from 400 to 500 g (88%). Regarding the farming cycles, most producers (54%) fatten fishes for only one cycle, while 44% practice a two-cycle fattening (Figure 4c, Table 1). Finally, 72% of the interviewees followed feeding protocols; however, 60, 24, and 16% feed the fishes twice, once, and thrice a day, respectively (Figure 5a). The amount of feed per ration mostly varies from 1-3 kg (66%) to 3-5 kg (26%), although some producers (8%) use ≥6 kg (Figure 5b). Throughout the production cycle, aquaculturists use 1 to 5 t of balanced feeds, divided as follows: 1 to 2 t (48%), 3 to 5 t (42%), and >5 t (10%) (Figure 5a). The most popular feed brands are Pedregal (34%), Grow Fish (32%), Malta Cleyton (32%), and Biofingerling (2%). Most producers scatter the feed in the whole cage (76%), although some (22%) pour it in the middle of the cage. Feeding from trays or baskets is uncommon (2%). Most producers (66%) use motorboats to feed the fishes, while 34% uses rowboats (Figure 5b).

Commercialization

The aquaculturists who farm tilapia in floating cages at Laguna de Tres Palos transport their fishes in any way possible to the wholesaler market. Subsequently, retailers and street vendors sell it to the final consumer. Therefore, aquaculturists, along with the fishermen and fisherwomen of the Laguna de Tres Palos, carry out three types of commercialization: 1) "producer-wholesalers/distribution center-retailers-final consumer"; 2) "producer-retailer-final consumer"; and 3) "producer-female sellers/housewives-final consumer," as

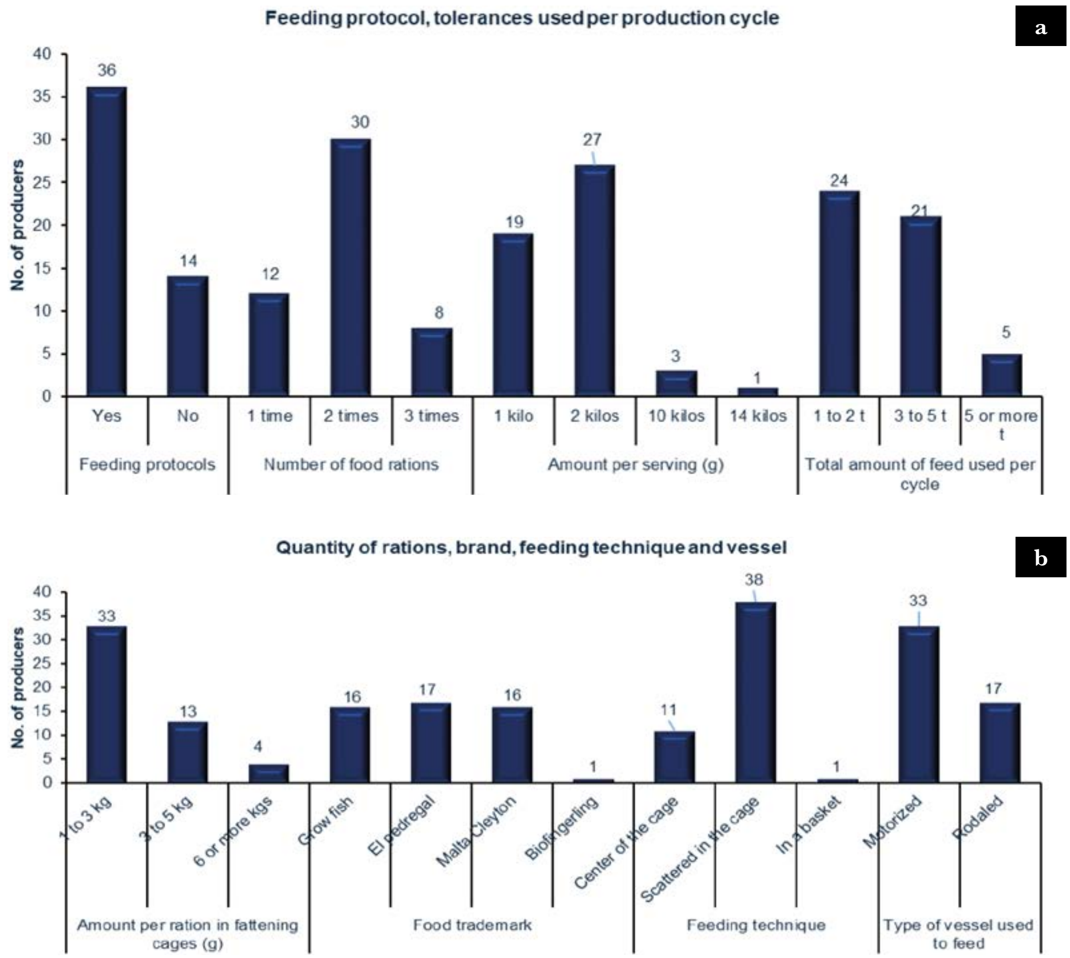

Figure 5. Feeding characteristics of tilapia farming in floating cages.

the most direct channel (Figure 1). Traditionally, the commercialization of the product, from the moment it leaves the farming cages, until it reaches the final consumer, takes place at the following levels: 1) local, from producers to wholesalers and retailers (74%); 2) regional, through wholesalers (20%); and 3) domestic, through wholesalers (6%). Producers sell their product either whole and fresh (94%) or whole and frozen (6%) (Figure 6b).

According to the information provided by the aquaculturists about the size of the tilapia commercialized, large fishes (500-1,000 g) account for most (56%) of the commercialized product and are sold for more than \$60 Mexican pesos per kilogram. Medium-sized specimens (400-450 g) have a 34% participation and are sold from \$35 to \$50 Mexican pesos per kilogram. Finally, small tilapias (300-350 g) have a 10% participation and are sold from \$25 to \$30 Mexican pesos (Figure 6a). Additionally, 60% of the producers allocate ≈5% of their production to self-consumption. Producers frequently eat tilapia: 76% of them eat this type of fish on a weekly basis (Figure 6c, d). The commercialization channel is composed of four wholesalers and 27 retailers. Wholesalers sell large, medium, and small fishes at \$100, \$80, and \$50 Mexican pesos, respectively. For their part, retailers sell tilapia at \$100, \$80, and \$60 Mexican pesos per kilogram (Figure 6f).

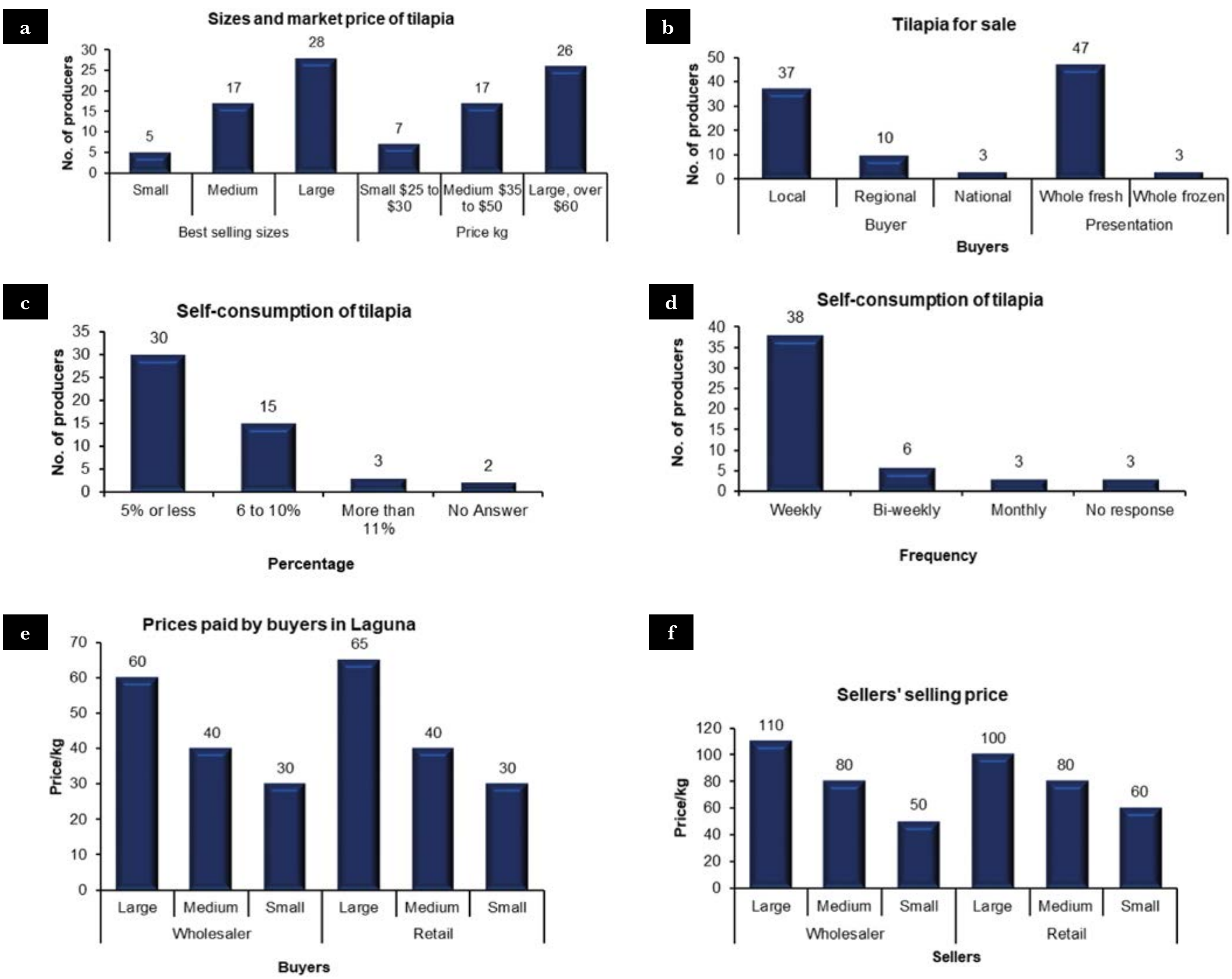

Figure 6. a) Best-selling size and price. b) Buyer type and tilapia presentations. c) Self-consumption percentage. d) Self-consumption frequency. e) Price per kilogram of tilapia paid by wholesaler and retailer buyers to the producer. f) Tilapia resale price charged by wholesaler and retailer buyers.

Meanwhile, according to the Kruskal Wallis test, only seven questions recorded significant differences ($p<0.05$) between the sites: 1) With what resources did you start this activity? (Plan de los Amates-El Quemado and San Pedro las Playas-El Quemado); 2) What is the size of your farming cages? (Plan de los Amates-El Arenal); 3) What is the size of your fattening cages? (Plan de los Amates-San Pedro las Playas); 4) Has your aquaculture unit recorded mortality cases? (Plan de los Amates-San Pedro las Playas); 5) Do you follow feeding protocols? (Plan de los Amates-San Pedro las Playas); 6) What is the ration you use in fattening cages? (Plan de los Amates-El Arenal); and 7) What type of boat do you use to feed the tilapias? (Plan de los Amates-San Pedro las Playas).

Likewise, based on the meetings with the producers, the research team was able to collect information about the production and commercialization cycles of tilapia farmed in floating cages and the factors that limit productivity.

Cycle of Tilapia Production in Floating Cages

Argenie Morales Martínez and Benito Morales (San Pedro las Playas), Norberto Castillo Victorio (Arenal), Jorge Nájera de la Paz (Laguna del Quemado), and Pedro Gómez Alonso (Plan de los Amates) are the leaders and/or chairpersons of the cooperatives. According to them, the production cycle usually starts in November or December with 1-2 g tilapia fingerlings mostly purchased from the reproduction center located in Atoyac de Álvarez, Guerrero. The size of the cage determines the number of fingerlings. Usually, each fattening cage holds 1,000 to 2,000 fingerlings, although that figure can sometimes reach up to 3,000. Tilapias are harvested at the end of March and in April; however, some producers harvest even in May. Producers estimate a 10-20% mortality rate, mainly caused by stress resulting from the lack of oxygen in the water body, as well as the pollution degree and even hurricanes.

Tilapia Commercialization

The San Pedro las Playas, Plan de los Amates, El Arenal, and Laguna del Quemado producers sell the tilapia they farm to wholesalers, retailers, and street vendors without any added value. Likewise, fish consumption reaches its peak during Easter week (March or April) and December; therefore, producers must plan ahead to have fresh product available for those festivities.

Finally, according to aquaculturists Argenie Morales Martínez, Benito Norberto Castillo Victorio, Jorge Nájera de la Paz, and Pedro Gómez Alonso, the main factors that impact tilapia productivity are the degree of water pollution, the reduction of oxygen, and the increase in water temperature. These phenomena usually take place in June or July of every year.

The production of tilapia in floating cages complies with the guidelines of the Instituto Mexicano de Investigación en Pesca y Acuacultura Sustentable (IMIPAS, 2018) and the Official Gazette of the Federation (DOF, 2012), as well as with the general production, building, and operation characteristics of floating cages established by Avilés and Lizawa (1993). For their part, Riveros *et al.* (2014) detailed the building of square cages with synthetic nets, using bamboo and polystyrene to keep them afloat. However, aquaculturists build square or rectangle cages with black net, anchored with mangrove branches from each corner.

The floating cages used by producers in this study match the square or rectangular cages reported by Estrada *et al.* (2023) and Pérez *et al.* (2021). Meanwhile, Estrada *et al.* (2023) found that 29, 33, and 23% of the producers started with 3-5, 6-10, and 11-20 cages, respectively. Regarding the size of the cages, 53% of the producers used 4 m × 4 m × 3 m cages, while 17, 15, and 3% used 3 m × 3 m × 2 m, 4 m × 4 m × 2 m, and 4 m × 4 m × 5 m cages, respectively. Some producers even use 3 m × 2 m × 1.5 m. For their part, Estrada *et al.* (2023) and Pérez *et al.* (2021) also reported square cages of the same size.

Various researches have reported variations in fish density per cubic meter. For example, Castillo-Capitan *et al.* (2014) determined that a 100 fishes/m^3 density favors greater growth, although Kunda *et al.* (2021) reported that 60 fishes/m^3 was an ideal density. Based on their years of experience, producers from Laguna de Tres Palos grow 80 to 100 fishes/

m^3. However, Costa *et al.* (2017) reported that 250 fishes/m^3 was the most adequate density to farm tilapia in floating cages. Given the discrepancies between the various studies, their specific factors must be taken into consideration, including their management system, good production practices, the size of the cages, and the environmental conditions, in order to determine the most appropriate culture density.

This research remedies the lack of published data about the tilapia commercialization chain in the State of Guerrero. The commercialization and productivity aquaculture practices in four key communities (San Pedro las Playas, Plan de los Amates, El Arenal, and Laguna del Quemado) are described, along with the prospects of the market participants (*e.g.*, wholesale and retail buyers, as well as local street vendors). In this sense, producers stick to traditional tilapia commercialization patterns: 1) "producer-wholesalers/distribution center-retailers-final consumer"; 2) "producer-retailer-final consumer"; and 3) "producer-female sellers/housewives-final consumer," as the most direct pattern. These results match the findings of Lango-Reynoso *et al.* (2015) who identified "producer-retailer market" and "producer-market-final consumer" patterns. Therefore, this research took into consideration local participants and described the specifics of the routes, reinforcing and deepening the understanding about the dynamics of the local or regional tilapia market.

For their part, Ahmed *et al.* (2012) and Hsiao *et al.* (2025) also identified the "producers to consumers" channel —including the intermediate "wholesaler to retailer" routes— as the traditional commercialization channel.

Eltholth *et al.* (2015) describe three different tilapia commercialization channels: "producer-wholesale," "producer-retail," and "producer-final consumer." According to them, these channels point out trends and help to achieve a basic understanding of the tilapia value chain. These results fully match the findings of this research.

Meanwhile, profitability is limited by several factors, including the high costs of inputs (fingerlings and feed), the low selling price of tilapia, and specific problems of local fish farms. In this last regard, the interviewees mentioned the pollution caused by the discharge of waters from point and non-point sources. A similar situation was reported by Antwi *et al.* (2017).

Likewise, Antwi *et al.* (2017) and Uddin *et al.* (2021) identified several limitations to the farming of tilapia in cages, including the lack of investment capital, fish robbery, the high cost of feed, education issues, and bad management. For their part, Aldama-Rojas *et al.* (2011) determined a wider list of obstacles, including the presence of predators, the lack of economic support and technical assistance, a defective oxygenation and changes in the color of water, strong winds, bad quality water, inadequate aquaculture practices, and water pollution resulting from inappropriate human practices. In contrast with production and environmental factors, Magcale-Macandog *et al.* (2014) highlighted producer experience as a determining factor for successful aquaculture. This human factor matches one of the key findings of this research. Likewise, the high cost of balanced feed and the lack of working capital force producers to diminish feeding rations. Given the weather conditions during the rainy season (*e.g.*, hurricanes) and the consequent loss of the whole production, producers prefer not to farm tilapia during that period.

In economic terms, on the one hand, Macfadyen *et al.* (2012) determined that tilapia commercialization does not achieve a satisfactory profit margin. This situation is attributed to the reduction of prices in real terms, the flotation of seasonal prices, and particularly buyer distrust caused by water pollution, just like in this research. On the other hand, the research of Villerías (2021) about commercialization channels concluded that, just like fishermen and fisherwomen, aquaculturists distribute their product from local buyers to final consumers. This arrangement matches the route identified in this research. Additionally, Villerias (2021) highlighted that producers obtain greater profits when they sell tilapia directly to the final consumer.

Regarding the different types of markets, Hernández-Arzaba *et al.* (2019) pointed out that tilapia commercialization is mainly concentrated in the local market (95.42%) and that it is almost non-existent in regional and domestic markets.

Acharjee *et al.* (2023) proved the existence of different routes for tilapia commercialization, particularly the "producer-middlemen (wholesaler)–middlemen–final consumer." Under this arrangement, producers sell 40% of their fish directly to middlemen. For their part, Reta-Mendiola *et al.* (2021) focused on the human factor and concluded that a large proportion of aquaculturists lack experience in both production and commercialization. This lack of experience results in a product with low productivity and competitiveness which consequently limits the capacity of producers to develop an industrialization plan. Therefore, their product can only be sold at the production unit, either to people or companies that collect the whole production or final consumers.

Hernández-Arzaba *et al.* (2023) divide the tilapia commercialization channels into direct routes —*i.e.*, "producer-local buyers-final consumer," based on their closeness and price— and routes where middlemen are involved — *i.e.*, "producer-middlemen (fisheries)-final consumer" and "producer-final consumer." In contrast to this commercialization channels, Jing *et al.* (2025) deploy a modernized approach, pointing out that the digital commercial channel for processed tilapia can be directly aimed to the final consumer. This sale method is attractive and provides a feasible opportunity for producers. Additionally, this digital channel justifies specific studies about the digital commercialization of tilapia in the region.

CONCLUSIONS

This research proved that aquaculturists have implemented inadequate production processes, mainly due to the prevailing lack of organization, resulting in favorable conditions for buyers during the tilapia sale negotiations. Meanwhile, the Laguna de Tres Palos aquaculturists have a brief participation in the commercialization chain of tilapias farmed in cages. The first tilapia commercialization chain in which producers are involved is the "producer-wholesalers/distribution center-retailers-final consumer" long form. The second route is the "producer-retailer-final consumer" chain. Finally, the most direct and slightly more profitable chain is composed of "producer-female sellers/housewives-final consumer." Despite the limited sale prices and the high costs of inputs, 88% of the participants reported that they were highly satisfied with their income; nevertheless, producers should sell their products through the direct commercialization channel.

All the tilapia produced by aquaculturists is commercialized whole and fresh. The main limitations to tilapia production are water quality and the cost of balanced feed. The limitations to tilapia commercialization are the low product prices and the point of origin of the fish. Interviewees considered that there are many potential pollution sources, including the discharge of polluted water from point-sources and non-point-sources in the vicinity of farming cages. However, they are acutely aware of the need to help in the preservation and restoration of the water body that they use as a source of income.

Participating aquaculturists should improve the commercialization chain through the enhanced integration of the various steps of production and distribution. An advertising and awareness campaign would promote the consumption of good quality tilapia farmed in floating cages at Laguna de Tres Palos. A project should be developed to improve the production and competitiveness of the tilapia value chain, taking into consideration the reality of the aquaculture producers.

In order to improve tilapia commercialization, two key actions have been proposed to achieve greater visibility: boosting trade through electronic tools (*i.e.*, digital marketing) and strengthening the distribution and supply chain. In addition, access to the product would increase consumer preference for tilapia.

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