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Chapter 3

TILAPIA PRODUCTION AND FEEDING MANAGEMENT IN THE SEMI-ARID OF BRAZIL: A VIEW OF SOME RECENT DEVELOPED TECHNIQUES

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ABSTRACT

The semi-arid is not one of the first climates that comes to mind when fish production is imagined. First of all, it is important to describe the semi-arid in Brazil since it enclosures 969.589,4 km^2, about 11% of the Brazilian territory, and more than 1.000 municipalities in 9 different Brazilian States. In this area live over 22 million people, which is about 10% of the Brazilian total population. However the Brazilian semi-arid

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has some particular characteristics that made it possible.The São Francisco River and large water reservoirs such as Castanhão and Orós are some of the water bodies where tilapia culture has been sucessfull. There are several production systems adopted ranging from tilapia in irrigation reservoirs on small rural properties to intensive cage culture. It does not matter which production system was adopted by the producer, since the area is semi-arid the water quality has to be extremely well managed and cared for in order to preserve it and guarantee the highest possible productivity per cubic meter of water. In order to achieve the best productivity, some management practices must be adopted. One of them is to select the best variety for breending. Several tilapia varieties have been introduced into the Brazilian semi-arid since the 1970's. However Tai tilapia has been the most successful and is cultivated nowadays. Red Koina and Saint Peters have also been introduced, but it did not succeed due to their low growth after 400g. Tilapia GIFT has already been tested in cage culture. The results are promising, but there is a lack of farms to produce this variety in the Brazilian semi-arid.

Tilapia feeding management is an important issue in tilapia culture in this region. Feeding practices may differ from areas within the semi-arid as well as production systems. Several local ingredients have been tested as examples mango meal, cassava chips and leucaena hay. Most of them are used by small producers as tilapia feed complement. Cage culture producers are well instructed to only use balanced extruded feed in order to achieve better growth and maintain the best possible water quality.

The semi-arid area is not one of the first climates that comes to mind when thinking about fish production. To understand this, it is important to describe the semi-arid area of Brazil: it covers 969.589,4 km^2, that is about 11% of the Brazilian territory, and includes more than 1.000 municipalities in 9 different Brazilian States. In this area live over 22 million people, i.e., about 10% of the Brazilian total population (ASA BRASIL, 2014). The Brazilian semi-arid area, however, has some specific characteristics that make fish production possible. For instance, it is the semi-arid area with the highest rainfall depth in the world, with average of 200-800 mm of water per year. The rain, however, is irregular when and where it falls. Also, the evaporation index is about three times higher than rainfall. Therefore to make the best use of the water available to raise fish in this region is a challenge, and to produce high quality protein for the local population is a need. As well, increased production helps to offer to the local young generation an opportunity to live and work locally, instead of migrating to other regions.

The Brazilian northeast includes most of the semi-arid area and is responsible for about 25% of the Brazilian total continental fish production (MAPA, 2011). Tilapia is the most cultivated fish species in Brazil and in the northeast. Total fish production in the northeast was 134.293 tons in 2011, but there is no official statistical data about how much tilapia was produced in the area. This semi-arid region has a large river basin the São Francisco River with its lakes and reservoirs, Sobradinho (400 km of extension; 4.214 m^2 of water surface; 34.000.000.000 m^3 of water) and Itaparica (11.000.000.000 m^3 of water capacity) for instance, built for power plant energy. It also has large water reservoirs such as Castanhão (6.700.000.000 m^3 of water capacity), Sítios Novos (126.000.000 m^3) and Orós (2.100.000.000 m^3 of water capacity), all of these these located in the state of Ceará. These are some of the water bodies where tilapia cultivation in cages has been successful. Ceará and Bahia are the Brazilian states with the largest tilapia production. In first place is Itaparica in the São Francisco River Basin, with an annual average production of 24.000 tons/year. Castanhão and Orós Lakes in Ceará State are the number two producers with 18.500 tons/year. This production is in 4 – 240 m^3 cages that can be square or round. A drought in 2013 was responsible for a decrease of about 17% in production. Due to facts like this and to the multiple uses that water reservoirs have in the Brazilian semi-arid area, it is important to be aware of the support capacity for fish production in order to avoid an eutrophication process.

In our research, we have investigated a number of production systems in use, ranging from raising tilapia in irrigation reservoirs on small rural properties and in saline water, to intensive cage culture and tilapia-shrimp integrated production. A case study of tilapia semi-intensive production in irrigation reservoirs (1.170 m^3) and its water parameters have already been evaluated in the Brazilian semi-arid area (Cardoso-Filho et al., 2010). Case studies in rural properties are important in order to evaluate the increase of water productivity. This is especially necessary in the semi-arid area and for small farmers. In the study by Cardoso et al., survival rate (96%) was considered excellent, since the fish were cultivated in earth ponds. Fish final weight (535g) was considered the average after a cycle of 217 days in semi intensive production systems. There was a biomass gain of 18.270 $kg.ha^{-1}$ and an apparent feed conversion rate (FCR) of 0.83. The excellent value of FCR was due to natural food available in the reservoir. Those results can be considered excellent since most of the producers from irrigated areas in the Brazilian semi-arid region do not make use of this resource. Besides the increase of water productivity, extra farm income can be made. During this trial, water temperature ranged from 23-28°C, which is considered the average for the area. The average value for pH ranged from 7-8.5. Electrical conductivity ranged from 64–173 ìS cm^{-1}. Pond bottom ammonia level ranged from 0.004 – 0.131 mg L^{-1}, and surface ammonia level ranged from 0.007 – 0.143 mg L^{-1}. Nitrite levels in the pond bottom and surface were 0.01 mg L^{-1}. Alkalinity values were of 39.09 mg $CaCO_3L^{-1}$ at the bottom and 41.92 mg $CaCO_3L^{-1}$ at the surface. Water hardness was 56.77 mg $CaCO_3$ L^{-1} at the bottom and 57.47 mg $CaCO_3$ L^{-1} for surface.

The Brazilian semi-arid region has several saline water reservoirs and water dams. Unfortunately there is no official data about how many there are. These are sometimes located in areas where potable or fresh water is difficult to access. Small farmers who live in these areas need a technology that can make use of saline water, especially for animal production. Since this water is not potable for goats and sheep over a long period, tilapia production is the most indicated type of production. Shrimp is also a possible alternative; but the fact that the larvae must be brought in from far away makes this alternative not viable. It does not matter if the production system adopted by the producer is intensive or not, because in a semi-arid region, the water quality has to be extremely well managed and treated in order to preserve it and guarantee the highest possible productivity per cubic meter of water. Therefore to achieve the best productivity, some management practices must be adopted. One of them is to select the best variety of fish to be raised in saline water. Several tilapia varieties have been introduced into the Brazilian semi-arid since the 1970's. However Thai tilapia has been the most successful and is cultivated nowadays. Red Koina and Saint Peters have also been introduced, but have not succeeded due to their low growth rate after 400g. A study conducted at Embrapa Tropical Semi-Arid Caatinga Experimental Station, comparing growth performance of Red Koina and Thailand tilapia cultivated in brackish water (average salinity of 6.12 $g.L^{-1}$), showed that fish of the Thailand strain had a significantly better growth (final weight for Thailand and Red Koina: 888.89g ± 20.09^{a} and 582.00g ± 78.97^{b}; daily weight gain: 7.55g ± 0.180^{a}; 4.71g ± 0.89^{b}; weight gain: 792.70g ± 18.43^{a}; 494.59g ± 93.14^{b}; feed consumption: 166.60g ± 2.40^{a}; 134.60g ± 3.1^{b}) as well as survival (Thailand: 100%; Red Koina: 97.62%) and feed conversion ratio (Thailand: 1.40^{a} and Red Koina: 1.56^{a}). Performance analysis showed that there was a significant difference ($P < 0.05$) for all the parameters analyzed. Thailand tilapia growth was about 40% higher than for Red Koina tilapia. The sample strains evaluated in this study were introduced in the semi-arid about 10-15 years ago and still show high genetic variability (Campeche et al., 2011b). From the

DNA analysis, all the primers selected produced different patterns of RAPD fragments for both populations. The number of clear reproducible fragments engendered from primers of both stocks showed a variation from 6 to 16 fragments and the size of these amplified products was maintained between 250-2,072 pb. From 70 fragments analyzed randomly, 60 were polymorphic (85.71%) and 10 monomorphic (14.29%). The percentage of polymorphic fragments was higher for Thailand tilapia (84.29%) when compared to Red Koina stock (64.29%). The results from this study proved that genetic variability obtained by the percentage of polymorphic fragments was high showing that the reproduction management for both populations guarantees a conservation of genetic variability. In the Campeche et al. (2001b) study, the Shannon index value found was higher for the Thailand tilapia stock (0.4614) than for Red Koina tilapia stock (0.3526). Therefore, as the percentage of polymorphic locos was high, the genetic variability of the stocks was also high. The need is high for a means of desalination in semi-arid communities isolated from any kind of potable water distribution system. With the aim to increase salt dam water productivity and also, provide an environmentally friendly destination for the water discharged from the desalination process, the Embrapa Tropical Semiarid Station has developed an agriculture-aquaculture production system. The system uses the rejected water from the desalination process to raise tilapia, and the effluent from the tilapia´s pond is used to irrigate a salt bush (*Atriplex nummularia*). This salt bush is used for hay and given to goats and sheep as a feed complement. This shows the importance of testing tilapia performance in brackish and water with high salinity in the Brazilian semi-arid regions.

Tilapia market demand in the northeastern states in Brazil that contain semi-arid areas is different than the market in the south of Brazil. Nowadays in the northeast, the market demands fish that weigh up to 1.3 kg, normally sold as whole fish and not for the fillet industry. Due to feed price, this demand became an important issue for the producers because the feed conversion rate increases after the fish reaches 800g and so the production cost also increases. In order to give to the producers an answer about how to predict fish growth and help to manage fishing enterprise, a recent study was carried out using a mathematical model to predict tilapia growth when raised in 4 m^3 cages in the São Francisco River (Sousa Junior et al, 2014 *posted in* Engenharia Agrícola ISNN 0100-6916). Five non-linear models were tested: Brody (1945) ($Y = A(1 - Be^{-kt}) + \varepsilon;$); Bertalanffy (1957) ($Y = A(1 - Be^{-kt})^3 + \varepsilon;$); Logístico (Nelder, 1961) ($Y = Ae^{-Be^{-kt}} + \varepsilon;$); Gompertz (Laird, 1965) ($= A(1 + Be^{-kt})^{-1} + \varepsilon;$) and Richards (1959) ($Y = A(1 - Be^{-kt})^M + \varepsilon;$). Where Y =

fish weight at certain age (g); A = weight at adult age; B = maturity level of the fish at its birth; k = velocity at which the fish get closer to adult body mass; M is the parameter that gives shape to the curve that corresponds to 1 on the Brody model, which is 3 for Bertalanffy, -1 for the Logístico, a tendency towards ∞ for Gompertz and variable for Richards. The estimated values for fish weight was higher for Brody (13.485 kg), Bertalanffy (4,122 kg), Gompertz (2.383 kg), followed by the models of Logístico (1.521 kg) and Richards (0.972 kg). Based on the average market demand, tilapia raised in cages on the São Francisco River can be harvested when reaching between 600 - 850g at 183; 247; 181; 184 and 183 days for the Bertalanffy, Brody, Gompertz, Logístico and Richard's models. For the demand of 1kg average fish, 244; 546; 244 and 243 days would be necessary according to the models of Bertalanfy, Brody, Gompertz and Logístico. The value (k) that indicates how fast tilapia will reach its market size was also evaluated. The highest k value was obtained by the Logístico (0.0183) model, followed by Richards (0.00856), Gompertz (0.00747), Bertalanffy (0.00369) and Brody (0.00011). In this study only 3 models were converted by the Gauss method. This means that the values estimated are close to what was found in field data. These models were those of Bertalanffy, Logístico and Gompertz. Therefore they were considered the best models to estimate tilapia growth in cage culture in the São Francisco River.

The semi-arid needs to optimize water productivity. In areas where water is abundant, such as the great water reservoirs built for power plant energy, this need can be overcome in order to generate more employment and food. Therefore, in order to evaluate the best growth for tilapia fingerlings in 4 m^3 cages, a trial was undertaken to test four different densities: 800, 950 and 1100 fish.m^3 (Saraiva, et al., 2009). The trial was carried out in the town of Paulo Afonso, in the State of Bahia, Brazil (9°31'16.2" S e 38°00'32.7" W). Fingerlings (0.85g initial weight) were fed a 55% crude protein diet for the first 20 days and a 45% crude protein diet for the other 34 days. At the end of the trial no statistical difference was observed in the growth performance parameters analyzed. For the three densities evaluated (800, 950 and 1100 fish.m^3), final weight (g) was respectively: 37.50; 37.20 and 32.80; weight gain (g): 36.65; 36.37; 32.00; specific growth rate (%): 7.00; 6.98; 6.76; final biomass (kg. m^{-3}): 28.5; 31.8; 34.1; survival (%): 94.9; 90.1; 94.5 and feed conversion rate: 0.99; 1.09; 1.06. So, the authors concluded that it is possible to stock Thailand tilapia up to 1100 fingerling.m^{-3} in 4 m^3 cages in order to obtain 30g juvenile after 54 days of growth. At this density, water productivity was increased since a greater number of fish were raised per area of water used. At this trial site, water quality parameters were considered optimal for tilapia growth (temperature: 28°C; pH: 7.5; dissolved oxygen: 6.7 $mg.L^{-1}$; total hardness: 49.5 $mg.L^{-1}$ $CaCO_3$; alkalinity: 14.8 $mg.L^{-1}$ $CaCO_3$; nitrite: 0.002 $mg.L^{-1}$; total ammonia: 0.505 $mg.L^{-1}$).

Thailand tilapia growth performance in cages fed different protein levels was evaluated in another area of the Brazilian semi-arid region. Water quality parameters and transparency constituted the main difference between the water reservoirs where tilapia growth performance cited in this chapter was evaluated. This study was conducted in a water reservoir near the town of Sapé (parallel of 7°05´38´´south latitude and 35°13´58´´ west longitude) in the State of Paraíba (Costa et al., 2009). Cages were also $4m^3$ in volume. Growth was evaluated during all phases with different crude protein levels in the feed, using a randomized block experimental design. Commercial diets containing three different crude protein levels (36, 32 and 28%) in three growth phases I – 80 to 300g; II – 301 to 650g and III – 651 to 1000g were tested. In phase I, two protein levels were tested: 32% and 36%. There was no statistical difference as to final weight (311g and 308g); biomass gain per cage (270kg and 267 kg); daily weight gain (5.97g and 6.01g); specific growth rate (3.57% and 3.54%); feed conversion (1.63 and 1.62); feed efficiency (61.21% and 61.23%) and final biomass (99.50 and 98.75 kg. m^3). The only statistical difference ($P < 0.05$) at this level was observed for the protein efficiency ratio (1.71^a and 1.92^b). Phase II evaluated all fish from the two different groups from phase I (32% and 36% respectively) then were fed 32% of crude protein in the diet. At the end of this phase all the growth performance parameters evaluated were statistically different ($P < 0.05$), except for the final biomass: final weight (650^a and 723^b g); biomass gain (219^a and 274^b kg); daily weight gain (5.64^a and 6.93^b $g.day^{-1}$); specific growth rate (1.23^a and 1.42^b %); feed conversion ratio (2.32^a and 1.96^b); feed efficiency (44.05^a and 50.91^b %); protein efficiency (1.71^a and 1.92^b %) and final biomass (99.50^a and 98.75^a $kg.m^3$). In phase III, the experimental groups were divided into three, where the first two values represent how much CP fish were fed in phases I and II and the last value indicates how much CP fish were fed in phase III: A (fed 32-32-32%); B (fed 36-32-32 %); C (fed 32-32-28%). At the end, all growth performance parameters showed statistical differences. The group that was fed 32-32-32% crude protein showed the best growth performance: final weight (1102^a; 1040^{ab}; 900^b g); biomass gain (159^a; 128^{ab}; 46^b kg); daily weight gain (7.7^a; 5.9^{ab}; 2.5^b $g.day^{-1}$); specific growth rate (0.82^a; 0.67^{ab}; 0.30^b %); feed conversion ratio (1.63^a; 2.33^{ab}; 2.83^b); feed efficiency (61.15^a; 47.86^{ab}; 37.23^b %); protein efficiency (2.26^a; 1.82^{ab}; 1.57^b) and final biomass (161^a; 152^{ab} ;

143^b kg.m^3). The results observed in this trial were considered optimal for the semi-arid water reservoir. High crude protein diets might indicate that a high amount of nitrogen will be excreted by fish and the as a consequence the water body will become eutrophic, since water exchange in the semi-arid is very slow. At the site of this trial, the water quality parameters were considered optimal: dissolved oxygen at 06:00 am was 5.62 and at 04:00 pm was 9.66 mg.L^{-1}; pH: 7.73; ammonia: 0.05 mg.L^{-1} and nitrite: 0.01 mg.L^{-1}; transparency: 62.33 cm (considered eutrophic); nitrate: 0.03 mg.L^{-1}; inorganic phosphate: 0,12 mg.L^{-1}.

Tilapia feeding management is an important issue in tilapia cultivation in this region. Feeding practices and production systems may differ among areas within the semi-arid regions. A number of local ingredients have been tested as examples of mango meal, cassava chips and leucaena hay. Small producers use most of these as a tilapia feed complement. These fish, however, are not raised for market purposes. Mango is highly produced in one area of the Brazilian semi-arid region and most of the time it is thrown out by the producers for not being accepted by the market. In order to have some use out of it, mango meal was tested on tilapia juvenile (Souza et al., 2013). Four treatments were evaluated: 0%, 33%, 66% and 100% of mango meal replacing corn meal. Results showed that up to 33% of corn meal can be replaced by mango in diets for tilapia juvenile without decreasing growth, weight gain, specific growth rate, carcass yield and survival (Table 1), or increasing feed conversion rate. Final weight and specific growth rate were lower for fish from the groups where 66% and 100% of the corn had been replaced by mango meal as the carbohydrate source. Fish from lower replacement levels had better growth performance results. However feed consumption was significantly lower ($p<0.05$) only at the 100% replacement level group. This result can be probably due to a palatability issue. The best feed conversion rate was observed with the groups where 0% and 33% of mango meal replaced corn meal. As the level of mango meal increased, energy (kcal/kg) levels in the feed also increased. For this reason it is possible that the source of carbohydrate tested in this trial caused the decrease in tilapia performance due to its fiber level or any anti-nutritional factor. Carcass yield and survival was not affected by the treatments. Fish that were fed diets containing 66% and 100% of mango meal had lower levels of lipid in the carcass. The group that was fed a diet containing 100% of mango meal had the lowest protein in the carcass. Those results proved that mango meal changes the carcass chemical composition. In short, the diets where 100% of corn meal was replaced by mango meal were not nutritionally well balanced.

Table 1. Performance and carcass composition of Nile Tilapia fingerlings fed different levels of inclusion of mango meal replacing corn meal

	Level of inclusion of mango meal replacing corn meal					
	0%	33%	66%	100%	Regression equation	R^2
Final weight (g)	37.51±0.75[a]	35.84±2.11[a]	32.04±1.34[b]	22.58±0.96[c]	Y= -4.376x+42.53	0.081
Weight gain (g)	32.85±0.88[a]	31.17±2.07[a]	27.32±1.34[b]	17.84±0.84[c]	Y= -4.885x+39.51	0.88
Specific growth index	4.63±0.11[a]	4.52±0.12[a]	4.25±0.10[b]	3.46±0.04[c]	Y= -0.378x+5.16	0.85
Feed consumption (g)	33.92±1.42[a]	33.34±0.94[a]	32.46±1.38[a]	26.95±1.33[b]	Y= -2.179x+37.115	0.77
Feed conversion ratio	1.03±0.03[c]	1.07±0.05[c]	1.19±0.01[b]	1.51±0.02[a]	Y= 0.156x+0.81	0.85
Carcass yield (%)	85.29± 1.68	85.36±1.7	86.57±1.74	84.87±1.98		
Survival (%)	97.78± 3.85	97.78±3.8	97.78±3.85	100± 0.00		
Carcass composition (%)						
Crude Protein	59.50±1.24[a]	59.94±0.62[a]	61.69±0.62[a]	54.36±0.16[b]	Y= -1.94x2+8.34x+52.57	0.81
Ether Extract	20.42±0.08[ab]	21.49±0.24[a]	19.71±0.53[b]	19.27±0.08[b]	Y= -0.37x2+1.36x+19.64	0.68
Ash	15.46±0.05	14.62±0.08	15.65±0.08	17.06±1.28		

Average ± SD.

Different letters within the lines indicate significant difference ($P < 0.01$) for the treatment using the Tukey test.

Sousa et al., 2013.

These results are very important, since for small agricultural producers in the Brazilian semi-arid regions, corn is important for the family meal as well as for livestock, such as sheep and goats, feed.

These small agricultural producers are used to adopting any kind of feed available on their property for animal consumption. For this reason, the digestibility of some feed commonly found on small farms was evaluated (Campeche et al., 2011a): cassava (*Manihot utilissima*) chips, sorghum (*Sorghum bicolor* L. Moench) grain, atriplex (*Atriplex nummularia*) hay, gliricidia (*Gliricia sepium*) hay, leucena (*Leucaena leucocephala*) hay and wine residues. Apparent digestibility coefficient (ADC) of dry matter (DM), crude protein (CP) and digestible energy (Kcal kg^{-1}) of the above cited ingredients, were evaluated for Red Koina tilapia. Among all ingredients, the best ADC values for dry matter were for cassava chips (69.96±10.13) and sorghum (74.97±5.4) (Table 2). Although it showed one of the best dry matter ADC values, sorghum is not considered to be one of the best digestible ingredients for tilapia when compared to other energetic conventional ingredients. The best ADC values for crude protein were for cassava chips (88.19±3.98), sorghum (88.56±2.46) and gliricidia hay (88.08±0.91). Atriplex hay was the ingredient with the best digestible energy value (2063.12). Our research concluded that all the ADC values found are considered low when compared to the ingredients conventionally used. However, depending on how much is used, and, in the case of small property fish producers, the ingredients evaluated in this research can be used for tilapia feed.

Table 2. Apparent digestibility of energetic and protein ingredients of vegetable origin ingredients for Red Koina tilapia

Ingredient	Digestibility (%) Dry Matter	Crude Protein	Digestible Energy (kcal kg^{-1})
Cassava chips	69.96 ± 10.13^{ab}	88.19 ± 3.98^{a}	1609.76^{a}
Sorghum seed	74.97 ± 5.4^{a}	88.56 ± 2.46^{a}	1119.87^{c}
Atriplex hay	47.56 ± 0.0^{c}	81.37 ± 0.0^{bc}	2063.12^{a}
Gliricidia hay	59.88 ± 3.09^{abc}	88.08 ± 0.91^{a}	1059.27^{d}
Leucena hay	59.15 ± 3.53^{abc}	87.18 ± 1.11^{a}	962.98^{d}
Wine residue	57.32 ± 0.0^{bc}	79.86 ± 0.0^{c}	858.18^{f}

Values expressed in % of dry matter. Average ± SD.

Different letters within the column indicate significant difference ($P < 0.01$) for the treatments by Tukey test.

Campeche et al., 2011 a.

Nowadays all the Brazilian shrimp production is destined for the domestic market and Brazil still imports shrimp, principally from Asia (MAPA, 2011). In order to have total production use, to make the aquaculture system in the semi-arid more sustainable and also to deal with the future of fishmeal high prices, the Enzimoly Laboratory of the Universidade Federal de Pernambuco, has conducted a number of trials using shrimp carcass hydrolysate replacing fishmeal for fish feed. The shrimp carcass is a by-product from the shrimp processing industry. A 45-day feeding trial was carried out to evaluate the use of shrimp protein hydrolysate (SPH) in diets for Nile tilapia juvenile. SPH was included in isonitrogenous (average of 35.5% PB) diets replacing fishmeal protein by 0, 5, 10 and 20%. Shrimp protein hydrolysate resulted in a product with 9.7% moisture, 43.63% crude protein, 6.25% ether extract, 7.32% ash, and 3.633 kcal/kg gross energy and a total amino acid content of 46.79 g/100 g (41.2% essential and 58.8% nonessential). The level of SPH incorporated into the diets (0; 1.5; 3 or 6%) did not affect ($P < 0.05$) final fish weight (27.18; 29.46; 26.02 and 25.19 g), weight gain (25.51; 27.73; 24.29 and 23.39 g), average daily gain (0.57; 0.62; 0.54; and 0.52 g day^{-1}) or specific growth rate (7.15; 7.38; 6.85 and 6.73% day^{-1}). Feed conversion ratio (1.15; 1.09; 1.13 and 1.17), protein efficiency ratio (2.26, 2.33, 2.20 and 2.14) and apparent net protein utilization (39.31, 40.39, 38.57, and 34.72) also were not affected by SPH inclusion. The fish fed actively on all diets. An analysis of mathematical models to evaluate length–weight relationships revealed statistical differences ($P < 0.05$) in fish growth. Fish fed SPH5 (1.5% inclusion rate) exhibited the best length–weight relationship. Higher SPH inclusion levels (3 and 6%) did not contribute to fish growth, resulting in similar or worse growth performance than that provided by the SPH0 diet. The inclusion of SPH in Nile tilapia diets significantly affected ($P < 0.05$) final fish body composition. Protein content decreased ($P < 0.05$) when SPH replaced 20% of fishmeal. Fish fed SPH 10 and SPH 20 had greater fat content (58.4 and 59.8 g kg^{-1}, respectively) than fish fed the control diet (51.2 g kg^{-1}) or that with the lowest SPH inclusion level (50.3 g kg^{-1}). Fish fed the diet with no SPH had higher ash content (40.5 g kg^{-1}) than those fed the other diets ($P < 0.05$). This study has demonstrated that SPH is a promising protein feedstuff and could account for as much as 6% of Nile tilapia juvenile diets with no adverse effects on growth and nutrient utilization (Leal et al., 2010).

Cage culture producers are well instructed to use only balanced extruded feed in order to achieve better growth and maintain the best possible water quality. There is only one local fish feed industry that uses local algaroba (*Prosopis juliflora*) meal in the feed formula. This specific feed industry has a commitment to local social sustainability. Some areas of the Brazilian semi-arid region are intensive producers of fruits and vegetables, since irrigation from the São Francisco River has been widely exploited. Therefore fruit residues are also used by small producers, to complement feed for tilapia in the irrigated area of the Brazilian semi-arid Local universities have also studied the use of fruit meal in fish feed. The results obtained so far are promising.

There is still a lot of field and laboratory research to be done in order to improve tilapia production and management in the Brazilian semi-arid regions. Improvement is certain owing to the number of governmental efforts, private producers, feed industries and others members of the production chain working together towards this cause.

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