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# Efficiency of mechanical aeration

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## Paddlewheel design greatly impacts standard aeration efficiency

Mechanical aerators are used increasingly in aquaculture because aeration can greatly increase the amount of production possible per unit area or volume of water. These devices usually are powered by electricity, but in some locations, small diesel engines are the power source.

During a recent visit to a shrimp-farming area in Thailand, the author saw ponds aerated at 24-36 hp/ha (18-27 kW/ha). These aerators often are operated about 20 hours daily over a 60- to 100-day crop period. At a farm with 24 hp/ha of aeration and a 100-day crop, about 36,000 kWhr of electricity would be used for aeration.

Shrimp production for successful crops of 14- to 18-g shrimp was reported to be around 7,000-9,000 kg/ha. Electricity costs about U.S. $0.10/kWhr in Thailand. Thus, aeration costs $0.41 to $0.53/kg of shrimp for electricity alone. Aeration costs for fish production usually are lower than for shrimp, but still represent a major production expense.

Although widely implemented, the long-arm paddlewheel aerators typically used in Asia do not reflect the most efficient designs.

## Oxygenation efficiency

Because of the high cost of mechanical aeration, why has there not been more effort to improve the oxygen-transfer efficiencies of mechanical aerators and determine how to use these devices more efficiently in ponds? There is a relatively simple procedure for testing the oxygen-transfer efficiency of aerators.

Water in a large tank is deoxygenated with sodium sulfite and a small amount of cobalt chloride to catalyze the reaction of sulfide with oxygen. The aerator under test is then operated to reoxygenate the water. The dissolved-oxygen concentration in the tank is measured at frequent intervals while it increases from 0 mg/L to 70 or 80% of saturation. A mathematical procedure is used to estimate the oxygen-transfer coefficient, the slope of the reaeration line.

## Standard aeration efficiency

The tank volume, water temperature, oxygen-transfer coefficient and power input to the aerator during the part of the test used in estimating the oxygen-transfer coefficient allow calculation of the standard aeration efficiency (SAE) of the aerator. SAE is an expression of the amount of oxygen that an aerator will transfer at 20° C to clean freshwater containing 0 mg/L of dissolved oxygen. SAE can be reported in any of the following units: lb oxygen ($O_2$)/hp/hour, lb $O_2$/kW/hour, kg $O_2$/hp/hour or kg $O_2$/kW/hour. The SAEs for aerators range about 0.5-2.0 $O_2$/kW/hour.

## "Much improvement in aeration efficiency could be achieved by modifying the designs of Asian paddlewheel aerators through adoption of paddle and paddlewheel design features already shown to be efficient through testing."

SAE is analogous to gas mileage ratings for cars. These ratings are determined by a highly standardized procedure in the laboratory, but passenger cars are operated under much different and varying conditions. One would not expect a car to actually use fuel at the same rate as it did in the standard test. Nevertheless, a car with a better fuel use rating will use less fuel than a car with a poorer fuel use rating when both are driven under similar road conditions by the same driver.

In an aquaculture system, the conditions existing in the SAE test will not occur. The water will not be clean, the temperature likely will not be 20° C, and dissolved oxygen certainly will be present. Nevertheless, the SAE is particularly valuable for comparing the performance of mechanical aerators. Under identical conditions, an aerator with a higher SAE will transfer more oxygen to the water than will an aerator with a lower SAE.

| Dissolved Oxygen Concentration (mg/L) | Factor |
|---|---|
| 0 | 0.95 |
| 1.0 | 0.87 |
| 2.0 | 0.74 |
| 3.0 | 0.62 |
| 4.0 | 0.49 |
| 5.0 | 0.36 |
| 6.0 | 0.23 |
| 7.0 | 0.10 |
| 7.8 | 0 |

An equation is available for estimating the oxygen-transfer rate of aerators under actual culture conditions if the SAE of the aerator is known. In most culture systems, the actual oxygen-transfer rate is 40 to 60 percent of the SAE (Table 1).

# Calculating SAE

In the late 1980s, an effort was initiated at Auburn University to develop an efficient aerator for channel catfish ponds. Several types of commercially available aerators were tested, and the paddlewheel aerator had the most potential for improvement.

A device was fabricated that allowed the testing of an array of paddle shapes, paddlewheel diameters, numbers of paddles per row around the aerator hub, paddlewheel speeds, paddle depths, paddle positioning on the hub and the amount of power input necessary for each combination. The resulting data were used to calculate SAE and determine the efficient paddlewheel design that is illustrated in Figure 1.

The optimum operating conditions established in the tests varied with aerator size, but the 10-hp paddlewheel illustrated

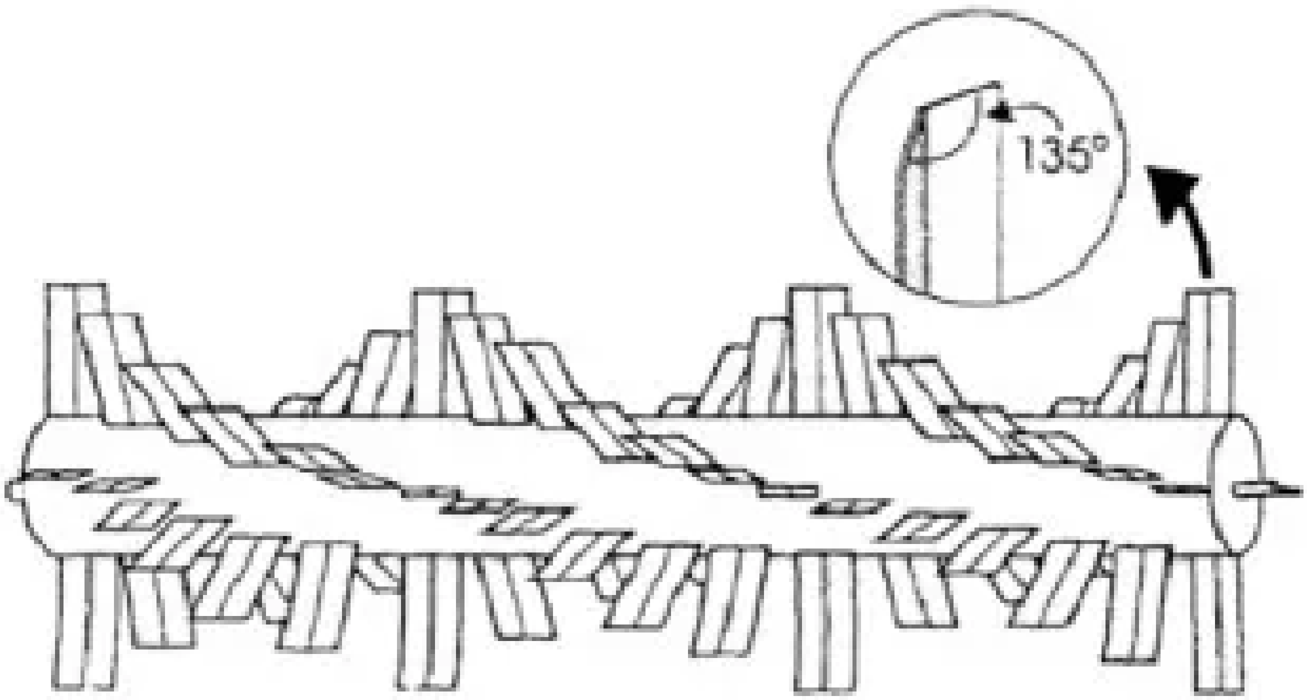


**Figure 1.** This highly efficient paddlewheel design, which resulted from extensive testing at Auburn University, is widely used in pond aquaculture in the United States. It features multiple rows of staggered paddles.

Fig. 1: This highly efficient paddlewheel design, which resulted from extensive testing at Auburn University, is widely used in pond aquaculture in the United States. It features multiple rows of staggered paddles.

in Figure 1 has become the standard aerator for catfish farming. This paddlewheel usually is operated at 80 to 90 rpm with paddle depth submergence around 8 to 12 cm.

The SAE of the paddlewheel aerator is typically around 2 kg $O_2$/kW/hour, and even higher values have been reported. Smaller paddlewheels fabricated according to this basic design also have similar SAEs.

## Cost, design issues

Paddlewheel aerators of the design shown in Figure 1 are used widely in the United States in catfish and shrimp ponds. However, apparently because of the greater initial cost, this type of aerator is not used as commonly as Asian paddlewheel aerators in other countries.

Tests showed that these typical paddlewheels have lower SAEs — usually no more than 1 kg $O_2$/kW/hour. The main reasons for the lower SAEs are related to the design of the paddles and paddlewheels.

The paddles have many holes in them. These holes lessen the amount of water splashed into the air to affect oxygenation, and water passing through the holes increases friction loss — also making oxygen transfer less efficient. There are typically six or eight paddles per row on the aerators. Tests have revealed that four paddles per row were more efficient.

Another problem with many paddlewheel aerators used in shrimp ponds in Asia is that the power of the electric motor or diesel engine used to power the devices often is not well matched with the load imposed by the rotating paddlewheel. The mismatch of power units and paddlewheels is particularly evident for the long-arm aerators used in Thailand.

Because aeration is a major expense in aquaculture, there is incentive to improve aeration efficiency and lessen costs. It also is important to note that it is usually more costly to use diesel-powered aerators than electric ones. To provide 1 kWhr of power to the shaft of an aerator using a small diesel engine with a typical mechanical efficiency of 0.3 would require an energy input of about 12 megajoules (MJ)/hour. About 0.335 L of diesel fuel per hour would be needed. At a fuel cost of U.S. $0.97/L, this much fuel would cost about $0.32. One kilowatt hour of electricity typically costs $0.10 to $0.15.

## Perspectives

Much improvement in aeration efficiency could be achieved by modifying the designs of Asian paddlewheel aerators through adoption of paddle and paddlewheel design features already shown to be efficient through testing. Where possible, diesel-powered aerators should be phased out in favor of electrically powered ones.

Aeration often is not applied at high enough rates to prevent dissolved-oxygen concentrations from falling low enough to stress the culture species at night. Conversely, excessive aeration may be used in the daytime, when dissolved-oxygen concentrations usually are adequate. Thus, greater effort should be devoted to developing better operational strategies for aerators.

In addition to lessening aeration costs per unit of aquaculture production, more efficient aeration would lessen energy input, embodied resource use and negative environmental impacts associated with energy use for aeration. Moreover, those involved in aquaculture eco-label certification should consider including the efficiency of aeration in the standards for these programs.

*Editor's Note: The author has offered to provide the procedure for measuring the SAE of mechanical aerators to anyone interested in conducting aerator performance tests.*

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