THE WATER HYACINTH REDUCES THE PRODUCTION COSTS OF FISH FEED DURING THE SMALL- SCALE TILAPIA CULTURE IN SOUTHERN OF SINALOA, MEXICO.

.

ABSTRACT

Tilapia culture is increasing such in Mexico as in other countries of world; however, one of main problem is the food cost; therefore, the aim this work was to use water hyacinth as a complement in tilapia feeding, and thus reduce production cost. Dried water hyacinth added with cane molasses, was fermented using Lactobacillus acidophilus. The fermented product was mixed with commercial feed and cornmeal, at 30-60-10 percent respectively. The mixture was extruded and dried to be used as tilapia feed. Tilapia juveniles were placed in plastic ponds; once tilapias reached 24-26 g, were divided in two groups; The experimental group was transferred to a 4,678-liter pond while the control group was distributed in three 100-liter ponds. The experimental group was fed with food prepared with water hyacinth, while control group with commercial food. To know the tilapias growth of each groups, the weight gain of both groups, was recorded every 2 weeks; also to check the water state, its physicochemical parameters were recorded. At end of 9 biweeklies, the experiment was stopped, and the tilapia growth of both groups compared, using a von Bertalanffy modified equation to calculate the growth, based on the weight increase. Results indicated that tilapia growth rate fed with water hyacinth-supplemented feed, was 6% higher than tilapia fed with commercial feed, at p=0.05. Another important point, is that feed cost prepared with water hyacinth was 30% lower than commercial food. This results demonstrate that tilapia farming to small and medium-scale, can be developed in southern Sinaloa, which will create jobs for inhabitants of small communities, strengthening the family economy and the social fabric.

Keywords: Tilapia culture, water hyacinth, cost reductions, jobs creating

.

1. INTRODUCTION

Accord a FAO report, in 2020, the global aquaculture production reached the record figure of 122.6 million tons, with a value about 264.8 billion of US dollars; from which 54.4 million tons were cultured in inland waters and 68.1 million tons from marine and coastal waters. The same report claim that a sustainable development of aquaculture, must be maintained to meet the growing demand for aquatic food. [1].
Other paper report that the world tilapia production reached around 6 million tons in 2020, with a light grew (3.3 percent) than previous year, [2]. Despite the impact caused by the COVID-19 pandemic; China and Indonesia were the greatest producer in the world with1.8 million tons and 900,000 tons respectively in 2019 [3]. On the other hand, in 2010 the aquaculture production in Latin America, reached 1 883 134 tons, and the main producing countries were Chile (701,062 tons), Brazil (479,399 tons), Ecuador (271,919 tons), Mexico (126,240 tons), Peru (89,021 tons) and Colombia (80,367 tons) [4]. However, in 2020. Mexico was the ninth tilapia producer in the world, reaching a production close to 100,000 tons [2]. However, according to the Mexican government, in 2020 the total production of tilapia was 114,769 tons. The same source report that the Sinaloa State, Mexico produced 13,283 tons [5].
On the other hand, by mid-2023 two large dams will be in operation in the south of the State of Sinaloa: The Picachos and Santa María dams (Fig. 1). The dams are located near the port of Mazatlán; right at the entrance to the Gulf of California and very close to the Tropic of Cancer, 23°27' N of the terrestrial equator [6]. The Picachos dam coordinates, are between 22° 54´ to 23° 32´ Lat. N, and 105° 59’ to 106°18’ Long W. [7] whereas the Santa Maria dam, is between 23° 05’ to 23° 75´ Lat. N., and 105° 40´ to 105° 42.5´ [8]. These dams will store a large amount of water, which be available to communities near the dams, and thus promoting the tilapia aquaculture and other freshwater fish in these places.

.

Fig. 1 The Picachos and Santa María dams are located in the south of the State of Sinaloa, Mexico, near the port of Mazatlán. The dams will boost aquaculture of tilapia, as well as other freshwater fish in small towns and villages close to dams.

On the other hand, a plentiful and uncontrolled growth of water hyacinths (*Eichhornia crassipes)* is very common in many dams and fresh water reservoirs, such as in Sinaloa State, as in other places of the world. This and other aquatic plants have been a big problem, since due to their rapid growth, they cause eutrophication and then, inability of water bodies for aquaculture. Normally, these aquatic plants are taken out from the water bodies and abandoned in up lands, without any use.

A recent document published by FAO, evaluated the social and economic performance of the aquaculture sector. The document report that in Mexico, the tilapia production on a micro and small scale, has a significant contribution to food security and subsistence of many families and also, to keep the socioeconomic tissue in the rural and suburban areas of the country; since help to improve the family nutrition, generate additional incomes and discourage the migration of family members [9].

.

Therefore, the aim of this work is to promote the tilapia aquaculture al small and semi craft scale, in the towns and villages located near the new damps, using commercial food, supplemented with water hyacinth, and the abundant availability of water.

2. MATERIAL AND METHODS

A batch of 59 juvenile tilapia, ranging between 13 and 16 g, was obtained from a commercial tilapia hatchery; once transferred to the experimental site, the tilapias were distributed in 6 plastic aquariums with 100 water liters each. The water of aquariums was constantly aired, using air pumps. The tilapias were fed two times per day with commercial feed, composed of soybean meal, fish meal, corn meal, wheat flour, calcium, phosphorus, vitamins, folic acid and minor minerals; supplied by Nutripec of the Purina® brand, at a rate of 3-4% of their body weight, until the fish reached 24 to 26 g of weight. Once the fishes reached this weight, 47 tilapias (the experimental group) were transferred to a cylindrical plastic pond, with a capacity of 4678 liters, Bestway® brand. The other tilapias were distributed in 3 plastic ponds of 100 water liters each and used as control group. (Fig. 2). As above indicated, the water of the small ponds, was aerated by air pumps, and the tilapias fed with commercial food; also, the water was changed 75- 80 % total volume each two weeks.

.

Fig 2. The tilapias of control group were transferred to three plastic ponds of 100 water liters each and aired by conventional pumps. The fishes were fed (3-4%) their corporal weight two time per day, using Purina® commercial food, along the experimental time.

In order to clean and recycle the water in the cylindrical pond, a submersible pump was installed on bottom of the pond. The pump impelled water through a cylindrical filter (30 cm diameter, 40 cm long) filled with porous stones, charcoal, sand, and pieces of sponge. This filter allowed a considerable amount of water to be saved; in fact, throughout entire experimental time, the water just was changed two times, discarding only 60-65 % of the total water from the pond. Moreover, to aerate the water, a system like a bypass, connected to a device such as an inverted watering can, who emerged 130-135 cm above the water surface, was connected to pump. This device sends a jet of water over the surface; thus, as the water drops fall, the air is trapped, aerating the pond water. In this way, no other device such as a blower or an aeration pump, to supply oxygen to the water was required (Fig. 3).

.

Fig. 3 Once the tilapias reached 24-26 g, they were transferred to a large pond (4678 liters) where remained until the end of experimental time. A submersible pump, an external filter and a device such as an inverted watering can, were used for filtering, recirculation and aeration the water.

2.1 Feed preparation with water hyacinth

The water hyacinth clusters were collected from a canal located near the hatchery from which the tilapias were obtained; then, transported to the place where the tilapia experiment was carried out. The water hyacinth was exposed to the sun during 4-5 days to be partially dehydrated. The semi-dry water hyacinths were cutting in small pieces and taken to the laboratory for total dehydration using a Quincy Lab E22 oven at 65 ^{o}C overnight (Fig. 4).

.

(A)

(B)

Fig. 4(A-B). Water hyacinth was dehydrated by sun exposition during 4-5 days; after, the semidry water hyacinth was cutting in small pieces and translated to laboratory for total dehydration using an Oven at 60-65 ^{o}C overnight.

Dried water hyacinth was ground using an Osterizer® kitchen blender. The crushed water hyacinths were transferred to 1 L Erlenmeyer flasks, cane molasses was added at a ratio of 2 parts of molasses by 3 of water hyacinth, and inoculated with 10 ml of (*Lactobacillus acidophilus*) 6 million CFU/ml, to be anaerobically fermented at 39 °C for 5 days, using a Thermo Scientific® Model 370 Incubator. Once the fermentation was finished, the fermented water hyacinth was dehydrated in the same oven at 65 °C overnight and then mixed with the commercial food Purina® Nutripec and corn flour at a rate of 30, 60 and 10 percent, respectively. The mixture was ground again, transferred to a stainless steel bowl and homogenized by hand, adding

.

small portions of distilled water, until a homogeneous mass was obtained. The homogenized mass was left to rest for 10 to 15 minutes and then passed through a manual mill to obtain small tube-shaped pieces, which were dried in same oven at 65 ^{o}C overnight.

A proximate analysis of this prepared feed, was realized following the methods proposed in [10]. The obtained values were compared whit the values obtained from commercial food Purina® brand using same methods. The results obtained, are shown in Table 1. Likewise, a comparison of the costs of two foods was estimated.

Table 1. Proximate analysis and cost of commercial food Purina® brand and comparative values of diet prepared based on water hyacinth

Compound	Commercial food (%)	Feed based Water hyacinth
Dry matter	9	11
Crude protein	31	29
Crude lipid	7.4	4.1
Ash	12.6	14.7
Crude fiber	4.2	6,2
Humidity	35.8	35
Gross energy (kcal/kg feed)	2700	2500
Cost (US$/kg)	1.2°	0.84*

° In 2022 the market price of a 25 kg bag of Purina® Nutripec commercial feed, is 500 MEX. (1 US = 20 MEX.)

*The cost was estimated based on the quantities and prices of the materials used.

2.2 Water quality parameters

The water temperature, pH, and dissolved oxygen were recorded by triplicate, every two weeks, such in the small ponds as in the large one, during all experimental time. The 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; the mean and standard deviation of these parameters are sown in (Table 2).

Table 2. Water physicochemical parameters in small and large ponds along experimental time

.

Data Record	Pond number	Nº. Tilapia per pond	Water Temp. (°C)	Water pH pH	Water diss.O2 (mg/L)	Tot. Ammonia (mg/L)
Apr. 16/2022	1	8	22.3	6.81	6.7	3.45
Apr. 16/2022	2	9	22.3	6.83	6.8	3.02
Apr. 16/2022	3	8	22.1 Mn=22.166	6.82 Mn=8.81	6.4 Mn=6.683	3.41 Mn=2.65
Apr. 16/2022	4	9	22 SD ± 0.150	6.82 SD±0.01	6.9 SD ±=0.194	3.55 SD± 1.108
Apr. 16/2022	5	8	22.3	6.8	6.8	1.23
Apr. 16/2022	6	8	22	6.81	6.5	1.25
	Pond number	Nº. Tilapia/pond	Water T °C	pH	O2 dissolved	Tot, ammonia
Apr. 30/2022	1	8	24.6	7.7	4.02	1.89
Apr. 30/2022	2	9	24.7	7.56	4.01	1.88
Apr. 30/2022	3	8	24.2 Mn=24.083	7.58 Mn=7.61	4.02 Mn=4.048	2.05
Apr. 30/2022	4	9	23.9 SD±0.503	7.54 SD±0.10	4.06 SD ±0.156	1.59
Apr. 30/2022	5	8	23.5	7.51	4.33	1.57
Apr. 30/2022	6	8	23.6	7.77	3.85	1.58
	Pond number	Nº. Tilapia/pond	Water T °C	pH	O2 dissolved	Tot, ammonia
May. 16/2022	1	8	25.4	7.63	4.05	2.82
May. 16/2022	2	9	24.4	7.59	3.81	2.81
May. 16/2022	3	8	23.9 Mn=2405	7.43 Mn=4.08	3.61 Mn=4.08	2.86 Mn=2.93
May. 16/2022	4	9	23.6 SD ±0.747	7.26 SD±0.15	4.95 SD±0.502	3.07 SD±0.113
May. 16/2022	5	8	23.4	7.69	4.35	3.01
May. 16/2022	6	8	23.6	7.53	3.71	3.01
	Small pond	Nº. Tilapia/pond	Water T °C	pH	O2 dissolved	Tot, ammonia
May. 31/2022	1	1	25.4	7.51	3.95	1.88
May. 31/2022	2	1	25.9 Mn=23.43	7.64 Mn=7.56	3.75 Mn=3.85	2.05 Mn=2.07
May. 31/2022	3	1	25 SD ±0.45	7.54 SD±0.068	3.87 SD±0.101	1.59 SD±1.11
May. 31/2022	Large pond	Nº. Tilapia/pond	Water T °C	pH	O2 dissolved	Tot, ammonia
	1	47	Mn 25.7 SD±0.43	Mn 7.56 ±0.41	Mn 3.94 ±0.45	Mn 2.81 ±0.21
	Small pond	Nº. Tilapia/pond	Water T °C	pH	O2 dissolved	Tot, ammonia
Jun 14/2022	1	1	26,4	7.61	4.05	3.35
Jun 14/2022	2	1	26.8 Mn=26.95	7.59 Mn=7.55	3.81 Mn=3.823	1.63 Mn=2.07
Jun 14/2022	3	1	27.1 SD±0.35	7.45 SD±0.87	3.61 SD±0.22	1.25 SD±1.12
Jun 14/2022	Large pond	Nº. Tilapia/pond	Water T °C	pH	O2 dissolved	Tot, ammonia
	1	47	Mn 26.2 SD±0.32	Mn 8.01,±0.42	Mn 4.12 ±0.36	Mn 2.04 ±0.27
	Small pond	Nº. Tilapia/pond	Water T °C	pH	O2 dissolved	Tot, ammonia
Jun/29/2022	1	1	27.2	7.26	4.06	1.88
Jun/29/2022	2	1	27.4 Mn=27.36	7.69 Mn=7.49	4.33 Mn=4.08	2.45 Mn=2.0
Jun/29/2022	3	1	27.5 SD±0.152	7.53 SD±0.21	3.85 SD±0.24	1.69 SD±0.39
Jun/29/2022	Large pond	Nº. Tilapia/pond	Water T °C	pH	O2 dissolved	Tot, ammonia
	1	47	Mn 27.4 ±0.23	Mn 7.97 ±0.32	Mn 4.21 ±0.28	Mn 3.01 ±0.51
	Small pond	Nº. Tilapia/pond	Water T °C	pH	O2 dissolved	Tot, ammonia
Jul/15/2022	1	1	28.1	7.54	3.66	2.72
Jul/15/2022	2	1	28.3 Mn=28.13	7.51 Mn=7.60	4.32 Mn=4.11	2.81 Mn=2.76
Jul/15/2022	3	1	28.1 SD±0.115	7.77 SD±0.142	4.35 SD±0.39	2.76 SD±0.045
Jul/15/2022	Large pond	Nº. Tilapia/pond	Water T °C	pH	O2 dissolved	Tot, ammonia
	1	47	Mn 28 SD± 0.46	SD 7.97 ±0.18	Mn 4.37 ±0.51	Mn 2.05 ±0.19
	Small pond	Nº. Tilapia/pond	Water T °C	pH	O2 dissolved	Tot, ammonia
Jul/31/2022	1	1	28.4	7.56	4.16	3.55
Jul/31/2022	2	1	28.5 Mn=28.16	7.58 Mn=7.56	4.23 Mn=4.11	1.53 Mn=2.44
Jul/131/2022	3	1	28.5 SD±0.57	7.54 SD±0.02	3.95 SD±0.145	2.25 SD±1.023
Jul/31/2022	Large pond	Nº. Tilapia/pond	Water T °C	pH	O2 dissolved	Tot, ammonia
	1	47	Mn 28.1 SD±0.42	Mn 8,06 ±0.18	Mn 4.03 ±0.122	MN 2.13 ±0.038
	Small pond	Nº. Tilapia/pond	Water T °C	pH	O2 dissolved	Tot, ammonia
Aug/18/2022	1	1	28.8	7.9	4.11	2.26
Aug/18/2022	2	1	28.7 Mn=28.73	7.82 Mn=7.91	4.05 Mn=4.07	3.07 Mn=. 2.44
Aug/18/2022	3	1	28.7 SD±0.057	8.01 SD±0.09	4.06 SD±0.032	2.01 SD±0.55
Aug/18/2022	Large pond	Nº. Tilapia/pond	Water T °C	pH	O2 dissolved	Tot, ammonia
	1	47	Mn 28.3 ±0.093	Mn 7.89 ±0.21	Mn 4.39 ±0.07	Mn 2.58 ±0.072

.

Moreover, the total ammonia (NH_3, NH_4^+) concentration in the water ponds, was quantified by the salicylate method, proposed by [11]. In order to know its concentration, a standard reference solution of (NH_3, NH_4^+) was prepared, and its absorbance measured using a UV-Vis spectrophotometer Thermo-Scientific®, model Evolution 600; then, with the absorbance values and ammonia standards, a linear correlation equation and its graph were obtained; then the ammonia concentration in the ponds water could be calculated (Fig. 5).

$Y=-0.0112+(0.0717)\ X$; where Intercept in Y axis= -0.0112, Slope=0.0717 and Correlation coefficient =0.998314282.

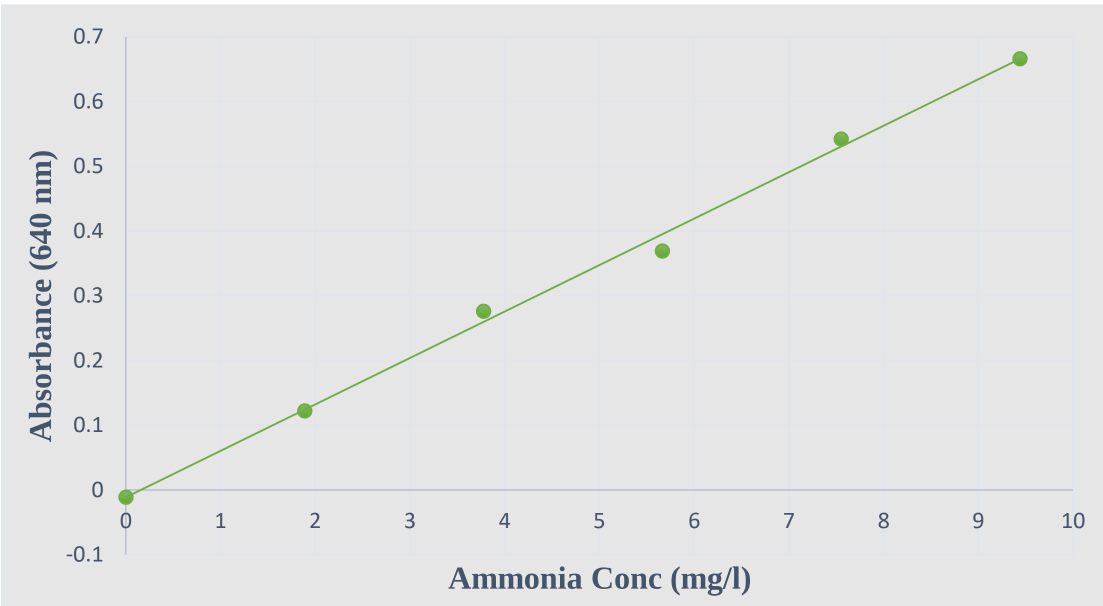

Figure 5. Total standard ammonia (NH_3, NH_4^+) and its correlation equation, where **Y** is Absorbance values (at 640 nm), and **X** is ammonia concentration in (mg/l).

2.3 Tilapia growth record.

The tilapia growth was determined by their weight gain throughout the experimental time. For realize this, 3 fish from the small ponds and 5 from the large pond were weighed every two weeks (biweekly), using a semi-analytic balance, Mettler-Toledo® model ML 802E.

As indicated above, before the third biweekly the tilapias were distributed in three small and a large pond; therefore, during this time, the bars are shown as an alone,

.

while after the third biweekly, the bars are shown in pairs. The left bar of each couple corresponds to the control, i.e., the tilapias in the small ponds, and the right bar to tilapia of experimental group in large pond (Fig.6).

Regarding tilapia mortality, no one fish dead thought experimental time

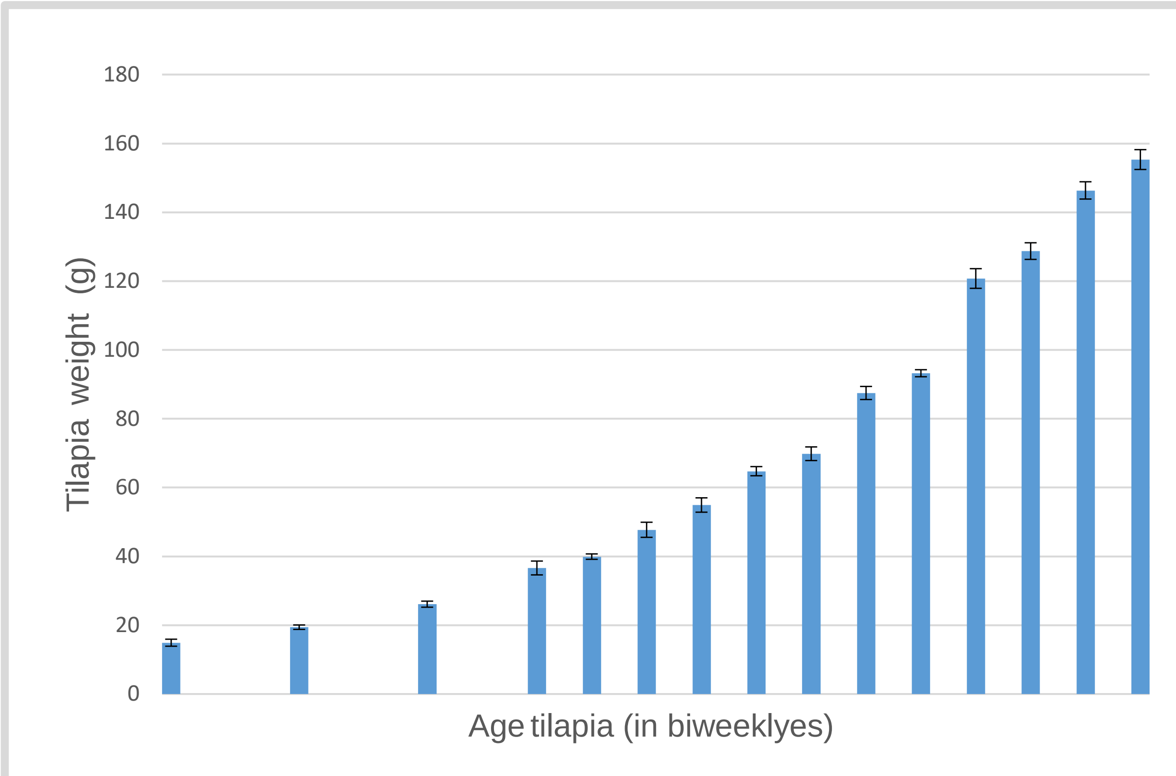

Fig. 6. Tilapia weight Increase along 18 weeks (9 fortnightly). The first three bars correspond to the time that all tilapias were in the small ponds; while the following bars are grouped in pairs. The left bar of each pair, are the control, i.e., tilapias in small ponds, and the right bars to tilapias of experimental group, in the large pond.

As can be seen in Fig. 6, the trend of the bars has a sigmoid shape; i.e., it corresponds to a logarithmic curve; therefore, the equation that best fits become to the von Bertalanffy growth model [12]. Although the original model was developed to determine the growth as age of the fish and is expressed as its length increase; however, since there is a direct relationship between length and weight; then, the growth can be expressed as weight gain. Based on this, the following equation can be used, which is a simplified equation of the von Bertalanffy model [13], [14].

$$\mathbf{W_t = W_\infty (l\text{-}e^{-K(t-t_0})\,); \quad then\ dW_t / W_\infty = - K(dt/t_0);}$$

.

therefore, Ln $W_{t\,=\,-}$ K (Ln t).
Where: $\mathbf{W}_{\infty}$ is the mean weight in (g) of the fish at infinitum (in practice at a time t)
K, is the growth rate, which can be calculated from the experimental data and expressed in (g/day), (g/week), (g/biweekly), etc.
$\mathbf{t_0}$ is the "age" that fish would have at time zero (in fact is zero).
and $\mathbf{W_t}$ is the fish weight reached at a time **t** (expressed in g, Kg, etc.)

2.4 Data analysis

Tilapia growth data and physicochemical parameters of pond water were analyzed by one-way ANOVA, using Statistical 7.0 software, VinceStatSoftware®, to obtain mean values, standard deviations, and significant value. Data that did not meet the normality requirements were analyzed non-parametrically using Kruskal-Wallis ANOVA and the median test.

3. RESULTS and DISCUSSION

Based on the results obtained on tilapia growth (Fig. 6), it is possible to said that the feed prepared with water hyacinth was totally accepted by the tilapia. In addition, the growth of tilapias fed with supplemented water hyacinth, grew moderately more than those fed with commercial feed, at a significant value of ($p= 0.05$). In other words, the tilapia weight gain of the experimental group was greater than the control group; or, the feed was utilized more efficiently by tilapias fed with supplemented water hyacinth than tilapias fed with commercial feed.
In addition, when comparing the cost between the Purina® brand food vs. the feed supplemented with water hyacinth, a cost reduction around 30% is observed (Table 1). This is of considerable importance, since one of the main issues in commercial tilapia hatcheries is precisely the feed price. Therefore, feeding the tilapias with fed based on water hyacinth, becomes very attractive for the managers or technicians of tilapia hatcheries. Other authors, conducted a field survey on Malaysia tilapia farms; they found that the main cost of production in hatcheries was the feed, in more than 90 percent of the farms surveyed. Also, the owners of hatcheries surveyed, claim that to reduce the feeding costs, they produced some feeds, based on copra meal, palm kernel cake, and kitchen wastes [15].
On the other hand, rearranging the modified growth equation of von Bertalanffy,

$$\mathbf{Ln\ W_{t\,=}\ -K\ (Ln\ t)}$$
$$\mathbf{Ln\ Wt\ /\ Ln\ t = -K}$$
$$\mathbf{K= Ln\ Wt + Ln\ t}$$

.

If **t** is equal to 6 biweeklies, and W_t the weight reached to this time, (155.8-25.0) g
Then **K**=Ln 130.8+Ln 6 = 6.66542890825

The growth rate for tilapia fed with feed supplemented with 30% water hyacinth, is 6.66542890825

Using the same equation, but with the tilapias fed with commercial feed, the K value is 6.59027357529. Therefore, the growth rate for tilapia fed with commercial food, will be 7.5 % lower than tilapias fed with food supplemented with 30% of water hyacinth.

On the other hand, the results of the statistical analysis indicated that there are significant differences ($p= 0.05$) between the growth of tilapia fed with water hyacinth supplemented feed and tilapia fed with commercial feed. This can be seen between pairs of bars from the third biweekly, until the end of the experimental time (Fig. 6). This fact is supported by the results shown in Table 1, since the crude fiber is 2 units (around 26%) higher in the feed based of water hyacinth than in the commercial feed, which make it more digestible. Other authors have reported benefits in tilapia farming using various waste compounds, such as shrimp heads, bones, blood, agriculture sub products [16]. They claim that many agriculture wastes have bioactive compounds such as phenols, terpenes, β-glucans and others, which improve the immune system and resistance to infections in aquaculture organisms; thus, can be used to reduce the production costs. Several animal by-products have been extensively studied as substitutes of fish meal in tilapia feeds, for instance, meat and bone meal extracts or blood meal, supplemented with Methionine, were satisfactory up to 50% of the fish meal [17]. However, the processes used to produce this substitutes or supplements are not simples and economics. Other authors report that the use of fish waste such as skin, fins, bones, heads, viscera, and scales can be used to generate a sustainable fish waste management such as collagen, peptides, chitin, enzymes, oils etc., and so from this fish by-product to produce a lot of value added products [18]. However, again the procedures to make these compound are complex and expensive. In other work, is reported that duckweed can be used as the sole food source for tilapia culture [19], the authors claim that the dried duckweed can also replace up to 30% of commercial feed, without adverse effects on fish growth. Other author reported that some aquatic plants such as pondweed (*Potamogeton pectinatus*); coontail (*Ceratophylim demersum*) and duckweed (*Lemna lemna*) can be used as substitute of fish carcass; however, the authors say that this plants are deficient in some essential amino acids [20].

Regarding to preparation and nutritional value of the tilapia feed, other authors used sunflowers meal fermented by yeast *Saccharomyces cerevisiae* and the bacteria *Bacillus subtilis* using a semi solid-state process; the authors report that sunflower

.

meal improved the feed and all nutritional parameters measured were significantly higher in fermented yeast than bacillus treatments [21]. In another work, water hyacinth was used to determine the nutritional value of tilapia diets, testing different fermentation methods. The author reports that yeast-fermented water hyacinth and cow rumen diets gave better weight gains than diets with unfermented water hyacinth; moreover, tilapia diets should have at least 20% fermented water hyacinth [22]. However, the author says that results of his work cannot be compared with other works on tilapia diets based water hyacinth, since the fish and the experimental conditions are diverse.

It is evident that above mentioned works present valuable results, which indicate that aquaculture is in full development and will be an important source of food for humans, in the near future. On the other hand, all the mentioned works give an important role to use of cheaper sources for tilapia feed, such as, by-products of plants and animals, or industrial waste, to replace the more expensive fish meal. However, comparing the results of the previous works with those obtained in the present work, it can be said that the procedures used are simpler and the materials less expensive than in the mentioned works; for example, the fermentation process was performed only by bacteria (Lactobacillus acidophilus) and the water hyacinth is an aquatic plant that in Mexico is not used for anything, even is considered as an undesirable plant in the water bodies.

Regarding to water quality, the results obtained indicate that there are no significant differences between the physicochemical parameters of the ponds water, such as control group as experimental group (Table 2). This becomes relevant because in any fish management, the control of water quality is necessary to avoid fish mortality along experimental time.

. Also, the physicochemical parameters, were within the ranges for commercial tilapia farming, recommended by other authors [23]. These ranges are the following: dissolved oxygen 4.86–10.53 mg/l, temperature 24-26 °C, pH 6.1–8.3, conductivity 35–87 µS/cm and ammonia 0.01–3.0 mg/l.

CONCLUSION

Based on the results obtained, it is possible to conclude that the objective of this work was achieved; since the food prepared from water hyacinth, was accepted by

.

the tilapias, just like the commercial food. Moreover, the weight gains of tilapia fed with supplemented water hyacinth, was higher than tilapia fed with commercial food; therefore, this work can contribute to tilapia aquaculture development in Mexico.

Competing interests. The author declares that he has no competing interest.

Acknowledgments. The author wishes to thank M.C. David Ocampo Peraza, for the place and facilities provided, to carry out this work at the Center for Ecology and Sustainable Agriculture. Also, I wish to extend a special thanks to my granddaughter Josefina Aguilar Galindo (a 15-year-old student) for her help to realize this work. Finally, I thank to the Rector of the Technological University of Escuinapa, Dr. Juan Manuel Mendoza for his support in carrying out this work

REFERENCES

1. FAO. 2020. The State of World Fisheries and Aquaculture 2020. Sustainability in action. Rome.
https://doi.org/10.4060/ca9229en

2. Rob Fletcher. Senior Ed. The Fish site. 2020 tilapia production figures revealed
https://thefishsite.com/articles/2020-tilapia-production-figures-revealed

3. Ahmed, N., & Azra, M. N. (2022). Aquaculture Production and Value Chains in the COVID-19 Pandemic. *Current Environmental Health Reports*, 1-13.).
https://doi.org/10.1007/s40572-022-00364-6

4. FAO. 2012. The State of World Fisheries and Aquaculture 2012. Food and Agricultural Organization of the United Nations.
www.fao.org/icatalog/inter-e_htm

.

5. Anuario Estadístico de Acuacultura y Pesca 2020.Comisión Nacional de Acuacultura y Pesca
https://www.gob.mx/conapesca/documentos/anuario-estadistico-de-acuacultura-y-pesca

6. Britannica, T. Editors of Encyclopaedia (2021, November 15). *Tropic of Cancer*. *Encyclopedia Britannica*.
https://www.britannica.com/place/Tropic-of-Cancer

7. FIHSIN - SINAT - Semarnat
http://sinat.semarnat.gob.mx › sin › estudios

8. SEMARNAT- IMTA 2014. Estudio en modelo físico del vertedor de la presa de almacenamiento Santa Maria, Mpio. de El Rosario, en el Estado de SINALOA. Convenio SGIH-IM TA-14-001-RF-Clave IMTA : HC-1445.3.
https://docplayer.es › 60949033-Estudio-en-modelo-fisi...

9. Martínez-Cordero, F.J., Delgadillo, T.S., Sanchez-Zazueta, E. and Cai, J. 2021. *Tilapia aquaculture in Mexico: assessment with a focus on social and economic performance*. FAO Fisheries and Aquaculture Circular No. 1219. Rome, FAO.
https://doi.org/10.4060/cb3290en

10. AOAC 2005. Official Methods of Analysis of AOAC International, 17th Edition. William Horwitz Ed. ISBN: 0-935584-89-7
https://catalogo.latu.org.uy › opac_css

11. Phuong, T.T.L., and Boyd, C.E. (2012). Comparison of phenate and salicylate methods for determination of total ammonia nitrogen in freshwater and saline water. J. of the World Aquaculture Society. 4,6, 885-889
https://doi.org/10.1111/j.1749-7345.2012.00616.x

12 von Bertalanffy, l. (1938). a quantitative theory of organic growth (inquiries on growth laws. ii). *Human Biology*, *10*(2), 181–213.

.

https://www.jstor.org/stable/41447359

13. Ansah, Y. B., and Frimpong, A. E. (2015). Using Model-Based Inference to Select a Predictive Growth Curve for Farmed Tilapia. *North American Journal of Aquaculture* 77:281–288.
http://www.tandfonline.com/doi/full/10.1080/15222055.2015.1020080

14. Dumas, A., France, J., Bureau, D. (2010). Modelling growth and body composition in fish nutrition: where have we been and where are we going? *Aquaculture Research* 41(2):161-181.
https://doi.org/10.1111/j.1365-2109.2009.02323.x
.

15. Ng, W. K., Teh, S. W., Chowdhury, K. M., Bureau, D. P., Ng, W. K., Teh, S. W., ... & Bureau, D. P. (2013). On-farm feeding and feed management in tilapia aquaculture in Malaysia. FAO fisheries and aquaculture technical paper, 583, 407-431.

16. Leyva-López N, Lizárraga-Velázquez CE, Hernández C, Sánchez-Gutiérrez EY. Exploitation of Agro-Industrial Waste as Potential Source of Bioactive Compounds for Aquaculture. Foods. 2020; 9(7):843.

https://doi.org/10.3390/foods9070843

17. El-Sayed, A.-F.M. 1999. Alternative dietary protein sources for farmed tilapia, Oreochromis spp. Aquaculture 179: 149-168.

https://doi.org/10.1016/S0044-8486(99)00159-3

18. Coppola D, Lauritano C, Palma Esposito F, Riccio G, Rizzo C, de Pascale D. Fish Waste: From Problem to Valuable Resource. Marine Drugs. 2021; 19(2):116.

https://doi.org/10.3390/md19020116

19. Fasakin, E.A., Balogun, A.M. and Fasuru, B.E. 1999. Use of duckweed, Spirodela polyrrhiza L. Schleiden, as a protein feedstuff in practical diets for tilapia, Oreochromis niloticus L. Aquacult. Res. 30: 313-318.

.

https://doi.org/10.1046/j.1365-2109.1999.00318.x

20. Essa, M.A. 1997. Utilization of some aquatic plants in diets for Nile tilapia, Oreochromis niloticus, fingerlings. Egyp. J. Aquat. Biol. Fish. 1(2): 19-34.

DOI: 10.21608/EJABF.1997.3373

21. Hassaan, M. S., Soltan, M. A., Mohammady, E. Y., Elashry, M. A., El-Haroun, E. R., & Davies, S. J. (2018). Growth and physiological responses of Nile tilapia, Oreochromis niloticus fed dietary fermented sunflower meal inoculated with Saccharomyces cerevisiae and Bacillus subtilis. *Aquaculture*, *495*, 592-601.

https://doi.org/10.1016/j.aquaculture.2018.06.018

22. El-Sayed, A.-F.M. 2003. Effects of fermentation methods on the nutritive value of water hyacinth for Nile tilapia Oreochromis niloticus (L.) fingerlings. Aquaculture 218, 471–478.

https://doi.org/10.1016/S0044-8486(02)00252-1

23._Makori, A.J., Abuom, P.O., 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* **20**, 30 (2017).

http://creativecommons.org/publicdomain/zero/1.0/

.