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Examination of tentatively explained food from locally accessible items with business nourishments of regular carp (*Cyprinus carpio*) in the Mexican good countries

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Abstract

Aquaculture increasingly contributes to human nutrition, but the expansion of semi-intensive systems is limited by the high cost of commercial food. This is the case of the semi-intensive production of carp (*Cyprinus carpio*) in artificial lakes and reservoirs in the state of Tlaxcala in the Mexican highlands. 24% cheaper alternative food from duckweed (*Lemna* sp.) (37%), soya (*Glycine max*) (36%), corn (*Zeamays*) (9%), wheat grain and bran (*Triticum vulgare*) (9% each) was elaborated on. The increased weightof carps fed with this cheap alternative food and the commercially available food was compared as well. The contents of proteins, carbohydrates and lipids were 35, 41, and 4% respectively for both kinds of food. Two hundred carps were evenly distributed over 4 concrete tanks of 100 m^2. Two tanks were assigned for feeding, each tank with one kind of food during 84 days at a rate of 5% of carp weight per day. The alternative food performed better than the commercial food. We conclude that the cost of food for carp production in the Mexican highlands can significantly be reduced by switching to the alternative food.

Keywords: *Common carp,*experimental food*, Lemna,*Mexican highlands.

INTRODUCTION

Aquaculture increasingly contributes to human nutrition, but production is limited due to high cost of fish food. Such is the case of aquaculture in the State of Tlaxcala in the Mexican Central highlands. Here, 550 of the available 886 water bodies are used for aquaculture, mainly carp (*Cyprinus carpio*) cultivation. They generate 83% of the aquaculture production in the State (INEGI, 2007).

Carp production in Tlaxcala was started in the 1980's, with stocking carps in dammed reservoirs locally called "jagueyes". Carp production gradually changed from an extensive to a semi-intensive system, whereas 3.6% is produced under intensive systems. This is similar to the global scale percentage of carp production under intensive systems (Kaushik, 1995). With intensification of production, carp cultivation increases its dependence on the availability of balanced food. Its cost represents currently between 60 and 80% of the production cost (Peters et al., 2009), impairing profitability as well as continuity of this economic activity. The design of cheap alternative food for improving the intensive and semi-intensive carp cultivation at low costs may contribute to consolidate this type of aquaculture (Sanz et al., 2000). In this context, there is an increased interest in evaluating the nutritional value of non-conventional food sources.

Efforts in this direction have concentrated on meeting the protein needs of the fish, which is the most expensive food component (Gaigher et al., 1984; Sanz et al., 2000). Currently, fish meal is the most used protein source in aquaculture, as it matches the nutritional requirements of fish (Sanz et al., 2000; Peters et al., 2009). It is, however, expensive and therefore researchers look for alternative protean sources (Peters et al., 2009). Since in the 1980s, the inclusion of vegetal proteins in diets for aquaculture is tested: oil seeds, legume seeds and leaves, and aquatic macrophytes (Bairagi et al., 2002; Peters et al., 2009). The aquatic macrophytes of Lemnaceae family (duckweed) are widely available at no cost in the larger eutroficated water bodies in Tlaxcala, in spite of their high protein content. Duckweed also contains vitamins and minerals, whereas levels of anti-nutritional factors are below tolerable thresholds and do not impair growth (Kalita et al., 2007). This makes duckweed a logical component of cheap food for herbivorous and omnivorous fish (Ponce et al., 2005; Peters et al., 2009; Gaigher et al., 1984; Hassan and Edwards, 1992). However, the use of duckweed for carp production in regional conditions has not also been evaluated experimentally, and it is presently not used in food products for aquaculture.

We therefore, conducted an experiment that compares the growth of carps (*C. carpio*) fed with an experimental food, made from corn, wheat grain and wheat bran, soya and duckweed, and the growth of carps fed with commercial food with the same content of protein and carbohydrates under controlled conditions. Our hypothesis is that we would not detect differences in growth obtained in both kinds of fish food, and that; therefore, production cost can be reduced substantially. This would contribute to the design of alternatives where local fisheries would be maintained in artificial water bodies as an attractive economic activity.

MATERIALS AND METHODS

Preparation of the experimental food

We used the lineal programming method to calculate the quantities of the ingredients for the mixture in the elaboration of the food (Taha, 2004). We looked for the lowest possible cost of the combination of ingredients required to obtain food of the desired composition, using an equation system that considered the contents of proteins, carbohydrates, and lipids of the ingredients, as well as restrictions for each of these contents as required by carps. The food was then elaborated mixing the previously milled ingredients. We determined the cost of the alternative fish food considering cost of ingredient in the local market and the cost of duckweed was estimated considering labor and transportation costs. The retail price of commercial food was recorded. The contents of protein and lipids of the alternative food were determined according to the methods described in the Mexican Official Norms (NMX-Y-118-SCFI-2001 (Kjeldahl method) and NMX-Y-103-SCFI-2004 (Soxhlet method)) and carbohydrates following Tacon et al. (2009).

Experimental design

We used 4, 10 × 10 × 1 m concrete tanks, which each of them containing 80 m^3 of water. The water was changed every 7 days. We placed 50 carps (*C. carpio*) in each tank (0.625 carps m^{-3}), obtained from tanks of regional carp producers. The average weight of the carps was 73.5, 67.4, 37.4 and 43.7 g for Tanks 1, 2, 3, and 4. We fed the carps during 84 days with 5% of their body weight per day. Carps in Tanks 1 and 3 were fed with the experimental food, and Tanks 2 and 4 with the commercial fish food MALTA CLEYTON^R (API-ABA). Both kinds of food contained 35% of proteins, 41% of carbohydrates and 4% of lipids. The weight and length of all carps at the beginning and at the end of the experiment were registered. During the experiment, registered the water temperature and dissolved oxygen in each tank were registered daily.

Data analysis

The average, standard deviation, maximum and minimum values of water temperature and dissolved oxygen were determined in each tank. The normality of the distribution of the weight of carps at the beginning and at the end of the experiment with the Shapiro-Wilk statistic was evaluated, in order to decide whether to use parametric or nonparametric methods. As the data were not normally distributed, Mann-Whitney nonparametric U-test was used to evaluate the differences of carp weight between the pairs of tanks with both types of food at the beginning and end of the experiment.

The carps specific growth rate (SGR) was calculated using the expression SGR = 100*(Ln W_f – Ln W_i)/t, where W_i is the weight at the beginning and W_f the weight at the end of the experiment, and t the number of days between the beginning and end of the experiment (Davies and Gouveia, 2010). The daily growth coefficient (DGC) was calculated with the expression, DGC = 100*($W_f^{0.33}$-$W_i^{0.33}$)/t (Kaushik, 1995), and the feed conversion ratio (FCR), with the expression FCR = $F_c/(W_f-W_i)$, where F_c is the food consumed by the fish during the experiment (Davies and Gouveia, 2010).

RESULTS

The cost of the alternative fish food was 24% lesser than the cost of the commercial food. Prices per kilogram on the local retail market were: maize, $ 0.51; soya, $ 1.02; wheat meal, $ 0.47; wheat husk, $ 0.39; duckweed, $ 0.16; and milling, $ 0.13. The cost of commercial fish food was $ 0.78 per kilogram.

During the experiment, the water temperature ranged between 12.3 and 19.5°C with an average and standard deviation of 14.8 and 1.5°C, respectively (Figure 1 and Table 1). Water oxygen concentration ranged between 2.50 and 5.98 ppm, with an average and standard deviation of 4.4 and 0.6 ppm, respectively (Figure 2 and Table 2). 18% mortality was observed in Tank 2, whereas in the other tanks there was no mortality.

At the beginning and end of the experiment, the weight of carps was not normally distributed (Shapiro-Wilk, p = 0.00), and there were no significant differences of fish

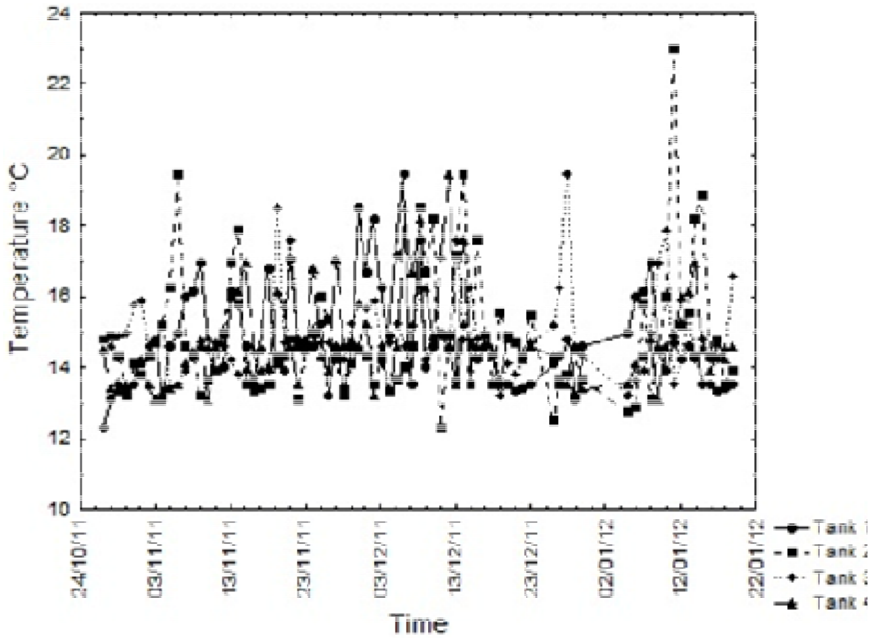

Figure 1. Water temperature in the different tanks during the experiment period.

Table 1. Average, minimum and maximum values and standard deviation of the watertemperature (°C) in the tanks, for a period of 85 days since October 17, 2011.

Tank	n	Mean	Minimum	Maximum	Std.Dev.
1	78	14.71	12.30	19.50	1.40
2	78	14.76	12.30	19.50	1.63
3	78	14.92	13.20	19.50	1.17
4	78	14.74	13.10	19.50	1.37

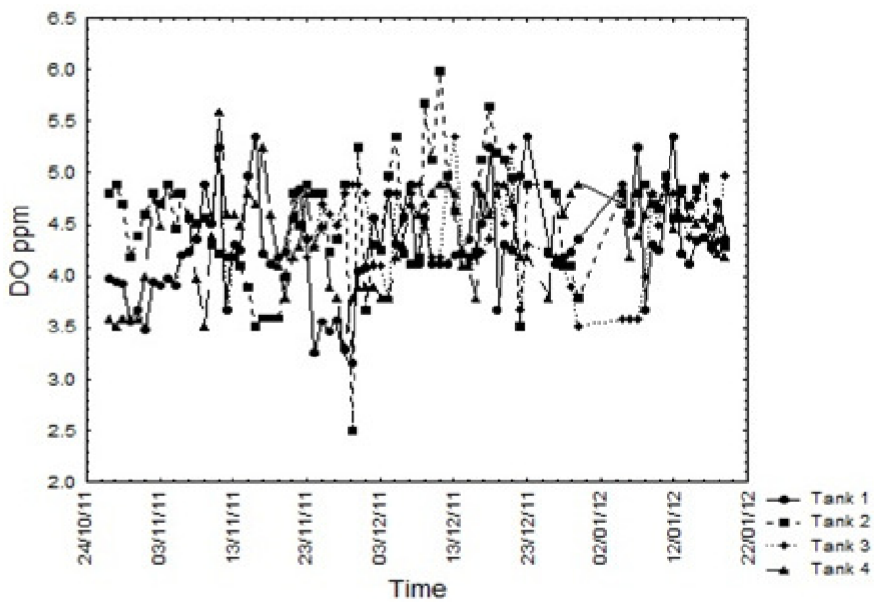

Figure 2. Water dissolved oxygen for the different tanks during the experiment period.

Table 2. Average, minimum and maximum values and standard deviation of the waterdissolved oxygen (ppm) in the tanks, for a period of 85 days since October 17, 2011.

Tank	n	Mean	Minimum	Maximum	Std. Dev.
1	78	4.30	3.14	5.36	0.79
2	78	4.54	3.50	5.98	0.55
3	78	4.37	3.47	5.36	0.75
4	78	4.38	3.30	5.60	0.46

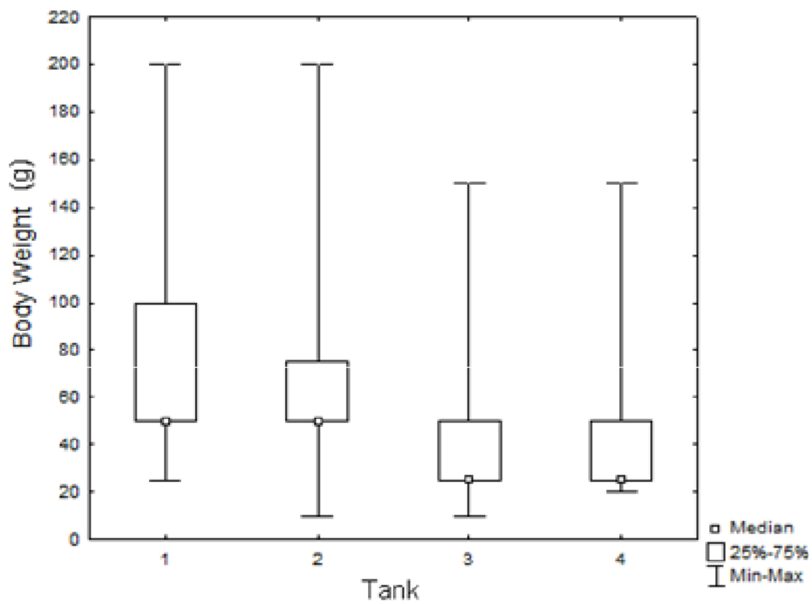

Figure 3. Median, confidence interval 25 to 75% and maximum and minimum ofcarp weight in four tanks at the beginning of the experiment.

Table 3. *p*values (2-tailed) of multiple comparisons; of carp weight (g) in tanks. (Kruskal-Wallis test: $H(3, N = 191) = 11.09$, $p = 0.011$).

Tank	1 - R:112.44	2 - R:100.61	3 - R:95.320	4 - R:76.460
1		1.000000	0.729084	0.006821
2	1.000000		1.000000	0.228786
3	0.729084	1.000000		0.528242
4	0.006821	0.228786	0.528242	

weight between pairs of tanks that used the two different kinds of foods ((Mann-Whitney U-test, p = 0.64) (Figure 3). At the end of the experiment, there were statistically significant differences in weight between the two different kinds of foods (Mann-Whitney U test p = 0.04; Table 3 and Figure 4).

The average increases of carp weight were 302.5, 281.4, 282.0 and 238.5 g in Tanks 1, 2, 3 and 4, respectively and length gains were 8.3, 5.9, 4.2 and 4.9 cm. The specific growth rate (SGR) was 2.19 g day^{-1} for the fish fed with the experimental food, and 2.06 g day^{-1} for the fish fed with the commercial food. The daily growth coefficient (DGC) was 3.73 and 3.44 for the experimental and commercial food, respectively. The feed conversion ratio (FCR) was 2.19 for the experimental food and 2.20 for the commercial food.

DISCUSSION

The results of the experiment showed that it is possible to reduce cost of carp production. The cost of the alternative

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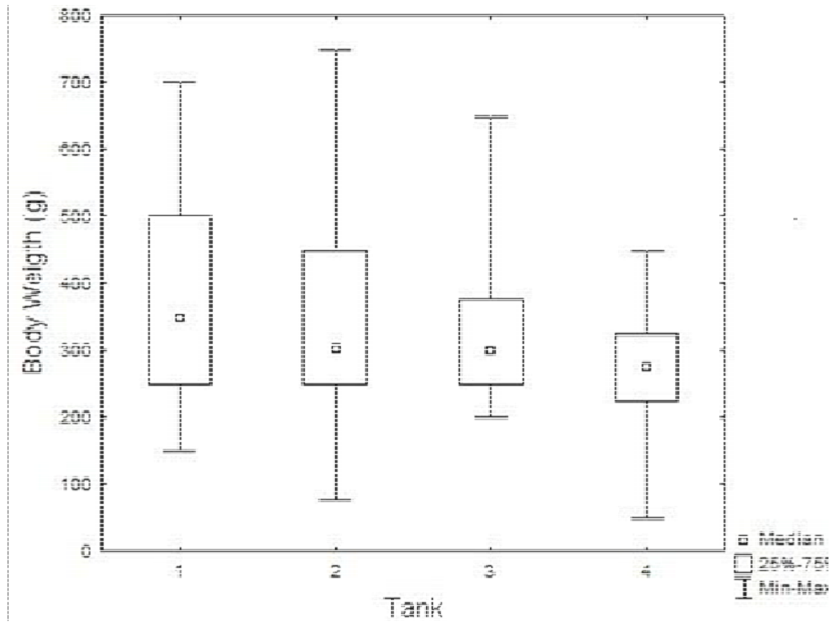

Figure 4. Median, confidence interval 25 to 75% and maximum and minimumvalues of the weight variable of the carps fed with commercial food (Tanks 2 and 4) and experimental food (Tanks 1 and 3) during 85 days.

food was 24% lesser than the cost of the commercially available food. It was readily consumed by the carps and weight increase of the carps was higher when they were fed with the alternative food than with the commercial food.

Growth of the carps was higher than expected. The temperature and dissolved oxygen during the experiment were sufficient for carp growth. However, low temperatures affected growth. During the experiment, the average water temperature was 14.78°C, similar to the temperature observed in the water bodies in central Mexico in this time of the year (Muñoz, 2005). This temperature is 8°C under the minimum optimal temperature for carps good development (FAO, 2004-2013), and this explains why the observed carp growth was low. Average water temperature in the region is higher from March to October, fluctuating between 18 and 23°C (Muñoz, 2005). We may therefore, expect higher weight increments during the warmer months. The fluctuations in water temperature during the experiment were due to the changes of water in the tanks (Figure 1), and were similar in all tanks.

The concentration of dissolved oxygen (DO) in the water was over 3 ppm at any moment during the experiment, with average values above 4 ppm. Fluctuations in DO were associated to water temperature fluctuations (Figure 2). This variable maintained adequate values for carp cultivation, as this species thrives well under conditions of low 0.3 to 0.5 ppm and high concentrations of oxygen, as well as oversaturation (FAO, 2004-2013). DO, thus, has not influenced carp growth during the experiment negatively. No mortality occurred in Tanks 1, 3 and 4, whereas in Tank 2 an accidental death rate of 18% occurred due to inadequate handling of fish at the onset of the experiment.

As carp weight was not normally distributed, we used non parametric tests to analyze the differences between treatments. Carp weight at the beginning of the experiment in Tanks 1 and 2 was not statistically different, as was the case with carp weight in Tanks 3 and 4. Therefore, Tanks 1 and 3 were assigned to one type of food (the experimental food) and Tanks 2 and 4 to the other (the commercial food). There was no significant difference in average fish weight between the two groups of tanks (Mann-Whitney U-test of compound data of Tanks 1 and 3 vs 2 and 4, $p = 0.64$). Carp weights obtained for both types of food were different at the end of the experiment (Mann-Whitney U test $p = 0.04$), and were higher when carps were fed with the experimental food.

The observed specific growth rate (SGR) is within the reported values for carps fed with swine manure (González et al., 2002), with pea seeds subjected to different thermal treatments (Davies and Gouveia, 2010), and in general for carp growth in water with temperatures between 23 and 26°C (Kaishik, 1995). It is also in the same range of results obtained with tilapia (*Oreochromisniloticus*) fed with *Lemna* (Hassan and Edwards, 1992),with food containing 15, 25 y 35% of dark *Lemna* meal (Peters et al., 2009), and with mixtures of pellets of commercial food and *Lemna gibba* (Gaigher et al., 1984). Also in trout (*Oncorhynchus mykiss*) and Indian carp

(*Labeo rothia* Ham.) fed with *Lemna* (Morales, 2004; Bairagi et al., 2002), similar results were obtained.

The daily growth coefficient (DGC) for carps fed with the experimental food was similar to the reported average for carps cultivated in water with temperatures between 23 and 26°C. The results that we obtained with the commercial food were in the confidence interval lowest range for carp cultivated at low temperatures (Kaishik, 1995). The foregoing suggests that we may expect higher DGC of carps cultivated in warm season.

The feed conversion ratio (FCR) observed in our experiment had values in the range observed in tilapia (*O. niloticus*) fed with food containing dark *Lemna* meal, as one of the ingredients (Peters et al., 2009), and with *Lemna perpusilla* (Hassan and Edward, 1992); also incarps (*C. carpio* L.) fed with *Sesbania aculeata* as a source of protein (Hossain et al., 2001). It presented better FCR than rohu (*Labeo rohita* Ham.) fed with diets formulated with meal of *Lemna polyrhiza* (Bairagi et al., 2002), but lower FCR than tilapia fed with *L. gibba* (Gaigher et al., 1984), common carp fed with diets which contained *Pisum sativa* liable to different thermal process methods (Davies and Gouveia, 2010) and trout cultivated in floating cages (Morales, 2004).

The results, with regard to carp specific growth rate (SGR) and feed conversion ratio (FCR) fed with the experimental mixture and the larger increments of weight, prove that the experimental food has a potential for regional carp production. It can reduce costs of production of this species. Our results confirmed that the meal of *Lemna sp.* has high potential to be used in the formulation of carp food, as it has been reported by other authors with other species of *Lenma* and of fish (Gaigher et al., 1984; Hassan and Edwards, 1992; Ponce et al., 2005; Kalita et al., 2007).

Conclusion

It is possible to reduce the price of food used for cultivation of the common carp, in the Mexican highlands, as much as 24% lesser than the commercial food. The behavior of temperature values and dissolved oxygen concentration in the tank water during the experiment were enough to make the carp grow. The experiment was done during the cold season, so it is expected to obtain a better growth of carp in the warmer months of the year (March to October).

The values of specific growth rate (SGR), daily growth coefficient (DGC) and feed conversion ratio (FCR), the best increase in weight and lower cost, observed with the use of the experimental food compared to commercial food, allow us to assume that the use of experimental food has a high potential in the cultivation of carp in the region.

The use of *Lemna sp.* flour as a source of protein has a high potential in the development of common carp food in the Mexican highlands.

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