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Dried duckweed and commercial feed promote adequate growth performance of tilapia fingerlings

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Abstract

The present study evaluated Nile tilapia when fed on dried duckweed in combination with commercial feed, aiming at reducing production costs. Three diets, which consisted of commercial feed (40% crude protein), dried duckweed or a combination of commercial feed and dried duckweed were fed to triplicate groups of 20 tilapia (*Oreochromis niloticus*) fingerlings. Fish weighing 3.2 ± 0.94g were stocked in nine 1-m^3 net cages and fed twice a day for 50 days. The final average weights of fingerlings fed commercial feed (21.67g) and 50% feed + 50% dried duckweed (19.53g) were not different ($p<0.05$). Likewise, the specific growth rate did not differ between fish receiving these dietary treatments. Weight gain decreased as water temperature decreased along the experimental period, increasing feed conversion mainly for fingerlings fed on dried duckweed only. Also, when fed alone dried duckweed promoted the lowest weight gain and specific growth rate. It was confirmed that dried duckweed can replace 50% (1:1 dry weight) tilapia fingerling 40% crude protein feed for a period of at least 50 days, without reducing growth.

Key words: alternative dietary source, duckweed, lemna, tilapia

Resumo

Desempenho de alevinos de tilapia nilótica alimentados com uma combinação de lemnas secas e ração comercial. O presente estudo avaliou a utilização de ração comercial e lemna seca no cultivo de alevinos de tilápias nilóticas com o objetivo de reduzir os custos de produção. Três dietas representadas por lemna seca, ração comercial (40% proteína bruta) e uma combinação de lemna seca e ração comercial foram fornecidas a um grupo de 20 alevinos de tilápia (*Oreochromis niloticus*) em triplicata. Peixes com peso médio 3,2 ± 0,94 g foram estocados em nove tanques-rede com volume de 1-m^3 e alimentados duas vezes ao dia durante um período de 50 dias. O peso médio final dos alevinos alimentados com ração comercial (21,67 g) e 50% ração +

50% lemna seca (19,53 g) não diferiram estatisticamente ($p<0,05$). Paralelamente, os peixes pertencentes aos mesmos tratamentos não apresentaram diferença significativa no crescimento específico. O ganho em peso foi menor em temperaturas mais baixas ao longo do período experimental, causando um aumento significativo na conversão alimentar principalmente dos alevinos alimentados apenas com lemna seca. Além disso, a dieta composta apenas de lemna seca proporcionou o menor ganho em peso e taxa de crescimento específico. Através dos resultados obtidos, conclui-se que a lemna seca pode substituir até 50% (matéria seca 1:1) da ração comercial (40% proteína bruta) utilizada na produção de alevinos de tilápia por um período de 50 dias, sem apresentar redução no crescimento.

Unitermos: fontes alternativas de alimento, lemnáceas, tilápias nilóticas

Introduction

In Brazil, Nile tilapia (*Oreochromis niloticus)* is cultivated in semi-intensive production systems in fertilized ponds or intensive systems such as "raceways" and cages. Depending on the culture system adopted, feed can represent 40 to 70% of the total production costs (Kubitza, 2000). However, due to its omnivorous feeding habit, tilapia can tolerate the inclusion of plant protein sources in their diet, thus reducing feed expenses. In Southern Brazil, Nile tilapia is raised in polyculture with Chinese carp (80% tilapia 20% carp) and integrated to swine production to optimize feeding at different trophic levels in the pond. This production system is adopted mainly by small farmers and has a low production cost since tilapia does not receive commercial feed until it reaches 100 to 150g body weight. Pond primary production is responsible for tilapia growth up to that size (Souza Filho et al., 2003).

The macrophytes of the Lemnaceae family, known as duckweeds, are the smallest flowering plants in the world. Duckweed meal has been used for cattle, poultry, swine and fish feeding, showing favorable results (Skilicorn et al., 1993). Duckweed productivity can reach from 10 to 30ton dry matter/ha/year, depending on the species, climatic conditions, available surface area, amount of nutrients and management. Duckweed protein production/ha is higher than that of most known vegetable crops and twice as high as that of soybeans (Gijzen and Khondker, 1997), assuming an annual production of 17.6ton/ha/year (as dry matter), with a crude protein content of 37% (as dry matter).

Fasakin et al. (1999) observed that the inclusion of up to 30% duckweed meal in tilapia diets promoted adequate growth. Hasan and Edwards (1992) evaluated duckweed as a feed item for Nile tilapia under different feeding rates (from 1 to 6% body weight) and observed that the optimum daily feeding rates of *Lemna* were 5, 4 and 3% (as dry matter) for fish of 25 to 44g, 45 to 74g and 75 to 105g in weight, respectively. Mohedano et al. (2005) obtained a reduction of 30% in tilapia feeding costs by substituting duckweed meal for fish meal for Nile tilapia. Although the nutritional value of duckweed for tilapia is well known (Iqbal, 1999), the manufacture of duckweed meal to include as an ingredient in commercial feed could be troublesome. Therefore, in the present study we investigated whether dried duckweed alone or in combination with commercial feed could be offered directly to Nile tilapia, without affecting growth performance.

Materials and Methods

Experimental design

The feeding trial was conducted in nine 1-m^3 net cages, housed in a 100-m^2 earthen pond, with water flow of approximately 50L/min. Net cages were set on bamboo stales and attached to wooden structures. Feeding rings (50-cm diameter) were placed in each cage to avoid feed mixing among experimental units.

Nile tilapia fingerlings were obtained from a commercial fish farm and were acclimated in 4-m^3 net cages before starting the feeding trial. From this group, 180 fish (average weight 3.2 ± 0.94g) were randomly distributed into nine 1-m^3 net cages. A completely randomized design was adopted, where three diets were fed to triplicate groups of 20 fingerlings.

Duckweed production

A small portion of duckweed was cultivated in two 1000-L plastic tanks to reach 2-kg biomass (as dry matter). Swine manure was added weekly as a fertilizer (1 kg/tank). The total duckweed biomass produced was dried and cut to a smaller size to facilitate feeding management. During the growth period, three samples of duckweed were collected from the surface of each tank with a plastic screen, dried at 50°C for 4h, stored in plastic bags, and cooled (-4°C) until proximate composition analyses were performed.

Experimental diets

The diets tested were: 40% crude protein commercial feed, dried duckweed, or 50% dried duckweed + 50% commercial feed. Proximate compositions of the diets are shown in table 1. Diet composition was determined using standard procedures (AOAC, 1999). The amount of feed offered (dry matter basis) was 10% body weight in the first week and 5% body weight from the second week onwards.

Daily feed allowance was offered twice a day (09:00h and 16:00h). For the 50% duckweed + 50% feed diet, duckweed was offered in the morning and the commercial feed in the afternoon.

TABLE 1: Composition of experimental diets (dry matter).

Component. %	Commercial Feed[1]	Duckweed	50% Commercial Feed + 50% Duckweed
Moisture	12.50	3.00	7.75
Crude protein	40.00	38.86	39.43
Crude fat	6.00	3.80	4.90
Crude fiber	8.00	13.22	10.61
Ash	14.00	16.00	15.00
Gross energy (kcal/100g)	360.00	325.70	334.10

[1]Commercial feed contained a vitamin and mineral premix with the following composition/kg product: folic acid 250mg, pantothenic acid 5000mg, biotin 125mg, copper 2000mg, coline 25000mg, iron 13820mg, iodine 100mg, magnesium 3750mg, niacin 5000mg, selenium 75mg, vitamin 1000000 UI, vitamin B_1 1250mg, vitamin B_{12} 3750mg, vitamin B_2 2500mg, vitamin B_6 1875mg, vitamin C 42000mg, vitamin D_3 500000 UI, vitamin E 20000 UI, vitamin K_3 500mg, zinc 17500mg.

Evaluation of fish performance

Fingerlings in each experimental unit were weighed and measured three times during the experimental period for estimation of average weight gain (final weight-initial weight), feed conversion ratio (total dry feed fed /total wet weight gain) and specific growth rate [(100 x Ln final average weight – Ln initial average weight)/ days].

Water quality monitoring

Water temperature and dissolved oxygen concentration were recorded twice a day. Other parameters, such as pH, turbidity, alkalinity, and total ammonia concentration, were determined weekly. The average water pH remained around 6.0; alkalinity around 20mgL^{-1} total ammonia concentration averaged 0.5mgL^{-1} during the experimental period. Water transparency determined by Secchi disc varied between 20 and 40cm. Water dissolved oxygen and temperatures recorded throughout the 50-day experimental period are shown in figure. 1. The average dissolved oxygen in the morning was lower than in the afternoon and declined as tilapia grew, but not to a concentration that was harmful for tilapia production. However, water temperature averaged 24.9°C in the first period, falling to 23.1°C in the second period, and finally dropping to 18.3°C in the third period.

Statistical analyses

Data were analyzed by one way ANOVA, and Tukey test was used to compare differences among treatment means. The level of significance adopted was 5%.

Results and Discussion

Final average weight

Final average weight was not different between fingerlings fed commercial feed (21.6g) and 50% feed + 50% dried duckweed (19.6g) ($p > 0.05$) (Figure 1). However, both diets promoted a higher final weight of the fingerlings ($p<0.05$) when compared to dried

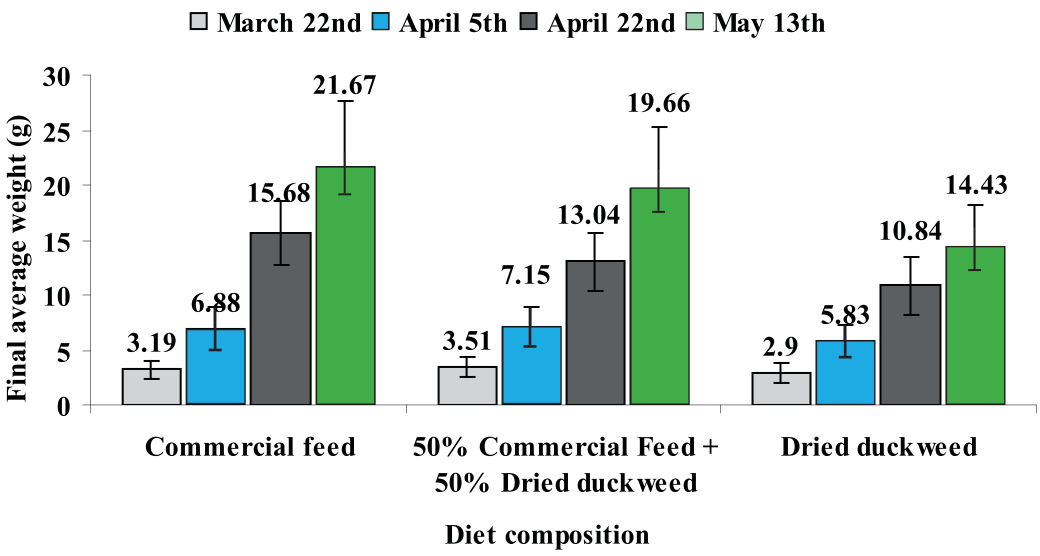

FIGURE 1: Final average weight of tilapia fingerlings when fed on commercial feed (40% crude protein), dried duckweed, and a combination of commercial feed and dried duckweed, for 50 days. [a,b] Values followed

duckweed alone (final weight 14.4g). A study conducted by Mohedano et al. (2005) reported no differences in weight gain between Nile tilapia fingerlings fed only on commercial feed and those fed on formulated feed (of similar nutritional composition) containing 30% duckweed meal, for 60 days.

Weight gain and feed conversion

Figure 2 shows that the weight gain was not different between fingerlings fed on commercial diets and those fed on 50% feed + 50% dried duckweed (3.70g and 3.53g, respectively) in the first growth period from March 22nd to April 5th. However, in the following two periods, fingerlings fed on the commercial feed presented higher weight gain (7.79g and 7.76g, respectively). During the three feeding periods, fingerlings fed on 50% feed + 50% dried duckweed presented a higher weight gain than the ones fed on dried duckweed alone.

Water temperature decreased throughout the trial from 24.9°C to 18.3°C (Figure 3). Therefore, average weight gain data were plotted in three feeding periods (Figure 2).

Lower water temperature caused a decrease in diet consumption during the second feeding period (April 5th to April 22nd), especially for fish fed on dried duckweed alone. However, in the last growth period (April 22nd to May 13th), a significant amount of duckweed was not consumed due to the even lower water temperature. As a result of decreased feed consumption, weight gain decreased for fingerlings fed on all diets.

In the first and third feeding periods, the fingerlings that received only commercial feed presented the best-feed conversion, being 1.3 and 2.0 respectively ($p<0.05$) (Figure 2). However, in the second period, the average feed conversion ratios for fingerlings fed on commercial feed and 50% feed + 50% duckweed were not different (1.7) ($p> 0.05$). The feed conversion of fingerlings fed on dried duckweed alone was always worse than that of fingerlings fed on commercial feed or a combination of 50% feed + 50% duckweed. In the first two feeding periods, the feed conversion ratio of fingerlings fed on dried duckweed alone ranged from 1.8 to 2.0, while for those fed on 50% feed + 50% dried duckweed, it varied from 1.4 to 1.7.

According to Hasan and Edwards (1992), the feed conversion ratio for tilapia fed on fresh duckweed ranged from 1.6 to 3.3, while tilapia fed on commercial feed in a re-circulation system showed a feed conversion ratio of 2.0 (Granoth and Porath, 1983). Therefore, during the first two feeding periods, the feed conversion ratios obtained in the present study are within the range reported by other authors. The worst feed conversion and lowest gain presented by fingerlings fed on duckweed alone in the third period (Figures 1 and 2) could be explained by the low water temperature recorded at that time. In May, the average water temperature was 17.2°C in the morning and 19.6°C in the afternoon. According to Lim (1989), tilapia activity and feeding becomes reduced when the water temperature is below 20ºC, and feeding stops around 16ºC. In the present study, fingerlings fed on commercial feed showed a better performance than fish fed on dried duckweed during the third feeding period only probably because the feed pellets sank and it was necessary for the fish to come up to the surface in order to eat.

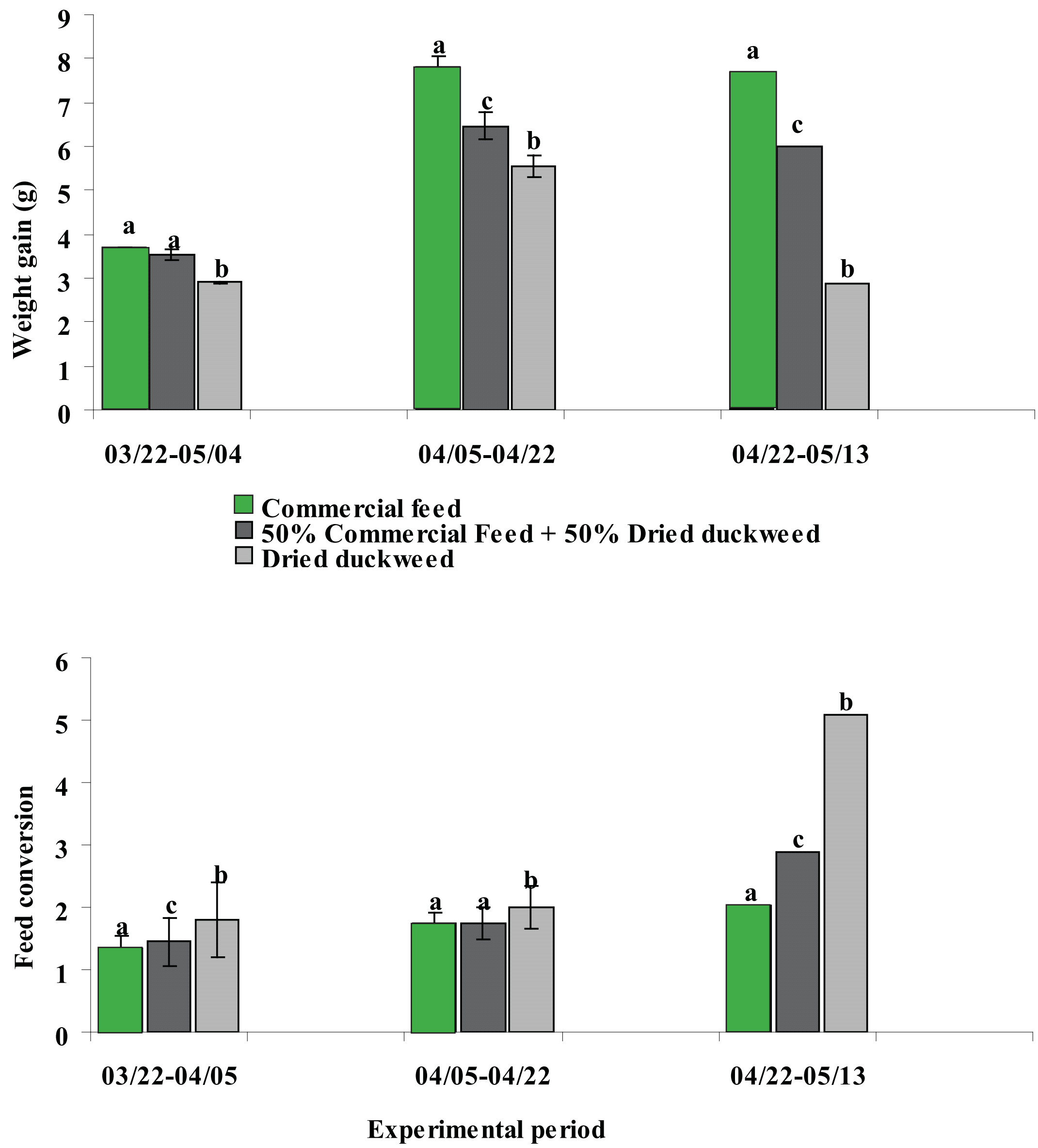

FIGURE 2: Average weight gain and feed conversion of tilapia fingerlings when fed on commercial feed (40% crude protein), dried duckweed, and a combination of commercial feed and dried duckweed, for 50 days. [a,b] Values followed by the same letter are not significantly different ($p<0.05$).

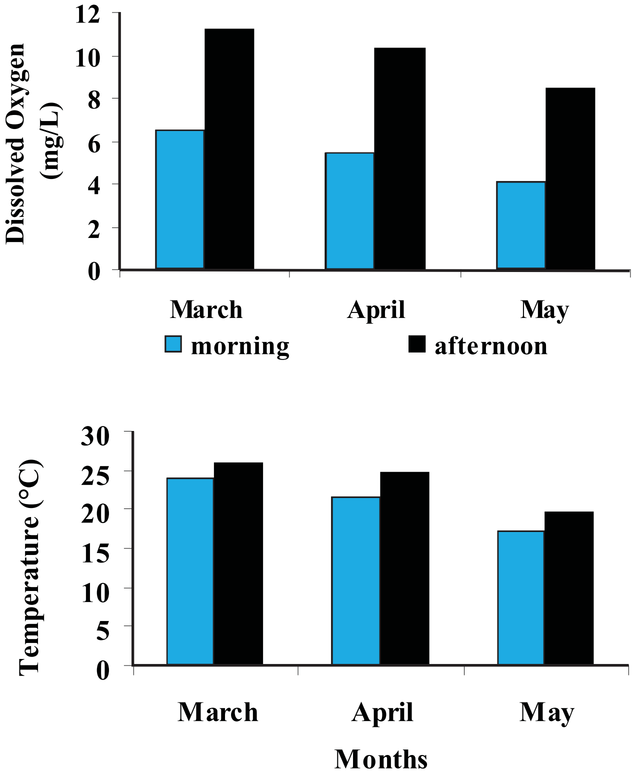

FIGURE 3: Average water dissolved oxygen content (mg L^{-1}) and temperature (°C) recorded daily throughout the 50-day experimental period.

Specific growth rate

During the whole feeding trial, the specific growth rate of fingerlings fed on commercial diet (3.72%) was superior to that presented by fish fed on 50% feed + 50% duckweed or duckweed alone (3.02% and 3.30%) ($p<0.05$). The specific growth rates found in the present study are relatively higher than those found in other studies with tilapia. Gaigher et al. (1984) obtained a specific growth rate ranging from 1.19 to 1.84% for tilapia fed on fresh duckweed and commercial feed. The reason for this difference could be the high water content of fresh duckweed, which might reduce diet intake and consequently reduce growth. Additionally, the present experiment was conducted outdoors and the fingerlings had access to natural feed present in the tank, which may have contributed to the higher growth rates observed.

Duckweed nutritional content

The crude protein and fiber contents of the dried duckweed used in the present study (38.86% and 13.22%, respectively) are similar to duckweed composition data determined by Gijzen and Khondker (1997). According to these authors, the protein content ranged from 30 to 40%, and the fiber content from 5 to 15%, when the duckweed was cultivated in nutrient rich media. Swine manure was used to fertilize and cultivate the duckweed in the present study, providing satisfactory growth when it was added at a proportion of 1kg/1000L/week. Once dried, duckweed can be stored in plastic bags, and no other treatment or process is necessary to use it directly as feed for tilapia. However, it is desirable to keep it stored in a cool environment (4°C) before using it for feeding. Furthermore, dried duckweed presents adequate stability in water, floating for up to 3h.

Duckweed protein production is higher than that observed for most vegetable crops if an annual productivity of 17.6ton dry matter/ha/year and 37% protein concentration is assumed (Iqbal, 1999). Duckweed productivity can vary from 10 to 30ton dry matter/ha/year. These fluctuations are due to species, climatic conditions, management, available surface area and available nutrients. Mgabwu and Adeniji (1988) reported that duckweed production in nutrient-rich water bodies, such as sewage or animal waste lagoons, can reach up to 14.9 g dry matter/m^2/day if proper management is adopted. Also, the production of duckweed in wastewater can be an alternative which contributes to the sustainability of sewage treatment plants, mitigating environmental impacts. According to Decamp and Warren (2000), duckweed can be used as a secondary treatment of effluents from activated sludge systems or stabilization ponds since it contributes with nutrient uptake from the wastewater, improving the effluent quality.

It has already been demonstrated that duckweed can serve as an alternative dietary source for tilapia (El Sayed, 1999; Fasakin et al., 1999; Mohedano et al., 2005). However, most growth studies evaluating fresh duckweed as a dietary item have shown low weigh gain results (Gaigher et al., 1984; Hasan and Edwards, 1992). Gaigher et al. (1984) evaluated the use of fresh duckweeds as feed for tilapia in a water recirculating unit and observed that fish fed only on duckweed presented lower weight gain. According to these authors, fresh duckweed intake was limited due to its high moisture content (96%) and the presence of air pockets in its leaves, which are used for flotation. The present study, however, is the first to evaluate dried duckweed fed directly to tilapia. Our findings show that up to 50% of a 40%-crude-protein commercial feed could be replaced by dried duckweed without reducing the growth of tilapia fingerlings for a period of at least 50 days. In the present study, the final average weight of tilapia (from fry to juvenile) fed on commercial pellets was not different when the diet included 50% dried duckweed fertilized with swine manure. However, the low water temperature recorded in May was limiting for growth, negatively affecting the weight gain of fingerlings fed dried duckweed alone. Therefore, it is not advisable to rely on dried duckweed as the only food source when water temperatures are below 18°C. Considering that feed can represent up to 70% of total production costs in tilapia culture in semi-intensive systems, feeding tilapia on a 1:1 mixture of dried duckweed and commercial feed could reduce production costs. However, the practical feasibility of such a feeding regime depends on duckweed production costs, which can vary depending on the resources available on each farm.

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