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BIOECONOMICS OF THE CULTURE FOR COMMON CARP IN FLOATING NET CAGES IN THE MANINJAU LAKE WEST SUMATERA

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Abstract

This study was conducted in Maninjau Lake, West Sumatera from April 1998 to February 1999. The objective of this study is: (1) to estimate the relation between aquaculture of production and its biological performance, economics as well as physical system, (2) to know which inputs are most important determinants of total output, (3) to identify the level of input efficiency. Data were collected by RRA and Survey using Semi-Structure Interview methods, and also from record keeping form of producers. The unconstrained Cobb Douglass production function was applied to estimate its relationship, and 8 explanatory variables consist of biological inputs, economical inputs and physical inputs were hypothesized to explain the production yields. This study shows that F-value and R^2 *or coefficient of determination were highly significant of the 8 independent variables, only 5 variables have the expected positive sign and rest of them result negative sign. T- test shows that 6 explanatory variables are significant in explain during the output. The highest contribution and the most important determinants of the total output are specific growth rate of biomass, stocking density and feed. The inputs of specific growth rate of biomas, stocking density and feeding labor for the fish fed should be increased to maximize profit, while reducing other inputs.*

Keywords: *Bioeconomics, common carp, gloating net cage, Maninjau Lake.*

INTRODUCTION

Fish production in open water can be increased, through fish culture. One of the most promising innovations is the use of floating net cage popularly known as cage fish culture technology. The cage fish culture has increased technically, ecologically, socially and economically over fisheries and conven-tional aquaculture (Schmittou, 1992; Schmittou, 1991). The cage fish culture is defined as the raising of fishes in water suspended containers enclosed on all sides and button by a material that hold the fish inside, while permitting relatively free water exchange with and waste loss into surrounding (Schmittou, 1992; Schmittou, 1991; Zoneveld. *et. al*., 1991; Christenesn, 1989; Sukardi *et al*., 1989).

In West Sumatera up to now, only Maninjau lake has been utilized for cage fish culture activities. The commercial of cage fish culture in Maninjau lake has been developed early in 1990. It rapidly increased from 6 units 1991 to 2.891 units in 1998, with 14 vary types of cage size, from 22,5 m^3 to 122,5 m^3 (Ahmady, et al, 1997). The driving force behind the development of cage fish culture in the Maninjau lake that it requires less initial capital than starting a pond culture operations, allows to engage relatively larger number of people and thus, providing employment opportunities to members of fishmen's families or other local members of community, the technology of cage fish culture is also relatively simple, more adaptable than conventional aquaculture, requiring not convertion of land into new bodies of mater.

Allen et al., (1984) defined, that bioeconomics of aquaculture is the relating of production yield of and aquaculture production system to its biological performance, economics, as well as physical system. Thus, there are three functionally important areas of aquaculture production system, i. e. biological performance, physical system, and economic considerations. Output from an aquaculture production system is a function of input applied in the production process (Smith, 1981). In the context of bioeconomics of aquaculture study, inputs have been classified as a biological inputs such growth rate, development and feed efficiency as: physical inputs as provision of space to allow growth and economical inputs as the labor for feeding strategy and number of feed following De Wit (1989). Inputs can be classified as material inputs, management input, and input of field work (labor). The relationship between input and output is commonly regarded to as the production function and well on the method of determining this physical input-output relationship. The estimation of production function identifies inputs that influence yield and shoes the efficiency of input use and the return to scale (Wattanuchariya and Panayotou, 1981).

The objectives of this study are to estimate the relationship of input used i.e. biological inputs, physical input and economical input; to know which inputs are the most important determinants and the highest contributors of total output; and to identify the level of input efficiency and economies of scale.

MATERIAL AND METHODS.

Data Collection

The study was conducted in the Maninjau lake, West Sumatera from April 1998 to February 1999. Data were collected by The Rapid Rural Appraisal (RRA) method and Survey using semi-structure interview methods (Suradisastra, 1993; Grandstaff and Granstatt, 1991). Addition data were also record keeping form of producers.

A number of 82 fish producers have interviewed as respondents, representing all types of cage size, which exist in the Maninjau lake. Because the year 1998-1999 was applied as the reference period for data and information collected, then the period's price structure of input-output was adhered too. The explanation of output variation through a production function required that the data are collected from sufficiently large number of fish producers, to allow reliable estimation of parameters. According to Sukarami (1990) and Smith (1981), a minimum sample size og 30 is often established, so that adequate degree of freedom are maintained.

Production Function Model

Three algebraic forms of production function model were initially estimated to determine their appropriateness and explainitially estimated to determine their appropriateness and explanatory or predictive power. These fuction were the linier, quadratic and Cobb Douglas forms. The best functional model chosen was based on its explanatory power. Based on that, the Cobb Douglas production function is an acceptable representation of underlying mechanics of production process.

A Common corp. fish culture in floating net cage results from combining various inputs in body water. Eight input or explanatory variables were examined to explain the production. They are biological inputs (i.e. specific growth rate of biomass, metabolic ration of biomas, and feed convertion ratio), physical input (that is stocking density, mortality rate, and cage size), and economic inputs (i.ie. number of feed and labor for feeding strategy). To evacuate the relative influence of each input on the output of common carp, the model is estimated by using multiple regression techniques. The basic Cobb Douglas model specified was based on Soekartawi (1990), Chong and Lizarondon (1981), Smith (1981). Wattanuchariya and Panayotou (1981) as in the equation (1) and line is early transformed in (2):

1) $\mathbf{Y = \alpha_o X^{\beta 1} X2^{\beta 2} X_3^{\beta 3} X_4^{\beta 4} X_5^{\beta 5} X_6^{\beta 6} X_7^{\beta 7} X_8^{\beta 8} \varepsilon}$
2) $\mathbf{Loq\ Y = Loq\ a_o + \beta_1\ loq\ X_1 + \beta_2\ loq\ X_2 + \beta_3\ Loq\ X_3 + \beta_4\ Loq\ X_4 + \beta_5\ Loq\ X_5 + \beta_6\ Loq\ X_6 + \beta_7\ Loq\ X_7 + \beta_8\ Loq\ X_8 + Loq\ \varepsilon}$

Where Y = output (kg/m3); X_1 = cage size (m^3); X_2 = stocking density (kg m^3); X_3 = mortality rate (gram m^3); X_4 = feed (kg/m^3); X_5 = feeding labor for the fish fed (hour/m^3); X_6 = specific growth rate of biomas (%/body) weight/day); X_7 = metabolic ration of biomass (kg/kg $^{0.8}$ of fish/day); X8 = feed convertion ratio (unit); a_o and B_i = estimate regression coefficients (parameter), and ε = random error or disturbance term. Biological inputs were calculated by using formulas according to Zonneveld, et al. (1991) and NRC (1977). The equation to compute specific growth rate of biomass (SGR_b) is:

$$\mathbf{SGR_b = (Ln\ W_t - Ln\ W_o/t)\ X\ 100\ \%}$$

In which W_o = initial weight, W_t = final weight, t = rearing period. Further the metabolic ration of biomass (Rmb) was calculated by following formula:

$$\mathbf{Rm_b = F/t/BW_g^{\ 0.8}}$$

In that F = the amount of feed, t = rearing period and BW_g = average of geometric weight. Where the formula to calculate feed convertion ratio (FCR) is:

$$\mathbf{FCR = F/(Wt - Wo) + D}$$

where D is the weight of mortality rate. To study efficiency of input use, the marginal physical products (MPP) of all inputs were calculated by Soekartawi (1990) and Wattanuchariya and Panayotou (1981) equations, as follows: $MPP_i = \beta_i\ (Y/X_i)$, where MPP_i = marginal physical product of input i: output at geometric mean of inputs; and X_i = geometric mean of input i.

The show that it is technical efficiency, MPP_i greater or less than 1. It implies that input applied is inefficient. Where as to efficiency of economic, if MPP_i greater or less than price ratio (Px_i/Py) use of input should be increased or decreased. Similarly, to price efficiency, value of the marginal physical product of an input ($VMPP_i = PyMPP_i$) greater or less than its price (Px_i), profit could be raised by increasing the use of that input, where Py = price of output; Px_i = price of input i.. Equality means that producers, on average are economically efficient.

RESULTS AND DISCUSSION

The average production of common carp in floating net cage in the Maninjau lake for all type cage size was 18.08 kg/m^3 of cage. While the means of cage size, stocking density, mortality rate, feed, feeding labor for the fish fed, specific growth rate of biomass, metabolic ratio of biomass and covertion ratio were 67.47 m^3, 3.10 kg/m^3 of cage, 165.47/m^3 of cage, 29.92

kg/m^3 of cage, 2.24 hours/m^3 of cage, 2.00%/bw/day, 1.96 kg/$kh^{0.8}$ of fish/day and 1.98 respectively (Table 1).

Table 1.
The Means Of Inputs And Output Of Floating Net Cage Operation In The Maninjau Lake, West Sumatera.

Code	Variable	N	Mean	Std. Error	Maximum	Minimum
Y	Production (kg/m3)	82	18,08	4 663	10,44	32,67
X_1	Cage size (m3)	82	67,41	30. 6147	22,5	122,5
X_2	Stocking rate (kg./m3)	82	3,1	0,68	1,94	5,33
X_3	Mortality rate (gram/m3)	82	165,47	104,5	30	500
X_4	Feed (kg/m3)	82	29,92	7,95	17	54,7
X_5	Feeding labor (hour/M3)	82	2,24	0,47	1,43	3,19
X_6	Specific growth rate (%/bw/day)	82	2	0,1	1,69	2,19
X_7	Metabolic ratio (kg/kg 0.8/day)	82	1,96	0,75	1,08	3,68
X_8	Feed convertion ratio	82	1,98	0,05	1,69	2,15

Table 2.
The Estimate Production Function (Cobb Douglas) For Common Carp In Floating Net Cage In The Maninjau Lake.

	V a r i a b l e							
	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Intercept	1,49							
Coefficient	0. 0160	0. 5675	-0. 0238	0. 4959	0. 0305	0. 7800	-0. 0283	-0. 3052
t-value	0. 232^o	7. 073**	-6 664**	4.368**	1.311*	4.784**	-0.351^o	-3.788**
Signf. Level	0. 8164	0. 0000	0. 0000	0. 0000	0. 1938	0. 0000	0. 7266	0. 0003
Std. Error	0. 0694	0. 0802	0. 0036	0. 1052	0. 0233	0. 1630	0. 0807	0. 0806
R^2	0. 9990							
F-value	10504. 8200							
GM. of Input	60. 01	3. 04	137. 94	28. 98	2. 19	2. 00	1. 83	1. 98
Est. output at X mean	17. 53							
Economies of scale (B_i)=	0. 0160+0. 5675+(-0. 0238)+0. 4959+0. 0305+0. 7800+(-0. 0283)+(-0. 3052) = 1. 5							

Note: ^{o} = non significant; * = significance at x = 10%; ** = significance at α = 1%; GM = geometric mean.

Before interpreting the result obtained from the estimated production function, it is necessary to examine the function to its ability to explain output variation. Two interrelated measures of goodness of fit are known as the correlation coefficient (R) and coefficient determination (R^2). The maximum possible value for R2 is 1.0, which implies that 100% of the output variation explained by the estimated function. The F-test usually used to test the overall significance of independent variable chosen for including in the model. Finally, t-test is used to test the significance of the individual production coefficients. Results of the estimation for common carp production in floating net cage are summarized in Table 2.

In general, the Cobb Douglass equation fitted the data well as indicated by the F-value and R^2. In the Table 2, the F-value (10504. 82) was highly significant at the x = 1% and R^2 (0.999) is also statistically significant. These values indicate that the model chosen is relevant to be used as a production function model to study of bioeconomics aquaculture for Common carp in floating net cage in the Maninjau lake. Chong and Lizarondo (1981) explained, that the F-value and R^2-value are a decision rule of fit of the model chosen. Smith (1981) stated, that the R2-value is a measure of goodness of fit of model chosen. Further, Rou and Miller (1971) stated, that the R2-value more than of 0.9, depicting that the model chosen has a highly precision as a estimate measure.

The value of coefficient of determination or R2 was 0.999, reflecting that 99, 9% of the variation of output can be explained by the independent variables. Of the 8 explanatory variables, 5 variables have the expected positive sign, and rests have the negative sign. The elasticity of production (B_i) that have positive sign are X_1 (cage volume), X_2 (stocking density), X_4 (number of feed), X_5 (labor for feeding strategy and X_6 (specific growth rate of biomass) showing values of 0.0160, 0.5675, 0.4575, 0.0305 and 0.78, respectively. A ten percent increase in input of specific growth rate of biomass, with other inputs constant, would increase production yield by 7.8%. The negative sign of the production coefficient showed that if a 10% increase input of metabolic ration of biomas, for example, would produce a 0.283% decrease in output.

The significantly contributors of total output for common carp in floating net cage in the Maninjau lake, west Sumatera were specific growth rate of biomass (X_6), stocking density (X_2) and feed (X_4), for which their shares of total output were 78%, 56,75%, and 45,75%, respectively. The production function for common carp in floating net cage in the Maninjau lake, according to the result of this study is:

Y = 1.489 X10. 016 X20. 5675 X3-0. 0238 X40. 4575 X50. 0305 X60. 78 X7-0. 0283 X8-0. 3052

Of the 8 independent variables in this model, 5 variables are significant at x = 1% i.e., X2 (stocking density), X3 (mortality rate), X4 (feed), X6 (specific growth rate of biomass) and X8 (feed convertion ratio) and one variable is significant at X= 10%, that is X5 (feeding labor for the fish fed) and two variables are not significant i.e., X1 (cage size) and X7 (metabolic ratio of biomass) (see Table 2).

The summation of all the production coefficients (Σb_i) is equal to 1.5 (see Table 2). This means that production function exhibits increasing return to scale, that is if all inputs specific in the function are increased by a certain percentage, common carp output in floating net cage will increase by a larger proportion. In the example above, if all inputs are increased by 1.0%, then output will increase by 1.5%.

Smith (1981) stated, that the Cobb Douglass function, which is linier in its logarithmic form, has several advantages i.e., the elasticity's of production which measure the responsiveness of output to increase unit of inputs are identical to the production coefficient (β_i), consequently a percentage change in input use can be easily determined, the sum of production coefficients ($\Sigma\beta_i$) can be interpreted as a measure of economies of scale, if $\Sigma\beta_i > 1$, for instance, positive economies of scale exist, this implies that a doubling of the use all inputs will result in more than a doubling of output; the unconstrained Cobb Douglass form can describe production surface that demonstrates increasing, unitary or decreasing return to scale; input and output can readily be used without aggregation to estimate the parameter of the model; a Cobb Douglass function that include no interaction term uses only one degree of freedom per explanatory variables.

According to this study, it can be known that the most important determinants of total output of common carp in floating net cage in the Maninjau lake are specific growth rate of biomass (X_6), stocking density (X_2) and feed (X_4), respectively. Initially, study of efficiency of input used, the average price of input-input should be known before. There for this study was conducted in year between 1998 and 1999, thus the 1998-1999 price structure of input-output was included, too. The mean price input-output was expressed in Table 3.

Table 3.
Mean Price Of Input-Output For Common Carp In Floating Net Cage In The Maninjau Lake.

No	Variable	Mean Price (Rp)
1	Cage size (m^3)	11 166.10
2	Stocking density (kg/m^3)	4 500.00
3	Mortality rate ($gram/m^3$)	4.50
4	Feed (kg/m^3)	935.00
5	Feeding labor for the fish fed ($hour/m^3$)	10.30
6	Specific growth rate of biomass (%/kg/day)	238.00
7	Metabolic ration of biomass ($kg/kg^{0.8}$/day)	79.70
8	Feed convertion ratio (unit)	935.00
9	Production (kg/m^3)	2 800.00

Table 4.
The Technical, Price And Economic Efficiency For Common Carp In The Maninjau Lake.

Efficiency	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Technical								
MMP_i	0. 0047	3. 2761	-0. 0030	0. 2782	0. 2441	6. 8281	-0. 2713	-2. 7082
Input use	Ineff	Ineff	Ineff	Ineff	Ineff	Ineff	Ineff	Ineff
Price								
P_i	11 166. 1	4 500. 0	4. 5	935. 0	10. 3	238. 0	79. 7	935. 0
$VMPP_i$	13. 2	9 173. 1	-8. 4	779. 0	683. 5	19 118. 7	- 759. 6	-7 583. 0
Input use	Dec	Inc	Dec	Dec	Inc	Inc	Dec	Dec
Economic								
Px_i/Py	3. 997	1. 607	0. 002	0. 334	0. 004	0. 029	0. 085	0. 334
Input use	Dec	Inc	Dec	Dec	Inc	Inc	Dec	Dec

Note:

MPPi = marginal physical product of input i;
VMPPi = value of marginal physical of input i;
Pi = price of input i;
Py = price of output;
Ineff. = Inefficiency; Dec = decrease;
Inc. = increase.

Yotopoulus and Nugent (1976) stated, that the efficiency accomplishment is dealing with the attempts to accelerate output increases over input values. Further Lou and Yotopoulus (1971) acknowledge, there exist three efficiency concepts i.e., technical efficiency, price efficiency and economic efficiency.

The technical efficiency is the relative size of the actual production yield to the potential production yield that will be possibly attained by a given technology use (Simnatupang and Mewa, 1987; Siregar, 1987). The Price efficiency that is a large of scale in order to measure manager decision fit to allocation of inputs used, and as a result of the marginal physical product of inputs is equal to isocost curve slope (Rahman, 1987, Santoso, 1987). While economic efficiency is resulted by multiplying technical efficiency to efficiency of price (Yotopoulus and Nugent, 1976). The result of input efficiency calculations is shown in Table 4.

From Table 4 was known, in term of increases the profitability of the floating net cage operations in Maninjau lake, the volume of cage should be reduced. Study of Dharma, et. al. (1992) revealed, that the production of walking catfish was not significantly effected by cage size. The expected optimum yield declines with increased volume of cage, by which the common carp yield decreased from about 150 kg in a-1 m^3 cage to approximate 130 kg/m^3 in a-10 m^3 cage (Schmittou, 1991; Schmittou, 1992).

Afterward, number of fish to stock per m^3 of cage was under optimum stocking density, and it means that the revenue of the input used can be raised to maximize profit by increasing of stocking rate. Stocking densities for cages vary according to several factors including species cultured, expected yield and average size desired at harvest. An optimum stocking density of 10 kg/m^3 of cage (initial average weight is 50 gram/fish) is recommended by Sukadi, et. al. (1989). High fish densities may result in production of significantly higher yields than lower densities without significantly affecting other production performance factors. Another research conducted by Ahmady, et. al. (1998) in Maninjau lake using small floating net cage (1,5 X 1,5 X 3,0 m^3) indicate that densities of 2000 fish/cage, 1250 fish/cage and 500 fish/cage produced significantly different yields of 432.7 kg/cage, 243.7 kg/cage and 120.9 kg/cage, respectively, without significantly differences either in specific growth rate, relative growth rate of the metabolic weight as well as feed convertion ratio, and the highest net profit, also dedicated by the highest stocking density as much as Rp.329.000.00/cage/harvest compare with the lower density i.e., Rp. 11.7000.00/cage/harvest and Rp. 44.000.00/cage/harvest, respectively. Hepher and Pruginin (1981) stated, that the addition of stocking rate would be increasing the production yield, if feed supply were available.

Feed of excellent quality is absolutely critical for common carp in floating net cage. The quality and quantity of feed influence fish growth, health and feed convertion ratio. Feed is usually about 45% to 65% of the total cost of production a crop of fish (Nikijuluw, et al., 1992; Schmittou, 1991). As shown in Table 4, the amount of feed applied by producers in Maninjau lake were inefficient. By a reason of, the returning of inputs used, which will be earned by farmers, were not optimum. To maximizing profit that will be attained by producers, the amount of feed for the fish fed should be declined, and its relates to the feeding strategy.

Feeding strategy can affect the profitability of floating net cage operations. Feeding rate values vary according to many factors, including fish species, fish size, and stage in life cycle, and metabolic rate. An optimum feeding rate for common carp in floating net cage is 4.0%/day/bw to the first month, and to second month is 3.5%/day/bw and after that until harvested fish is 2.0%/day/bw (Sukardi, et al., 1989). While the optimum feeding frequency is 3 to 4 times/day (Schmittou, 1992; Schmittou, 1991; Sukardi, et al., 1989). In general, fish farmers in Maninjau lake practiced feeding rate and feeding frequency as much as 15% - 20%/body weight/day, and 3-4 times/day. Iriana, et al. (1992) reported, that the highest feeding frequency of 6 times/day for common carp in floating net cage in Saguling, Ciratas and Jatiluhur reservoirs, West Java, have resulted the largest production yields than the lower feeding frequency.

According to Effendi (1979) and Huet (1971) fish growth is affected by the internal and external factors. One of the most important of the external factors is sufficiently of feed available. The amount of food required to maintain a given weight of cultured fish is less than that required for growth, and the amount of consumed food used for maintenance increases impro-portionately with increased weight of cultured fish until all consumed food is eventually required for maintenance. To increase, therefore, specific growth rate of biomass for common carp in floating net cage (see Table 4), thus the properly feeding strategy should be done by producers, through compatibility of fish species fish size, stage in life cycle and metabolic rate feeding rate and frequency. The research of Ahmady, et la. (1996) demonstrated, that the harmonizing of feeding rate and frequency to fish species, stage in life cycle, fish size and metabolic rate, has resulted the excellent of specific growth rate that is 3.70%/bw/day for common carp in floating net cage in Maninjau lake over the practices have been doing by farmers.

Metabolic ration of biomass is a amount of used by cultured fishes to metabolism activities. The high of metabolic ration value, it implies that feed efficiency is low, and vice verse. There are several means to reduce the metabolic ration of biomass, as shown in Table 4 that is, such by declines the volume of cage and increases stocking rates as. In these fasdhions, the needed energy to swimming activities of cages can be minimized, and this energy, eventually will to be turn as growth energy. Besides, Ahmady, et al., (1996) reported, the lowest of metabolic ration value of 0.38 kg/kg $^{0.8}$/day has obtained by the harmonizing of feeding strategy.

Feed convertion fish ratio (FCR) is influenced by several factors, but especially feed quality (i.e., efficiency improves with protein quality and quality), feed quantity (i.e., optimum daily amount gives better efficiency than excessive amounts), fish species (tilapias are usually more efficient than common carp), fish size (i.e., small fish of a species are more efficient than larger fish of that species), FCR becomes lower as the efficiency of feed utilization increases. At feeding rates above and below the optimum for condition that existed during culture, the FCR will increase with the lowest FCR value occurring at the feeding level where feed convertion efficiency was highest. As shown in Table 4, the compatibility of strategy should be taken into account by producers to reduce the FCR values. The lowest FCR values about 1.2 to 1.7 for common in small floating net cage were achieved by regulation feeding rate and frequency that suitable either by fish size, fish species, and stage in life cycle as well as metabolic rate (Ahmady, et. al., 1996; Ahmady, et. al., 1998).

CONCLUSIONS

From this study it can be concluded that: The unconstrained Cobb Douglass production was an acceptable and relevant function to explain bioeconomics of aquaculture study for common carp in floating net cage, as shown by statically significant of F-value (10504.82) and coefficient of determination or R^2-value (0.999). This R^2 value reflecting that 99.9% of output variation can be explained by 8 explanatory variables. Of the eight explanatory variables used to explain the variation of output, five variables showed the expected positive sign and the others had the negative sign. The elasticity's of production (Bi), which showed the positive sign, were cage size (0.0160), stocking density (0.5675), number of feed (0.4595), labor for feeding strategy (0.0305), and growth rate of biomass (0.7800). Where the negative sign were indicated in the mortality rate (-0.0238), metabolic ration of biomass (-0.0283) and feed convertion ratio (-0.3052). These signs indicate that a givencentage increase in any input, while holding other inputs constant, will increase or decrease production yield at a given level. Based on t-test, only five independent variables are significant at x = 1% in explaining the output i.e., stocking density (X_2), mortality rate (X_3), number of feed (X_4), specific growth rate of biomass (X_6), feed convertion ratio (X_8), while labor for feeding strategy (X_5) is significant at x = 10%, and stocking density (X_2) and metabolic ratio of biomass (X_7) are not significant. The most important determinants of total output are specific growth rate of biomas (X_6), stocking density (X_2) and number of feed (X_4). Based on the input efficiency this study suggested that to increase the revenue of inputs used in term of, to maximize profit of floating net cage operation in the Maninjau lake, the using of inputs of stocking density (X_2), labor for feeding strategy (X_5) and specific growth rate of biomass (X_6) should be increased, whereas the other inputs should be decreased.

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