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Full Length Research Paper

Temperature effect on fish culture tank facilities inside greenhouse

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This study was performed to evaluate the effect of tank position on the water temperature of fish culture tanks in aquaculture facilities inside a greenhouse. The temperature was measured in four 20 m^3 capacity tanks. Three points were measured for each tank: point A, the water in the fish culture tanks; point B, the environment outside of the tanks and point C, a point 0.3 m below the soil level. The measurements were recorded in periods of five minutes with data loggers. Significant differences in water temperature were found among the fish culture tanks with a grade of significance of 0.05 and environmental and soil temperature proved to exert an important influence on the water of the fish culture tanks. The mean value of the r-Pearson correlation found is 0.87.

Key words: Aquaculture, temperature, greenhouse, culture tanks, thermal behavior.

INTRODUCTION

In recent years, consumers around the world have increased the consumption of fish due to the recognition of their nutritional value (Tingman et al., 2010); for this reason, intensive aquaculture aims to increase fish production capacity per cubic meter of water. However, when fish densities are large, the influence of temperature, dissolved oxygen and water quality on fish survival and growing rates increases. Aquaculture facilities therefore require an automated method of keeping these parameters within acceptable ranges to optimize their efficiency by reducing labor and operational costs (Lee, 2000; Avnimelech, 2006); when these parameters are outside of the optimal ranges, stress and slow fish growth is fostered, which has a direct effect on quality, quantity and harvest time (Soto-Zarazúa et al., 2008). According to Burel et al. (1996), the control of these factors is complicated, and they can only be monitored and kept within tolerable ranges. To solve water quality problems, various systems for replacement, filtration and recirculation of water have been proposed in various scientific studies (Shnel et al., 2002; Al-Hafedh et al., 2003; Piedrahita et al., 2003; van Rijn et al., 2005). In these systems, mechanical and biological clarification and ultraviolet sterilization processes were applied in different configurations to keep the water properties within the acceptable ranges for fish survival and growth. Regarding dissolved oxygen, some controllers have been developed (Bergheim et al., 2005), and fish behavior has been analyzed (Xu et al., 2006) to evaluate the optimal ranges for fish production.

In relation to temperature control, fish production in greenhouses has been practiced to inhibit extreme temperature changes in the water tanks. In the previous decade, various scientific studies of aquaculture have been performed in facilities that use greenhouses for temperature control (Snell et al., 2002; Soto-Zarazúa et al., 2010b), which mitigates the high economic cost of temperature control by mechanical heating systems that require energy sources, such as gas or electricity (known as forced methods) (Soto-Zarazúa., 2011). The natural water heating method, using greenhouses and solar radiation, requires only an initial investment for building the greenhouse structure and plastic cover, is economically viable (Omer, 2009), and has been proven effective in a great variety of applications (Medugu and Ndatuwong, 2009; Aliyu and Jibril, 2009). However, there

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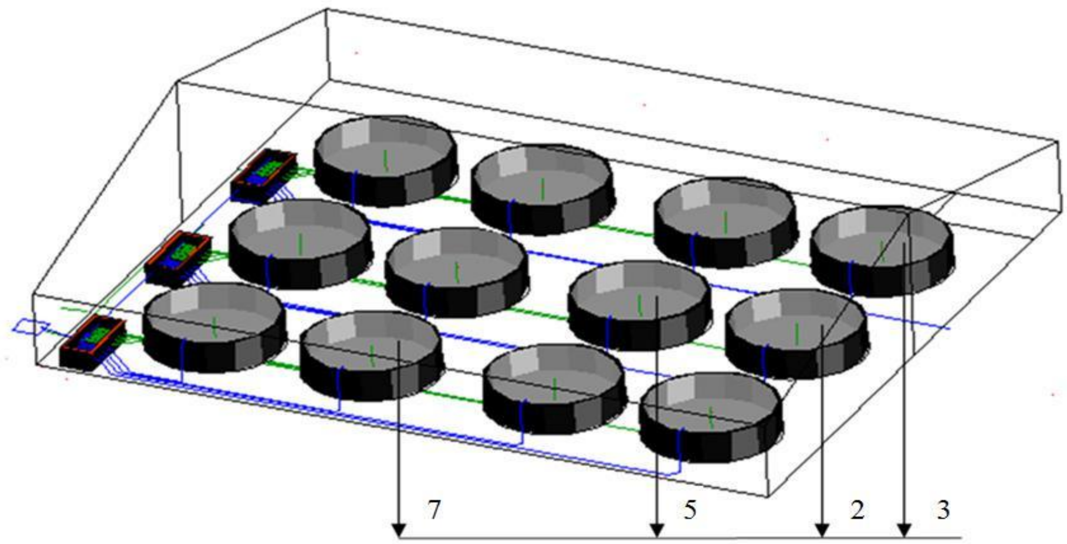

Figure 1. Aquaculture system facility under greenhouse. 2, 3, 5 and 7 tanks were used to temperature data collecting.

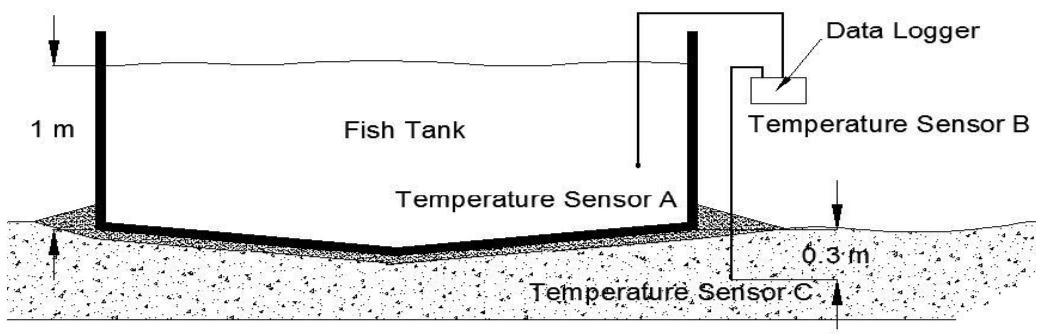

Figure 2. Temperature sensors installed in the fish culture tanks. A, B and C indicates the measure points: water, environment and soil respectively.

are often significant differences among the tanks with respect to water temperature, which have been attributed to the tanks' positions inside the greenhouse. In this paper, the evaluation of the effect on the water temperature caused by the tanks' positions inside the greenhouse is presented; this information can be used for the design of controllers that distribute the water among the tanks during filling and administer the fish-stocking densities in the tanks during production cycles, which can be explicitly tailored to optimize water parameters for fish production in commercial-scale systems under greenhouse conditions.

MATERIALS AND METHODS

Experimental setup

The experiment was performed in an aquaculture system producing Tilapia (*Oreochromis niloticus*) inside a polyethylene greenhouse 672 m^2 in area (24 m × 28 m) in Amazcala, Querétaro State, Mexico. The aquaculture system contains 12 tanks with 20-m^3 capacity and conical bottoms to allow self-cleaning, but only four tanks, which constitute a representative sample of all positions inside the greenhouse due to the symmetry of the tanks' layout, were selected for temperature change evaluation. The tanks were labeled with the numbers 2, 3, 5 and 7, as shown in Figure 1.

Temperature data collection

Data were collected from September 01, 2010 (beginning at 11:10 am) to September 21, 2010 (ending at 10:30 am). Measurements were taken every five minutes. The temperature data were collected with a data logger (WatchDog Model 450, USA), which was placed in a different location for each tank. The measurements were taken at three points, as shown in Figure 2. The temperature sensors were installed in the water inside the fish tank (A), in the environment outside the fish tanks (B) and 0.3 m below soil level (C). Data were downloaded from the data logger to the computer

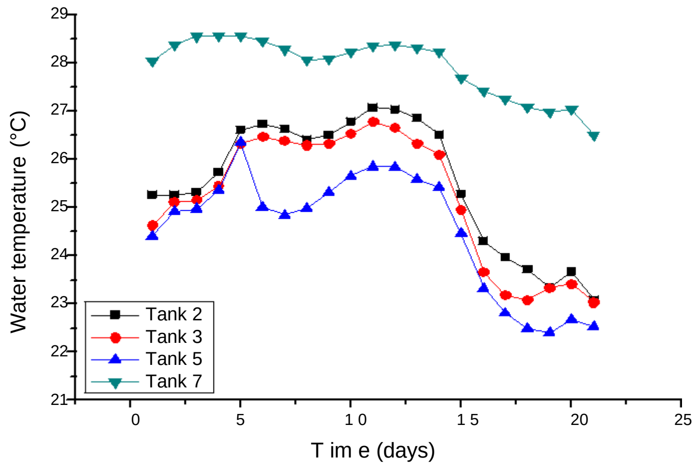

Figure 3. Water temperature trends in the tanks; the points represent the mean value of temperature in each one of the twenty days measured.

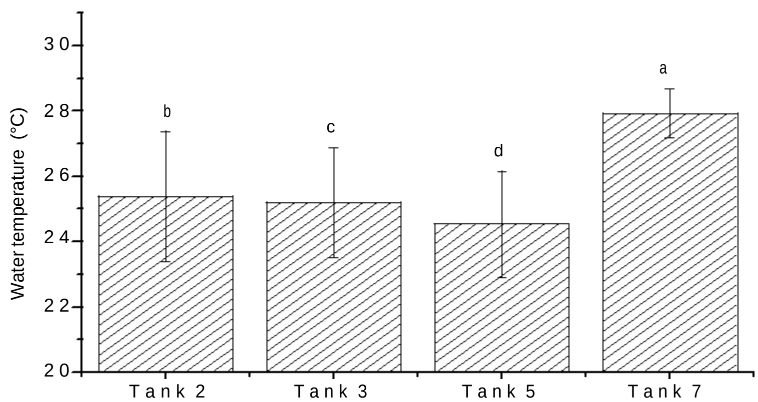

Figure 4. Statistical analysis of one way ANOVA in water temperature data.

for additional statistical analysis.

Statistical analysis

Data were statistically analyzed with the commercial software Origin Pro 8 for Windows. A one-way analysis of variance (ANOVA) was performed to evaluate the degree of significance of the differences among temperature measurements in the fish tanks with a $P<0.05$ level of significance. The degree of association among the temperatures in the water, environment and soil was quantified by the r-Pearson matrix analysis, correlating the temperature measurements.

RESULTS AND DISCUSSION

Water temperature behavior in the tanks

Water temperature behavior in the tanks during the measuring time is presented in Figure 3. Each point represents the average temperature of the total data collected during the 24 h of each day. As shown, the temperature in tank 7 exhibited more-stable behavior than did the temperature in the other tanks. The mean temperature in tank 7 was 27.92°C, whereas in tanks 2, 3 and 5, the behavior was more unstable, with mean temperatures of 25.4, 25.2 and 24.54°C, respectively. Among the tanks, significant statistical differences were present ($P<0.05$) in the water temperature data analyzed (Figure 4). The differences can be attributed to the position of the tanks inside the greenhouse. This result may contribute to the design of new strategies for water distribution among tanks when they are filled, or it may be integrated into controllers of recirculation systems for water treatment in aquaculture systems in such a way as to take these temperature differentials into account when distributing the required quantities of water to maintain

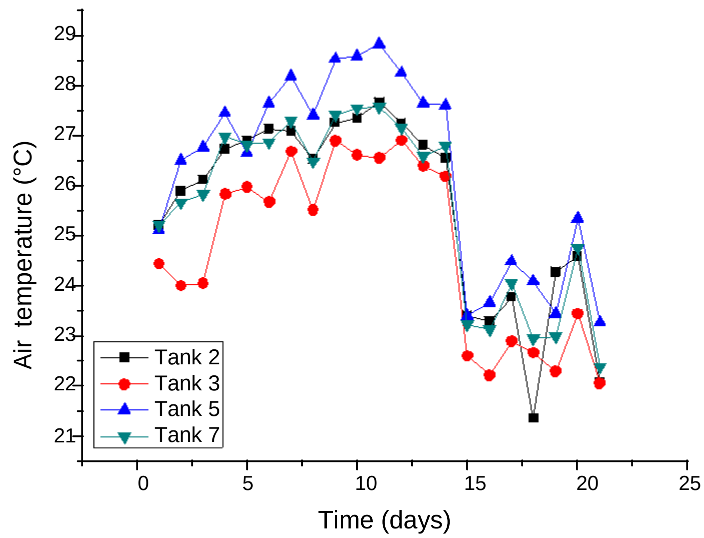

Figure 5. Internal air temperature behaviors inside the greenhouse; every one points represent the mean value of each twenty one days measured.

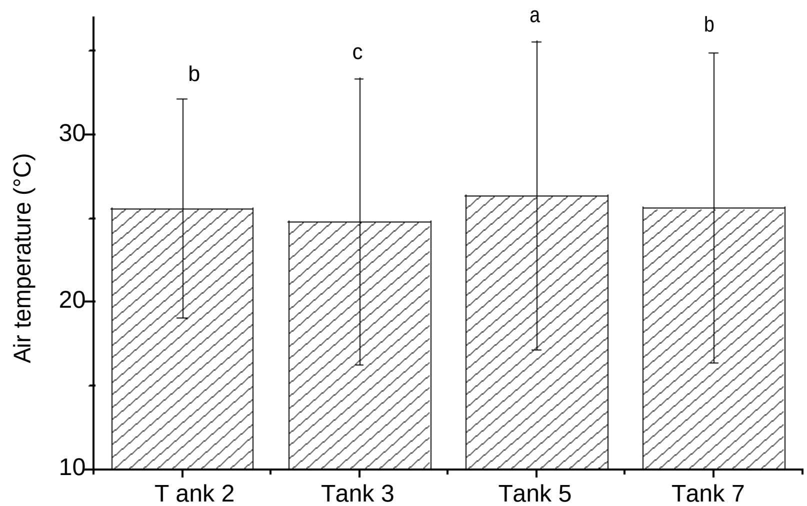

Figure 6. Statistical analysis of one way ANOVA in air temperature data.

the temperature within the acceptable ranges for optimal fish growth and survival.

The temperature in tank 7 was kept near to 28°C, which is the optimal temperature to obtain low feed-conversion rates 1.61, reported by Shnel et al. (2002), and 1.64, reported by Soto-Zarazúa et al. (2010a), in greenhouse conditions.

Air temperature behavior inside the greenhouse

Figure 5 illustrates the air temperature fluctuations at the different positions of the tanks inside the greenhouse on each day of the experiment. The temperature variations in the air are stronger than those in the water. However, the air temperature data present statistically significant differences *($P<0.05$)* among the tank positions. The mean air temperatures near tanks 2, 3, 5 and 7 were 25.58, 24.77, 26.34 and 25.62°C, respectively (Figure 6).

Soil temperature fluctuations

The soil temperature fluctuations are shown in Figure 7.

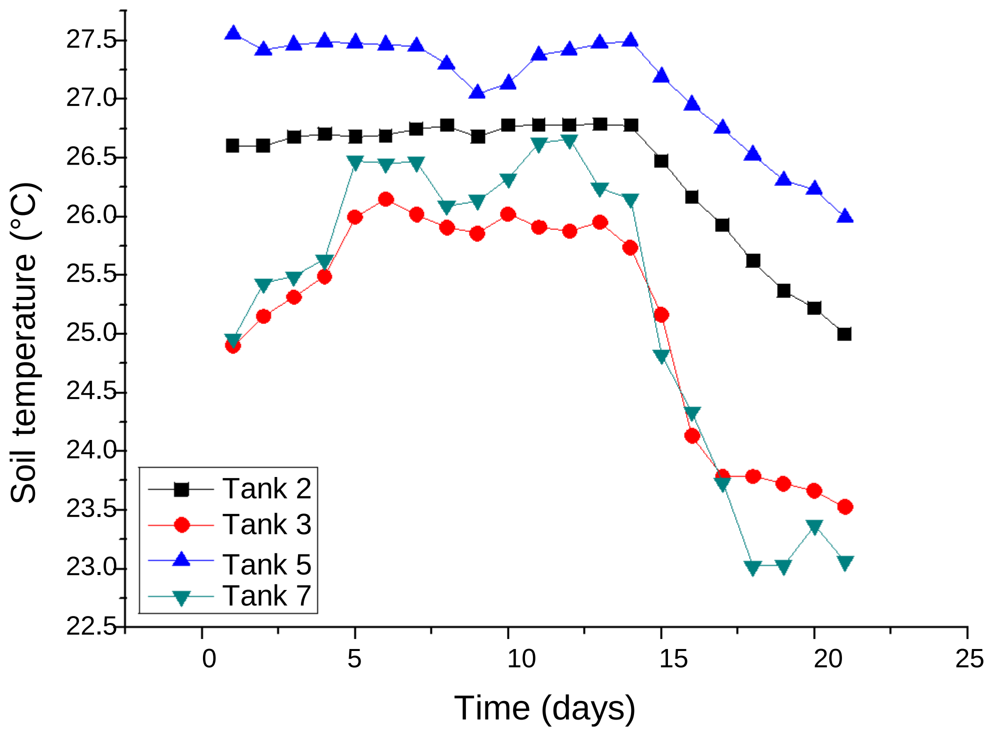

Figure 7. Soil temperature behaviors under the tanks in the greenhouse; every one points represent the mean value of each twenty one days measured.

Table 1. r-Pearson correlation analysis between the temperatures measured in the water, air and soil in each tank during the experiment from September 01, 2010 (beginning at 11:10 am) to September 21, 2010 (ending at 10:30 am).

	r-Pearson	
Tank	**Water-soil**	**Water-air**
2	0.88	0.80
3	0.99	0.90
5	0.86	0.67
7	0.92	0.92

As can be seen, the soil temperature is more stable than the temperature in water or air; however, the soil temperature's influence on the water temperature is greater than the influence of the air temperature (Table 1). The data analysis reveals significant differences in soil temperature among the tank positions ($P<0.05$). The mean soil temperatures in tanks 2, 3, 5 and 7 were 26.38, 25.15, 27.12 and 25.27°C, respectively, as shown in Figure 8.

Statistical correlation between water-soil and water-air

The statistical correlation between the water-soil and water-air temperatures of each tank was tested by the r-Pearson correlation matrix analysis. The obtained r-Pearson values are presented in Table 1. The data obtained show a high correlation between the measured points; therefore, the water temperature in the tanks is modified by the temperatures in the air and soil. Additionally, the temperatures at the three points of measurement (water, soil and air) are influenced by the position inside the greenhouse. As a consequence of its effect on the water temperature, a tank's position in the greenhouse also affects fish metabolism, growth and ultimately productivity. This result should be taken into consideration in designing the strategy for water distribution and circulation during the production cycles in aquaculture systems.

Conclusions

Fish culture in facilities inside greenhouses represents an important alternative method of maintaining water temperatures within the acceptable range for fish survival and thereby obtaining high growth rates with low feed-conversion rates, due to the effect of temperature on fish metabolism and consequently on food consumption. However, the temperature control can be improved by the design of new strategies for water distribution among the tanks, taking into account the tanks' position inside the

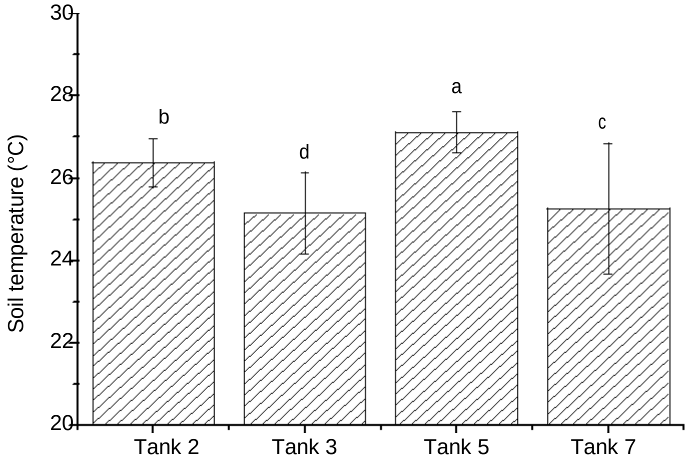

Figure 8. Statistical analysis of one way ANOVA in soil temperature data.

greenhouse and the temperature effect of air and soil on the water, as shown by the results of this work.

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