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A Smallholders' Mariculture Device for Rearing Seafood: Environmentally Friendly and Providing Improved Quality

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Abstract: The aquaculture industry in Taiwan grosses more than USD 1.1 billion annually; however, it also generates considerable waste discharge (causing eutrophication in estuarine and coastal waters) and heavy groundwater withdrawals (causing land subsidence in coastal areas). Many aquaculture facilities using earth ponds are affected by benthic algae, resulting in an earthy odor, and fixed-cage farms are difficult to relocate during cold weather events. In this study, we tested small-scale (~15 ton) mobile cage tanks for the nearshore rearing of white shrimp and grouper in the Yung-An district of Kaohsiung, Taiwan. At the conclusion of the mariculture experiment, the content of free amino acids in shrimp and groupers reared in our mobile tanks surpassed that in animals reared locally in traditional earthy ponds. In a blind taste test involving 42 volunteers, groupers reared in mobile cage tanks were deemed more palatable than those raised in ponds. Our results demonstrate that small-scale mobile cage tanks are a feasible approach to the sustainable rearing of high-quality shrimp or fish. Note that wastewater from the mobile tanks is easily diluted by seawater, thereby reducing the likelihood of eutrophication in coastal regions. The proposed system could also be used for recreational fishing activities to increase income for smallholders of fishermen and/or aquaculture farmers.

Keywords: sustainable food production; mobile cage farms; flavors improvement

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1. Introduction

According to projections in the latest revision of the UN population prospects (medium variant), the world population will grow from 7.79 billion in 2020 to 9.74 billion in 2050 [1]. This is expected to impose enormous pressure on the global food system, particularly against the background of climate change [2]. Global environmental changes and human activities have led to profound readjustments in ecosystems [3–5]. Wild fish stocks are under pressure in most parts of the world, and marine fisheries have declined sharply due to overexploitation [6–8]. Aquaculture is expected to play an important role in the supply of fish and food security for the foreseeable future [9–12].

The aquaculture industry in Taiwan includes marine culture, freshwater ponds, brackishwater ponds, ornamental fish culture, amounting to production output of 278,500 tons in 2020 [13]. Note however that these facilities also discharge tremendous quantities of organic matter, feces, and uneaten feed, which can lead to eutrophication in estuarine and coastal waters. Many aquaculture farmers also pump groundwater to dilute nutrient concentration in fish ponds, which contributes to land subsidence in coastal areas [14–21].

It has been reported that consumers prefer seafood that is cultivated in seawater, rather than in low salinity water, due to its superior flavor, texture, and odor [22,23]. Pond-cultured fish tend to exude earthy-musty (muddy) flavors [24,25], resulting from bottom sediment and algae (*Scillatoria tenuis* and *Anabaena macrospore*). The former produces earthy components (Geosmin and 2-Methylisoborneol), and the latter is resulting in a muddy taste [26]. This phenomenon is frequently observed in freshwater fish (e.g., tilapia, carp, silver carp) as well as brackishwater fish (e.g., milkfish and grouper). Note that the flavor of seafood can be attributed to the content of amino acids, sugars, nucleotides, and mineral salts [27]; however, amino acids are believed to play a particularly important role in the sensory quality of seafood [27,28].

There is a pressing need for sustainable aquaculture systems capable of increasing productivity, enhancing product quality, and reducing the negative impact on the environment [28–31]. Numerous countries have sought to reduce the environmental impact of aquaculture installations by implementing large-scale cage farms; however, the cost of the equipment is very high (> USD 0.6 million; Ever Spring Marine Aquaculture Co., Ltd. [32,33]), far exceeding the capability of most small-scale fisheries. These systems are also difficult to manage [34–36], particularly during extreme weather events (e.g., typhoons and cold shocks) [24].

The concept of the mobile cage tank originated with live-fish transportation firms seeking ways to refresh seawater within the tank. In this study, we tested small-scale (~15 ton) mobile cage tanks for the nearshore rearing of white shrimp and grouper in the Yung-An district of Kaohsiung, Taiwan. At the conclusion of the mariculture experiment (short-term and long-term), the content of free amino acids in shrimp and groupers reared in our mobile tanks surpassed that in animals reared locally in traditional earth ponds. In a blind taste test involving 42 volunteers, groupers reared in mobile cage tanks were deemed more palatable than those raised in ponds. We also compared the chemical composition of muscle in the two systems to further assess the quality of seafood flesh.

2. Materials and Methods

2.1. Proposed Mobile Cage Tank System and Experiments

This study was part of a larger project referred to as the Land-Ocean Interactions Changing Coastal Zones of Taiwan: Scientific Basis and Societal Engagements Project. The experiment site was in the semi-enclosed water of Yongxing bay with an average depth of 5~6 m (Figure 1). Two self-flushing cylindrical mobile cage tanks (SEFLU-TANK) were clad in a polystyrene donut for floatation and held in place at the surface via attachment to two powerful anchors. Each cylindrical tank contained roughly 13 tons of seawater (diameter with caps ~3 m) with 14 honeycomb inlets on the hull and bottom allowing the free exchange of seawater via tidal action without the need for an aeration system (Figure 2). Note that to ensure flow, biofilm around the water inlets and outlets had to be cleared out manually at intervals of roughly two weeks. Throughout 2019 and 2020, each mobile tank was respectively used to rear white shrimp (Tank A) or grouper (Tank B). During that period, the tanks remained in excellent condition, (requiring only the replacement of a few anchor lines) despite experiencing two typhoons and one low-temperature event.

A total of 200 Pacific white shrimp from Pingtung county, Taiwan (Penaeus Vannamei, 7–8 cm) were transferred to Tank A (stocking density was 28.3 shrimp/m^2) for seawater cultivation. The animals were fed twice a week using a commercial diet (38% crude protein, 3% crude fiber, 3% crude fat, 11% moisture, and 17% ash). The shrimp grew to roughly 14.6 cm (22.2 g) over a period of 160 days. Free amino acid levels were measured at day-27 (n = 3) and day-160 (n = 6). As a reference, we also measured free amino acid levels in local white shrimp reared in a traditional facility using brackish water in an earth pond.

A total of 30 groupers from Pingtung county (*Epinephelus lanceolatus*; average length = 20 cm; average weight = 0.6 kg) were transferred directly into tank B to undergo short-term (27-day) cultivation at a stocking density of 4.2 animals/m^2). The animals were fed twice a week using coarse fish (mainly small mackerel). During this period, the groupers grew to roughly 30 cm (0.9~1.2 kg). Free amino acid levels were measured at day-27 (n = 3).

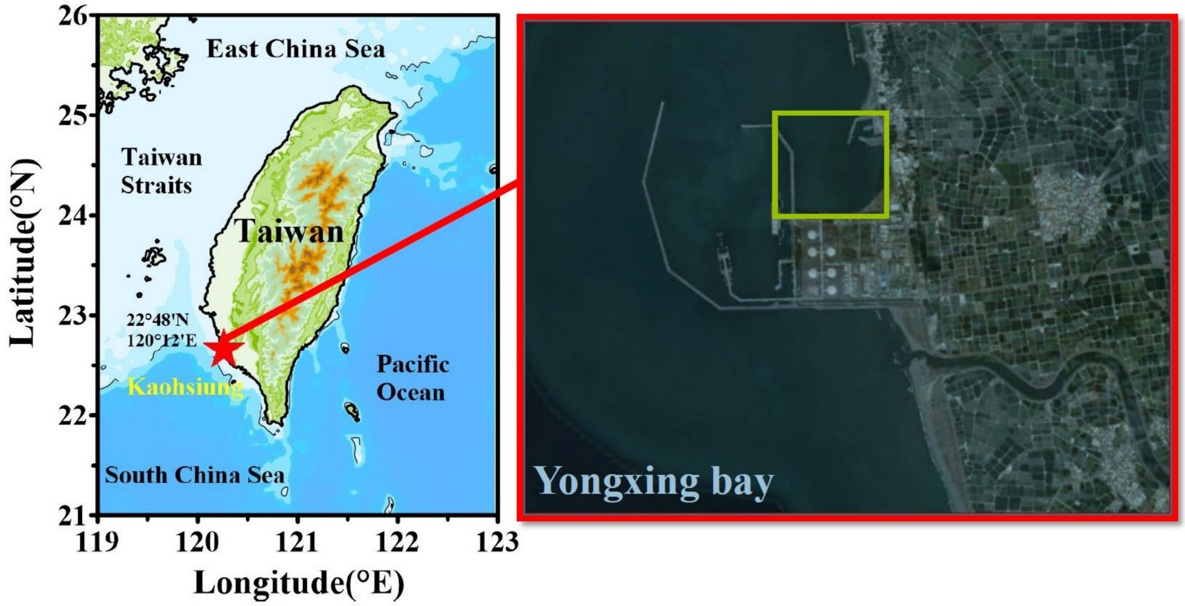

Figure 1. Small-scale mobile cage farm tanks located at Yongxing bay, Kaohsiung.

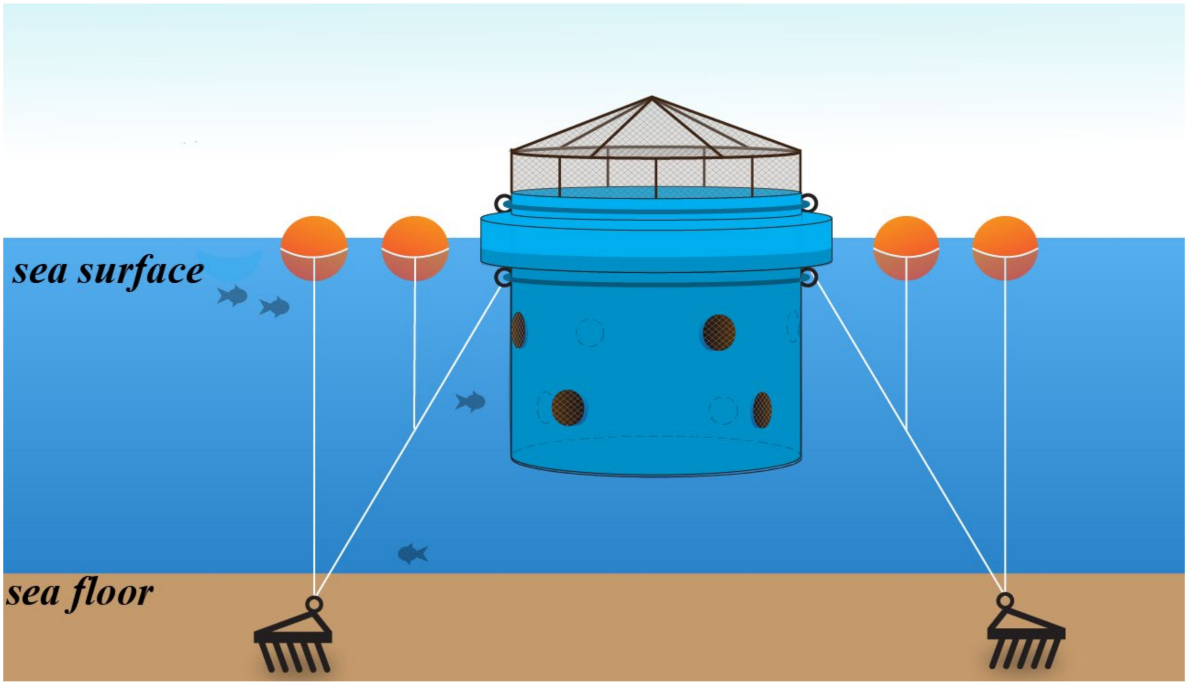

Figure 2. Prototype tank (SEFLU-Tank) system comprising a fiber-reinforced polymer (FRP) main tank with 14 honeycomb pores on the hull and bottom allowing the free exchange of seawater.

Following the completion of this short-term cultivation trial, an additional 30 groupers (average length 25 cm; average weight 0.7 kg) underwent long-term (75-day) cultivation in tank B. The groupers were fed small mackerel once a week. During that cultivation period, the groupers grew to roughly 35 cm (1.2~1.5 kg). Free amino acid levels were measured at day-75 (n = 6). As a reference, we also measured free amino acid levels in grouper reared locally in a traditional facility using a brackish water pond (Pingtung County, Kaohsiung). Note that the reference animals were purchased from random sellers at a local market, and farm records were available, ensuring suitable rearing conditions. Note also that salinity value ranged from 15–28 psu and farm records were not documented.

2.2. Surrounding Hydrographic Conditions

Weather information, including air temperature, precipitation, and wind speed, were obtained from the Yong An station (Central Weather Bureau, Taiwan). Surface seawater temperature and light intensity were monitored using a HOBO Pendant Temperature/Light Data Logger (Type: UA-002-08). Multiple sensors were used to obtain weekly measurements of in-tank conditions, including salinity levels, pH, and dissolved oxygen concentrations (Model: pH 3110 SET2; W.T.W. Cond 3310 SET1; and H.Q. 40d LDO electrode). Nitrite concentrations in the tanks were measured using the pink azo dye method, in accordance with the methods outlined by Pai et al. (1990) [37]. Note that nitrate (NO_3^-) was the primary source of nitrogen; however, nitrite (NO_2^-) is toxic [38–40]. We therefore focused on nitrite as a long-term indicator of nitrogen accumulation in the tanks.

2.3. Free Amino Acids

As mentioned above, free amino acid (FAA) levels in the shrimp tank were measured at day-27 and day-160. FAA levels were measured in the groupers at day-27 and day-75. Briefly, 0.5 g samples of *Penaeus Vannamei* (white shrimp) or *Epinephelus lanceolatus* (grouper) flesh were homogenized in 25 mL of 0.1 N HCl and then filtered through a 0.45 µm nitrate fiber filter (Millipore). We then added 20 µL aliquots of the filtrate to 100 µL of 0.4 M boric acid buffer for storage. The resulting extracts were subsequently used to quantify the free amino acids using a Pico T.A.G. Amino Acid Analysis System (Waters Corporation, USA). All values are reported as the mean ± and standard deviation (S.D.).

2.4. Blind Taste Test

Following short-term (27-day) cultivation, three of the groupers were bled and then soaked in icy cold seawater for a few minutes. At the same time, three groupers from Yong-An's traditional earth pond underwent processing using the same procedure. The animals were immediately cut into small pieces and boiled in fresh water for 10-min with a small amount of added salt. After cooling for a couple of minutes, the flesh was served to 42 volunteers (28 males and 14 females; 18–72 years) to assess to quality of the meat in terms of texture, overall taste, and earthy taste, assigning scores of 0 (bad) or 1 (good).

2.5. Statistical Analysis

Statistical analysis was performed on the background environmental conditions (Yongxing bay) and conditions inside the mobile cage tanks with the aim of characterizing seawater quality. We also analyzed FAA levels in grouper and shrimp flesh. Data are expressed as mean ± S.E. (standard error) and differences between samples were analyzed using Student's *t*-test. The level of significance was set at $p < 0.05$. Statistics analysis was conducted using Excel 2019 (Microsoft Excel for Windows, Albuquerque, NM, USA).

3. Results

3.1. Hydrographic Conditions in Tanks

Table 1 lists the hydrographic data (Temperature, T; salinity, S; dissolved oxygen, DO; pH, and nitrite (NO_2) concentration) in the surrounding water and inside tanks A and B. In situ measurements revealed that water conditions (T and S) inside and around the tanks were similar, indicating good water exchange performance. The average DO concentration in shrimp and group tanks (7.06 ± 0.23 ppm) was very close to the values in the surrounding water (7.12 ± 0.28 ppm). The difference in average salinity between the tanks (31.27 ± 1.96 psu) and surrounding water (31.31 ± 1.84 psu) did not reach the level of statistical significance ($p = 0.93 > 0.05$).

Table 1. Environment parameters in the tanks and surrounding water.

Parameters	Surrounding Water	Tank A	Tank B	Average
Temperature (°C)	23.52 ± 1.78	23.18 ± 2.24	23.72 ± 1.72	23.45 ± 2.01
Salinity(psu)	31.31 ± 1.84	31.24 ± 1.93	31.30 ± 2.02	31.27 ± 1.96
DO (ppm)	7.06 ± 0.23	7.14 ± 0.30	7.11 ± 0.26	7.12 ± 0.28
pH	8.12 ± 0.11	7.91 ± 0.20	8.09 ± 0.18	8.00 ± 0.21
NO_2^- (µM)	0.04 ± 0.08	0.08 ± 0.08	0.04 ± 0.08	0.06 ± 0.08

Nitrite (NO_2) concentrations in the two tanks (average 0.06 ± 0.08 µM) and the surrounding water (0.04 ± 0.08 µM) were close to the detection limit (0.05 µM), indicating that nutrients were not accumulated in the tanks.

3.2. FAA Concentrations in White Shrimp (Penaeus vannamei)

Total FAA concentrations in white shrimp flesh were as follows: day-27 (3307.3 ± 704.4 mg/100 g) and day-160 (1476.3 ± 123.2 mg/100 g), local shrimp (1265.6 ± 182.2). Note that the total FAA content was far higher under short-term mariculture than under long-term mariculture or traditional earth ponds. Note also that under short-term mariculture conditions, glycine and arginine levels were 2- to 5-fold higher than under long-term or earth pond conditions. Other FAAs included aspartic acid, glutamate, serine, threonine, alanine, proline, tyrosine, valine, methionine, cysteine, isoleucine, and leucine. Finally, it should be noted that FAA concentrations of shrimp reared in mobile cage tanks exceeded those of traditional earth ponds, regardless of growth duration (Figure 3, Table 2). Detailed information on amino acid raw data is shown in the supplement (Table S1).

Table 2. Free amino acid levels in white shrimps (*Penaeus vannamei*).

Unit (mg/100 g)		A	B	C	D	E
Aspartic acid	Asp	1.2 ± 2.1	1.1 ± 2.6	5.3 ± 5.9	8.5 ± 1.1	9.9 ± 2.1
Glutamate	Glu	53.5 ± 9.5	0 ± 0	0 ± 0	34.5 ± 1.7	28.2 ± 1.8
Serine	Ser	16.3 ± 3.6	7 ± 0.6	114.2 ± 33.9	21.6 ± 1.5	19.6 ± 2.4
Glycine	Gly	1561.8 ± 266.4	675.6 ± 37.7	313.1 ± 49	333.7 ± 2.5	301 ± 1.5
Histidine	His	0 ± 0	0 ± 0	0 ± 0	16.5 ± 0.6	11.2 ± 0.9
Arginine	Arg	1225 ± 292.2	567.8 ± 104.1	311 ± 63	244.5 ± 8.2	136.6 ± 2.3
Threonine	Thr	7.4 ± 12.8	0 ± 0	0 ± 0	14.8 ± 0.8	19.5 ± 1.1
Alanine	Ala	81.2 ± 42	38.4 ± 8.4	73.3 ± 16.4	97.8 ± 2.3	177.4 ± 3.1
Proline	Pro	246.3 ± 156.7	23.9 ± 12.4	319 ± 24.4	74.6 ± 1.2	69.4 ± 1
Tyrosine	Tyr	14.7 ± 6.8	13.3 ± 11.5	15.8 ± 5.7	16.8 ± 0.8	24.9 ± 1
Valine	Val	12.4 ± 5.6	6.4 ± 3.3	17.6 ± 5	32 ± 0.8	41.9 ± 0.7
Methionine	Met	8.7 ± 1.4	8.5 ± 1.9	7.5 ± 1.6	15.1 ± 3.1	11.8 ± 2.1
Cysteine	Cys	14.8 ± 15.9	18.6 ± 3	21.6 ± 5.1	22.4 ± 1.4	25.3 ± 2.1
Isoleucine	Ile	11.1 ± 7	9.8 ± 11.2	9.7 ± 5.8	16.4 ± 1.2	25.7 ± 2
Leucine	Leu	24.2 ± 9.3	59.6 ± 13.8	20.6 ± 11.2	27.4 ± 0.7	45.4 ± 1.2
Phenylalanine	Phe	7.3 ± 3.8	6.9 ± 3.4	16.8 ± 17.6	20.5 ± 2.1	23.9 ± 1.1
Lysine	Lys	21.3 ± 9.1	39.6 ± 3.2	20.1 ± 17.8	23.2 ± 1.9	32.3 ± 2.2
Total		3307.3 ± 704.4	1476.3 ± 123.2	1265.6 ± 182.2	1020.2 ± 10.9	1003.9 ± 11.6

Note: A: Short-term culture (27 days, $n = 3$); B: Long-term culture (160 days, $n = 6$); C: Local samples (N/A days, seawater 15–32 psu, $n = 6$); D:Seawater (120 days, Seawater 30 psu, $n = 10$); E: Low salinity (120 days, Brackish water 0.5–1.5 psu, $n = 10$); The data of D and E were obtained from [41].

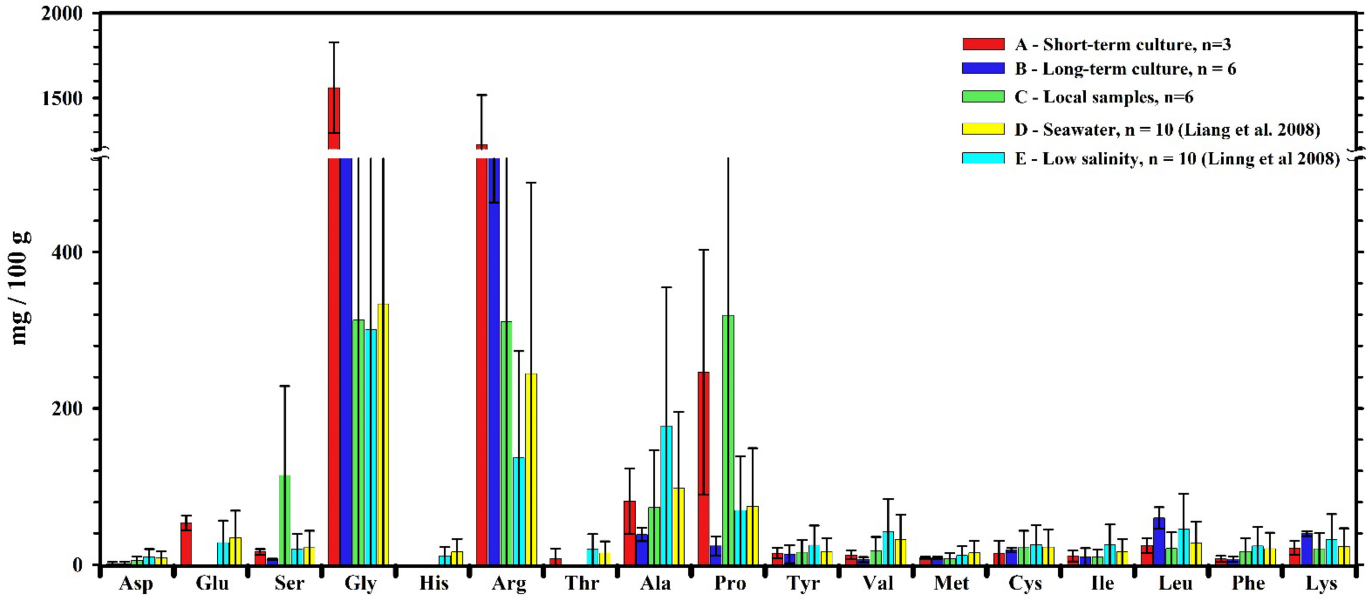

Figure 3. FAA analysis in white shrimp (*Penaeus vannamei*); The data of D and E were obtained from [41].

3.3. FAAs Concentration in Groupers (Epinephelus lanceolatus)

Total FAA concentrations in grouper meat were as follows: Day-27 (845.1 ± 141.2 mg/100 g), day-75 (564.9 ± 121.9 mg/100 g), and traditional earth pond cultivation, where salinity = 15~28 psu (416.8 ± 59.5 mg/100 g) (Figure 4, Table 3). Note that FAA concentrations in grouper meat were higher after short-term cultivation than after long-term cultivation (t-test, $p = 0.02 < 0.05$) or cultivation in traditional earth ponds (t-test, $p = 0.01 < 0.05$). The FAAs in groupers included glutamate, serine, glycine, arginine, threonine, alanine, proline, tyrosine, valine, methionine, cysteine, isoleucine, leucine, and lysine. Detailed information on amino acid raw data is shown in the supplement (Table S2).

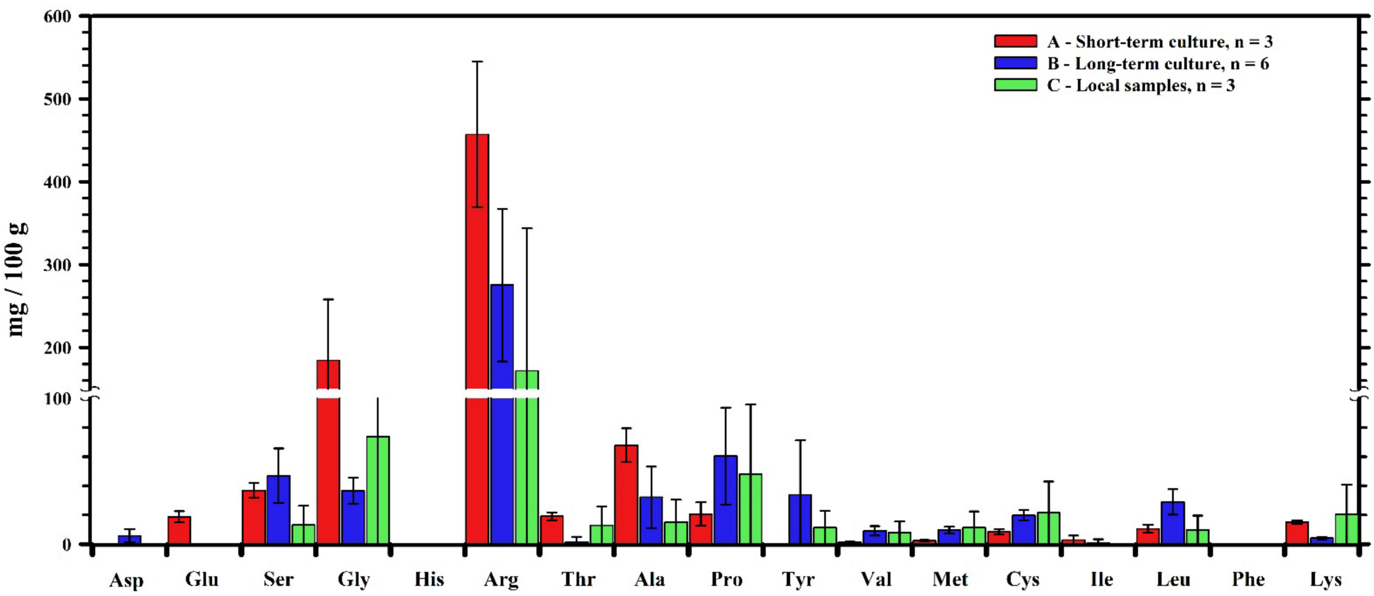

Figure 4. FAA analysis in groupers (*Epinephelus lanceolatus*).

Table 3. FAA analysis in groupers (*Epinephelus lanceolatus*).

mg/100 g		A	B	C
Aspartic acid	Asp	0 ± 0	5.7 ± 4.6	0 ± 0
Glutamate	Glu	18.7 ± 3.9	0 ± 0	0 ± 0
Serine	Ser	36.8 ± 5.1	47 ± 18.6	13.1 ± 22.7
Glycine	Gly	184.4 ± 73.6	36.6 ± 9	73.8 ± 26.6
Histidine	His	0 ± 0	0 ± 0	0 ± 0
Arginine	Arg	457.1 ± 87.7	275.4 ± 92.1	171.9 ± 35.1
Threonine	Thr	19 ± 2.8	1.5 ± 3.6	12.9 ± 2.3
Alanine	Ala	67.8 ± 11.5	32.1 ± 21	15.2 ± 3.2
Proline	Pro	20.6 ± 8.1	60.4 ± 33.2	47.8 ± 6.8
Tyrosine	Tyr	0 ± 0	33.8 ± 37.4	11.4 ± 0.7
Valine	Val	1.4 ± 0.4	9.1 ± 3.3	7.8 ± 1.4
Methionine	Met	2.4 ± 0.4	9.7 ± 2.3	11.3 ± 0.6
Cysteine	Cys	8.4 ± 1.9	19.7 ± 3.5	21.5 ± 1.8
Isoleucine	Ile	2.8 ± 3.1	1 ± 2.4	0 ± 0
Leucine	Leu	10.5 ± 2.8	28.8 ± 8.7	9.8 ± 1.7
Phenylalanine	Phe	0 ± 0	0 ± 0	0 ± 0
Lysine	Lys	15.1 ± 1.1	4.2 ± 0.8	20.4 ± 4.9
Total		845.1 ± 141.2	564.9 ± 122	416.8 ± 59.5

Note: A: Short-term culture (27 days, $n = 3$); B: Long-term culture (75 days, $n = 6$); C: Local samples (N/A, $n = 3$).

3.4. Blind Sensory Test: Groupers

The sensory tests revealed significant differences between groupers reared in seawater and those raised in traditional earth ponds in terms of flavor and texture (Figure 5). Note that this approach to sensory testing is semi-quantitative; however, our results are consistent with the higher FAA levels. In assessing samples in terms of the taste, agreed with the meat without earthy odor, the results were very clear: seawater mobile cage tanks (100%) and traditional earth ponds (71.4%). In other words, all assessors reported that the groupers raised in seawater were free from an earthy taste (Table 4).

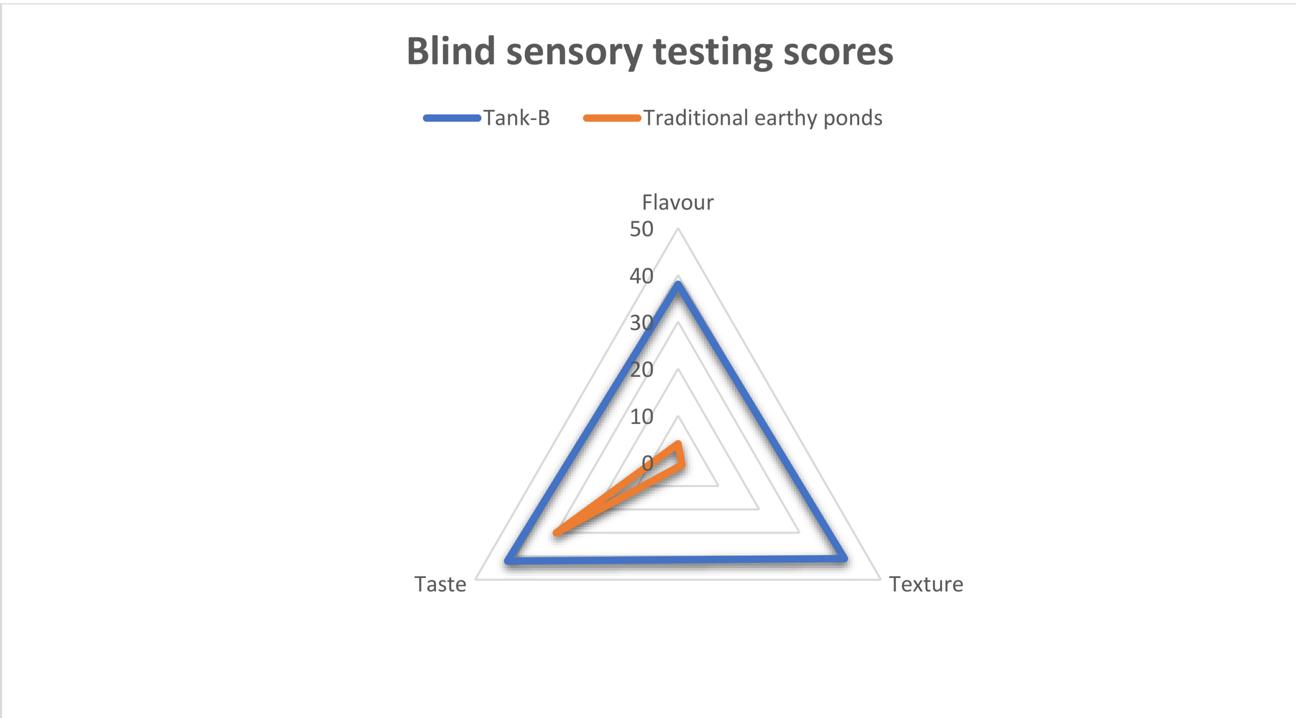

Figure 5. Blind taste test of grouper flesh.

Table 4. Blind taste test of grouper flesh.

n = 42		Scores (Percentage of Agreement)	
		Tank-B	**Traditional Earth Pond**
Flavor	Umami/Sweetness	38 (90.5%)	4 (9.5%)
Texture	Springy/Firm	41 (97.6%)	1 (2.4%)
Taste	Without Earthy-odor	42 (100%)	30 (71.4%)

Note: Tank-B samples were cultivated at sea for 27 days, whereas traditional earth pond grouper were cultivated in treated seawater. In comparing two samples, the assessors assigned 1 point for each item.

4. Discussion

4.1. Operating the SEFLU-TANK in the Marine Environment

The SEFLU-TANK is designed to facilitate the tide-induced flow of seawater into and out of the tank, the effectiveness of which can be assessed indirectly in terms of salinity, DO, and nutrient concentrations (Figure 1 and Table 1). Nonetheless, biofilms forming around the water inlets grew sufficiently to impede flow when temperature, irradiance, and water conditions were suitable. This necessitated bi-weekly cleaning.

During the 2-year experiment period, we determined that the number of honeycomb inlets could be increased (up to 20 in a single tank) to further promote the exchange of seawater. Note that we are planning to test this in the future. We also found that attaching black screens to the top of the tanks improved the conditions for shrimp by reducing solar radiation. The tanks also survived the experiment with very little wear and tear, despite the onslaught of storms and cold fronts. Note that the effects of heavy rainfall will have to be tested in the future.

Harmful algae blooms (HABs), such as red tide, are a persistent threat to marine aquaculture in coastal waters [42–44]. Under HAB conditions, it should be possible for aquaculture farmers to close the seawater inlets and thereby prevent ingress by toxic organisms from outside the tanks. Nonetheless, the SEFLU-TANK system will have to be tested in a HAB-prone region, such as Hong Kong. Note also that in this study, the SEFLU-TANK was tested in a coastal region. Future experiments in freshwater systems should be conducted in the future.

Our experience gained in these experiments revealed that operating the SEFLU-TANK system is far easier than operating large-scale commercial cage farms. Systems such as this are also highly versatile, allowing cooperation with traditional aquaculture farmers who could provide juvenile groupers and/or shrimps for short-term mariculture. This strategy should improve the quality of the products and thereby create new vending opportunities [45,46], especially when Taiwan's aquatics were forbidden to export to mainland China for non-economic reasons [40,41].

These small-scale mobile cage tanks proved highly effective in reducing nutrient concentrations via water exchange. When dealing with earth ponds, it is exceedingly difficult to dilute the copious quantities of organic matter and nutrients [21]. The accumulation of waste in earth ponds can have detrimental effects on the quality of the product and increase the risk of pathogen contamination. A shift away from traditional aquaculture farms to mobile cages would also mitigate the risk of eutrophication and hypoxia in coastal waters [30,31].

The coastal waters of Taiwan have for decades been subjected to overfishing and improper fishing techniques (e.g., bottom drags, drift nets), leading to ecological catastrophes and a collapse of fisheries [47–49]. According to the Yearbook of Fishery Statistics, offshore fisheries production in Taiwan dropped from 410,000 metric tons in 1980 to just 2000 metric tons in the early 2000s [50]. Environmentalists have yet to observe any increases in fishery production [50–52]. In an effort to preserve the livelihood of fishermen, the Taiwanese government has sought to establish multi-functional fisheries, such as the recreational fishing and artificial reefs established on Penghu Island [53]. Nonetheless, after years of waiting, many fishing harbors have been all but abandoned [54–56]. The newly vacated dock spaces could theoretically be used by vessels dedicated to recreational fishing; however, this would also require a notable increase in fish stocks [55,56].

This paper presents a viable approach to rearing high-quality fish featuring elevated FAA concentrations without an earthy odor. The modest size of the tanks (<15 tons) is ideally suited to small-scale operations based on fish farming for specialty markets of recreational fishing [51,57]. The small scale of the tanks would also make it far easier to maneuver them into safe areas during typhoons, especially when it causes massive freshwater influxes to coastal regions [58]. Finally, small-scale operations should also make it possible to remove the fish temporarily in the event of marine pollution, red tide, or extremely cold weather events [59–61].

4.2. Improvements in the Quality of Fish and Shrimp

Aquaculture farmers are well versed in the use of brackish water to increase fish and shrimp growth rates by reducing the energy spent resisting the osmotic pressure induced by seawater. However, this strategy imposes a tradeoff in terms of quality of the flesh, which falls far short of that in wild-caught fish or shrimp. The small-scale mobile cage tanks described in this paper were shown to enhance the quality of flesh. We also found that caged fish mariculture is an effective approach to eliminating the earthy odor common to fish raised in traditional earth ponds. Farmers use algaecides to remove Oscillatoria and Anabaena, and pond-raised fish are generally moved to clean water for 1–2 weeks prior to sale [62,63]. Nonetheless, the reference fish and shrimp in this study (purchased in a market) were unable to match the quality of cage-raised animals.

In the current study, we obtained objective evidence (FAA levels) as well as the subjective assessment of consumers (sensory test), indicating that the flesh of cage-raised fish and shrimp is superior to that of pond-raised animals. It is reasonable to assume that most consumers would be willing to pay a higher price for seawater-reared animals, considering that the taste and texture are very similar to those of wild-caught products. We believe that a higher quality product represents a solid opportunity for smallholders. Note that in the FAO report "Food and Agriculture: Key to achieving the 2030 agenda for sustainable development", this is precisely the type of endeavor required to end poverty and bring about sustainable development [64].

Note that the FAA levels in the experiment group (1.5–3.3 $g/100\ g^{-1}$) exceeded those obtained in aquaculture ponds; however, they fell far short of those in tiger shrimp (19.5 ± 0.69 $g\ 100\ g^{-1}$) [65]. This is reasonable, considering that FAAs account for only a fraction of the total amino acid (TFAAs) in shrimp flesh. Furthermore, shrimp cover a wide variety of arthropod crustaceans with a wide variety of biologically active peptides [66].

4.3. Implications of Short-Term Cultivation

Our comparison of short-term versus long-term shrimp and grouper cultivation (Tables 2 and 3) revealed significant differences in FAA concentrations (shrimp t-test, $p = 0.04 < 0.05$; grouper t-test, $p = 0.02 < 0.05$). Taken together, it appears that short-term rearing is superior to long-term rearing in terms of quality, regardless of the animal type.

When the grouper cultivation duration was extended to 75 days, FAA concentrations in cage-raised animals were higher than in pond-raised animals; however, the difference did not meet the level of significance (t-test, $p = 0.09 > 0.05$). It is possible that this was due to a reduced feeding rate (once per week); however, this issue should be studied in the future. It is also important to note that this phenomenon did not occur with the shrimp (t-test, $p = 0.04 < 0.05$). Overall, FAA concentrations in shrimp showed a gradual decline over time. Note that all of the tank-raised shrimp (short-term and long-term rearing) presented elevated FAA levels. In the current study, we did not perform a blind taste test on shrimp; however, it is very likely that juvenile shrimp reared in seawater mobile tanks taste better than their counterparts raised in traditional ponds.

At this point, it is difficult to surmise why the FAA levels in shrimp and groupers from short-term mariculture were higher those from long-term rearing. There are a number of possible explanations including salinity [67–70]; nitrite concentrations [71,72], stocking density [73]; water conditions (dissolved oxygen, stable salinity levels) [74,75]; and competition for food. Nonetheless, further research will be needed to study differences in quality under short-term and long-term mariculture.

4.4. Public Policy and Industrial Transformation

The fishing industry is currently affected by climate change, rising energy prices, the designation of special economic zones, catch quotas in the high seas, and the depletion of fishery resources. The transformation of fisheries into tourism is a global trend, which has been proceeding in Taiwan for over three decades [51].

The Taiwan government recently proposed the Coastal Blue Economy Growth (CBEG) program to promote sustainable ocean-related industries. The government also launched the Community-Based Sea Farming (CBSF) project in 2015 to promote sea farming and the transformation of capture fisheries [57]. As mentioned previously, the fish cultured in mobile cage tanks could be used as targets in recreational fishing activities. Aquaculture farmers could provide fish for mobile tanks or release them into the wild to generate an environment suitable for recreational fishing.

5. Conclusions

This study evaluated the small-scale mobile cage, "SEFLU-Tank System," as a nearshore or offshore farming device. In experiments involving the short-term (close to one month) cultivation, we obtained objective evidence (FAA levels) as well as the subjective assessment of consumers (taste tests) indicating that the flesh of cage-raised fish and shrimp is superior to that of pond-raised animals. Our results demonstrate that small-scale mobile cage tanks are a feasible approach to the sustainable rearing of high-quality shrimp or fish. Furthermore, the small scale of these tanks is ideally suited to smallholders seeking to diversify and increase their income.

We recommend that local governments in Taiwan consider allowing the operation of small-scale mariculture systems to generate economic opportunities for small operators while reducing the negative environmental effects of traditional aquaculture.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su15010862/s1, Detailed information on amino acid raw data is shown in the supplement (Tables S1 and S2).

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