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Practical diets and stocking densities in the cultivation of juvenile *Centropomus poeyi*

Dietas prácticas y densidades de siembra en el cultivo de juveniles de robalo prieto *Centropomus poeyi*

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Abstract

Two 60-day experiments were conducted to evaluate the effects of different diets and stocking densities on juvenile *Centropomus poeyi*. Three diets were tested: poultry by-product meal (POU), pork by-product meal (POR), and a commercial control diet (CD). The pork by-product meal diet yielded the highest final weight (12.48 g ± 3.54) and total length (11.83 cm ± 1.18), with survival rates across treatments ranging from 75% to 95%. In the second experiment, three stocking densities were assessed using the optimal diet from the first experiment. The highest density resulted in the greatest weight gain (18.52 g ± 4.42) and average length (13.55 cm ± 0.91), with survival rates ranging from 94.44% to 100%. These findings suggest that pork by-product meal may be a promising ingredient for juvenile *C. poeyi* diets under the conditions evaluated, and that juveniles can be managed at a density of 12 fish/m^3. However, this density should be further evaluated in relation to the experimental duration and the system's carrying capacity.
Keywords: Growth performance, feed conversion ratio, protein replacement, by-product meal.

Resumen

Juveniles de *C. poeyi* fueron sometidos a dos experimentos de 60 días cada uno para evaluar diferentes dietas y densidades de siembra. Se evaluaron tres dietas: harina de subproductos de ave (POU), harina de subproductos de cerdo (POR) y una dieta comercial como grupo control (CD), obteniéndose el mejor resultado con la harina de subproductos de cerdo, en la que los peces alcanzaron un peso de 12.48 g (± 3.54). Resultados similares se obtuvieron para la longitud total, pues la dieta POR alcanzó 11.83 cm (± 1.18), con una sobrevivencia del 75% al 95% entre los tratamientos. En el segundo experimento, los organismos fueron sometidos a tres densidades utilizando la mejor dieta del primer experimento, obteniendo la mayor ganancia de peso en la densidad más alta, de 18.52 g (± 4.42), así como la mayor longitud promedio, de 13.55 cm (± 0.91), con sobrevivencias entre 94.44% y 100%. Estos resultados sugieren que la inclusión de dietas a base de subproductos de cerdo es prometedora para incorporarlas al cultivo de robalo prieto y que la especie es manejable a densidades de 12 peces/m^3, aunque este patrón deberá evaluarse en función del tiempo y de la capacidad de carga del sistema empleado.
Keywords: Rendimiento del crecimiento, índice de conversión alimentaria, sustitución de proteínas, harina de subproductos.

Introducction

Aquaculture is one of the activities with the highest international demand, as fish are an important source of protein (FAO, 2024). This industry needs to develop new techniques and methods to produce feeds more quickly to meet human consumption demand; to this end, it draws on knowledge from biology, engineering, and ecology, making it one of the largest sectors of the local and international economy (García-Medel 2022; FAO 2022). Freshwater fish are in high demand for aquaculture in Latin America, as they possess significant global biological diversity (Flores-Nava and Brown 2010). To reduce dependence on freshwater aquaculture products, research is underway to introduce a variety of fish in the market, including salmon, sturgeon, pompano, and horse mackerel (Luchini, 2005). Starting in 1989 in Mexico, studies began on the reproductive biology of high-value marine species, such as cabrilla, snapper, sea bass, red snapper, corvina, pompano, totoaba, and flounder (Avilés, 2000).

Marine species of the genus *Centropomus* are widely available in the market and are among the most consumed fish in southeastern Mexico due to their flesh quality, flavor, and abundance (Reyes 2004; Lorán-Núñez *et al.* 2012). The common snook, *Centropomus undecimalis*, is the most extensively studied species within this genus, with considerable knowledge regarding its biology, ecology, and reproduction in captivity (Alvarez-Lajonchère & Tsuzuki, 2008). In contrast, the Mexican snook, *C. poeyi,* remains understudied, with existing research primarily focusing on reproduction, sexual maturity, and taxonomy *(*Lorán-Núñez *et al., 2012; Chávez, 1963).* Species of the Centropomidae family have high potential for aquaculture. However, despite their high potential for incorporation into production systems, the group requires the development of formulated diets that meet their specific nutritional requirements. In *C. undecimalis*, juveniles respond positively to diets high in protein and lipids, with a protein-sparing effect observed when lipid intake is increased (Concha-Frías, 2018; Arenas *et al*., 2021). These results are particularly relevant for less-studied species such as *C. poeyi*, for which available nutritional information remains limited.

The search for alternative ingredients to fish meal is a priority in current aquaculture nutrition, due to pressure on marine resources, price volatility, and the need to develop more sustainable feeds. Among these alternatives, meals derived from animal by-products, such as poultry or swine by-products, have been evaluated for availability, protein content, and potential to reduce production costs (Freire-Silvão & Pinto-Nunes, 2017). In particular, poultry by-product meal has been the subject of numerous studies as a partial substitute for fish meal. Galkanda-Arachchige *et al*. (2020) indicated that its effectiveness depends on inclusion level, farmed species, ingredient quality, amino acid profile, and digestibility. Consequently, for emerging species such as *C. poeyi*, evaluating animal by-products is needed to avoid the assumption that total fish meal replacement is suitable without specific experimental validation.

Stocking density is a key variable in aquaculture, as it affects growth, survival, feeding behavior, water quality, and fish welfare. The response to density varies across species, juvenile size, rearing system, and management conditions. In the case of *C. poeyi*, evaluating different densities is particularly relevant given the limited specific information available and the need to establish technical criteria for its domestication for aquaculture. However, any recommendations regarding density should be made with caution, as the best performance within an experimental range does not guarantee an optimal productive density (Ellis *et al*., 2002). The present study seeks to generate data to facilitate the incorporation of C. *poeyi* into aquaculture, thereby providing an alternative species for regional producers. Additionally, this research is the first to evaluate unconventional commercial diets as replacements for live feed, addressing both the unknown nutritional requirements of C. *poeyi* and the potential for cost reduction in feed procurement.

Materials and methods

Study Area

This study was conducted at the Marine Aquaculture Station (MAS) of the Tropical Aquaculture Laboratory (LAT), from the Academic Division of Biological Sciences at the Juárez Autonomous University of Tabasco. It consisted of two experiments: evaluation of three diets (two experimental and one control) and evaluation of three stocking densities in the culture of Mexican snook juveniles. The first experiment evaluated different diets, and the best diet was used in the second experiment to evaluate stocking densities.

Obtaining and rearing juveniles

Juvenile fish for this study were produced at the MAS facility through induced spawning with LHRHa. Following 45 days of larviculture, the juveniles were transferred to a 2,000-liter tank and reared for nine months before experimentation.

Experimental design diets

A completely randomized design was used, consisting of three treatments: commercial trout feed (El Pedregal®, Silver cup Mexico) (control diet; CD), feed based on poultry by-product meal (POU), and feed based on pork by-product meal (POR). Each treatment was replicated three times; the experimental units consisted of 70-L fiberglass tanks containing 20 fish each. A recirculation system was used, consisting of 70 L cylindro-conical fiberglass tanks connected in a closed loop to maintain water quality, with a fine-sand filter and two 1 m^3-capacity fiberglass tanks connected to a biofilter and reservoir. These tanks were equipped with biospheres used for bacterial colonization and solid sedimentation. A 1 HP Jacuzzi® pump was used for water recirculation.

Experimental design density

A completely randomized design was used with three treatments: 4 fish/m^3 (D4), 8 fish/m^3 (D8), and 12 fish/m^3 (D12). Each treatment was replicated three times; the experimental units consisted of 2000-L tanks. A recirculating system was used, consisting of 2000-L polyethylene tanks connected in a closed loop with a fine-sand filter serving as a mechanical filter, and a 5-m^3 tank biofilter and reservoir, equipped with biospheres and PVC pieces to support bacterial colonization and solid sedimentation. A 2 HP Jacuzzi® pump was used for water recirculation. In this experiment, a feed containing pork by-product meal (POR) was used in all treatments.

Diet preparation

The diets based on poultry meal (POU) and pork meal (POR) were prepared and estimated to contain 40-45% crude protein. The meals were sieved through a 400 µm sieve. All ingredients, both liquid and solid, were weighed separately and mixed for 30 minutes; once mixed (Table 1), they were passed through a Torrey® M-22R1 meat grinder to produce pellets, which were cut to a size suitable for the fish's mouth and dried in a Thermo Scientific™ oven for 12 hours at a temperature of 40 °C. The dried feed was then stored, properly labeled, under refrigeration at 4 °C.

Feeding

The fish were fed four times a day to apparent satiety, with a 2-hour interval between feedings, for 60 days.

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Formulation-based estimated proximate composition

The proximate composition of the experimental diets was estimated using large language models based on ingredient inclusion levels and typical proximate composition values reported for each ingredient in published feed composition databases and the scientific literature (Heuzé et al., 2015; Villareal-Cavazos et al., 2014; Hernandez et al., 2008). This method provides a preliminary, formulation-based estimate of crude protein, lipid, ash, fiber, moisture, and nitrogen-free extract. Comparable indirect approaches are widely employed in food and feed formulation. Although recent studies have evaluated large language models for estimating human dietary nutrient content, the present values were calculated from diet formulation data. Since the present values were not obtained by laboratory chemical analysis, they should be regarded as estimates (Table 2).

Table 1. Percentage of inclusion used to prepare 100 g of diet.

Ingredients	POU (g)	POR (g)
Poultry by-product	44.00	0.00
Pork by-product	0.00	58.00
Soybean meal	12.45	11.25
Sorghum flour	34.00	22.40
Fish hydrolysate	2.00	2.00
Fish oil (rockfish)	2.10	1.50
ADONAJI soy lecithin	1.60	1.00
Gelatin	3.00	3.00
Vitamin C (Rovimix-Roche)	0.50	50
Vitamin premix (UJAT)	0.20	0.20
Mineral premix (UJAT)	0.15	0.15
Total	**100.00**	**100.00**

Biometric measurements

Initial weight and total length were analyzed to ensure homogeneity among the experimental populations. To determine fish growth, data were measured at 30 and 60 days. Weight (± 0.01 g) and total length (± 0.1 cm) were recorded for all fish used in the experiments. Feeding was suspended 24 hours prior to each biometric measurement to ensure that gastric emptying was complete.

Table 2. Estimated proximate composition based on formulation and published ingredient composition values (% dry-matter basis).

Component	Diet POU	Diet POR
Crude protein	41.96	45.4
Crude lipid	17.78	10.3
Crude fiber	1.47	2.94
Ash	6.57	19.65
NFE	32.22	21.71

Note: Proximate composition was estimated from ingredient inclusion levels and published average ingredient composition values. Values are expressed on a dry-matter basis. Diet formulations were normalized to 100% from the ingredient inclusion levels reported for Diet POU and Diet POR. Proximate composition was estimated from published average ingredient-composition values; therefore, these values should be interpreted as calculated estimates and not as laboratory-analyzed proximate composition.

The poultry by-product ingredient was treated as rendered poultry by-product meal. Reference values were taken from published analyses of poultry by-product meal used in aquaculture feeds, with an approximate composition of 60.0% crude protein, 13.0% crude lipid, 2.5% crude fiber, and 20.0% ash on a dry-matter basis. Moisture was assumed at 8% for conversion to an as-fed basis (Heuzé et al., 2015)

The pork by-product ingredient was treated as rendered pork meal (porcine meat meal). Reference values were taken from published analyses of pork meal used in aquaculture feeds, with approximate composition of 57.4% crude protein, 12.4% crude lipid, 2.41% crude fiber, and 25.29% ash on a dry-matter basis. Moisture was assumed at 8% for conversion to an as-fed basis (Villareal-Cavazos et al., 2014; Hernandez et al., 2008).

Absolute growth (AG), absolute growth rate (AGR), relative growth (RG), relative growth rate (RGR), specific growth rates (AGR), and feed conversion rate (FCR) were calculated for each diet used according to the formulas proposed by Busacker et al. (1990):

AG = Y2−Y1

AGR = (Y2−Y1)/(T2-T1)

RG = (Y2−Y1)/Y1

RGR = (Y2 – Y1)/[Y1(t2 – T1)]

SGR = (lnY2 - lnY1)/(t2-t1) * 100

FCR = (TFC/TWG)

Where: Y1 and Y2 are the wet weight at the beginning and end of the experimental period, T2 – T1 refers to the time period elapsed, lnY1 and lnY2 are the natural logarithms of the weight at the beginning and end of the growth phase. TFC is the total feed consumed, and TWG is the total weight gained.

Survival

The survival rate was estimated during the experimental period by calculating the difference between the initial and final numbers of fish:
% Survival = (Final number of organisms / Initial number of organisms) * 100

Water quality

During the experiments, physicochemical parameters were recorded daily (mean ± standard error): pH was measured using a Hanna® potentiometer, temperature and dissolved oxygen with a YSI 55® oximeter, and weekly readings of ammonia, nitrates, and nitrites were taken with a Hanna® photometer to determine water quality in both experiments.

Data analysis

The assumptions of parametric statistics were assessed; standardized coefficients of skewness and kurtosis were used for normality, while Levene's Test was used to evaluate homoscedasticity. Since the data were parametric, the results of each experiment were analyzed using a one-way analysis of variance (ANOVA) at each sampling time. A Tukey HSD test was used to identify significant differences after the ANOVA. Weight and length were included as response variables. A chi-square test (χ^2) was also used to evaluate whether there were statistically significant differences in survival among the treatments. Statistical tests were performed at a confidence level of $\alpha = 0.05$ using STATGRAPHICS Centurion™. All graphs were created using SIGMAPLOT™ v 11.0.

Results

In the evaluation of diets, data analysis at the start of the experiment indicated that there were no statistically significant differences for weight or length between treatments (ANOVA; P>0.05). Initial fish weight averaged 5.97 ± 1.94 g, with an average length of 9.68 ± 0.97 cm. At 30 days of growth, highly significant statistical differences were observed in both weight and length (ANOVA; P<0.001 in both cases); the POR treatment had the highest average weight (9.42 ± 2.87 g) and the POU treatment the lowest (7.08 ± 2.28 g), the CD had 8.52 (± 3.21) g; in the case of length, the POR treatment (10.91 ± 1.17 cm) had the highest average, and the POU treatment (10.07 ± 0.98 cm) had the lowest. At the end of the experiment (60 days), statistical analysis indicated that there were highly significant differences (ANOVA, P < 0.001); the POR treatment had the highest average weight (12.79 ± 4.27 g), the CD averaged 12.36 ± 3.86 g, and the POU treatment had the lowest average weight (8.88 ± 3.06 g). A similar pattern was observed for length, with the highest average in the POR treatment (11.83 ± 1.18 cm; Fig. 1), and the lowest was in the POU treatment (10.70 ± 1.09 cm). No significant differences in survival rates were observed (χ^2; p > 0.05), with averages of 95% for GC, 92% for POR, and 75% for POU.

Absolute growth ranged from 3.38 to 6.29, with the highest value observed in the POR diet (Table 3). Relative growth, absolute growth rate, relative growth rate, and specific growth rate are shown in

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Table 3. The physicochemical parameters observed during this experiment are summarized in Table 4.

Regarding density evaluation, data analysis at the start of the experiment showed no statistically significant differences among treatments (ANOVA; P > 0.05), suggesting good randomization of organisms across experimental units. The mean initial weight for all treatments was 13.44 (± 2.27) g, with a mean length of 11.90 (± 0.77) cm. Significant differences were observed between treatments at day 30 (ANOVA; P<0.01), with the highest mean value in D12 (16.38 ± 3.38 g), while D8 and D4 showed lower values (14.27 ± 3.40 and 14.11 ± 2.92 g, respectively). For length, the average value for D12 was 13.02 (± 0.81 cm), and the lowest for D4 was 12.44 (± 0.60 cm). At the end of the experiment, the statistical values were significant (ANOVA P<0.01), with the same pattern holding for weight and length; the highest average weight was for D12 (18.52 ± 4.42 g) and the lowest for D4 (15.74 ± 4.67 g). For length, the highest average was observed in D12 (13.55 ± 0.91 cm), and the lowest in D4 (12.95 ± 0.77 cm; Fig. 2). Survival at the end

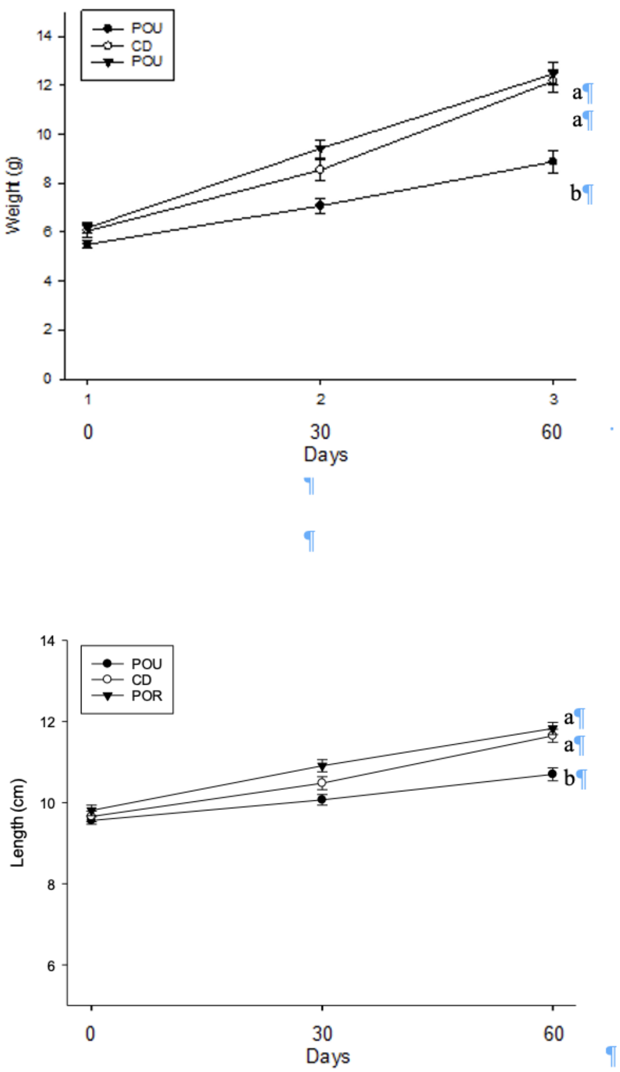

Figure 1. Growth in weight (A) and length (B) of C. *poeyi* fed three different diets during a 60-day experiment. POU = Poultry-based by-product; GC = Control group; POR = Pork-based by-product. The number of observations per treatment was n = 45 (POU), n = 57 (GC), and n = 55 (POR).

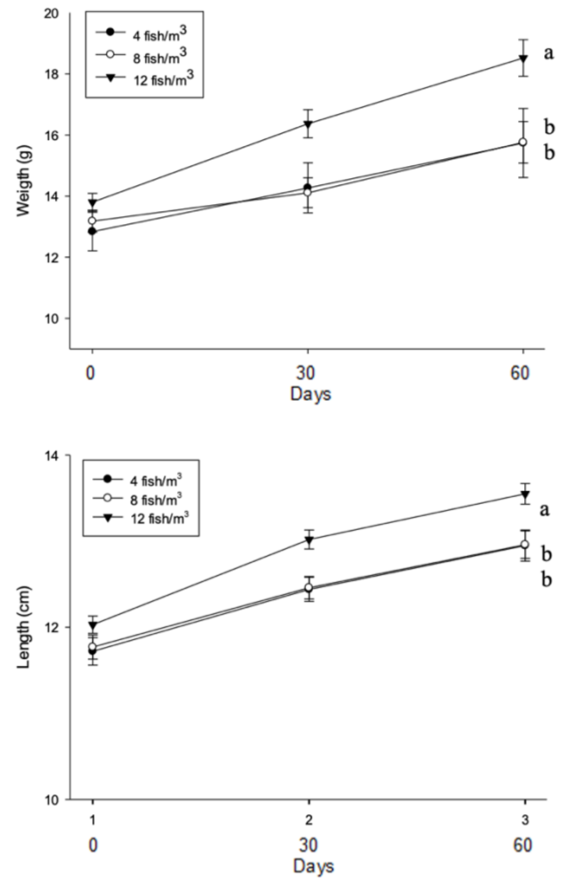

Figure 2. Growth in weight (A) and length (B) of *C. poeyi was* maintained at different stocking densities during 60 days of experimentation. The number of observations per treatment was D4=17, D8=35, and D12=54.

of the experiment ranged from 94.44% to 100%, showing no significant differences between treatments (χ^2, p > 0.05).

Absolute growth ranged from 2.74 to 4.72, with the highest value observed at a density of 12 fish/m³ (D12; Table 5). Relative growth, absolute growth rate, relative growth rate, and specific growth rate are shown in Table 5. The average water quality values in the recirculation system were 8.66 (± 0.27) for pH; 26.29 (± 2.06) for temperature; 4.47 (± 1.79) for dissolved oxygen; 0.19 (± 0.13) for ammonia; 2.02 (± 1.43) for nitrates; and 0.36 (± 0.76) for nitrites.

Table 3. Growth parameters of *C. poeyi* using different diets.

Parameter	Units	CD	POU	POR
Initial weight	g	6.05±1.43a	5.5±1.16a	6.18±1.22a
Final weight	g	12.18±3.65b	8.88±2.94a	12.47±3b
Absolute growth (AG)	g	6.47±0.96	3.37±0.24	6.52±0.91
Absolute growth rate (AGR)	g/day	0.11±0.016	0.06±0.004	0.11±0.015
Relative growth (RG)	%	107.09±16.82	61.14±2.84	102.48±11.82
Relative growth rate (RGR)	%/day	0.86±0.06	0.63±0.02	0.84±0.05
Specific growth rate (SGR)	%/day	1.21±0.13	0.80±0.03	1.17±0.10
Feed Conversion Ratio	-	0.94	2.79	0.94

Different letters indicate statistically significant differences between treatments.

Table 4. Water quality parameters for the three different diets used in *C. poeyi* juvenile growth.

Treatment	pH (UI)	Temperature (°C)	Dissolved Oxygen (mg/L)	Ammonia (mg/L)	Nitrates	Nitrites
GC	7.60±1.34	29.57±1.63	6.71±0.94	3.22±8.28	7.60±5.25	11.14±7.90
POU	7.60±1.34	29.57±1.63	6.71±0.94	0.17±0.11	6.51±5.25	13.43±9.03
POR	7.60±1.34	29.57±1.63	6.71±0.94	0.27±0.24	9.17±6.24	7.14±8.95

Table 5. Growth parameters at different densities in *C. poeyi*.

Parameter	Units	D4	D8	D12
Initial weight	g	12.84±2.13a	13.18±2.14a	13.80±2.18b
Final weight	g	15.74±3.35a	15.76±2.09a	18.52±0.92b
Absolute growth (AG)	g	4.28±1.33	2.74±1.21	4.72±0.98
Absolute growth rate (AGR)	g/day	0.07±0.022	0.05±0.020	0.08±0.016
Relative growth (RG)	%	34.59±8.45	20.97±9.74	34.14±6.58
Relative growth rate (RGR)	%/day	0.42±0.08	0.28±0.11	0.43±0.06
Specific growth rate (SGR)	%/day	0.49±0.11	0.31±0.13	0.49±0.08
Feed Conversion Ratio (FCR)	-	1.88	1.38	0.95

Discussion

The findings of this study demonstrate that juvenile Mexican snook (*C. poeyi*) can be successfully reared in captivity using a diet formulated with pork by-product meal (POR) at a stocking density of 12 fish/m³ without compromising growth performance. These results support the use of animal by-products as a viable dietary alternative to fish meals. The POR diet produced favorable growth outcomes, similar to those of the commercial feed, with weight gain approximately 3.59 g higher than with the poultry by-product meal (POU) diet, and superior length increases. The feed conversion ratio (FCR) was optimal at 0.94 for both the POR and GC diets, indicating their suitability for promoting growth in juveniles. Fish in the POR diet also exhibited higher feed intake and better physical condition than those fed the POU diet. Physiological and environmental factors influence growth rates in fish (Phillips *et al.*, 1998; Moyle & Cech, 2000), and the present study maintained stable physicochemical parameters conducive to optimal development. Additionally, the high protein content (45.40%) in the POR diet was comparable in efficiency to the trout diet containing 45% protein, consistent with data reported by Kaushik for carp culture (1995). Similar outcomes have been reported for juvenile common snook (*C. undecimalis*), with average daily growth rates of 0.33 g/day, FCRs ranging from 1.11 to 6.1, and survival rates of 45% to 84% (Contreras-Sánchez *et al.*, 2015). In contrast, C. *poeyi* exhibited improved FCRs ranging from 0.94 to 2.70, indicating its potential as a candidate species for aquaculture.

Gracia-López *et al.* (2003) indicated that common snook specimens weighing 2.9 g, reared at 26.6 °C, exhibit adequate weight gain, specific growth rate, and feed conversion ratio when fed diets contained 40.4% and 65.8% protein, derived from shrimp, soybean, and fish sources. These results suggest that the metabolism of the Mexican snook may be similar to that of the common snook. Arenas *et al.* (2021) indicate that in 8.7-g juvenile common snook, growth performance improves when lipid levels are high, with a protein-sparing effect. An appropriate growth diet for this species is one containing 30% lipids relative to protein content. The results indicate that the common snook has a greater capacity to gain weight and retain nutrients when dietary protein is of terrestrial animal origin.

Furthermore, the partial dietary replacement of 45% of fish meal protein with soybean meal protein, as well as the inclusion of chitosan—a functional additive—on growth, feed efficiency, and digestive capacity, does not affect growth in *C. viridis* (Hernández *et al.*, 2022). In this same species, feed efficiency is affected by dietary protein level, with the best feed efficiency ratio observed in diets containing 52% protein; the protein efficiency ratio was significantly lower in diets containing 58% protein, without compromising growth parameters. Juveniles of *C. viridis* can be fed diets containing as much as 40% protein and 10% lipids without compromising survival or hematological and biometric indices (Abdo-de la Parra *et al.*, 2023).

Regarding the use of poultry by-product meal (PBM), favorable results have been observed in some fish species. Yildirim *et al.* (2009) conducted a 45-day experiment with *Tilapia zillii* in brackish water using a diet in which fish meal was replaced by 50% and 100% with poultry by-product meal (PBM), finding that substitution up to 50% did not affect fish growth, with an average weight of 8.66±0.68 g, a feed conversion ratio of 2.76±0.74, a growth rate of 245.36±22.7, and a specific growth rate of 2.98±0.17. In contrast, the protein in poultry by-product meals produces a more balanced amino acid composition in the diet in relation to fish muscle, but possibly in excess of the needs of the common snook (Freire & Pinto 2017). In the case of *C. poeyi,* it was determined that replacing fish meal with by-product meal is not favorable for the species' growth, as it showed lower growth in both weight and length, as well as lower weight gain. However, the studies mentioned above indicate that partial substitution of POU promotes growth in other species; therefore, it could be suggested that a substitution of less than 50% in *C. poeyi* would yield better results. Based on our results, the possibility of including POU-derived meals as a total replacement in this species' diet is ruled out, as they do not provide the nutrients necessary for adequate growth and development. Fish fed this diet exhibited physical signs of malnutrition, with reduced feed intake observed; subsequently, they stopped consuming it, developed a dark coloration, and eventually died, with the lowest survival rate recorded in this treatment.

Feed conversion ratios below 1, as observed in this study, require cautious interpretation; however, such values do not inherently indicate biological or methodological errors. In aquaculture, FCR is typically calculated as the ratio of feed supplied to the increase in the organisms' wet biomass. As a result, differences in water content between feed and fish tissue can yield FCR values near or below unity. Additional factors, including accelerated juvenile growth, high nutrient utilization efficiency, the presence of natural food sources, and the methodology used to quantify feed intake, can also substantially affect FCR outcomes. Boyd (2021) reports that FCRs of 1.0 or lower are occasionally observed, particularly in species exhibiting rapid growth and high feed efficiency. However, these results must be evaluated in light of material balances and the specific methods used to estimate feed intake. Similarly, Stone *et al*. (2024) highlight that FCR is highly sensitive to management variables, including survival rates, feed intake estimates, and environmental conditions. Therefore, FCR interpretation should be contextualized within each farming system. The results of the present study indicate efficient feed utilization by *C. poeyi* under the evaluated experimental conditions. Nonetheless, future research should incorporate assessments of digestibility, nutrient retention, and mass balances to verify the actual extent of feed efficiency.

Regarding studies on stocking density, densities of 7.5 and 12.5 individuals/m³ have been reported for *C. undecimalis*, with better results at lower densities, yielding a survival rate of 80% (Cabrera *et* al., 1998). Souza-Filho and Cerqueira (2003) also indicate that, at densities of 3, 6, and 9 fish/m³, the best growth occurs at the lowest density, with 100% survival. Similarly, for *C. parallelus*, Tsuzuki et al. (2008) tested three stocking densities (50, 100, and 200 fish/m³) and found that the lowest density yielded the best results. In contrast, in our study, the greatest weight gain was observed in D12 (approximately 2.78 g), compared to D4, which could be due to what was observed during the experimental phase: *C. poeyi* fish tend to feed better when there are more fish. In D4, the fish showed stress each time they were fed, reducing their intake. This is of great importance in aquaculture, as higher fish densities with good growth result in greater profits for producers. Fish density influences feeding behavior, but it is important to consider the addition of uridine, inosine, L-isoleucine, glycine, L-proline, L-arginine, L-leucine, and L-glutamic acid when formulating diets for common snook, as these are appetite stimulants for the species (Borquez & Cerqueira, 1998); therefore, this should be taken into account for future studies on *C. poeyi.*

The highest growth, feed conversion ratio (FCR), and weight gain were observed at the stocking density of 12 fish/m³ (D12), indicating that *C. poeyi* demonstrates optimal growth and aquaculture performance when reared at higher densities. A positive correlation between stocking density and growth was identified. Further research is required to evaluate densities above D12 and determine whether this trend continues. Additionally, comprehensive characterization of diets, including proximate analysis and digestibility assessments (Glencross 2020), is necessary to optimize fish meal replacement strategies in Mexican snook diets.

Conclusions

The present study provides preliminary evidence that diets containing pork by-product meal can support the growth and survival of juvenile *C. poeyi* under recirculating aquaculture conditions. Likewise, fish maintained at 12 fish m^{-3} exhibited the highest growth performance among the densities evaluated. Further studies incorporating nutritional characterization, digestibility analyses, and higher stocking densities are required before establishing definitive culture recommendations.

Ethical statement

All experiments were conducted in accordance with the National Institutes of Health Guide for the Care and Use of Laboratory Animals.

AI use statement

Artificial intelligence assistance was used to support the calculation and drafting of the formulation-based estimated proximate composition table. All ingredient inclusion levels, reference composition values, calculations, and interpretations were reviewed and verified by the authors. No AI tool was used as a primary scientific source.

Conflict of interest

The authors declare that they have no financial conflicts of interest or personal relationships that, to their knowledge, could have influenced the work presented in this article.

Authors' contributions

Jenny Vázquez-Gómez: Writing original draft, conceptualization, methodology, research, data management, and review. Wilfrido Miguel Contreras-Sánchez: Writing – review and editing, resources, data management, and conceptualization. María de Jesús Contreras-García: Writing, review and editing, formal analysis, and data management. Alejandro Mcdonal-Vera: Methodology, research, and data management. Leonardo Cruz-Rosado: Methodology, research, and data management.

Data availability

Data will be provided upon request.

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