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Impact on Energy Consumption in Greenhouse Fish Production

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Abstract: An experiment was conducted to examine the energy use pattern in open and greenhouse fish ponds. The energy consumption was around 584.99 and 1027.22 MJ/50 m^2 for open and greenhouse pond, respectively. The energy input-output, specific energy and energy productivity were found to be 0.070, 71.55 MJ kg^{-1} and 0.014 kg MJ^{-1} for open pond and 0.079, 63.60 MJ kg^{-1} and 0.015 kg MJ^{-1} for greenhouse pond, respectively. The energy ratio was higher in the greenhouse due to lower inputs and the specific energy was recorded low due to the higher yield.

Key words: Greenhouse, fish, energy ratio, specific energy, energy productivity, embodied energy

INTRODUCTION

Fish is one of the main sources of animal protein used in the diet of the human population. In most of the developing and under developing countries, large numbers of populations suffer from malnutrition. Thus, it is encouraged to have fish as food in the human diet. Generally, fish culture is carried out in open pond system. The production level is not uniform throughout the year due to fluctuations in water temperature. Water temperature directly influences the growth and fish food production in its environment. Greenhouse pond, is a good alternative to enhance the water temperature in the colder period of the year and encourage proper growth of fish as compared to an open pond.

Fish production requires energy input in various forms. Energy use in fish production has become more intensive, with the increasing use of fertilizers, balanced feed, aeration, high stocking density and maintenance of water quality parameters in addition to the proper management practices. Efficient use of the energy resources is important in terms of increasing production, productivity and sustainability of rural living. Energy use pattern and contribution of energy inputs vary depending on farming system. Several authors have focused on energy use in greenhouse (Ozkan *et al*., 2004; Canakci and Akinci, 2005) mainly for agriculture crops. Singh and Pannu (1998) studied the energy requirements in fish production and energy ratio of a village fish pond in the state of Punjab, India. Tiwari and Sarkar (2006) analyzed the energy use pattern for production of fish in a smaller cemented greenhouse tank, to determine the energy input-output ratio and their relationship with *Labeo rohita* fish. However, the studies related to the energy consumption in greenhouse fish production are very limited. Therefore, the main objective of this study is to calculate energy output-input ratio, specific energy and energy productivity in greenhouse earthen fish pond.

MATERIALS AND METHODS

Greenhouse fish production (Fig. 1) experiment was conducted in the farm of CIFA, Bhubaneswar during 28 October, 2002 to 27 March, 2003. The place is located in the eastern part of India

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Fig. 1: View of the experimental greenhouse

Table 1: Energy equivalents inputs-outputs analysis in fish production

Input (Unit)	Energy equivalent (MJ)	References
Human power-Man (h)	1.96	Sarkar and Tiwari, 2006
Output of fish (kg)	5.04	Ayyappan *et al*., 1990
Feed (kg)	10.76	Li, 1987
Diesel oil (L)	56.31	Singh, 2002
Lime (kg)	120.00	Sarkar and Tiwari, 2006
Manure (tons)-cow dung	303.10	Yaldiz *et al*., 1993
Chemicals (kg)	101.20	Yaldiz *et al*., 1993
Fertilizers-P_2O_5 (kg)	12.44	Shresta, 1998

Table 2: Embodied energy used for construction of Pond (11×7×1m)

Items	Density	Total quantity	Weight (kg)	Embodied energy (MJ kg^{-1})	Total embodied energy (MJ)
Soil excavation work (Man/h) /77 m^3	-	115.5 h	-	1.96	226.38
Dressing of pond	-	32h	-	1.96	62.72
Laterite stone	2.64 g cc^{-1}	250 nos	3500	0.79	2765.00
Sand	2.66 g cc^{-1}	0.336 m^3	893.76	0.10	89.37
Cement	3.15 gcc^{-1}	100 kg		7.80	780.00
Laying of laterite stone	-	48 h	-	1.96	94.08
Site preparation and development	-	24 h	-	1.96	47.04
			Total embodied energy: 4064.59 MJ		

(Latitude-20°15′, Longitude- 85°52′, and altitude 33 m above mean sea level). The inputs and outputs used in fish production were converted to the form of energy to evaluate the output-inputs ratio. The energy equivalents of inputs used in the fish production are illustrated in Table 1. The input energy is classified as direct and indirect energy. The indirect energy are fertilizer, lime, chemicals, etc., while direct energy include human energy, power, diesel, feed, fish seed, etc.

In order to analyze the energy input-output ratio, one open and one greenhouse pond was used for this purpose. The embodied energy used in both the ponds is shown in equal, as size and shape of the ponds are same (Table 2). The effective greenhouse area and water volume were 104 and 50 m^3, respectively. The different material used to construct the typical aquaculture greenhouse including man-hour is given in Table 3. To calculate the annual embodied energy, the life of greenhouse was considered as 25 years (Tiwari and Sarkar, 2007). Under this circumstances, greenhouse embodied energy was 382.17 MJ per production area of 50 m^3 for five months operation.

Table 3: Embodied energy used for construction of arch shape greenhouse (13×8 m)

Items	Density	Total length (m)/Qty	Weight (kg)	Embodied energy (MJ kg^{-1})	Total embodied energy (MJ)
G.I.Pipe					
i) 1.5″ diameter	1.87 kg m^{-2}	34.00	63.58	49.97	3177.09
ii) 1 ″ diameter	1.10 kg m^{-2}	192.66	211.92	49.97	10589.64
iii) 3/4″ diameter	0.76 kg m^{-2}	78.00	59.28	49.97	2962.22
UV-stabilized LDPE film (200 μm)	0.231 kg m^{-2}	183 m^3	42.27	92.32	3902.64
Screw and Nail	-	-	1.50	31.06	46.59
Electrode rod	-	200 m	5.60	12.30	68.88
Sand	2.66 g cc^{-1}	0.504 m^3	1340.64	0.10	134.06
Stone chips (20 mm)	2.64 g cc^{-1}	0.252 m^3	665.28	0.79	525.57
Cement	3.15 g cc^{-1}	3 bags	150.00	7.80	1170.00
Cutting and bending (Man h^{-1})	-	80	-	1.96	156.80
Earth work for greenhouse foundation	-	12	-	1.96	23.52
Grouting (Man h^{-1})	-	16	-	1.96	31.36
Welding	-	48	-	1.96	94.08
Fixing of plastic film (Man h^{-1})	-	32	-	1.96	62.72
			Total embodied energy: 22.945.17 MJ		

For 5 months operation the total energy required: 382.41MJ

Before stocking the fish, the ponds were prepared as per the recommended standard aquaculture practices. The ponds were filled with water and the fertilization was carried out with application of cow dung at the rate of 10 tons ha^{-1} $year^{-1}$; one fifth of which was applied two weeks prior to stocking of fish fingerlings as basal dose. The remaining amount was applied in equally divided doses at fortnightly intervals. Inorganic fertilizers in the form of nitrogen and phosphorus were applied fortnightly in split doses. The water level in the experimental ponds was maintained at 1.0 m during the study period, compensating the loss of water due to seepage and evaporation. Liming by $CaCO_3$ at the rate of 80 kg ha^{-1} was done in a interval of one month to maintain the desired pH of water and also for pond hygiene. Advanced carp fingerlings and ten days old post-larvae of prawn (*Macrobrachium rosenbergii*) were stocked in the open and greenhouse ponds. The stocking density of fishes was 10,000 nos ha^{-1} and prawn was 25,000 nos ha^{-1}. The size ranges were 8-15 g for fishes and 10-12-mm/10 mg for prawns. The carp species stocked were Silver carp (*Hypophthalmichthys molitrix*) -10%, Catla (*Catla Catla*) -20%, Rohu (*Labeo rohita*) -25%, Common carp (*Cyprinus carpio*) -5%, Puntius (*Puntius Javanicus*) -25%, Grass carp (*Ctenopharyngodon idella*) -10% and Mrigal (*Cirrhinus mrigala*)-5%. Supplementary formulated feed with crude protein level of 35% was given at the rate of 2-3% of body weight twice in a day at 10:00 and 15:00 h. The feeding quantity was adjusted at monthly intervals after estimating the biomass increase through intermittent sampling. Fish production was assessed for both the ponds at the end of culture period.

Energy use in the production of fish was calculated per m^2 basis. During rearing period, various operations were involved for greenhouse fish production viz., water filling, weed control, fertilizer and cow dung application, aeration, feeding of fish, monitoring of water quality, sampling of fish and finally harvesting of fish. In this experimental study, input-output ratio, specific energy and energy productivity for the greenhouse fish production were calculated using the following relations (Tiwari and Sarkar, 2007):

$$\text{Output} - \text{input ratio} = \frac{\text{Energy output}\left(\text{MJ}/50\,\text{m}^2\right)}{\text{Energy input}\left(\text{MJ}/50\,\text{m}^2\right)} \quad (1)$$

$$\text{Specific energy} = \frac{\text{Energy input}\left(\text{MJ / 50 m}^2\right)}{\text{Fish output}\left(\text{kg / 50 m}^2\right)} \tag{2}$$

$$\text{Energy productivity} = \frac{\text{Fish output}\left(\text{kg / 50 m}^2\right)}{\text{Energy input}\left(\text{MJ / 50 m}^2\right)} \tag{3}$$

RESULTS AND DISCUSSION

The energy consumption and its sources for open pond are presented in Table 4. The total energy used in various farm inputs was 584.99 MJ/50 m^2 in open pond. Diesel energy had the biggest share in the total energy with 43.32% followed by human (30.49%), feed (9.90%), chemicals (6.92%), lime (6.15%), manure (2.59%) and phosphate P_2O_5 (0.63%). The energy inputs for human included water filling, lime application, weed control, fertilizer application, cow dung application, feeding of fish, testing of water quality parameters, sampling of fish and finally harvesting. The diesel energy was mainly used for operating the pump set for water filling and compensation of seepage and evaporation. Feed energy was used for providing artificial feeding to the fish. Lime, manure and P_2O_5 were mainly used for pond fertilization and to provide natural food organisms to the fish. Chemicals were used for testing of water quality parameters. Embodied energy used for pond construction could not be considered, for evaluating energy input-output analysis, since both the values were same and ponds are permanent in nature. Table 5 shows the energy consumption and its sources for greenhouse fish production. The total energy used in various farm inputs was 1027.22 MJ/50 m^2 for five months operation in greenhouse pond.

Table 4: Energy inputs-output ratio, specific energy and energy productivity in open pond

Inputs (Unit)	Quantity per unit area (50 m^2)	Total energy equivalent (MJ)	Contribution (%)
Human power-man (h)	91.00	178.36	30.49
Feed (kg)	5.38	57.88	9.90
Diesel oil (L)	4.50	253.39	43.32
Lime (kg)	0.30	36.00	6.15
Manure (tons)-Cow dung	50.00	15.15	2.59
Fertilizes-P_2O_5 (kg)	0.30	3.73	0.60
Chemicals (kg)	0.40	40.48	6.92
Total energy input (MJ)		584.99	100.00
Yield (kg)	8.18	41.20	
Energy output-input ratio		0.07	
Specific energy		71.55	
Energy productivity		0.014	

Table 5: Energy inputs-output ratio, specific energy and energy productivity in greenhouse

Inputs (Unit)	Quantity per unit area (50 m^2)	Total energy equivalent (MJ)	Contribution (%)
Human power-man (h)	91.00	178.36	17.36
Feed (kg)	11.76	126.53	12.32
Diesel oil (L)	4.13	232.56	22.65
Lime (kg)	0.40	48.00	4.67
Manure (tons)-Cow dung	50.00	15.15	1.47
Fertilizes-P_2O_5 (kg)	0.30	3.73	0.36
Chemicals (kg)	0.40	40.48	3.94
Greenhouse structure		382.41	37.23
Total energy input (MJ)		1027.22	100.00
Yield (kg)	16.15	81.39	
Energy output-input ratio		0.079	
Specific energy		63.60	
Energy productivity		0.015	

Of all the inputs, greenhouse structure had the highest share of 37.23%. This was attributed to the high-energy value that was used for constructing the greenhouse structure. The second highest was the diesel oil with share of 22.65%. However, diesel energy consumption was slightly less due to increase in humidity inside greenhouse. The others were human energy (17.36%), feed energy (12.32%), fertilizer and lime (4.67%), manure (1.47%) and P_2O_5 (0.36%). Feed energy consumption was more in greenhouse due to increase in yield.

After five months of culture, fish yield was 8.8 and 16.15 kg/50 m^2 in open and greenhouse ponds, respectively. The higher yield was obtained in greenhouse due to stable water temperature and higher feed intake. The total energy output was calculated multiplying by the equivalent energy input and output coefficients.

Output-input ratio is one of the essential indicators, which provide the efficiency of the farming system. Among both the investigations, greenhouse had the highest energy output-input ratio. The lowest energy ratio was observed in open condition, mainly because of lower water temperature and poor feed intake by fish. These energy ratios were quite low, in general, when compared with to the values of agricultural crops. The average input-output ratio was calculated as 0.070 and 0.079 in case of open and greenhouse ponds, respectively. The results indicated that specific energy and energy productivity were 71.55 MJ kg^{-1} and 0.014 kg MJ^{-1} incase of open pond, whereas, 63.60 MJ kg^{-1} and 0.015 kg $MJ^{-1}$for greenhouse pond. In the greenhouse, the energy ratio was higher due to lower inputs and the specific energy showed lower value due to the higher yield. Thus, efficient use of these energy sources helped to achieve increased production, productivity and higher profitability of greenhouse aquaculture. In comparison with the previous studies, Tiwari and Sarkar (2006) reported that the energy input- output ratios of *Labeo rohita*, in open and greenhouse ponds are 0.078 and 0.090, respectively for five months culture operation. Singh and Pannu (1998) from a case study reported the energy ratio of 0.15 in a village pond for more than one-year culture period. The results of Singh and Pannu are obtained from the culture of fish from larger water body. But, in the present case, the ratio is quite lower than that were reported by Singh and Pannu (1998) and Tiwari and Sarkar (2006). The main reason for this difference may be attributed to the different species used having different energy content, which is directly influence the output of fish.

CONCLUSIONS

The following conclusions are drawn from the present study:

- Fish culture in greenhouse has low specific energy use (63.60 MJ kg^{-1}) and higher energy ratio (0.079). Rearing of fish was economical in terms of energy in greenhouse pond.
- Use of greenhouse structure in term of energy for fish rearing was the maximum (382.41MJ). It is because of high energy value material was used for constructing the structure.
- In the research area for greenhouse operations the amount of inputs used in fish production are still increasing. It is expected that the yield will go up with the advancement of fish technology and use of larger pond, and will become more profitable in the near future.

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