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Research Article

Bioeconomic profitability analysis of tropical gar (*Atractosteus tropicus*) grow-out using two commercial feeds

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ABSTRACT. Tropical gar (*Atractosteus tropicus*) aquaculture is a potential economic activity in southeast Mexico. This study analyzed the economic profitability of tropical gar grow-out using two commercial feeds (Silver Cup® and Super®). The last one was designed based on the digestive physiology of the species. The experiment was conducted in six concrete ponds of 4 m^3 (two treatments with three replicates) for 210 days; in each experimental unit 40 juveniles were stocked with an initial average weight and a total length of 104 ± 10 g and 27.7 ± 0.88 cm, respectively. At the end of the grow-out, there were statistics differences ($P < 0.05$) among treatments, where fish fed with Silver Cup® obtained the highest final average weight and total length (450.29 ± 5.36 g and 41.7 ± 1.81 cm, respectively), compared with fish fed Super®, which obtained a final average weight and total length of 415.05 ± 5.38 g and 41.4 ± 1.57 cm. Proximal analysis indicated a better protein content and fewer lipids in fish fed with Super®. The profitability analysis showed that fish fed with Silver Cup® diet had the highest values, with a Net Present Value (NPV) = US$55,332.63, Cost/Benefit (C/B) = US$1.5 and Internal Return Rate (IRR) = 48.38%, while for fish fed with Super® diet was NPV = US$50,852.28, C/B = US$1.49 and IRR = 47.03%. In conclusion, it is considered that both grow-out foods are profitable, although better nutritional value and less production cost are using Super® diet.

Keywords: *Atractosteus tropicus*; tropical gar; grow-out; net present value; internal return rate; bioeconomic profitability analysis

INTRODUCTION

Tropical gar *Atractosteus tropicus* is distributed from southeast Mexico to Central America, including countries such as Costa Rica, Guatemala, Nicaragua, Honduras and El Salvador; it represents a high consumption fishery resource in southeast Mexico (Miller *et al*., 2009). *A. tropicus* fishery represents a substantial income in rural areas as a food resource, handcraft, and aquarium product (Márquez-Couturier & Vázquez-Navarrete, 2015).

Its high adaptability gives it great potential for captivity production (Márquez-Couturier *et al*., 2013). Studies about its biology and development have been essential for understanding its reproduction and captivity growth (Márquez-Couturier *et al*., 2006), nutritional requirements of larvae and juveniles (Frías-Quintana *et al*., 2010, 2016, 2017), digestive system development and enzymatic activity (Guerrero-Zarate *et al*., 2013; Frías-Quintana *et al*., 2015), as well as grow-out (Vázquez-Navarrete & Márquez-Couturier, 2010; Márquez-Couturier *et al*., 2013). Also its have been developed specific diets in order to satisfy its nutritional requirements in early stages of larvae (Frías-Quintana *et al*., 2016), experimental grow-out of juveniles in concrete ponds and the flesh organoleptic evaluation (Jesús-Contreras, 2016) and finally a financial analysis in polyculture (González *et al*., 2011).

Considering those mentioned above, the absence of bioeconomic analysis in pilot production systems is one of the reasons why tropical gar aquaculture is not yet at a high commercial level (Márquez-Couturier & Vázquez-Navarrete, 2015). For this reason, the object-

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tive of the study was to analyze the profitability on the tropical gar grow-out at a commercial level, based on biological information obtained from the culture development reaching a commercial size, flesh proximal analysis, as well as the costs generated from the production cycle. During the culture, it was compared fish growth under conventional diet with a trout commercial feed (Silver Cup®) (Márquez-Couturier *et al*., 2013) and a commercial diet explicitly designed for tropical gar (Super®) (Jesús-Contreras, 2016). Also, it was evaluated the investment return and the benefits/cost relationship from the tropical gar grow-out and finally, several economic indicators that allowed the financial profitability analysis on this monoculture activity.

MATERIALS AND METHODS

Tropical gar juveniles

Fish were obtained from the tropical gar hatchery of Otot ibam farm, located at the 7.5 km Comalcalco-Potrerito Zapotal second section in Comalcalco, Tabasco, México. Produced from captivity spawnings and results from the feeding and growth system mentioned by Márquez-Couturier *et al*. (2013).

Experimental design

The growth-out of *Atractosteus tropicus* juveniles was evaluated using two commercial foods for 210 days. Feeds used were the Super® diet (specific formulated diet for tropical gar) 4.5 mm particle size, with 38% protein and 7% lipids (Jesús-Contreras, 2016), and trout commercial feed, Silver Cup® 5.5 mm particle size, 42% protein and 15% lipids, conventional feed for culture (Márquez-Couturier *et al*., 2013). Feed Super® was formulated at the Biochemistry Laboratory UJAT-DACBIOL and manufactured by Consorcio Super S.A. de C.V. in Guadalajara, Jalisco, México, by a double extrusion process (Jesús-Contreras, 2016).

For the economic evaluation was designed a complete random experiment with three replicates by treatment. We used six concrete ponds (5×1×1 m), 240 fish were used with an average weight of 104 ± 10 g and a length of 27.7 $\pm$ 0.88 cm. The first grow-out phase used 20 fish m^{-3} with a water volume of 2 m^3, at the final phase the density was corrected for 10 fish m^{-3} and a water volume of 4 m^3.

In both phases, fish were fed three times per day (9:00, 13:00 and 17:00 h). In the first phase, fish were fed with 5% of body mass and in the second phase with 3%. Left overfeed was weighted in order to develop the daily consumption analysis.

Growth evaluation

For growth evaluation in weight (g ± SD, standard deviation) and total length (cm ± SD), an initial and monthly sampling with a digital scale (Torrey) and length with a conventional ichthyometer were performed. Feeding was corrected monthly. Survival rate was calculated with a direct count of dead fish.

Ponds management

Water quality was evaluated weekly with a total water exchange and cleaning of each pond. Dissolved oxygen (7.8 ± 3.7 mg L^{-1}) and temperature (28.2 ± 5.9°C) was recorded with an oximeter (YSI^{MR} model 55), and pH (7.8 ± 0.6) was recorded with a pH meter (Denver instrument® ultraBASIC).

Proximate composition analysis

The proximate composition analysis was performed using muscle tissue of 12 fish at the beginning of the experiment with an average weight of 90 ± 6 g and a total length of 26.6 ± 0.5 cm; the muscle was obtained from the dorsal area and then lyophilized. At the end of the experiment 15 fish (five per replicate) were sampled from Super® feed (421 ± 40 g and 41.3 ± 1.24 cm) and Silver Cup® feed (454 ± 58 g and 42.3 ± 1.72 cm). The lyophilized samples were analyzed at CIBNOR (Centro de Investigaciones Biológicas del Noroeste) in Baja California Sur, México, for protein content (Microkjeldahl %N × 6.25), lipids (Soxtec-Avanti Tecator), humidity (weight difference at 70°C 24 h^{-1}), ash (weight difference calcination at 500°C 24 h^{-1}), fiber (hydrolysis acid/base method) and energy (calorimeter determination) following method described by AOAC (2000).

Investment

The necessary investment to implement an economically sustainable culture was estimated for a minimum of six tanks of 6 m diameter (35 m^3), with a capacity of 3,600 fish (600 per tank) and one-production cycle per year (Table 2). The cost of two water pumps was estimated, a water well, a concrete pond for water storage, hydraulic material, land preparation, electric plant and set up. Finally, the land cost was estimated according to agriculture land cost (US$12.68 per m^2) for 500 m^2.

Profit and costs

Operational costs were defined as fixed and variable costs and were estimated a cost per fish, for each diet. Fixed costs (F_C) are the depreciation of the investment (calculated over 5% of the annual investment), for example, the cost of the fry. Variable costs were calculated depending on the culture time or biomass. Costs depending on culture time were: labor (L_C), calculated using the daily minimum wage in Mexico, published in the Diario Oficial de la Federación (DOF, 2017) (US$4.23) multiplied for worked days and number of workers (1 worker per 6 tanks is enough), energy costs (E_C), calculated estimating the use in kW h^{-1} from the pump and illumination; veterinary costs (V_C), material for preventing biological risks during culture, and feeding cost (f_C), not only depends on time but also on biomass, since the daily feeding amount depends on growth (ω), therefore, the use of a function was necessary (Poot-López *et al*., 2014).

Total costs were estimated following:

$$Tc = F_C + L_C + E_C + V_C + \int_0^{\omega} (f_C(\omega))\, d\omega$$

Income was calculated according to the total biomass produced (W), multiplied by the annual average cost per kilogram of *A. tropicus* (p) in Tabasco. The value of the produced biomass (income) was calculated with the following equation (Poot-López *et al*., 2014):

$$Tv = p(W_T)$$

With the individual cost per fish, a unitary production cost was projected over a 3,600 fish production. Further analysis was performed for the investment cost for this production.

Net present value and internal rate of return

The net present value (*NPV*) was calculated with the annual net cash flow (*NFC*) considered for 10 years (investment depreciation time), using a discount rate (i) of 10%. The following formula was used for the NPV calculation (Barry & Ellinger, 2010; Kay *et al*., 2012):

$$NPV = -INV + \sum_{t=1}^{T} \frac{NCF_t}{(1+i)^t}$$

Where *INV* is the total costs of the initial investment, and T is the total time of the project. The cost-benefit relation (C/B) was estimated with the following equation (Kay *et al*., 2012):

$$\frac{C}{B} = \sum_{t=1}^{T} Vt(1-r)^{-t} \,/ \sum_{t=1}^{T} Ct\,(1-r)^{-t}$$

The internal rate of return (IRR) was calculated when NPV = 0. Finally, NPV, C/B and IRR were compared for each treatment.

Statistical analysis

Individual weight, total length, proximate composition, NPV, IRR and C/B data were analyzed in order to fulfill normality (Kolmogorov-Smirnov) and variance homoscedasticity (Levene) using a Student-*t* analysis; survival was analyzed with chi square. All statistics were performed using Statistica v.10.0, $\alpha = 0.05$.

RESULTS

Growth and survival

Growth results showed a significant difference among treatments ($P < 0.05$). The final average weight was 450.29 ± 5.36 g for Silver Cup® and 415.05 ± 5.38 g for Super® (Fig. 1). Length also showed significant differences ($P < 0.05$) from the first to the fifth month. Although the two final months were not statistically different. The final average length was 41.7 ± 1.81 cm for Silver Cup® and 41.4 ± 1.57 cm for Super® (Fig. 2). Survival was 98.7% for both with no statistical differences.

Proximal composition analysis

Proximal analysis of tropical gar flesh tissue at the end of the experiment showed significant differences among treatments ($P < 0.05$), except for ash and fiber content (Table 1). The highest protein content was found in fish fed with Super® (75.5%), compared with those with Silver Cup® (65.8%). Lipids content was statistically different, Silver Cup® (24.7%), followed by Super® (16.6%). The highest significant humidity was for Super® (9.4%) compared to Silver Cup® (1.2%). Highest caloric content was found in Super® (5.95 ± 0.041 Kcal g^{-1}).

Investment costs

In order to produce 3,600 fish, an investment of US$13,526.73 was estimated for both cases. This investment includes the purchase of land 500 m^2, equipment and material, land preparation and electrical installation, among others (Table 2).

Production cost

Fish fed with Super® consume daily on average (163.02 g d^{-1}), more than those fed with Silver Cup® (138.93 g d^{-1}). The total feed used was 260.69 kg for Super® and 232.995 kg for Silver Cup® during all experiment. The cost of Silver Cup® was US$1.26 per kg, compared with that of Super® US$0.92 per kg. Each fry had a cost of US$0.66. Thus, the total cost of the fry was US$158.56. The total cost of electricity was US$184.50, labor was US$888.39, and the expenses for veterinary materials were US$47.57 (Table 3).

Benefits and income

The total biomass produced with Super® was 48.98 kg, compared with the biomass produced with Silver Cup® 53.13 kg. The commercial value of the farmed tropical

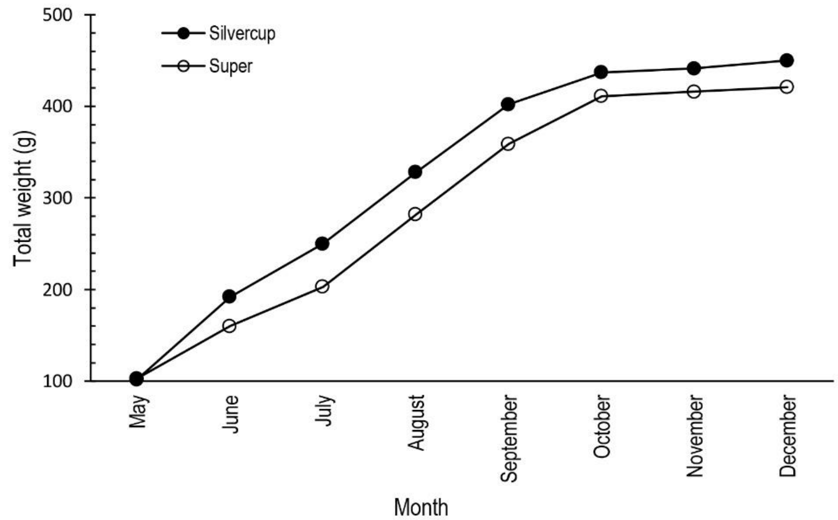

Figure 1. Mean growth weight (g) of tropical gar juveniles cultivated with commercial diets.

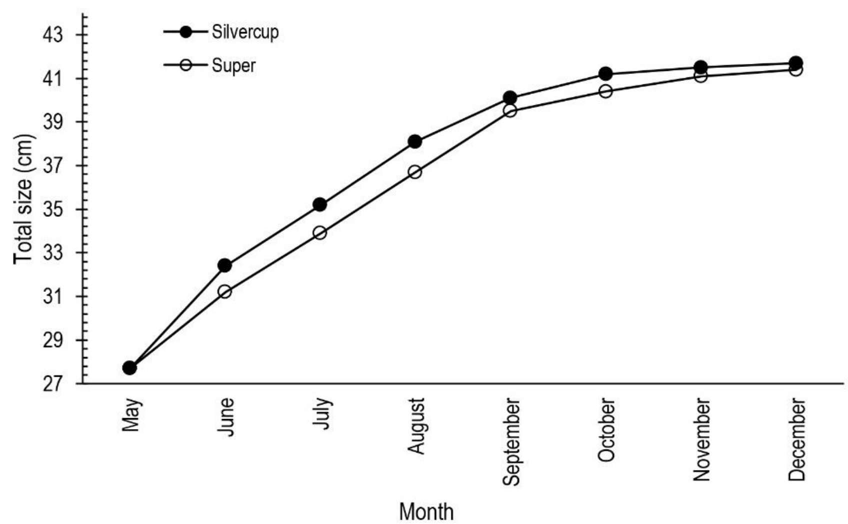

Figure 2. Mean growth size (cm) of tropical gar juveniles cultivated with commercial diets.

gar, between 400 and 500 g, is US$4.23 for each organism.

The estimated biomass produced in six concrete ponds of 35 m^3 with 600 fish for Super® diet was 1,479.24 kg, with a value of US$414.17. For the Silver Cup® diet, the biomass produced was 1,604.83 kg, with a value of US$449.34 (Table 4). The produced cost per fish decreased with the increment of organisms from 120 to 3,600 fish. Thus, the production cost for Super® decreased to US$1.74. The production cost of 3,600 fish fed with Silver Cup® was US$1.90 per fish. Therefore, the total production cost for Super® would be US$6,253.76, while for Silver Cup® US$6,852.97 (Table 4). The estimated income for production with Super® would be US$12,509.41, with a profit of US$6,255.65. For Silver Cup® the income would be US$13,571.53, with a profit of US$6,718.56.

Net present value and internal rate of return

The NPV at a minimum acceptable rate of return (MARR) of 10% during 10 years from cash flow produced from the tropical gar grow-out with Silver Cup® was US$55,332.63. The cost-benefit relation (C/B) was US$1.50, and IRR was 48.38%. For Super® NPV was US$50842.28, (C/B) of US$1.49 and IRR of 47.03% (Table 5). NPV was estimated for one production cycle per year (210-240 days). In tropical weather conditions, the environmental temperature does not affect growth. However, it is advisable to harvest before the end of December.

Table 1. Muscle proximal composition of tropical gar fed with two commercial diets. Different letters in a row indicate significant differences (P < 0.05).

Nutrients	Initial	Silver Cup®	Super®
Proteins (%)	85.62 ± 0.28[a]	65.8 ± 2.26[c]	75.5 ± 0.20[b]
Lipids (%)	5.49 ± 0.04[c]	24.7 ± 1.76[a]	16.6 ± 0.48[b]
Humidity (%)	8.55 ± 0.03[a]	1.2 ± 0.54[b]	9.4 ± 1.41[a]
Ashes (%)	4.65 ± 0.07[a]	3.4 ± 0.12[c]	4.0 ± 0.07[b]
Fibers (%)	0.04 ± 0.02[b]	0.11 ± 0.04[a]	0.11 ± 0.03[a]
Energy (Kcal g^{-1})	5.03 ± 0.007[c]	5.54 ± 0.048[b]	5.95 ± 0.041[a]

Table 2. Initial investment required to produce 3,600 tropical gars. [a]Hidromecánica y Sistemas de Bombeo S. de R.L. de C.V., Villahermosa, Tabasco, México. [b]Estimated budget made by a local construction company, Villahermosa, Tabasco, México. [c]Comisión Federal de Electricidad (CFE), México. [d]ARIGEM, Centro, Tabasco, México. [e]The Home Depot, Local Store in Villahermosa, Tabasco, México.

Input	Unitary cost (US$)	Quantity (units)	Total cost (US$)
Water pump[a]	121.51	2	243.02
Ground preparation[b]	369.98	1	369.98
Power plant[c]	1,003.17	1	1,003.17
Well construction[b]	475.69	1	475.69
Geomembrane pond[d]	528.54	6	3,171.24
Pond materials[d]	281.43	6	1,688.57
Electrical installation[c]	179.70	1	179.70
Water reservoir filters[e]	52.85	1	52.85
Land/m^2	12.68	500	6,342.49
Total			13,526.73

Table 3. Production cost calculated for producing 120 fish with two different commercial feed.

Input	Cost (US$)	
	Silver Cup®	Super
Fry	158.56	158.56
Feeding (f_c)	111.80	91.83
Energy (E_c)	184.49	184.49
Labor (L_c)	888.39	888.39
Veterinarians (V_c)	47.57	47.57
Total (T_c)	1,390.81	1,370.84

DISCUSSION

Results indicated that fish fed with Super® diet obtained a less than average growth than those fed with Silver Cup®. Super® diet contained less protein (4% less). In this sense, Carrillo (2011) did not find differences among weight and size in tropical gar fed with three commercial feeds (Tilapia 38% CP; Tilapia 38% + oil and trout feed), although was observed a high weight and length dispersion between diets.

Water quality parameters did not exceed the allowable limits (Márquez-Couturier *et al*., 2013); thus, they did not have an impact on growth. The experiment showed the survival of 98.87%, which agrees with other carnivorous and omnivorous fish in growth experiments; rainbow trout *Oncorhynchus mykiss* 96.3% (García-Macías *et al*., 2004) and channel catfish *Ictalurus punctatus* 97% (Yildirim *et al*., 2007).

Table 4. Costs and revenues estimated for producing 3,600 tropical gars per diet.

Description	Value (US$)	
	Silver Cup®	Super®
Total cost (Tc)	6,852.97	6,253.76
Sales income (Tv)	13,571.53	12,509.41
Profit (U)	6,718.56	6,255.65

Table 5. Economic profitability for producing 3,600 tropical gars per diet. [a]Calculated on a 10% annual minimum acceptable rate of return (MARR). NPV: Net Present Value, C/B: Cost/Benefit, IRR: Internal Return Rate.

Description	Silver Cup®	Super®
NPV	US$55,332.63[a]	US$50,842.28[a]
C/B	US$1.50[a]	US$1.49[a]
IRR	48.38%	47.03%

Average weight and size for each fish were suitable concerning market price (Márquez-Couturier *et al*., 2013) of US$4.23 year average (with fluctuations to US$5.29 in seasons of supply shortages), for fish between 400 to 550 g and 40 to 50 cm in size.

The chemical proximal analysis suggested that the nutritional quality of tropical gar fed with Super® is better than those fed with Silver Cup®, because fish fed with Super® contained a higher amount of protein, and hence, could have a less viscerosomatic index and greater carcass meat yield, as happen in *O. mykiss* (Francesco *et al*., 2004; García-Macías *et al*., 2004). In the near future, better meat quality could result in an advantage for the market, as this could allow greater diversity in products (such as fillets and meat medallions), increasing the income potential. Jesús-Contreras (2016), found that *Atractosteus tropicus* fed with Super® had better sensory quality (taste, texture, color, etc.) than those fed with Silver Cup®, and wild fish.

The production cost per fish was US$1.90 for Silver Cup® and US$1.74 for Super®, not taking into consideration the initial investment. These costs allow us to obtain almost double profits having a market value of US$4.23, which may indicate that producing 3,600 fish is superior to the break-even point. Both methods are better than the one used by González *et al*. (2011), where they found that in order to reach the balance point is need it to produce 7,875 organisms of 500 g in average.

Profitability indicators of this study (Table 5), indicated that both treatments have economic viability because NPV in both cases was positive; C/B was greater than 1, indicating that with each dollar invest the profit will be US$0.49 for both cases. Both IRR is acceptable, which are greater than the MARR set in 10% yield, according to proposed by Barry & Ellinger (2010), that the grow-out of tropical gar with both diets is a profitable business.

As the profitability is greater with Silver Cup®, added to the differences found in individual growth during grow-out with Super® could suggest that an increment in protein availability in the diet might result in better growth as proved in *O. mykiss* (García-Macías *et al*., 2004), which also improve the profitability indicators with diet Super®.

The NPV and C/B obtained in this study for both cases (Table 5) was superior to those reported by González *et al*. (2011) with Silver Cup®, obtaining an NPV of US$6333.25 and a C/B of US$1.08. Our IRR for both diets is higher than those obtained by González *et al*. (2011) (25.6%), which suggest that a monoculture with both diets, could be an activity with high potential for investment return. This same author suggests that a polyculture with species such as; Mayan cichlid (*Cichlasoma urophthalmus*) and tilapia (*Oreochromis niloticus*), could considerably increment the profitability indicators having an IRR of 145%. Even if polyculture could amortize the investment in tropical gar production, this will increment the grow-out time considerably by decreasing the feed conversion ratio from 1.9 in monoculture to 0.9 in polyculture (Márquez-Couturier *et al*., 2013), suggesting a considerable increment in electric and labor costs.

Despite lower growth using Super® diet, the proximal analysis showed that the nutritional value based on higher protein and fewer lipids content was greater than using Silver Cup®. This suggests a better product with higher carcass meat yield. More protein in muscle and less mesenteric fat suggest better market opportunities for *A. tropicus*, like fillets commercialization and gourmet dishes, thus giving support to the conclusion that Super® represents a better way to grow out this species in the long term.

Additionally, IRR, C/B and NPV of tropical gar production indicated profitability using both diets. A better nutritional quality was observed using Super® diet, less feeding cost, as well as better market adaptability, so it is concluded that using Super® feed for grow-out tropical gar is a better alternative in a pilot commercial scale.

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