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Research Article

Analyzing and Evaluating of Recirculating Aquaculture Systems (RAS) of Rainbow Trout in Order to Designing a Conceptual Model of Efficient RAS in Iran (Tehran)

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Abstract: In this study, Recirculation Aquaculture Systems (RAS) of rainbow trout were analyzed and evaluated in Iran (Tehran). After analyzing these systems it was found which of them were better than others and then their parameters were used for designing a conceptual model of efficient RAS. This study was conducted in Iran (Tehran) in 2012 and statistical population and samples were 8 systems. Systems were analyzed and evaluated by five criteria which were as follows: economy, energy, consumption and recycling of water, technical and engineering and management. Analyzing and evaluating were conducted by Data Envelopment Analysis (DEA) method and also GAMS software was used for solving DEA model. It was found that in economy, energy, water consumption and recycling, technical and engineering and management criteria systems were efficient systems respectively. Based on the results, system 3^{th} with regard to all the criteria was efficient system. Quality and quantity factors and equipments of system 3^{th} were used in order to design a conceptual model of RAS in rainbow trout.

Keywords: Conceptual model, Data Envelopment Analysis (DEA), design, Recirculating Aquaculture System (RAS)

INTRODUCTION

The dual objective of sustainable aquaculture, i.e., to produce food while sustaining natural resources is achieved only when production systems with a minimum ecological impact are used. Recirculating Aquaculture Systems (RASs) provide opportunities to reduce water usage and to improve waste management and nutrient recycling. RAS makes intensive fish production compatible with environmental sustainability. Aquaculture has been on the frontline of public concerns regarding sustainability. Different issues are raised, such as the use of fish meal and oil as feed ingredients (Naylor *et al*., 2000). Recirculation Aquaculture Systems (RAS) are systems in which water is (partially) reused after undergoing treatment (Rosenthal *et al*., 1986). RAS offer advantages in terms of reduced water consumption (Verdegem *et al*., 2006), improved opportunities for waste management and nutrient recycling (Piedrahita, 2003) and for a better hygiene and disease management (Summerfelt *et al*., 2009; Tal *et al*., 2009), biological pollution control (Zohar *et al*., 2005) and reduction of visual impact of the farm. These systems are sometimes referred to as ’indoor 'or ’urban’ aquaculture reflecting its independency of surface water to produce aquatic organisms. In addition, the application of RAS technology enables the production of a diverse range of (also exotic) seafood products in close proximity to markets (Schneider *et al*., 2010; Masser *et al*., 1999), thereby reducing Carbon Dioxide (CO_2) emissions associated with food transport and the negative trade deficits related to EU imports of seafood. Despite its environmentally friendly characteristics and the increasing number of European countries applying RAS technology, its contribution to production is still small compared to (sea) cages, flow-through systems or ponds. The slow adoption of RAS technology is in part due to the high initial capital investments required by RAS (Schneider *et al*., 2006). High stocking densities and productions are required to be able to cover investment costs. As a consequence welfare concerns may arise (Martins *et al*., 2005). However, due to the possibility to maintain a constant water quality, RAS may also contribute to an improved welfare (Roqued’Orbcastel *et al*., 2009a). Managing disease outbreaks pose specific challenges in RAS in which a healthy microbial community contributes to water purification and water quality. Minerals, drug residues, hazardous feed compounds and metabolites may accumulate in the system (Martins *et al*., 2009a, b) and affect the health, quality and safety of the farmed

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animal. How these different factors interact and influence the fish and the various purification reactors is still poorly understood. Furthermore, RAS historically developed producing freshwater fish species that are rather tolerant to poor water quality. The expansion of RAS being used for the production of marine and brackish water species often focuses on hatchery operations which pose extra requirements on water quality and require further innovations in RAS technology.

Most of the non-parametric applications are based on the DEA (Data Envelopment Analysis) model as proposed by Charnes *et al*. (1978). In recent years, DEA has become a central technique in productivity and efficiency analysis, applied in different aspects of economics and management sciences. DEA models are linear programming methods that calculate the frontier production function of a set of Decision-Making Units (DMUs) and evaluate the relative technical efficiency of each unit, thereby allowing a distinction to be made between efficient and inefficient DMUs. Those identified as ''best practice units'' (i.e., those determining the frontier) are given a rating of one, whereas the degree of technical inefficiency of the rest is calculated on the basis of the Euclidian distance of their input-output ratio from the frontier (Coelli *et al*., 1998). DEA has been used in comparing organizations (Athanassopoulos and Shale, 1997; Abbott and Doucouliagos, 2003; Sheldon, 2003), firms (Fa¨re *et al*., 1996; Chen and Ali, 2004) and regions or countries (Karkazis and Thanassoulis, 1998). In agriculture, DEA has also been applied to studies of various products ranging from horticulture and cotton to aquaculture (Shafiq and Rehman, 2000; Sharma *et al*., 1999a; Iraizoz *et al*., 2003). A further comparative review of frontier studies on agricultural products can be found in Thiam *et al*. (2001). Applications in assessing the efficiency of livestock farms are growing (Cloutier and Rowley, 1993; Fraserand Cordina, 1999; Reinhard *et al*., 2000) but they are mostly focused on dairy farms. A key question arising from frontier analysis is whether it is possible to determine common characteristics among best practice units. Existence of such characteristics implies that a certain pattern (behavioral and/or managerial personal characteristics) can be associated with efficiency levels and its influence on farm performance assessed. In the literature, numerous empirical studies attempt to explain variation in the success of farms by regressing efficiency scores on a set of explanatory variables. Most studies concentrate on the influence of personal characteristics such as age, education, experience and specialization, or physical aspects such as farm size and certain input usage (Iraizoz *et al*., 2003; Sharma *et al*., 1999b; Lansink and Reinhard, 2004; Fousekis *et al*., 2001a, b; Wilson *et al*., 2001). The remainder of the study is organized as follows: In the following section DEA methodology is discussed and the applied model is presented. Results are presented and discussed subsequently, while concluding remarks are given in the final section.

In this study, analyzing and evaluating of Re-circulating Aquaculture Systems (RAS) of Rainbow Trout will conduct. This analyzing and evaluating will be conducted by five criteria which are included economy, energy, consumption and recycling of water, technical and engineering and management and each criterion is divided into sub-criterion. Efficient and inefficient systems in each criterion and also in term of all the criteria will be designated after analyzing and evaluating all the Re-circulating Aquaculture Systems (RAS) which are on the study. At the end, a conceptual model of Re-circulating Aquaculture Systems (RAS) of rainbow trout in Iran (Tehran) will be designed and developed base on the quality and quantity factors and the equipments of the efficient system.

MATERIALS AND METHODS

A conceptual model have been designed and developed in order to better understanding of all the research steps. A complete understanding of all phases of this study will be obtained by reading top-down a conceptual model (Fig. 1). Non-radial model in Data Envelopment Analysis (DEA) method has been used in analyzing and evaluating that will be seen after showing the conceptual model.

Decision Making Units (DMU_S) have been shown for 5 criteria as follows economy, energy, water consumption and recycling, technical and engineering and management in the Table 1. Inputs and outputs of each DMU_S have been shown as x and y (Table 1) and then they used in non-radial model Eq. (1) as x and y of equations. This table is formed for all the 8 systems and analyzing and evaluating were done base on information of this table and DEA model.

Non-radial model in Data Envelopment Analysis method (DEA): In order to evaluating Decision Making Units (DMU_s) the following model is considered in which each input and output will be modified by independent ratio Eq. (1):

$$
\begin{aligned}
& Min\ Re = \frac{\frac{1}{m}\sum_{i=1}^{m}\theta_i}{\frac{1}{s}\sum_{r=1}^{s}\varphi_r} \qquad (1)\\
& s.t. \sum_{j=1}^{n}\lambda_j x_{ij} \le \theta_i x_{i0}\ \ i = 1,2,\dots,m\\
& \sum_{j=1}^{n}\lambda_j y_{rj} \ge \varphi_r y_{r0}\ , r = 1,2,\dots,s\\
& \theta_i \le 1\ , i = 1,2,\dots,m\\
& \varphi_r \ge 1\ , r = 1,2,\dots,s\\
& \lambda_j \ge 0\ , j = 1,2,\dots,n
\end{aligned}
$$

The non-radial model Eq. (1) must be solved for all the RAS in the case study area (Iran). In this study should be considered that:

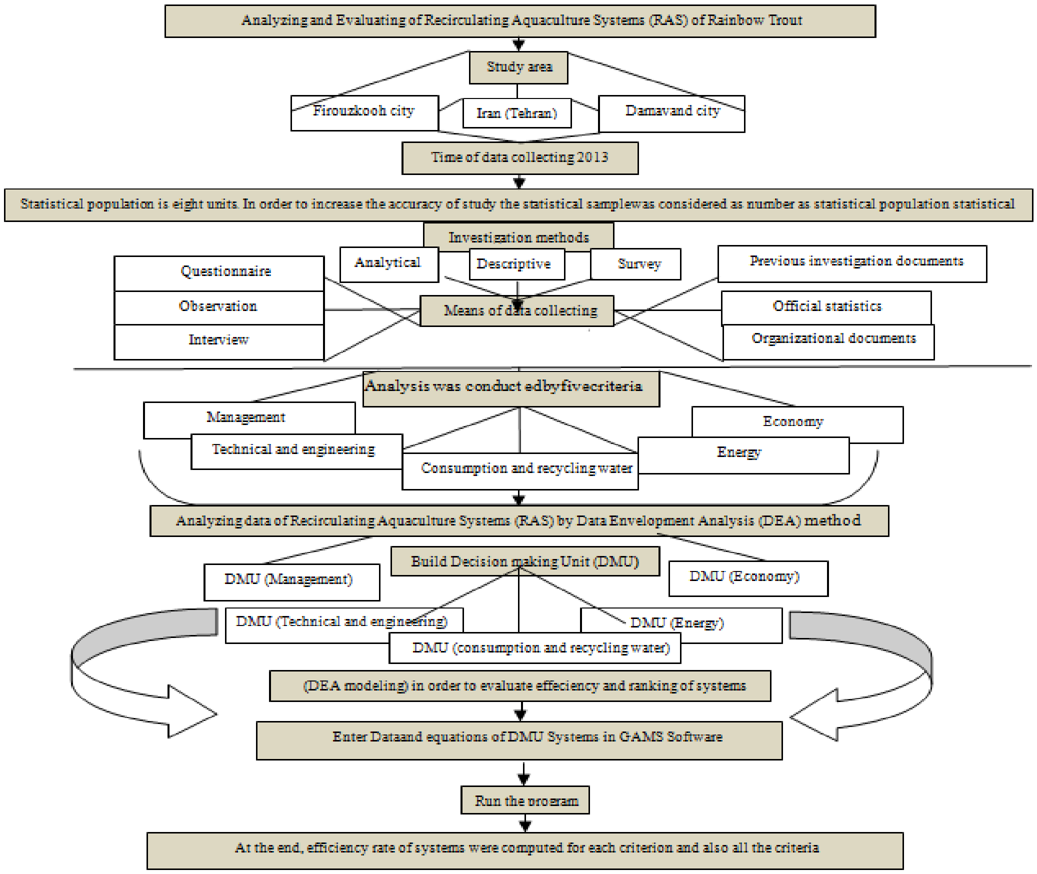

Fig. 1: A conceptual model of the research steps

Table 1: Table of DMU$_s$ (Decision Making Units)

DMU$_s$ (Decision Making Units)			
Number	Criteria	Inputs (x)	Outputs (y)
1	Economy	1. Labor cost 2. Electricity cost 3. Cost of fish food 4. Cost of baby fish 5. Oxygen cost 6. Cost of medicine and vitamin 7. Maintenance cost	1. Income
2	Energy	1. Energy of labor 2. Energy of electricity	1. Income 2. Fish production 3. Baby fish production
3	Water consumption and recycling	1. Flow rate of input water 2. Circulate rate of water 3. Total water in the system 4. Tonnage of fish in the system	1. Replacement frequency of water per day
4	Technical and engineering	1. Pond geometry 2. Pond volume 3. Number of pond 4. Type of mechanical filter 5. Capacity of mechanical filter 6. Type of bio-filter 7. Surface of bio-filter 8. Number of water pump 9. Disinfection system	1. Income 2. Fish production 3. Baby fish production
5	Management	1. Distance to market or city 2. Educational background 3. Experience of staff 4. Passing training courses 5. Nominal production capacity 6. Consumption of fish food 7. Qualified staff	1. Income 2. Mortality rate 3. Fish production 4. Baby fish production

Table 2: Table of showing efficiency rate of systems for each criterion and also all the criteria

Systems	Criteria Economy	Energy	Consumption and recycling of water	Technical and engineering	Management	In terms of all the criteria
System 1	0.430374	0.194545	1	0.111111	0.074556	0.343906
System 2	0.416232	0.250000	0.124594	0.111111	0.127801	0.187725
System 3	1	1	0.161831	1	1	0.668346
System 4	0.380479	0.250000	0.115362	0.111111	0.128909	0.178950
System 5	0.668922	0.217557	0.162208	0.270000	1	0.419455
System 6	0.395932	0.194545	1	0.111111	0.074087	0.336923
System 7	0.606718	0.209440	0.195369	0.345556	1	0.414750
System 8	1	0.250000	0.100983	0.111111	0.066729	0.287542

$o \in \{system\ 1, \ldots, system\ 8\}$

After solving the model Eq. (1) the optimal value of objective function (R^*) will be found which means the efficiency value of oth RAS. If Value of (R^*) in RAS would be 1 it is indicative of full efficiency of RAS and also if it would be lesser than 1 it is indicative of inefficiency of RAS. How much value of RAS efficiency would be lesser than 1 is indicative of inefficiency of RAS which means RAS that is under analyzing and evaluating would be in bad situation in term of evaluation criteria.

RESULTS AND DISCUSSION

Non-radial model Eq. (1) designed for 8 RAS and 5 criteria in order to evaluate relative efficiency of 8 RAS by 5 criteria which include as follows economy, energy, water consumption and recycling, technical and engineering and management. Therefore results have obtained by putting inputs and outputs values (According to Table 2) instead of X and Y in non-radial model Eq. (1) and solving it with GAMS software.

Based on the results as can be seen in the following Table 2 in terms of economy, energy, consumption and recycling of water, technical and engineering and management criteria systems were designated efficient systems respectively and also in term of all the (Verdegem *et al*., 2006; Schneider *et al*., 2010; Naylor *et al*., 2000; Tal *et al*., 2009; Summerfelt *et al*., 2009; Zohar *et al*., 2005) criteria system 3 was designated efficient system.

As can be seen in Fig. 2 in term of all the criteria of efficiency first, second, third, fourth, fifth, sixth, seventh and eighth ranking are belonged to systems (Verdegem *et al*., 2006; Summerfelt *et al*., 2009; Zohar *et al*., 2005; Naylor *et al*., 2000; Tal *et al*., 2009; Schneider *et al*., 2010; Rosenthal *et al*., 1986) and Piedrahita (2003) respectively. Based on the results first ranking is allocated to system 3^{th}.

As can be seen in Fig. 3 a conceptual model of efficient Re-circulating Aquaculture Systems (RAS) of rainbow trout in Iran (Tehran) is designed and developed. This model is formed by three parts which are quality and quantity factors and equipments and also it should be expressed that each part includes other different sections. Information contained in these parts

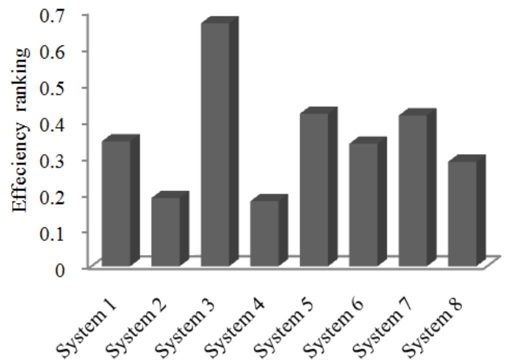

Fig. 2: Diagram of showing efficiency ranking of each system in term of all criteria

of the conceptual model is obtained by analyzing all the specifications of efficient system which are included by quality and quantity factors and equipments. It should be considered this conceptual model is designed and developed based on the potential and relative efficiency of economy, energy, consumption and recycling of water, technical and engineering and management criteria of exciting RAS in Iran (Tehran).

CONCLUSION

In this study a conceptual model of efficient Re-circulating Aquaculture System (RAS) of rainbow trout in Iran (Tehran) was designed and developed. At first, in order to designing a conceptual model it was necessary to identify all the quality and quantity factors and equipments of efficient RAS. Therefore were identified and evaluated all the RAS in Iran (case study: Tehran). In this study Data Envelopment Analysis (DEA) was very effective method in analyzing system because it could consider all the quality and quantity factors simultaneously. This conceptual model could be as an effective means to develop remote areas where growth and development potential have. Accordingly, it is suggested that Agriculture Ministry boosts Fisheries Organization in order to introduce RAS in Iran as a new technology and effective means to convert fish breeding from a non-industrial level into an industrial level. Subsequently, government as to provide support

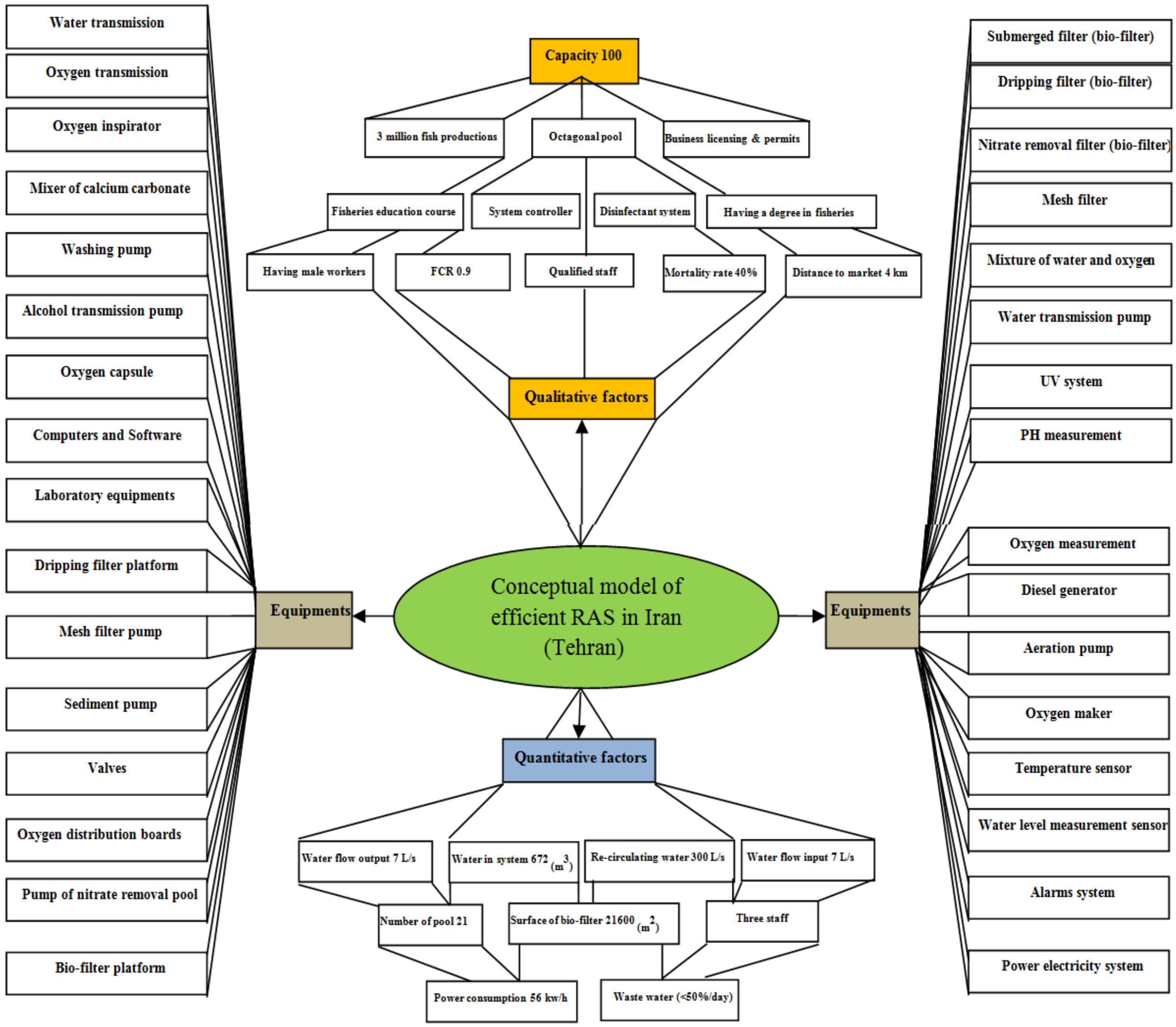

Fig. 3: Conceptual modal of designing efficient Re-circulating Aquaculture System (RAS) in Iran (Tehran)

packages for developing and extending this technology in Iran and also they could provide mechanization and modernization in fish production systems.

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