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Economic Analysis of the Use of Restrictive Food Management in the Cultivation of Tilapia (*Oreochromis niloticus*) in a Recirculation System

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Abstract: The development of more adequate food programs regarding the intensity and duration of the restriction can be an effective way to minimize the effects of exaggerated food consumption and its negative consequences for the economy of the business. In this sense, juvenile Nile tilapia (*Oreochromis niloticus*) (137 ± 3 g) were submitted to different feeding strategies in a recirculation system. Five feeding strategies were tested in subsequent weekly cycles: continuous feeding; skipping one meal a week; suppression of two non-consecutive meals a week; suppression of three non-consecutive meals a week; suppression of four non-consecutive meals a week. Productive performance, feed consumption in the post-restriction period and economic indicators were evaluated through projections and profitability analyses. Compensatory intake occurred in all tested groups, so that the total feed intake (FI) did not differ significantly between them ($p > 0.05$). Moderate food restriction provided a linear increase in the relative gross margin for each treatment with each change in salary level, as well as greater profitability when compared to the respective control group ($p < 0.05$).

Key words: Feed management, feed restriction, carcass quality, carcass yield, operational yield, economic efficiency.

1. Introduction

Restrictive feeding strategies vary between species and fish farms, including feeding at apparent satiation, feed restriction based on body weight ratio, or restriction based on food input into the farming system [1, 2]. It is still necessary to determine the exact strategies for using feed restriction and compensatory growth as an effective management method, especially under field conditions [3].

Other studies involving the adoption of several meals a day through automatic feeders have shown good results regarding the performance of tilapia grown in cages. The increase in feeding frequency associated with day or day/night feeding improved the performance of net cage Nile tilapia, which suggests that a large number of feedings allow better exploration of food and availability of dissolved oxygen [4, 5].

On the other hand, it is likely that in some situations, a single daily meal gives more opportunity for all fish in each batch to feed themselves sufficiently, thus being able to provide satisfactory zootechnical performance to them.

However, it is necessary to define which food managements are well associated with moderate forms

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of food restriction, in order to configure optimized and more personalized food plans for each species, production system and other production factors/inputs, with recognized influence on the final result.

2. Material and Methods

2.1 Experimental Modeling

The experiment was carried out at the Fish Farming Station of the Experimental Farm of Leopoldina, EPAMIG (UREZM) (Fig. 1), located in the municipality of Leopoldina, in the Zona da Mata region, Minas Gerais. Aiming at evaluating food restriction strategies for tilapia produced in a recirculation system, an experiment was carried out in a completely randomized design with 5 treatments (restriction strategies) and 3 replications each. For this, 15 boxes adapted in polyethylene (Fig. 1) with a volume of 1,000 L were used, arranged in a recirculation system and 450 juvenile tilapia fish weighing an average of 137 ± 3.0 g according to the density worked in the literature [5].

The system was provided with continuous water circulation and forced aeration by means of radial air compressors and porous stones with 1 hp for every 500 kg of fish [6]. Every 3 d, the organic matter deposited at the bottom of the boxes was siphoned off. The culture water in the boxes was recirculated daily around five times, after passing through mechanical and biological filters. Losses by evaporation and general management represented around 3% of the total volume, with daily compensation being made with water from the upstream stream, after passing through mechanical gravel filters.

During 120 d, the fish were fed with a commercial ration specific for tilapia of granulometry 2-4 and 4-6 mm, with 32% of crude protein. The experimental diets were offered in two daily meals (09:00 h and 16:00 h), according to the following feeding strategies (Table 1).


(a) (b)

Fig. 1 (a) Aquaculture laboratory in recirculation system; (b) Adapted fiberglass boxes with a total volume of 1,000 L.

Table 1 Programmed food restriction strategies applied to batches of tilapia grown in adapted boxes (recirculation).

Treatments	Food management	Days in restriction	Restriction level (RL, %)
1	Controlno skipping	None	0
2	Skipping 1 meal	Sunday	7.1
3	Skipping 2 meal	Sunday + Thursday	14.3
4	Skipping 3 meal	Sunday + Tuesday + Thursday	21.4
5	Skipping 4 meal	Sunday + Tuesday + Thursday + Saturday	28.6

In biometrics, all fish in each plot (box) were individually weighed on a digital scale and measured in an ichthyometer. Feed intake (FI), occurrence of compensatory intake, daily weight gain (DWG), biomass gain (BG) in the period, survival rate (SR), specific growth rate (SGR), feed conversion, proximate carcass composition, fish water activity, yields were evaluated in the animals tested. Somatic and morphometric indices of digestive organs were evaluated. Additionally, an evaluation of economic indices was carried out through projections and sensitivity analyses.

The water temperature of the boxes was measured daily on the surface, at 09:00 and 16:00, using an analog thermometer (Incoterm, Porto Alegre, RS, Brazil). Dissolved oxygen and pH were measured daily at 9:00 am using a multiparameter meter (Hanna model HI-9828). Ammonia is analyzed using ancolorimetric kit (Alfakit, Florianópolis, SC, Brazil). The averages of the main water quality parameters were 5.0 ± 0.5 mg L for dissolved oxygen, pH values of 6.9 ± 0.3 and toxic ammonia levels of 1.0 μg/L. Water temperature is 26.2 ± 4.2 °C. According to Boyd [6], the parameters presented fit the water quality standards recommended for aquaculture.

The verification of the occurrence of compensatory intake was carried out by measuring the volumes of feed consumed by the lots of each plot in the last two normal meals, before the application of the weekly restrictive treatments, and the comparison with the volume consumed in the first meal also at satiety, immediately after the restriction. Food was offered ad libitum until satiety.

2.2 Response Evaluation in Zootechnical Indices

To evaluate the response to food intake, three to four observations were performed per treatment at least five different times, throughout the experimental period, in both trials. At the end of the experiments, the fish were submitted to final biometry to determine length and total weight. Average initial weight (AIW), average final weight (AFW), average DWG, weight or BG, SR, total FI per treatment, SGR and apparent feed conversion (AFC) were estimated as proposed by Standen *et al.* [7], respectively, by the following mathematical expressions :

- AIW = average of the initial weights of stocked juveniles, by treatment;
- AFW = average final weights of adult fish caught, per treatment;
- DWG (g/day) = (AFW - AIW) / time in days of cultivation;
- BG (kg/pond or kg/box) = final biomass - initial biomass;
- SR (%) = (final number of fish / initial number of fish) × 100;
- FI = ration supplied/day (kg) × total number of days referring to the experimental period;
- SGR = [100 × ((Ln final weight - Ln initial weight)/days of experiment)]
- AFC = feed provided (kg) / GB (kg)

Results obtained were submitted to analysis of variance (ANOVA), and the means were compared by the Student-Newman-Keuls (SNK) test ($p > 0.05$), using the Statistical Analyses System (SAS) statistical program, version 8.2.

2.3 Economic Analysis of Food Restriction Strategies

The economic evaluation was carried out taking as a basis for the two tests and their respective projections, only the costs with food (feed) and those involved with labor, both that used exclusively in feeding and also through layoffs in shifts. In this sense, the other cost items were understood as constant and similar for the contexts considered, thus not being objects of analysis.

The cost of man-hours (MH) was measured based on the minimum wage in force in January 2014 ((R$ 724.00 + 65% of direct social charges) / 200 h), having as a criterion the use of MH plus of overtime and/or paid rest when calculating labor layoffs on Saturdays and Sundays. In this sense, the remuneration values considered for MH and overtime on weekends were R$ 5.97 and R$ 10.45, respectively.

The study of the economic indicators of the different treatments was carried out by adapting the calculations described by Lanna [8] and Togashi [9].

- Average Gross Income (AGI): value in Reais (R$) obtained as a function of the gain in biomass in the period evaluated in kilograms (BG) and the price of a kilo of tilapia in R$ (TP).

RBM = BG × TP

- Average Feed Cost (AFC) or Feed Cost: total cost related to feed consumption in the evaluated period (CR) as a function of the average cost per kilogram of feed and feed conversion (FC) of the fish batch.

AFC = CR in the period ×FC× feed conversion

- Average Gross Margin (AGM) = difference between AGI and AFC.

AGM = AGI-AFC

Average Profitability (AP): division between the average gross margin (AGM) and the average cost of food (AFC).

AP = AGM/AFC× 100

- Relative Profitability Index (RPI): relationship between the AP of treatments and the control.

RPI = Relative margin (RM) of the tested treatment / RM of the control treatment× 100

To calculate the RPI, it was taken into account that fish fed to satiation and without suppressing any meals (treatment 1) would be taken as a base, and therefore, the value considered for this treatment was 100. Other indices were calculated as a function of this treatment.

This system is similar to that called by Shang [10] as Partial Budget Analysis in Aquaculture. Such a system consists of the partial analysis of the production cost, being used in situations where only one item of the operational cost varies.

The average selling price considered was R$ 4.65 per kilogram of live tilapia. The estimated cost for acquiring commercial finishing feed was R$ 2.00/kilo, this price being taken in January 2014, considering the average price in the Belo Horizonte region, when the exchange rate was U$ 1.00: BRL 2.20.

The MH spent in the feeding operation in intensive fish farming in adapted boxes was set at 0.62 h (≈ 37 min), with 1 handler capable of operating up to 50 production units per day.

For the realization of the projections, hypothetical fish farms with sizes of 1, 5 and 10 productive modules were considered, with the module consisting of 5 boxes with an individual volume equal to 2,000 L (≈ 2 m^3).

Production projections were based on yields and feed conversions found in the research itself and based on other variables such as stocking densities (40.0 kg/m^3) and survivals (80.0%) for the recirculation system.

Optimization of the workforce in each of the projections resulted from the reduction of MH used exclusively in the operations of feeding and/or dismissing in shifts. This was possible thanks to the application of the labor-feed equivalence method, which in turn allowed the estimation of the reduction in the unitary food cost for each of the food strategies adopted in the present study.

The measurement of labor productivity (LP) was performed based on the following calculations:

- MH: number of hours dedicated exclusively to feeding the production units, per cycle (experimental period);

MH = number of hours/man/day × number of days × number of months × number of hectares

- Man-Days (MD) = number of days dedicated exclusively to feeding the production units, per cycle (experimental period);

DH = MH/8

- Labor productivity (LP) = performance of the labor dedicated exclusively to feeding the production units as a function of the gain in biomass in the evaluated period, in kilograms (BG);

LP = DH/GB

3. Results and Discussion

3.1 Zootechnical Indices

The zootechnical indices analyzed in the work showed no statistical difference ($p > 0.05$) between all treatments tested (Table 2). In this way, the use of any of the feeding strategies will result in the same productivity of the control which did not undergo food restriction. This result is important from the point of view that it sets the precedent for the use of restriction without damage to productivity, aiming at the best adaptation of the intended management practices up to the limit of 4 restrictions per week. The productive performance demonstrated zootechnical indices in the present work are within the standards for the species and production system [5].

3.2 Economic Projections and Analyses

In the planning of fish farming, the economic aspects of the activity are highly relevant. Investments carried out without proper economic analysis may constitute a loss [11]. In this sense, in research studies involving programmed food restriction, the phenomenon of compensatory growth should not be analyzed in isolation, as this can lead to hasty and/or mistaken conclusions in terms of economic viability, when one intends to apply food restriction plans in the commercial fish farms.

Table 3 presents some economic indices resulting from the application of food management in the batches of fish in that trial. Treatment 2 showed an increase of 15% in the relative gross margin compared to the control treatment. The adoption of feeding strategies with short restriction and refeeding cycles are feeding practices that can have significant effects on the cost of production and profitability of fish production [12].

Final average weight and the greater uniformity of the batches of fish belonging to group 2 may have been decisive for the best economic result, verified for

Table 2 Average initial weight (AIW), average final weight (AFW), biomass gain (BG), daily weight gain (DWG), specific growth rate (SGR), survival rate (SR), total consumption of ration (CR) and apparent feed conversion (AFC) of Nile tilapia reared in an intensive recirculation system, under different feed restriction regimes.

Treatments	AIW (g)	AFW (g)	BG (g)	DWG (g)	SGR	SR (%)	CR (kg)	AFC
1	0.140	0.602	0.461	3.84	2.08	70.0	12.17	1.50
2	0.143	0.578	0.435	3.63	2.17	82.2	12.84	1.29
3	0.136	0.518	0.381	3.18	2.03	75.6	12.61	1.72
4	0.137	0.533	0.396	3.31	2.12	81.1	12.12	1.37
5	0.133	0.509	0.376	3.14	2.08	81.1	11.78	1.41
CV (%)	16.88	13.42	17.55	17.48	4.04	7.40	4.84	15.93

CV = coefficient of variation. There was no statistical difference between treatments. SNK (0.05).

Table 3 Data on average gross revenue (AGR), cost with food (CF), average gross margin (AGM), average profitability (AP) and relative profitability index (RPI) of the intensive recirculation system (1 module with 5 boxes-terminators), due to the food restriction strategy imposed, without deducting labor.

Items	Food strategy				
	1	2	3	4	5
AGR (R$)	1.91	1.91	1.91	1.91	1.91
CF (R$)	1.17	1.06	1.17	1.17	1.17
AGM (R$)	0.73	0.85	0.73	0.73	0.73
RPI (%)	100.0	115.6	100.0	100.0	100.0
AP (%)	62.59	80.23	62.59	62.59	62.59
RPI (%)	100.0	128.2	100.0	100.0	100.0

this feeding strategy. Allied to this, the fish of this group showed good feed conversion, which contributed to a better use of the food ingredients provided. The SGR corroborates this statement, by proving that the fish submitted to treatment 2 exhibited a good growth rate.

Although the statistical method did not find a significant difference ($p > 0.05$) for AFW and BG among all treatments evaluated, the economic analysis, when considering exact values, was able to demonstrate the financial implications resulting from the aforementioned feeding strategies. By setting the deducted food cost and applying the profitability analysis, it can be seen that with the reduction in labor, the average gross profitability is maximized by up to 47% (Table 3), when adopting the different forms and intensities of management restrictive food.

When considering other costs inherent to the operational routine of fish farms when applying restrictive food management, treatments 2, 4 and 5 can bring advantageous economic results, especially in situations of high production scale (economy of scale).

Through the projections in Table 3, it is also possible to verify the degree of positive influence that food efficiency has on the profitability of the business, especially in relation to treatment 2, which obtained practically the same AGM as treatment 4, even applying 2 d less food restriction. Severe restriction in the consumption of broilers for a short period of time and at an age that allows recovery before the age of slaughter can lead to compensatory growth, in addition to reducing feed consumption and, consequently, increasing economic viability [13, 14].

The simple fact of allowing the maintenance of satisfactory food efficiency and greater rationalization of labor, makes treatments 4 and 5, mainly, provide greater economic profitability to hypothetical fish farms, simulated from these data.

Therefore, even with no marked differences in zootechnical performance, labor optimization can make ecological-economic food management more interesting from a financial point of view. When taking into account the reduction of direct labor costs, groups 4 and 5 started to present better profitability than the control group, when compared to the previous situation. This result comes from the direct implication of the increase in the efficiency of the workforce, in these cases, as can be seen in Table 4. From the data presented above, it can be noted that treatment 5 obtained 11.22% increase in LP of work, when compared to the control group.

3.3 Sensitivity Analyses

Analyses regarding the stability of economic indices were measured with the objective of evaluating the best way to conduct hypothetical fish farming in the midst of market variants. The results of these analyses are shown in Tables 5-7 below.

From the data in Table 5, it can be seen that when the price of the feed increases, the batches of fish submitted to all the strategies of programmed food restriction, in the present study, obtained an increase in relative gross profitability of the order of 25 to 55 points percentages compared to the control group. This type of reflex is mainly due to the improvement in feed conversion in group 2 ($p < 0.2$) and the optimization of manpower in groups 3, 4 and 5. Even

Table 4 Labor performance indicators according to restrictive food management adopted in an intensive system in clear water (recirculation), using adapted boxes.

Operating performance indicators (cycle)	Treatments				
	1	2	3	4	5
Man hours (MH)	120	112	104	96	88
Man days (MD)	15	14	13	12	11
Labor productivity (LP)	29.50	29.83	28.14	31.68	32.81

Table 5 Relative gross margins as a function of restrictive food management and variation in commercial feed prices, considering projections for recirculation fish farming (1 module) and deduction of labor employed exclusively in feeding.

Treatments	Variation in feed prices (R$/kg)				
	10% lower	5% lower	R$ 2.00	5% higher	10% higher
1	100%	100%	100%	100%	100%
2	125.03%	127.61%	130.60%	134.10%	138.28%
3	120.26%	121.76%	123.50%	125.54%	127.97%
4	127.63%	129.68%	132.05%	134.83%	138.14%
5	140.53%	143.52%	147.00%	151.08%	155.94%

Table 6 Relative gross margins as a function of restrictive food management and variation in fish sales prices (live kg), considering projections for recirculation fish farming (1 module) and deduction of labor employed exclusively in feeding.

Treatments	Sale price (R$/kg)				
	10% lower	5% lower	R$ 2.00	5% higher	10% higher
1	100.0%	100.0%	100.0%	100.0%	100.0%
2	141.3%	135.2%	130.6%	127.1%	124.3%
3	131.7%	127.0%	123.5%	120.8%	118.7%
4	143.3%	136.8%	132.0%	128.4%	125.4%
5	163.5%	154.0%	147.0%	141.6%	137.3%

Table 7 Relative gross margins due to restrictive food management and the increase in the value of labor (base salary), considering projections for fish farming in recirculation (1 module) and deduction of labor employed exclusively in feeding (BS = basic salary).

Treatment	Values of labor (base salary: R$)				
	BS	10% higher	20% higher	30% higher	40% higher
1	100.0%	100.0%	100.0%	100.0%	100.0%
2	130.6%	132.1%	133.6%	135.1%	136.6%
3	123.5%	125.9%	128.2%	130.6%	132.9%
4	132.0%	135.3%	138.5%	141.7%	144.9%
5	147.0%	151.7%	156.4%	161.1%	165.8%

though there was no effective feed restriction, as a result of the compensatory consumption, these factors promoted a compensatory-economic effect, in view of the increase in FC.

The potentiation of economic gains from the restrictive strategies was so expressive that, even in situations where the price of the feed was lower, the superiority of the relative gross margins was maintained, in relation to the control group. Interpretations of the information contained in Table 6 allow us to infer that treatment 5 was the one that presented the highest gross returns at all simulated sales price levels, in relation to the respective control group. Additionally, restrictive food management can bring greater financial benefits to aquaculture enterprises that sell products with a lower degree of processing and/or that generate narrower profit margins.

As shown in Table 6, restrictive food management provided a linear increase in the relative gross margin within each treatment with each change in salary range, as well as greater profitability when compared to the respective control group. Among all the dietary strategies tested, the one concerning treatment 5 was the one that generated the highest relative gross margins, at all levels of basic remuneration.

As shown in Table 7, restrictive food management provided a linear increase in the relative gross margin within each treatment with each change in salary range, as well as greater profitability when compared to the respective control group. Among all the dietary strategies tested, the one concerning treatment 5 was the one that generated the highest relative gross margins, at all levels of basic remuneration.

Analysis of the set of rules contained in the Consolidation of Labor Laws (CLT) reveals that a premise was established that the employer is only entitled to dispose of the employee's workforce if it observes the rules that authorize it, especially when it is overloaded [15]. Brazilian labor legislation guarantees the employer the unilateral right to demand overtime work, regardless of agreement or collective bargaining agreement, in the event of unusual, brainy situations, caused by imperative necessity and totally beyond the control of the employer [16]. By offering an appropriate economic response in contexts marked by high feed prices and labor costs, treatment 5 proves to be a good alternative in conducting the food management of intensive fish farms, which fit into conditions similar to those of the present study.

Cost domination is a tool for companies that cannot differentiate themselves by quality or attributes extrinsic to the product, such that the reduction of costs becomes a differential that elevates the company to be one of the market leaders, not only by prices, but also by profitability [17]. In Vale do Ribeira, SP, small fish farms (< 50 ha) are associated with other agricultural activities, where only 36% of producers have fish farming as their main activity, with a predominance of creation in excavated ponds and with the use of feed [18]. In these, the high costs of feed have reduced the profit margin and made small fish farmers look for alternative ways of feeding the fish.

In order to meet demands such as the latter, raised in diagnoses [19] or even in the case of other more intensive and more feed-dependent production systems (e.g. net-tank; recirculation), it is possible to dismiss the employee/keeper in the respective shift in which the meal will be suppressed. This decision should take into account the size of the fish farm, the diversification of activities on the property, the division of labor and whether or not it is necessary to rearrange operations or routines for days when there is no meal suppression.

If the producer is unable to feed the fish for a short period of time, due to diseases or adverse conditions in the ponds, or even in cages, where structures can often be difficult to access, a period of food deprivation could be used, since for many species there may be a compensation of the period of growth retardation when fed to satiety after the end of deprivation [20]. This type of operational maneuver can be convenient in fish farms located far from the shore, whether in freshwater reservoirs or seas. However, the observations made so far are very important because they are useful in planning and formatting food plans with programmed food restriction for some fish species. Based on the information above, partial quantitative restrictions (meal) can be interspersed every 2 d or more in order to allow an adequate recovery in the levels of the main energy contents.

4. Conclusion

The labor savings, made possible by the adoption of moderate food restriction, significantly increases the profitability of tilapia farming, especially when this resource has its price increased. Moderate restrictive food management combined with optimized labor management can bring greater economic efficiency to intensive tilapia farms, regardless of the size of the enterprise.

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