ABSTRACT

The success of intensive and semi-intensive aquaculture system depends on different water quality parameters. At high stocking density, dissolved oxygen (DO) is the most important parameter. Therefore, it is essential to supply oxygen through artificial aeration in the intensive and semi-intensive types of aquaculture systems. Different types of artificial aerators have been developed over the years, design modification of cascade aerators have been carried out to improve the aeration efficiency. The circular stepped cascade (CSC) and pooled circular stepped cascade (PCSC) are the common types of gravity aerators. The performance of an aerator is generally measured in terms of standard aeration efficiency (SAE), which is significantly affected by the different geometric and dynamic parameters of the aerator. In the present study, a perforated pooled circular stepped cascade (PPCSC) aerator was developed as an improvised design of CSC and PCSC aerators, and the geometric and dynamic parameters of the developed aerator were optimized using the hybrid ANN-PSO technique for maximizing its aeration efficiency. The geometric parameters of a PPCSC aerator include consecutive step width ratio (W_{i-1}/W_i) and the perforation diameter to the bottom-most radius ratio (d/R_b), whereas the dynamic parameter includes the water flow rate (Q). A 3-6-1 ANN model coupled with particle swarm optimization (PSO) approach was used to obtain the optimum values of geometric and dynamic parameters corresponding to the maximum SAE. The optimal values of the consecutive step width ratio (W_{i-1}/W_i), the perforation diameter to the bottom-most radius ratio (d/R_b), and the water flow rate (Q) for maximizing the SAE were found to be 1.15, 0.0027 and 16.7 L/s, respectively. Further aeration experiments were conducted with four different sizes of cascade aerators (R_b values of 0.75 m, 0.90 m 1.05 m and 1.20 m) to evaluate the aeration characteristics of the PPCSC aeration system, based on the optimized geometric parameters. The maximum standard aeration efficiency of the developed PPCSC aerator under standard experimental conditions is obtained as 4.56 kg O_2/kWh for R_b = 0.75 m. Simulation equations for prediction of aeration efficiency and power characteristics of the PPCSC aerator were formulated based on Froude (Fr) criterion, subject to $0.00141 \leq Fr \leq 0.01441$. Finally, an economic feasibility of nine different types of aerators, namely, perforated pooled circular stepped cascade (PPCSC), pooled circular stepped cascade (PCSC), circular stepped cascade (CSC), paddle wheel (PWA), spiral aerator (SA), propeller-aspirator-pump (PAA), submersible (SUBA), impeller aerator (IA) and air-jet aerator (AJA) was assessed based on capitalization method. The results revealed that, the PPCSC aerator can be considered as the most suitable aerator with a minimum capitalized aeration cost of ₹2,62,341 per year for initial dissolved oxygen content (C_P) of 1 mg/L, and pond water volume (V) of is 2000 m^3 compared with other aerators. The study clearly indicates that the developed PPCSC aerator is an efficient and economical system for sustainable aquaculture, particularly for small and marginal farmers.

Keywords: Aquaculture; Artificial neural network (ANN); Particle swarm optimization (PSO); Perforated pooled circular stepped cascade (PPCSC) aerator; Standard aeration efficiency (SAE); Life cycle costing