Boletim do Instituto de Pesca, São Paulo, 25 (único): 85 - 94, 1998/1999

TAGUCHI'S LOSS FUNCTION APPLIED IN THE BREEDING OF NILE TILAPIA *Oreochromis niloticus* FED WITH DIFFERENT LEVELS OF ALCOHOL YEAST, STOCKED IN AMIANTHUS BOX

[Função perda de Taguchi aplicada na criação de tilápia do Nilo, *Oreochromis niloticus,* alimentada com diferentes níveis de levedura alcooleira, alocada em caixa de amianto]

Vandir Medri[1,4], Geny Varéa Pereira[2], Júlio Hermann Leonhardt[3]

[1]Prof. Associado - Department of Applied Mathematics, State University of Londrina, Londrina, Paraná
[2]Prof[a] Adjunto - Departament of Biochemistry, State University of Londrina, Londrina, Paraná
[3]Prof. Associado - Departament of Animal and Vegetal Biology, State University of Londrina, Londrina, Paraná
[4]Endereço/Address: Rua Borba Gato, 1078, Apt[o] 1104 – Centro CEP 86010-630, Tel: (0xx43) 322-8412 - Londrina, PR

ABSTRACT

Two hundred and forty 45-day-old fingerlings of Nile tilapia *(Oreochromis niloticus),* sexually reverted with an initial average weight of 1.25 ± 0.14 g and placed in amianthus box, were used. The effect of rations with 10%, 20% and 30% of distillery yeast on the function Taguchi's loss, was evaluated. The average results obtained in the limnological parameters for the water quality control by means of the chemical analysis were considered normal. Taguchi's losses for the total production, for the dead and for the discarded fish do not show a correlation with the different levels of alcohol yeast in the ration, showing that the choice of the yeast level for these fishes depends on its availability and cost. It was observed that the losses can be attributed to the density limit, absence of natural feeding and great scattering in the fishes' size.
Key Words: yeast, quality, ration, Taguchi loss function, *Oreochromis niloticus*

RESUMO

Foram utilizados 240 alevinos de tilápia do Nilo *(Oreochromis niloticus)* com 45 dias, sexualmente revertidas, com peso médio inicial de 1,25 ± 0,14 g alocados em caixas de amianto. Foi avaliado o efeito da ração contendo 10%, 20% e 30% de levedura de destilaria sobre a função perda de Taguchi. Os resultados médios obtidos nos parâmetros limnológicos para o controle da qualidade da água através da análise química foram normais. As perdas de Taguchi para a produção total e para os peixes mortos e descartados não revelou uma correlação com os diferentes níveis de levedura alcooleira na ração, indicando que para este peixe, a escolha do nível de levedura na ração para estes peixes depende da sua disponibilidade e custo. Observou-se que perdas acentuadas nas caixas de amianto podem ser atribuídas à densidade, ausência de alimentação natural e grande dispersão no tamanho dos peixes.
Palavras-chave: levedura, qualidade, ração, função perda de Taguchi, *Oreochromis niloticus*

Introduction

Yeast

Yeast is a worth product, adequately balanced, resultant from the process of alcoholic fermentation, and an important alternative source of protein on formulation of animal ration, so as high levels of protein, carbohydrates, lipids, etereo extract, vitamins and minerals are obtained (Mattos, Dantas D'Arce e Machado, 1984).

Tilapias are able to utilize the wastes of agroindustry such as yeast, and also to assimilate carbohydrates contained in the vegetable ration ingredients. These agroindustrial wastes can be utilized as supplement in animal ration, reducing the production costs and pollution (Litchfield, 1983; ALCOPAR,1992).

Young tilapia eat mainly zooplancton and phitoplankton; while the adults, accept a variety of artificial food, vegetables, larvae and insects (Castagnolli, 1992; Wu *et al.*,1995).

Loss Function

The Taguchi's loss function or the quality function is defined as the value of the expected monetary loss caused by the characteristic deviation of performance, related to the wished value or a specific value. This concept of loss shows a new thought of investments in quality improvement, because in a competitive economy, the continuous improvement of the quality and the reduction of costs are necessary to

Artigo Científico – aprovado para publicação em 21/06/99

keep the product in market (Kackar, 1986). The loss considered is calculated in monetary values and is associated to quantifiable characteristics of the product.

Taguchi, Elsayed e Hsiang (1990) have as hypothesis, generally accepted, that the probabilistic distribution of the values obtained from a large scale production is normal and not uniform, so it follows the reduced function of Gauss.

Taguchi, Elsayed e Hsiang (1990) consider as loss for the society the difference between the nominal values **m** and the obtained values **x**, in a simplified case where the quality depends on only one dimension. In general cases, where the quality depends on many dimensions, the loss function is applied to each dimension and the value of one loss is summed to the other individual losses. In other words, each unity causes a loss, which is not kept to the owner, but is distributed to all the society (Stange, 1996, apud Medri,1997).

The concept of Taguchi's loss function that relates the value of the monetary loss caused by the quality decrease to the removal of the nominal value (m) of the specification, was shown to be a quadratic function. The maximum value is obtained when the deviation exceeds the specification limits (Taguchi, Elsayed e Hsiang, 1990, Guedes, 1996).

When the loss function grows symmetrically with the deviation of the functional characteristics around the normal value, "the nominal is the best one", although Phadke (1989), mentioned by Guedes (1996), extended this concept to other two special cases of functional characteristics of quality: "The smaller is the best one" and "the biggest is the best one".

The objective of the experiment was to verify the existence of correlation between the Taguchi's loss function and the total production and for the dead and rejected fishes and the four balanced rations isoproteic (28% PB) and isocaloric balanced (2933 kcal/kg) with T_1=0% (control group), T_2=10%, T_3=20% and T_4=30% of yeast from alcoholic distillery.

Material and Methods

Experimental conditions

Two hundred and forty fingerlings of Nile tilapia (*Oreochromis niloticus*), from the Fish Breeding Station of the Animal and Vegetal Department of Biology of the Biological Science Center of the Universidade Estadual de Londrina, were used in the experiment.

The initial average weight and length of the fingerlings were respectively 1.25 ± 0.14 g and 3.84 ± 0.17 cm. The fish were reverted by the supply of rations with 60 mg/kg of diet of the male hormone 17a–metiltestosterone, during a period of 30 days.

A computational program was utilized in order to elaborate the ration BRUN 10 adequated to the needs of the species. The four isoproteic (28% PB) and isocaloric balanced rations (2933 kcal/kg) with 0% (control group), 10%, 20% and 30% of yeast from alcoholic distillery remains (Table I).

The fingerlings were randomly distributed in 12 groups of 20 individuals. Each group was placed in an amianthus box with capacity of 500 liters, with continuous aeration and water exchange. They were supplied with water from a semi-artesian well, with discharge of 6liters/second/hectare and placed in a closed environment.

The boxes were cleaned weekly, siphoning the residues and algae deposited on the bottom and walls. Fish were daily observed aiming to verify any uncommon behavior, morphological variation and death. The experiment lasted for 330 days (03/15/95 to 02/15/96).

Using a paquimeter and a balance of precision, the total weight (Wt), in grams, and the total length of the fishes (Lt), in centimeters, were monthly measured. The water temperature was checked every day with a mercury thermometer. Monthly, the alkalinity was measured through the addition method, the dissolved oxygen through Winkler method, ammonia through photometer method of Berthelot, nitrite through Griess-Hosvay, total phosphorus and dissolved phosphorus through Murphy method and pH through potentiometer. The methodology used to test these parameters was according to Lind (1979) and Standard Methods (1980).

Each treatment named (T_j) was given to three groups of fishes (triplicate). The fingerlings were daily fed according to Wilson (1991).

Taguchi's loss function in Nile tilapia breeding

The functional characteristic of quality used was: "the biggest one is the best". In this case, the best value is not defined, the bigger is the characteristic value (fish weight), the better it is. The loss caused by a fish that has passed the inferior limit of tolerance is represented by A, and its corresponding deviation is DA. The function is expressed by:

$L(Y) = K\,[1/Y^2] = A\,D^2\,v^2$ (Phadke, 1989), were K is the number of fish.

Table 1. Composition of the experimental rations for the Nile tilapia

Ingredients (%)	Control (T_1)	Test (T_2)	Test (T_3)	Test (T_4)
Yeast	0.00	10.00	20.00	30.00
Ration	100.00	90.00	80.00	70.00
Total	100.00	100.00	100.00	100.00
Ration Formulation (%)				
Yeast	0.00	10.00	20.00	30.00
Fish flour	27.00	25.00	23.00	15.00
Wheat flour	13.00	15.00	17.00	15.00
Crushed maize	47.30	41.01	35.31	30.11
Soybean flour	11.05	7.75	3.99	9.89
Vegetable oil	1.65	1.24	0.70	...
Total	100.00	100.00	100.00	100.00
Ration nutrients (%)				
Dry matter	87.86	87.86	88.90	89.24
Crude protein	28.00	28.00	28.00	28.00
Methabolizable energy (kcal/kg)	2933.00	2933.00	2933.00	2933.00
Calcium (Ca)	1.54	1.55	1.34	0.97
Phosphorus (P)	1.15	1.14	1.13	0.97

Calculus of cost of each fish

P1 = ration + yeast + fingerling + population + biometry + medicines + ...+ harvest

P2 = ration + yeast + fingerling + population + biometry + medicines + ... + harvest

... = ... + ... + ... + ... + ... + ... + ... + ...

Pk = ration + yeast + fingerling + population + biometry + medicines + ... + harvest

....

$$\sum_{1}^{k} P_i = \sum_{1}^{k} (\text{ ration + yeast + fingerling + population + biometry + medicines + ... + harvest})$$

<u>**A calculus :**</u>

$$A = \frac{1}{k} . \sum_{i=1}^{k} P_i \quad \text{com} \quad i = 1, 2, \ldots, k$$

Where k is the number of fishes.

A is the loss caused by fishes that passed the inferior limit of tolerance.

<u>Δ *calculus:*</u>

The fish production that presents high dispersion will have a higher cost on account to the rejects and consequently bigger quality loss. In this case, it is better to divide the fishes in lots to calculate the tolerance and the reduction of losses.

In general, the procedure to calculate the tolerance (Δ) is:

Δ = average of fishes / 2

<u>*v^2 calculus:*</u>

$$v^2 = \frac{1}{n} . \left(\frac{1}{y_1^2} + \frac{1}{y_2^2} + \ldots + \frac{1}{y_n^2}\right) = \frac{1}{n} . \sum_{i=1}^{n} \left(\frac{1}{y_i^2}\right) \text{; where,}$$

v^2 is the quadratic average deviation and y_i is the value of the studied characteristic (weight).

Results and Discussion

Tilapia growth

The results of length and total average weight of the control group (T_1) and the tested groups (T_2, T_3 and T_4) of tilapias are on Table II and Figure 1.

Data of literature (Medri, 1997) demonstrate low index of growth, length and weight in the amianthus box during the experimental period. This can be associated to the absence of natural feeding, besides the little space per fish, that do not follow the population density limits, which according to Coda (1996), has great influence on the growth index of the fish.

Physico-chemical Analysis of the Water in the Amianthus Boxes

The average values obtained for the physico–chemical variables are within the limits considered ideal for fish breeding, according to Tavares (1995). The rate of water change was kept high during the experimental period, so that the values obtained for the physical–chemical variables of the water did not represent significant differences ($P < 0,05$) among the treatments T_1, T_2, T_3 and T_4.

The most important variables that must be controlled in fish breeding, after Boyd (1990), are: temperature, alkalinity, dissolved oxygen, ammonia, nitrite, phosphorus and pH.

Application of the Taguchi's loss function

Tables 3, 4, 5, 6 and Figure 2 present the Taguchi's loss in the treatments T_1, T_2, T_3 and T_4 for the cost of production.

The Taguchi's loss function for the fish production in amianthus box shows that the treatment which included T_4=30% of yeast in ration (Figure 2) resul-

Table 2. Average length (cm) and weight (g) of fishes on treatments T_1, T_2, T_3 and T_4.

	Length (cm)				Weight (g)			
Months	T_1=0	T_2=10	T_3=20	T_4=30	T_1=0	T_2=10	T_3=20	T_4=30
0	3.75	3.75	3.73	3.93	1.29	1.31	1.16	1.36
1	5.43	5.61	5.88	6.39	3.45	4.32	4.15	5.05
2	6.25	6.57	7.02	8.038	5.98	7.91	7.37	10.68
3	6.94	7.64	7.46	8.86	7.92	11.14	9.14	14.08
4	7.81	8.56	8.66	9.91	11.29	15.42	13.56	19.85
5	9.141	9.83	9.74	11.05	17.41	22.71	19.43	27.32
6	10.67	11.12	11.11	12.33	30.14	36.03	31.90	43.86
7	11.78	12.13	12.30	13.18	44.10	49.15	45.17	57.06
8	13.38	13.36	13.70	14.60	64.60	69.84	68.13	79.16
9	15.23	14.40	15.56	15.86	90.19	81.37	99.28	102.32
10	17.22	16.65	17.09	17.61	116.75	113.75	115.75	122.43
11	18.28	17.40	18.09	18.69	154.18	139.35	151.29	161.65

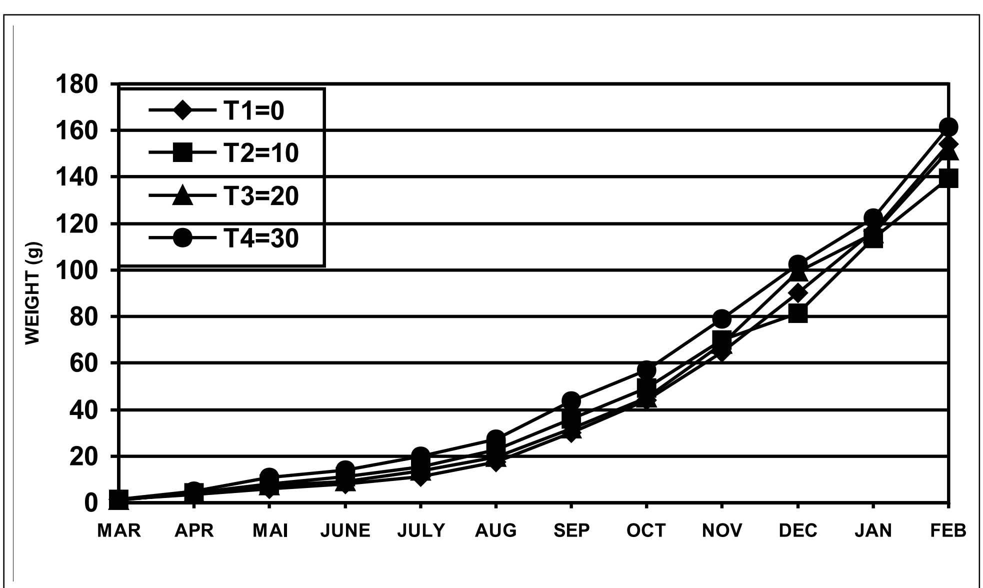

Figure 1. Average weight of the fishes (g)

ted in an inferior production cost comparing to the other treatments. For treatments T_1=0%, T_2=10%, T_3=20% and T_4=30% of distillery yeast in ration, the losses were, respectively, R$ 70.33, 27.90, 120.13, 24.55. These results confirm the possibility of using these residues as partial substitute of fish ration, since it colaborates to lower the production costs.

Tables 7, 8, 9 and 10 and Figure 3 present the Taguchi's loss in the treatments T_1, T_2, T_3 and T_4 for the dead fish.

The treatments T_2 and T_4, that included 10% and 30% of distillery yeast in ration (Figure 3), resulted in losses of R$ 7.09 and 6.06 respectively, less than the control group (T_1=0%), which lost was R$ 18.08 on account of the great number of dead fishes in the amianthus boxes.

Tables 11, 12 13 and 14 and Figure 4 present the Taguchi's loss in the treatments T_1, T_2, T_3 and T_4 for the discarded fishes.

In the Figure 4, the losses of the discarded fishes were R$12.21, 8.15, 27.24 and 4.69 for the respective treatments T_1=0%, T_2=10%, T_3=20% and T_4=30% of distillery yeast included in the ration. The losses of treatment T_4 numerically were lower than the treatments. The T_2 and T_4 treatments presented numerically losses lower than the control group (T_1=0%).

Table 3. Cost of production (T_1 = 0% of yeast)

Specification	Quantity	Unitary cost (R$)	Total (R$)
Ration	24.180kg	0.30	7.250
Yeast	0.000kg	0.23	0.000
Fingerling	60	0.04	2.400
Population	0.250h	1.00	0.250
Biometry	2.750h	1.00	2.750
Food supplied	5.500h	1.00	5.500
Medicines	...	5.00	1.250
Harvest	0.1250h	1.00	0.125
Total	...	...	19.525
L(y)	...	...	70.330

A Calculus

$$A = \sum_{1}^{k} P_i / k = 19.525/60 = \underline{0.3254}$$

V^2 Calculus: $v^2 = 1/42(0.025455831)$

Calculus of the Taguchi's loss function (L)

Δ Calculus

$\Delta = m / 2 = 154.19/2 = \underline{77.095}$

$L = A\,\Delta^2 v^2 = 0.3254(77.095)^2\ 1/42(0.025455831)$

$L = \underline{1.17222}$, logo, 60 x 1.17222 = R$ $\underline{70.33}$.

Table 4. Cost of production (T_2 = 10% of yeast)

Specification	Quantity	Unitary cost (R$)	Total (R$)
Ration	21.390kg	0.30	6.420
Yeast	2.380kg	0.23	0.550
Fingerling	60	0.04	2.400
Population	0.250h	1.00	0.250
Biometry	2.750h	1.00	2.750
Food supplied	5.500h	1.00	5.500
Medicines	...	5.00	1.250
Harvest	0.125h	1.00	0.125
Total	...	...	19.245
L(y)	...	...	27.900

Conclusion

In the regression analysis there is no positive correlation of the Taguchi's loss for the total production, dead and discarded fish with the four balanced rations in all the experiments, showing there is not a harmful effect up to the maximum tested level of 30%, and that the choice of the yeast in the ration for these fishes depends on its availability and cost.

The losses in the amianthus boxes could be attributed to the density, absence of natural feeding, and big dispersion of the fish size (Medri, 1997).

Table 5 - Cost of production (T_3 = 20% of yeast)

Specification	Quantity	Unitary cost (R$)	Total (R$)
Ration	19.790kg	0.30	5.940
Yeast	4.950kg	0.23	1.140
Fingerling	60	0.04	2.400
Population	0.250h	1.00	0.250
Biometry	2.750h	1.00	2.750
Food supplied	5.500	1.00	5.500
Medicines	...	5.00	1.250
Harvest	0.125h	1.00	0.125
Total	...	...	19.355
L(y)	...	...	120.130

Table 6. Cost of production (T_4 = 30% of yeast)

Specification	Quantity	Unitary cost (R$)	Total (R$)
Ration	21.230kg	0.30	6.370
Yeast	9.100kg	0.23	2.090
Fingerling	60	0.04	2.400
Population	0.250h	1.00	0.250
Biometry	2.750h	1.00	2.750
Food supplied	5.500h	1.00	5.500
Medicines	...	5.00	1.250
Harvest	0.125h	1.00	0.125
Total	...	...	20.735
L(y)	...	...	24.550

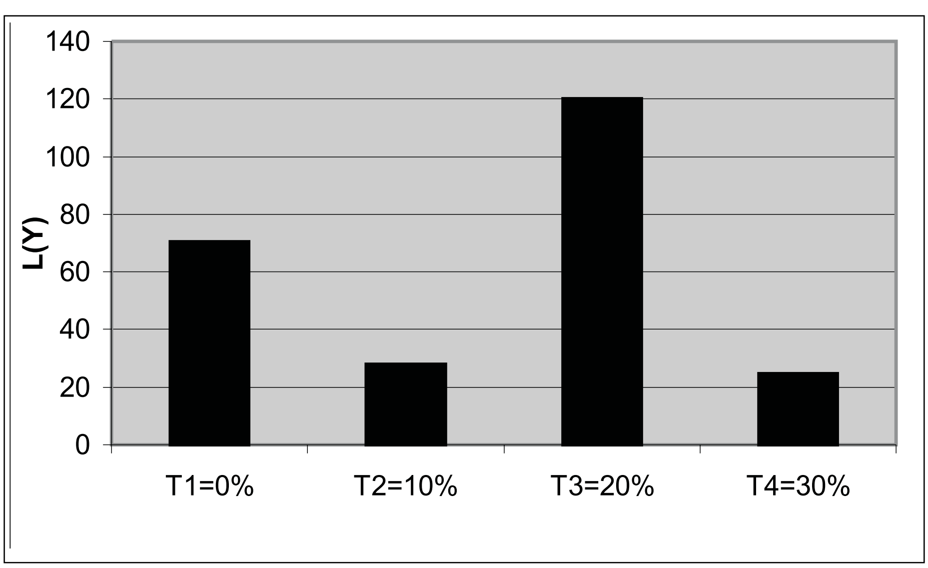

Figure 2. Taguchi's loss function in the treatments T_1, T_2, T_3 and T_4 for the cost of production

Table 7. Dead fishes (T_1 = 0% of yeast*)* – k = 18

Specification	Quantity	Unitary cost (R$)	Total (R$)
Ration	4.458kg	0.30	1.340
Yeast	0.000kg	0.23	0.000
Fingerling	18	0.04	0.720
Population	0.070h	1.00	0.070
Biometry	0.830h	1.00	0.830
Food supplied	1.650h	1.00	1.650
Medicines	...	5.00	0.370
Harvest	0.040h	1.00	0.040
Total	...	...	5.020
L(y)	...	...	18.080

A Calculus

$$A = \sum_{1}^{k} P_i / k = 5.02/18 = \underline{0.2789}$$

Δ Calculus

$\Delta = m / 2 = 154.19/2 = \underline{77.095}$

V^2 Calculus: $v^2 = 1/42(0.025455831)$

Calculus of the Taguchi's loss function (L)

$L = A\,\Delta^2\, v^2 = 0.2789(77.095)^2\ 1/42(0.025455831)$

$L = \underline{1.00471}$, logo, 18 x 1.00471= R$ 18.08.

Table 8. Dead fishes (T_2 = 10% of yeast*)* – k = 19

Specification	Quantity	Unitary cost (R$)	Total (R$)
Ration	3.056kg	0.30	0.920
Yeast	0.340kg	0.23	0.080
Fingerling	19	0.04	0.760
Population	0.080h	1.00	0.080
Biometry	0.870h	1.00	0.870
Food supplied	1.740h	1.00	1.740
Medicines	...	5.00	0.400
Harvest	0.040h	1.00	0.040
Total	...	...	4.890
L(y)	...	...	7.090

Table 9. Dead fishes (T_3 = 20% of yeast*)* – k = 16

Specification	Quantity	Unitary cost (R$)	Total (R$)
Ration	3.197kg	0.30	0.960
Yeast	0.799g	0.23	0.180
Fingerling	16	0.04	0.640
Population	0.070h	1.00	0.070
Biometry	0.730h	1.00	0.730
Food supplied	1.470h	1.00	1.470
Medicines	...	5.00	0.330
Harvest	0.030h	1.00	0.030
Total	...	...	4.420
L(y)	...	...	27.370

Table 10. Dead fishes (T_4 = 30% of yeast) – k = 16

Specification	Quantity	Unitary cost (R$)	Total (R$)
Ration	4.948kg	0.30	1.480
Yeast	2.120kg	0.23	0.490
Fingerling	16	0.04	0.640
Population	0.070h	1.00	0.070
Biometry	0.730h	1.00	0.730
Food supplied	1.470h	5.00	1.470
Medicines	...	0.33	0.330
Harvest	0.030h	1.00	0.030
Total	...	...	5.240
L(y)	...	...	6.200

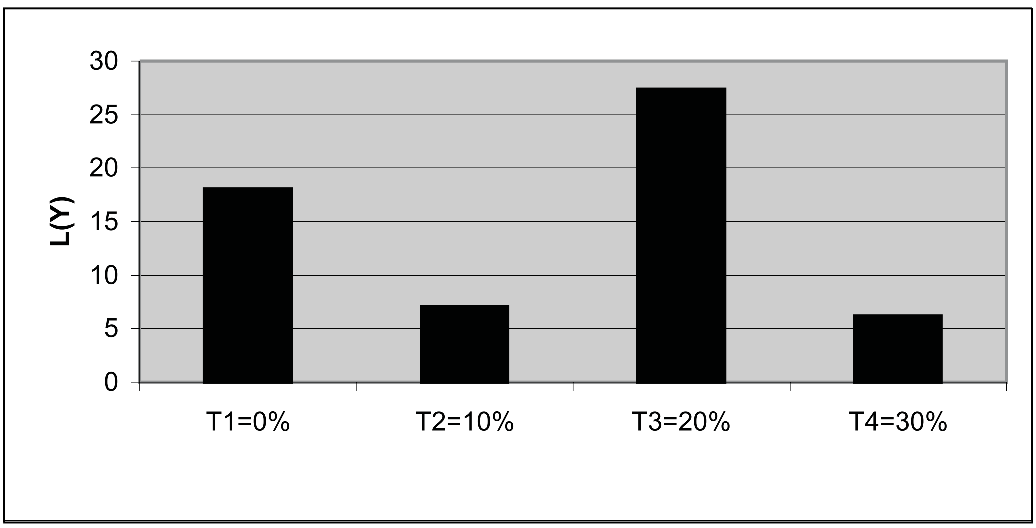

Figure 3. Taguchi's loss function in the treatments T_1, T_2, T_3 and T_4 for the dead fishes.

Table 11. Discarded fishes (T_1 = 0% of yeast) – k = 9

Specification	Quantity	Unitary cost (R$)	Total (R$)
Ration	5.180kg	0.30	1.550
Yeast	0.000kg	0.23	0.000
Fingerling	9	0.04	0.360
Population	0.040h	1.00	0.040
Biometry	0.410h	1.00	0.410
Food supplied	0.820h	1.00	0.820
Medicines	...	5.00	0.190
Harvest	0.020h	1.00	0.020
Total	...	...	3.390
L(y)	...	...	12.210

<u>A Calculus</u>

$$A = \sum_{1}^{k} P_i / k = 3.39/9 = \underline{0.3767}$$

<u>Δ Calculus</u>

$\Delta = m / 2 = 154.19/2 = \underline{77.095}$

<u>V^2 Calculus</u>: $v^2 = 1/42(0.025455831)$

<u>Calculus of the Taguchi's loss function (L)</u>

$L = A\,\Delta^2 v^2 = 0.3767(77.095)^2\ 1/42(0.025455831)$

$L = \underline{1.35702}$, logo, $9\text{x}\ 1.35702$ = R$ <u>12.21.</u>

Table 12. Discarded fishes (T_2 = 10% of yeast) – k = 15

Specification	Quantity	Unitary cost (R$)	Total (R$)
Ration	7.830kg	0.30	2.350
Yeast	0.870kg	0.23	0.020
Fingerling	15	0.04	0.600
Population	0.060h	1.00	0.060
Biometry	0.690h	1.00	0.690
Food supplied	1.380h	1.00	1.380
Medicines	...	5.00	0.310
Harvest	0.030h	1.00	0.030
Total	...	...	5.620
L(y)	...	...	8.150

Table 13. Discarded fishes (T_3 = 20% of yeast) – k = 12

Specification	Quantity	Unitary cost (R$)	Total (R$)
Ration	5.400kg	0.30	1.620
Yeast	1.350g	0.23	0.310
Fingerling	12	0.04	0.480
Population	0.050h	1.00	0.050
Biometry	0.550h	1.00	0.550
Food supplied	1.100h	1.00	1.100
Medicines	...	5.00	0.250
Harvest	0.030h	1.00	0.030
Total	...	...	5.620
L(y)	...	...	27.240

Table 14 - Discarded fishes (T_4 = 30% of yeast) – k = 10

Specification	Quantity	Unitary cost (R$)	Total (R$)
Ration	4.823kg	0.30	1.450
Yeast	2.067kg	0.23	0.480
Fingerling	10	0.04	0.400
Population	0.040h	1.00	0.040
Biometry	0.450h	1.00	0.450
Food supplied	0.920h	1.00	0.920
Medicines	...	5.00	0.200
Harvest	0.020h	1.00	0.020
Total	...	...	5.620
L(y)	...	...	4.690

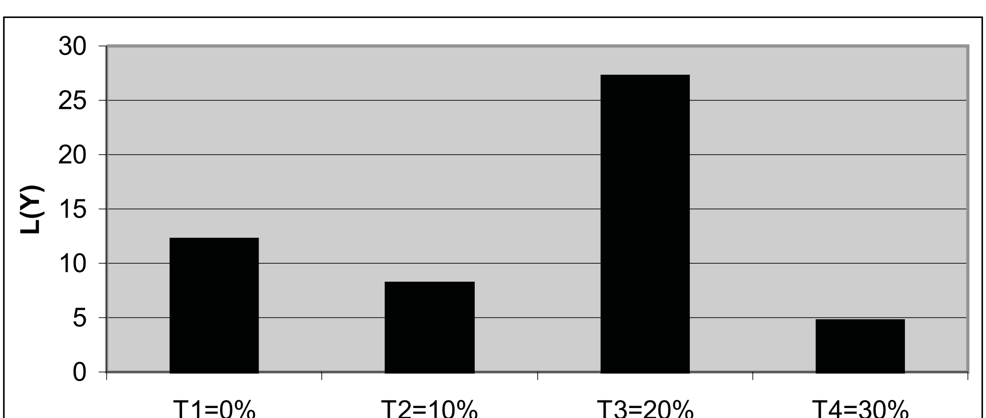

Figura 4. Taguchi's loss function in the treatments T_1, T_2, T_3 and T_4 for the discarded fishes.

References

ALCOPAR 1992 *Relatório do setor sucro-alcooleiro.* [S.l.]: ALCOPAR,. p. 13-18: Sub-produtos: na indústria sucro-alcooleira nada se perde, tudo se transforma.

BOYD, C. E. 1990 *Water quality in ponds for aquaculture.* Birmingham: Alabama Agricultural Experiment Station, 477p.

CASTAGN0LLI, N. 1992 *Piscicultura de água doce.* Jaboticabal: FUNEP. 189p.

CODA, S. 1996 Efeito da densidade de estocagem no cultivo intensivo de tilápia do Nilo, *Oreochromis niloticus.* In: SIMPÓSIO BRASILEIRO DE AQÜICULTURA, 9, Sete Lagoas, MG. p. 131. *Resumos...* Sete Lagoas, Simbraq.

GUEDES, T. A. 1996 *Procedimentos de otimização no planejamento e controle da qualidade de produtos e processos.* Florianópolis, 140p. Tese (Doutorado em Engenharia de Produção). Universidade Federal de Santa Catarina.

KACKAR, R. N. 1986 Taguchi's quality philosophy: analysis and commentary. *Quality progress, 19* (12) : 19-29.

LIND, O. T. 1979 *Handbook of common methods in limnology.* London: Ed. Mosby, p. 59-85.

LITCHFIELD, J. H. 1983 Single-ceel Proteins. *Science, 219* : 740-746.

MATTOS, W. R. S.; DANTAS D'ARCE, R.; MACHADO; P. F. 1984 O uso de levedura da fermentação alcoólica na alimentação de ruminantes. *Informe Agropecuário***,** Belo Horizonte, *10* (119) : 56-60.

MEDRI, V. 1997 *Técnicas estatísticas e de engenharia da qualidade para avaliar o desempenho de diferentes níveis de levedura na criação de tilápia (**Oreochromis niloticus**).* Florianópolis, 180p. Tese (Doutorado em Engenharia de Produção) Universidade Federal de Santa Catarina.

PHADKE, M.S. 1989 *Quality engineering using robust design.* Englewood Cliffs: PTR Prentice Hall, p. 18-22.

STANDARD METHODS: FOR THE EXAMINATION OF WATER AND WASTEWATER. 1980 15 ed APHA-AWWA-WPCF 1, p. 380-491.

TAGUCHI, G., ELSAYED, E. A., HSIANG, T. C. 1990 *Engenharia da qualidade em sistemas de produção.* São Paulo: Mc Graw - Hill, 235p.

TAVARES, L. H. S. 1995 *Limnologia aplicada à aqüicultura.* Jaboticabal: FUNEP, p. 14-37.

WILSON, R. P. (ed.). 1991 *Handbook of nutrient requirements of finfish.* Boca Raton: CRC, p.176.

WU, V. Y., ROSATI, R. R., SESSA, D. J., BROWN, P. B. 1995 Evaluation of corn gluten meal as a protein source in tilapia diets. *J. Agric. Food Chem., 43* : 1585-1588.