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Potential Use of Water Hyacinth (Eichhornia Crassipes), to Reduce Production Cost in Tilapia Culture at Small and Median Scale

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ABSTRACT

Tilapia farming is increasing in the US, Mexico, and other countries, but anywhere the cost of feed is the big problem. Therefore, to reduce production costs the water hyacinth aquatic plant was used as a food supplement. Dehydrated water hyacinth was combined with cane molasses and anaerobically fermented with (*Lactobacillus acidophilus*). The fermented product was mixed with cornmeal and commercial food (Purina®), at proportions of 30-20-50, respectively. The mixture was extruded and dried, to be used as a feed supplement for tilapia. Tilapia juveniles between 5-7 g were obtained from a commercial hatchery and fed with Purina®, until fishes reached 24-26 g; then, tilapias were separated into two groups, the experimental and the control groups. The experimental group, 40 tilapias, was transferred to a 4032 L pond while the control group,15 tilapias, were distributed in 5 ponds of 300 L. This ensured that the stocking density was around (10 fish/m^3) in all ponds. The experimental group was fed with water hyacinth-supplemented food, while the control group with Purina®. Tilapia from both groups were weighed every 2 weeks for 3 months; moreover, the water quality parameters pH, O_2, T (^{o}C), TSS and total ammonia were recorded in all the ponds. To know the tilapia growth from both groups, several growth parameters, such as: weight gain, relative growth rate, feed conversion ratio and specific growth rate were calculated. Results showed that weight gain in tilapia fed with supplemented water hyacinth food was 8.6 g higher, than tilapias fed with only Purina®. Also, the food cost of tilapias fed with water hyacinth-supplemented feed was 15.37 % lower than tilapia fed with Purina®. Therefore, it can be concluded that tilapia aquaculture at small and medium scale can developed satisfactorily using water hyacinth-supplemented feed.

Keywords: Tilapia aquaculture, Water hyacinth, Cost reductions, Small hatcheries.

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I. Introduction

In ancient cultures, there are several cases of the use of aquatic plants in the cultivation of fish, or co-cultures of plants and fish. The Chinese and other Asian cultures have cultivated fish in their rice fields for thousands of years. In Mexico, the Aztecs and other pre-Hispanic cultures developed a system where corn, bean, flowers, shrimp and freshwater fishes grew together. This system is known as Chinampas. Currently it is practiced only in the Xochimilco lake, in south Mexico City, Fig.1. The Chinampas are small islands with channels in the lake where plants and aquatic animals grow together, conforming an ecosystem in equilibrium. Unfortunately, these forms of aquaculture production have disappeared.

Today, the largest number of fish farms use soybean or fish meal-based feed for the fish growth, which increases production costs, since these flours are not cheap. Also, the unconsumed food and the chemical added to combat diseases increase the organic charge and pollution in the disposable waters from the hatcheries. Therefore, currently much research is focused on the use of plants or organic wastes in aquaculture as alternative feed or supplements to feed.

Fig. 1. The Chinampas in the Xochimilco lake, in South Mexico City. As can be observed, they are small islands with channels where corn, bean, flowers, shrimp, and freshwater fishes are cultivated together; also, Ahuehuetes trees (*Taxodium huegelii* C. Lawson1851) grow along the channels and the trees' roots prevent erosion. The Chinampas are a system where the wastes produced by aquatic organisms supply nutrients for plants growing, which in turn purify the water.

On the other hand, in tropical and subtropical regions there are many aquatic and terrestrial plants which have not been used or are underutilized in freshwater aquaculture, like tilapia and other fishes, as in other productive activities. This is the case with water hyacinth, melaleuca, water chestnut, juncus, etc. Incorrectly, these plants are considered invasive or plagues, since they can "invade" diverse freshwater environments, such as wetlands, lakes, rivers, irrigation fields and aquaculture facilities [1].

In Mexico the water hyacinth has no use, and sometimes is considered as a plague, since due to its rapid growth it can cover large areas of lakes and others body water, causing low levels of dissolved oxygen and then eutrophication, thereby rendering the water unsuitable for aquaculture of fish and other freshwater animals. However, recent research has shown that some aquatic and terrestrial plants have been used as feed or to protect fish from diseases caused by pathogen agents [2]. In this work, the authors carried out an important review of many plants with potential uses in aquaculture and veterinary medicine: for instance, the rosemary plant (*Rosmarinus officinalis*) has gained importance for its biological proprieties as anti-inflammatory, antimicrobial, antioxidant and anticancer properties, due to its secondary metabolites, such as carnosic acid, carnosol, rosemary acid and camphor, with beneficial effect on fishes, particularly in tilapia *(Oreochromis niloticus)* [3], [4]. Also this aquatic plant known in Mexico as Romero, has compounds with pharmacological properties of interest in the medicinal field due to their diverse aromatic compounds, essential oils and bioactive compounds [5], [7].

The garlic (*Allium sativum*) is a species within the Liliaceous family with nematicide properties in as the common carp *(Cyprinus carpio)* and tilapia *(Oreochromis niloticus)* [5], [7]. Another fairly common plant is (*Leucaena leucocephala*), known in Mexico as huaxyacac, huaje or guaje. It is an arboreal species of the legume family with anthelmintic properties in fishes such as catfish and tilapia [9], [10]. Another very common plant in Mexico is the (*Calendula officinalis*) known as gold button. Calendula or "flower of the dead", since it is used during the celebration of the day of the dead is an herb of the Asteraceae family; the extracts of this flower have antibacterial properties particularly on (*Staphylococcus aureus and Pseudomonas aeruginosa*) that cause infections in the stomach and gills of tilapia [11].

All these plants have active ingredients such as alkaloids, tannins, flavonoids, coumarins, quinones, terpenoids, simarubalidans, melicianins, limonoids, lactoses and lignans [6]. The red mangrove (*Rhizophora mangrove)* is an aquatic plant of the family Rhizophoraceae, the genus Rhizophora being the best known, and is widely found in mangrove ecosystems and marshes. It has strong antibacterial, antiseptic and antifungal action on many fish and other aquatic organisms [12]. In another work, the antiviral capacity in the phytotherapy of medicinal and aromatic plants in salmonid fish is addressed [13]. The development of drug resistant pathogens is a phenomenon that is affecting aquaculture. The treatment of microbial infections in fish and crustaceans involves dissolving large amounts of chemotherapeutic agents in the water pond or in feed. Most of these antibiotics are prohibited in the European Union, the United States and other countries. Plant products present a viable alternative to the use of antibiotics, as they are safer for culture organisms, humans, and the environment [14].

On the other hand, a recent FAO document reports that world aquaculture production in 2022 reached a record of 122.6 million tons, of which 54.4 million tons were cultivated in continental waters and 68.1 million tons in marine and coastal waters. This production had a value of the order of 264.8 billion USD [15]. The same source reports that between 2011 and 2020, in China, the aquaculture production in inland waters was around 35 million tons, followed by the other Asian countries with 16 million tons. Meanwhile, in the Americas, the aquaculture production in continental waters was of the order of 3 million tons. The same report claims that nearly 19.3 million people were employed in Asian countries, while in American countries the employments were of the order of 606 thousand jobs. The same document declared that a sustainable development of aquaculture must be maintained to meet the growing demand for aquatic food. [15]. In Mexico, the aquaculture production of tilapia in 2020 was close to 100 thousand of metric tons, with a value of 66.43 million pesos (approximately 3.4 million US dollars). However, the Mexican government reported that this year, the total production of tilapia was 114.69 thousand of metric tons, ranking ninth as tilapia producer in the world [16].

Moreover, despite the impact caused by the COVID-19 pandemic, world tilapia production reached around 6 million tons in 2020, with a light growth (3.3 percent) over the previous year. China and Indonesia were the greatest producers in the world with1.8 million tons and 900 thousand tons respectively in 2019 [15], [17].

Based on the above information and the use of aquatic plants in tilapia aquaculture, the objective of this work was to produce a feed, based on water hyacinth, as a tilapia food supplement, in order to reduce production costs and improve tilapia aquaculture, mainly in small scale hatcheries.

II. Material and Methods

70 tilapia juveniles between 5-7 g were obtained from a commercial hatchery and transported to the Experimental Center of the Technological University of Escuinapa, where they were distributed in 8 plastic ponds of 150 L, for a stocking density of 8 fishes per 1000 L. (8 fish/m^3). The tilapia juveniles were feed two times per day with Purina® brand, a commercial feed composed basically of fish meal, corn meal, soybeans meal, wheat meal, rice bran, wheat bran, cassava, fish oil, calcium, phosphorus, vitamins, folic acid, and other minerals, at rate of 3-4 % their corporal weight, until the fishes reached 24 to 26 g of weight. The ponds water was constantly aired, by conventional (aquarium) air pumps, and filtered using biological filter, composed of small stones, synthetic sponge, and diffusing pipes. The water in the ponds was changed (around 75-80% total volume) once every 2 weeks and the filters were cleaned every time that the water was changed. Once the tilapias reached the above-mentioned weight, the fish were divided into two groups: the experimental and the control groups. The experimental group consisted of 40 tilapias which were transferred to a rectangular plastic pond 2.8 m long × 1.6 m wide × 0.9 m deep with a total volume of approximately 4032 L, giving a stock density of 9.9 fish/m^3; this pond was settled on the

ground and covered with a plastic mesh 1.2 mm of pore size (Fig. 2). The tilapias of the control group (15 tilapia) were distributed in five plastic ponds, 3 tilapias per pond of 300 L, to get a stocking density of 10 fishes/m^3 (Fig. 3). The water from the large pond was pumped through a cylindrical filter, filled with porous stones, charcoal, gravel, and small pieces of plastic sponge; then the water passed through plastic tubes in H shape. In this way, the water drops spilled on the surface of pond water and the ponds were aerated without the need for another aeration system, such as a blower, paddle wheels, diffused air systems, etc.

Fig. 2. The Tilapias of experimental group were transferred to 4032 L plastic ponds and feeding with water hyacinth supplemented food during the experimental time.

Fig. 3. The Tilapia of control group were transferred to 300 L plastic ponds and feeding with commercial food Purina during all experimental time.

A. Tilapia Feed Preparation Using Water Hyacinth

At same time as the tilapias were obtained from the commercial hatchery, water hyacinth clumps were collected from a canal located near the hatchery; the roots were cut and then transported to the laboratory, where they were first exposed to the sun for 5-6 days until being partially dehydrated. Subsequently, the semi-dried water hyacinths were cut into small pieces and placed in a Quincy® model E22 laboratory oven at 65 °C for 12-14 h. for total dehydration.

Once dried, the water hyacinth was homogenized using an Osterizer® blender. The homogenized water hyacinth was introduced into 1 L Erlenmeyer flasks; then, cane molasses was added at a proportion of 2 parts of molasses to 3 of water hyacinth and inoculated with 15 ml of *(Lactobacillus acidophilus)* 9 million CFU/ml, for be anaerobically fermented at 39 °C for 4-5 days, using an incubator Thermo Scientific® model 370. At end of the fermentation, the fermented water hyacinth was dehydrated in a Quincy® model E22 laboratory oven at 65 °C overnight and then the fermented water hyacinth was mixed with commercial feed Purina® and cornmeal at 30, 50 and 20 proportions, respectively. The mixture was ground again, poured into a stainless-steel pan, and manually homogenized, adding small amounts of distilled water, until a homogeneous mass was achieved. The obtained mass was left to rest for 8 to 12 minutes and then extruded, using a manual mill to obtain pieces in the shape of small tubes. The small tubes were dried using the above referred oven at 65 ºC overnight.

B. Water Quality Parameters

The water temperature, pH and dissolved oxygen were recorded one time per week during all experimental time in all ponds. These parameters were recorded using a mercury thermometer (range -20 to 110 °C) an Orion Star® model A121 pH meter, and a Hanna® portable dissolved oxygen meter model HI 98193, respectively. To determine the concentration of ammonia in the water samples, a standard solution of total ammonia was first prepared and its absorbance were measured using a Thermo-Scientific® Spectrophotometer, UV-Vis, Evolution model 600; then, a correlation equation of the standard concentration of ammonia Vs. absorbance, was performed; absorbance of the standard solution was compared with absorbance of the water samples; finally, the ammonia concentration in water samples was calculated according to the salicylate method proposed by [18].

C. Tilapia Growth Analysis

To estimate the tilapia growth, several growth parameters were calculated such as Weight gain, Relative growth rate, Specific growth rate and Feed conversion ratio according to the following equations, proposed in [19].

$$\text{Weight gain (g)} = \text{Final weight } (W_f) - \text{initial weight (Wi)}$$

$$\text{Relative growth rate \%} = [(W_f - Wi)/ Wi] \times 100$$

$$\text{Specific growth rate (\%/day)} = [(\text{Ln } W_f - \text{Ln } Wi)/\text{experimental days}] \times 100$$

$$\text{Feed conversion ration} = \text{Dry food consumed}/(W_f - Wi)$$

D. Statistical Analysis

All results are presented as mean ± standard deviation of the mean. Data were analyzed by One-Way Analysis of Variances (ANOVA) at a significant level of ($P < 0.05$) to know if there are significant differences between experimental group Vs the control group. The statistical analyses were made using the statistical software GraphPad Prism 5.

E. Food Commercial vs. Feed Water Hyacinth Based Costs

The cost of feed supplemented with water hyacinth was compared with the cost of commercial feed for tilapia. This was done by adding the costs of the materials used to prepare the supplemented water hyacinth and comparing it to the commercial feed; this is presented in Table III.

III. Results and Discussion

The results obtained from the water quality and tilapia growth parameters are summarized in Tables I and II, respectively.

TABLE I: Results of Water quality parameters from Small and Large Pond during the Experimental Time (3 Months)

Sample	Total Dissolved Solids (TDS) (mg/l)	Mean of Total Ammonia (mg/l)	Mean of Temp. °C	Mean Hydrogen potential (pH)	Mean of Dissolved Oxygen (mg/l)	Mean Tilapia weight & SD(g)
1a week						
Small Pond 1	940	0.2413	27.7	8.4	7.4	25.2
Small Pond 2	828	0.2511	27.1	8.04	7.5	25.46 ± 1.71
Small P3	724	0.1503	27.3	8.06	7.6	27.3
3 Samples in Large Pond	788 mean of 3	0.2591 mean of 3	22.5	8.08	7.7	26.08 ± 2.01
2a week						
Small Pond 4	910	0.2582	28.7	8.85	7.52	36.6
Small Pond 5	886	0.2935	29.2	8.48	7.44	36.6 ± 1.25
Small Pond 1	802	0.2091	29.1	8.28	7.57	35.3
3 Samples in Large Pond	770 mean of 3	0.2823 mean of 3	28.4	8.26	7.65	39.9 ± 1.62
3a week						
Small Pond 2	868	0.3512	28.4	8.82	7.23	47.7
Small Pond 3	870	0.3455	29.5	8.3	7.34	45.8 ± 1.9
Small Pond 4	858	0.3641	28.4	8.31	7.51	49.6
3 Samples in Large Pond	1088 mean of 3	mean of 3 0.2623	28.3	8.32	7.68	54.9 ± 2.45
4a week						
Small Pond 5	885	0.2881	28.5	8.87	7.31	64.7
Small Pond 1	893	0.2169	29.7	8.19	7.24	66.5 ± 2.10
Small Pond 2	830	0.2498	28.4	8.29	7.31	62.3
3 Samples in Large Pond	884 mean of 3	mean of 3 0.2362	28.5	8.42	7.35	69.8 ± 2.35
5a week						
Small Pond 3	985	0.2636	27.8	8.85	6.42	87.4
Small Pond 4	993	0.2663	28.8	8.16	6.51	85.2 ± 2.2
Small P5	930	0.2715	27.9	8.27	6.65	89.6
3 Samples in Large Pond	984 mean of 3	mean of 3 0.2768	27.6	8.12	6.73	93.2 ± 3.1
6a week						
Small Pond 1	954	0.2996	27.8	8.84	6.55	110.4
Small Pond 2	920	0.2813	28.8	8.87	6.27	113.2 ± 2.85
Small Pond 3	916	0.2703	27.9	8.05	6.17	116.1
3 Samples in Large Pond	917 mean of 3	mean of 0.2625	27.8	8.05	6.28	128.8± 2.35
7a week						
Small Pond 4	912	0.2906	27.2	8.35	5.91	139.3
Small Pond 5	969	0.2982	28.6	8.68	5.78	142.1 ± 2.81
Small Pond 1	944	0.2963	27.5	8.14	5.75	136.5
3 Samples in Large Pond	931 mean of 3	mean of 3 0.2945	27.7	8.79	5.76	154.2 ± 2.15
8a weekly						
Small Pond 2	907	0.3011	27.8	8.87	5.58	167.8
Small Pond 3	988	0.3018	27.7	8.28	5.54	168.1 ± 3.70
Small Pond 4	987	0.2984	28.1	8.16	5.56	171.9
3 Samples in Large Pond	996	mean of 3 0.3018	28.2	8.07	5.56	181.6 ± 3.45
9a Week						
Small Pond 5	970	0.3122	28.3	8.43	5.56	202.6
Small Pond 1	983	0.3275	28.5	8.47	5.27	201.5 ± 1.46
Small Pond 2	997	0.3175	28.4	8.21	5.34	199.7
3 Samples in Large Pond	929	mean of 3 0.3207	28.1	8.14	5.22	217.3 ± 3.15
10a Week						
Small Pond 3	1033	0.3293	29.2	8.92	5.09	234.5
Small Pond 4	1038	0.3288	29.7	8.77	5.17	231.4 ± 2.34
Small Pond 5	1089	0.3053	29.7	8.99	5.14	237.6
3 Samples in Large Pond	1002	mean of 3 0.3249	29.8	8.91	5.12	249.2 ± 3.1

Sample	Total Dissolved Solids (TDS) (mg/l)	Mean of Total Ammonia (mg/l)	Mean of Temp. °C	Mean Hydrogen potential (pH)	Mean of Dissolved Oxygen (mg/l)	Mean Tilapia weight & SD(g)
11a Week						
Small Pond 1	1019	0.3299	29.2	8.81	5.01	265.5
Small Pond 2	1021	0.3287	29.1	8.91	5.17	263.4 ± 2.15
Small P3	1197	0.3288	28.7	8.19	5.08	261.2
3 Samples in Large Pond	1189	mean of 3 0.3251	28.8	8.71	5.02	278.1 ± 3.05
12a Week						
Small Pond 4	1199	0.3301	29.8	8.82	4.85	293.4
Small Pond 5	1192	0.3315	28.7	8.87	4.87	300.1 ± 4.84
Small Pond 1	1198	0.3274	29.7	8.59	4.84	290.7
3 Samples in Large Pond	1201	mean of 3 0.3315	29.1	8.93	4.72	308.7 ± 4.21

As can be seen in Table I, the total dissolved solids and the total ammonia concentration oscillated between 4.72 and 7.7 mg/l and between 0.1503 and 0.3315 mg/l, respectively. Also, the water temperature increased slightly in both the small and large ponds as the experiment progressed. This raise was normal because the ambient temperature increased during the months of experiment. The pH was maintained with small variations, while the dissolved oxygen decreased throughout the experimental time; this was basically due to the increase in water temperature and the increment of organic matter in water, since as the tilapias grew the amount of food supplied augmented, and consequently the amount of feces also increased. However, the values were within the recommended values in tilapia hatcheries [20]. Other authors report similar values in the tilapia culture; the reported ranges of the physicochemical parameters are: dissolved oxygen 4.86-10.53 mg/l, temperature 24-26 °C, pH 6.1-8.3 and ammonia concentration 0.01- 0.75 mg/l [21]. Some authors claim that values out of following ranges can cause stress in the fishes: temperature 20-30 ºC, dissolved oxygen 5, pH 6.5-9, ammonia 0.025 to 0.35 mg/L [22]. However, other authors report that the ammonia concentration in the tilapia aquaculture ponds at semi-intensive level (5000 to 10000 kg/ha) is from 0.1 to 0.5 mg/L [22], [23]. Based on this, the average weight of tilapia is 10000 kg/ha, or 10000 kg/10^4 m^3 (if the pond depth is 1 m), or 1 kg/m^3 [24]. In this work the mean weight of the tilapia in the large pond is 128.8 g (in the 6a week) or 0.1288 Kg; therefore, the total weight of 40 fishes will be 5.152 kg in 4.032 m^3 of water, or 1.278 kg/m^3; that means the kg of tilapia/m^3 in this study is in same order of magnitude. Since the mean ammonia concentration in this work was around 0.2900 mg/L, it is similar to values reported by the referred authors (0.1 to 0.5 mg/L).

TABLE II: Growth Parameter of Tilapia in Control and Experimental Groups for 3 Months

Initial weight (g)	25.46 ± 2.85	26.08 ± 2.01
Final weight (g)	300.1 ± 4.84	308.7 ± 4.21
Weight gain (g)	274.64	282.62
Relative growth rate (%)	1078.711	1083.6656
Specific growth rate (%/day)	2.74111	2.74579
*Feed conversion ration	1.641	1.714

* Since the amount of food supplied to tilapia was increasing as fishes increased in weight, it is not possible give a specific value; therefore, a mean value of food supplied such in control as in experimental group was used (i.e., an estimated value (7-9 g /10 tilapia in first month, 20-22 g /10 tilapia in second month, and 40-42 g /10 tilapia in the third month) from start, to end of experiment time).

Regarding to tilapias growth, the values of growth parameters found indicate that the tilapias fed with the supplemented water hyacinth grew more than tilapia fed with commercial food, since all the growth parameter were higher in the experimental group than in control one, such as is shown in Table II, particularly the Weight gain, since tilapia fed with supplemented water hyacinth, gained 8.6 g more than tilapia fed with Purina® and the Feed conversion ratio.

On the other hand, as can be seen in Table III, the cost for preparing 20 kg of feed based in water hyacinth is around 38 US dollars, compared with 44.9 US dollars of a 20 kg bag of commercial food, Purina brand. This means that the cost of feed based in water hyacinth will be 6.9 US dollars lower than commercial food, or 15.37% less. This is important when the food cost of a tilapia hatchery at median scale with 1000 or 2000 kg of fishes per ha is considered [24].

TABLE III: Estimated Cost to Prepare 20 Kg of Supplemented Water Hyacinth vs 20 Kg of Commercial Feed

Compound price in US. 1 US~20 Mexican pesos (MXN)	20 Kg Water hyacinth Feed (dry basis)	1 bag of 20 Kg of Commercial food have a cost of 40.9 US
Water hyacinth (WH) Collecting	A trip in truck (7 L gasoline) ~ 7 US. to collect 100Kg (WH)	A trip in truck (4 L. of gasoline)~4 US
Molasses/Kg WH	A pitcher of 30Kg/15US then 20 Kg/10US; then 10 US x 0.66=6.6 US	
Lactobacillus spp.	1 flask with 180 caps Lactobacillus~27US, then 1 capsules x10^9 Lactobacillus each~0.15 US; then 20 capsules=3 US.	
Corn-meal	0.2Kg mealx20 Kg =4 Kg=~1 US	
Cost in US per 20 kg	Total cost 20 Kg WH 7+6.6+3+ =22 US + 16 Kg of commercial food (32 US x 0.5) =16 US. Total 38 US	Total=40.9+4 US=44.9 US

Values were estimated based on the Mexican market prices of each component plus trips to obtain them.

In another work, the authors reported growth parameters and diet costs that are relatively similar to those found in the present work despite some differences in their procedures. They used cages instead of the traditional pond culture for tilapia culture and two brand diets named: Nicoluzzi and Raanan. Moreover, they did not use water hyacinth for feed preparation; Even with such differences, the values obtained in the current work were equivalent to the referred work [19] [25].

As can be seen, successful tilapia aquaculture depends on several factors that influence the growth of fish, such as amount and quality of feed consumption [26], stocking density [27] and water chemistry, particularly the water temperature [20], ammonia concentration and dissolved oxygen [28]. Naturally there are other factors such fish sex and age [29] and genetic variance, which were not considered in this work.

IV. Conclusion

Based on the results obtained in this work, can be concluded that the objective was reached, i.e., we proved that water hyacinth can be used as food supplement in tilapia hatcheries, an aquatic plant without any use. In addition, we have shown how this plant, and perhaps other unused plants, could be used to improve tilapia farming and reduce feed production costs, particularly on a small and medium scale.

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Conflict of Interest

Authors declare that they do not have any conflict of interest.

Ethical Approval

All the fishes used in this work were not sacrificed or damaged in any part of its body. Once this work was finished, the tilapias were returned to the hatchery from which they were obtained.

References

[1] Anderson LW. Freshwater plants and seaweeds. In: *Encyclopedia of Biological Invasions*. Simberloff, D. and M. Rejmanek. Berkeley: University of California Press, 2011. https://www.invasivespeciesinfo.gov/aquatic/plants.

[2] Delgado Ruiz D.R. Phytotherapy in aquaculture, a global look from zootechnics. M.Sc. thesis. UDR Cubará, Boyacá, Colombia, 2020. https://repository.unad.edu.co › drdelgador.

[3] Goudjil MB, Zighmi S, Hamada D, Mahcene Z, Bencheikh SE & Lajel S. *South African Journal of Botany*, 2020;128:274-282. https://doi.org/10.22201/fesz.23958723e.2020.0.266.

[4] Fikry S, Khalil N. & Salama O. Chemical profiling, biostatic and biocidal dynamics of *Origanum vulgare* L. essential oil. *AMB Express*, 2019;9:41:1-10. https://doi.org/10.1186%2Fs13568-019-0764-y.

[5] Peña N, Auró A, Sumano HA. Comparative trial of garlic, its extract and ammonium-potassium tartrate as anthelmintics in carp. *J Ethnopharmacol.*, 1988;2-3:199-203. doi: 10.1016/0378-8741(88)90152-3.

[6] Silveira-Coffigny R. The phyto-pharmaceutical products in REDVET aquaculture. *Electronic Veterinary Journal*, 2006;VII(8): 1-10.

[7] Ali A, Chua BL, & Chow YH. An insight into the extraction and fractionation technologies of the essential oils and bioactive compounds in Rosmarinus officinalis L.: past, present and future. *TrAC Trends in Analytical Chemistry*, 2019;118:338-351. https://doi.org/10.1016/j.trac.2019.05.040.

[8] Rubio BA. Evaluation of the costicidal effect of fresh chopped onion (Allium cepa) on hybrid tilapia (Oreochromis sp.) Bachelor's thesis. National Autonomous University of Mexico, 1991.

[9] Compean-Martínez J, Salazar-Ulloa M, Chávez-Soriano L, Muñoz-Córdoba G, von Son-de Fernex E. Anthelmintic-like Activity of *(Leucaena leucocephala)* Aqueous Extract Against Gyrodactylus spp. in Naturally Infected Tilapia Fingerlings North American Journal of Aquaculture. 2021;83(4):354-362. https://doi.org/10.1002/naaq.10206.

[10] López Tirado JR. Use of fresh papaya (Carica papaya L.) seed as nematodicide vs. Spirocamellanus sp. in hybrid tilapia (Oreochromis sp.). (Undergraduate Thesis). Autonomous National University of Mexico, 1994. https://repositorio.unam.mx/contenidos/3443376.

[11] Hamad M, Mohammed H, & Merdaw M. Antibacterial Activity of *(Calendula Officinalis)* Flowers in Vitro. *Ibn AL-Haitham Journal for Pure and Applied Sciences*, 2017;24(3). https://doi.org/10.30526/24.3.735.

[12] Berenguer B, Sánchez LM, Quilez A, López-Barreiro M, De Haro O, Galvez J, & Martin MJ. Protective and antioxidant effects of *(Rhizophora mangle L.)* against NSAID-induced gastric ulcers. *Journal of ethnopharmacology*, 2006; 103(2):194-200. https://doi.org/10.1016/j.jep.2005.08.029.

[13] Modak CB. Antivirals of natural origin in the aquaculture industry: A challenge to Phytotherapy. *Latin American and Caribbean Bulletin of Medicinal and Aromatic Plants*, 2011;10(4):292.

[14] Kolkovski S. Green medicine in Aquaculture. Australia, 2013. In Spanish. https://aquafeed.co/entrada/medicina-verde-en-acuicultura-20325/.

[15] FAO. The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation. Rome, FAO. https://doi.org/10.4060/cc0461en.

[16] Tilapia aquaculture in Mexico. Statistical Yearbook of Aquaculture and Fisheries, 2020. National Aquaculture and Fisheries Commission. In Spanish. www.gob.mx/inapesca/acciones-y-programas/acuac.

[17] The fish site. Rabobank / Gorjan Nikolik reports 2020 tilapia production figures, 2020. https://thefishsite.com/articles/2020-tilapia-production-figures-revealed.

[18] Phuong TTL and Boyd CE. Comparison of phenate and salicylate methods for determination of total ammonia nitrogen in freshwater and saline water. *J. of the World Aquaculture Society*. 2012;4(6):885-889. https://doi.org/10.1111/j.1749-7345.2012.00616.x.

[19] Mensah ETD and Attipoe F K. Growth parameters and economics of tilapia cage culture using two commercial fish diets. *International Journal of Development and Sustainability*, 2013;2(2):825-837. www.isdsnet.com/ijds.

[20] Makori AJ, Abuom PO, Kapiyo R. *et al.* Effects of water physico-chemical parameters on tilapia (*Oreochromis niloticus*) growth in earthen ponds in Teso North Sub-County, Busia County.*Fish Aquatic Sci*, 2017;20:30. https://doi.org/10.1186/s41240-017-0075-7.

[21] Bhatnagar A, & Singh G. Culture fisheries in village ponds: a multi-location study in Haryana, India. *Agriculture and Biology Journal of North America*, 2010;1(5):961-968. https://doi:10.5251/abjna.2010.1.5.961.968.

[22] Bhatnagar A, and Devi P. Water quality guidelines for the management of pond fish culture. *International Journal of Environment Sciences*. 2019;5(2):1980-2009. doi: 10.6088/ijes.2013030600019.

[23] Seim WK, Boyd CE, and Diana JS. Environmental considerations, pages 163-182. In: *Dynamics of Pond Aquaculture*. H. S. Egna and C. E. Boyd (eds.), CRC Press, Boca Raton, Florida, USA, 1997.

[24] Boyd CE. Farm-level issues in aquaculture certification: Tilapia. *Report commissioned by WWF-US in*, 2004:1-29. http://fisheries.tamu.edu/files/2013/09.

[25] Engle RC and Wossink A. Environmental Best Management Practices for Aquaculture. Craig S. Tucker, John A. Hargreaves, Eds. 2008, pp. 519-552. Blackwell Publishing, 2121 State Av. Ames, Iowa 50014, USA.

[26] Ridha TM. Comparative study of growth performance of three strains of Nile tilapia, *Oreochromis niloticus*, L. at two stocking densities. *Aquaculture Research*. 2006;37(2): 172-179.

[27] Aijun M, Chao C, Jilin L, Siqing C, Zhimeng Z, & Yingeng W. Turbot *Scophthalmus maximus*: stocking density on growth, pigmentation and feed conversion. *Chinese Journal of Oceanology and Limnology*, 2006;24(3):307-312.

[28] Bhatnagar A and Devi P. Water Quality Guidelines for the Management of Pond Fish Culture. *International Journal of Environmental Science*, 2013;3:1980-2009. https://doi.org/10.6088/ijes.2013030600019.

[29] Imsland AK, Jonassen TM. Growth and age at first maturity in turbot and halibut reared under different photoperiods. *Aquaculture International*, 2003;11:463–475.