Mitigation of Carbon Dioxide Emissions in a Warming System for Chicks by Using Solar Energy

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Abstract: Controlling the environmental temperature during in the incubation period of a poultry heater is of priority concern. In practice, the poultry heater of this warming system is operated by using a tungsten lighter, subsequently making it difficult to maintain the temperature for chicks between 30 and 32℃ for chicks and also lowering the electronic-energy effect. Therefore, this study investigates the feasibility of using a highly effective warming system for chicks by using solar energy. A poultry heater structure is also developed for saving energy and ensuring comfort of the chicks. When raising chicks, the warming system should function continuously for 1-4 weeks, depending on the season. When water in the solar system has a fluidity of 5.7 kg/min and of 35-57℃, the proposed poultry heater is more effective than the tungsten lighter heater, saving around 148.6 Kg of carbon dioxide emissions for growth of approximately 1000 chicks.

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Keywords: Solar energy; poultry heater; chicks warming system; carbon dioxide emmision.

1. Introduction

Global environmental efforts highly prioritize energy savings and carbon reduction. 97% of GHG emissions originate from fossil fuels (Mohammed et al., 2012). Based on data, carbon dioxide emissions of 1 kg of petroleum gas, 1℃ of natural gas and 1 of diesel during burning are around 3.0 kg, 2.0 kg and 2.7 kg, respectively. According to 1999 data of, the electricity emission factor of power plants is about 0.638 kg of carbon dioxide emissions for 1℃ of electricity. During hatching of chicks, the temperature should remain constant, allowing for the chicks to stay warm. In practice, chicks are kept warm by using two to three 60W lighter as the heat source. Additionally, in Taiwan, chicks may gradually stop keeping warm for about one week in the summer, two weeks in the spring and autumn, and three or four weeks in the winter. According actual circumstances, a change may be made to use of a 120W tungsten lighter during the winter. Each poultry heater can accommodate about 150-200 chicks. After hatching, the temperature reaches its maximum, and the time and temperature to keep the chicks warm should be decreased. Moreover, the poultry heater system should function for an additional two weeks. However, body temperature of the chicks can be controlled with them increment of weight and the growth of feather gradually (Charles, 1986; Deaton, 1995; Purswell et al., 2012). From an energy waste perspective, each poultry heater that uses a tungsten lighter costs an average of about 50.4℃ of electricity for two weeks, subsequently increasing 32 kg of carbon dioxide emissions in a power plant.

Located in a subtropical environment, Taiwan has abundant sunlight, which is an environmentally friendly and inexhaustible natural energy source. Taiwan is thus highly attractive for developing solar energy, greatly facilitating alternative energy and environmental protection efforts. For energy savings and carbon reduction policies, solar energy can replace a portion of the demand for animal husbandry in the manufacturing process (Daneshmand et al., 2012; Eman and Hegazy, 2011; Han et al., 2007; Huang et al., 2005; Lin and Lee, 2012). For instance, solar energy can be used to keep chicks warm. By using solar energy technology to supply many poultry heaters, this work presents a novel poultry heater to keep chicks warm for the local poultry sector and achieve carbon reduction targets.

2. Materials and Methods

2.1. Solar thermal collectors

Figure 1 shows a commercial solar hot water system with high efficiency vacuum tube collectors. The vacuum tube collectors must be vacuumed between double transparent glass of inner and outer glass tubes. Vacuum degree must lower than 10^{-4}mmHg, subsequently inhibiting air convection and conduction heat loss. The inner glass tube is coated with selective absorbing coating to ensure radiation heat loss. The absorptive effect of the current solar thermal collectors is higher than 93% (Kalogirou, 2004). The current system with water pump forced circulation possesses 18 vacuum tubes and the area is 1.6 m2.

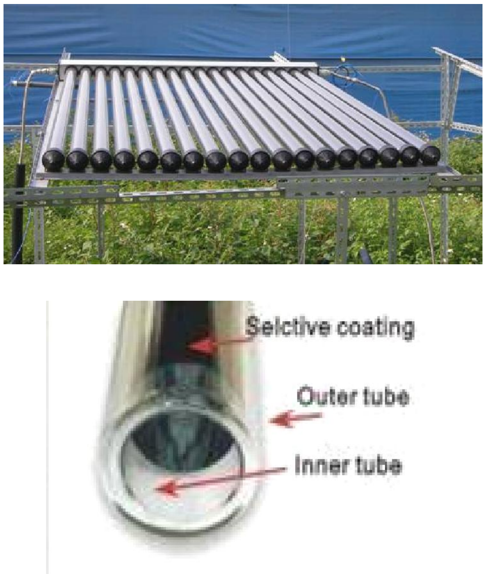

Figure 1. the solar thermal collectors

2.2. Efficiency of the solar hot water system

Efficiency of the solar hot water system can be defined as the ratio of the heat absorbed capacity in the water-storage tank and solar-radiation ratio in the collector board for a complete work day. The system efficiency is described in formula 1. Additionally, based on the measurement data, efficiency of the collector can be calculated (Daneshmand et al., 2012; Huang and Du, 1991; Huang, 1993).

$$\eta = \frac{\Sigma Q_a}{\Sigma I_T} = \frac{M c_p \left(T_f - T_i\right)}{H_t A_c}.$$

ΣQ_a: total heat absorption of a water-storage tank, MJ/ m^2

ΣI_T: total heat absorption of a solar collector, MJ/ m^2

M : mass of water-storage tank, kg

C_p : specific heat of water, 4.184 kJ/kg℃

A_c : area of collector, m^2

T_i : initial temperature of water in water-storage tank, ℃

T_f : final temperature of water in the water-storage tank ℃

H_t : total sunshine on solar collector, kJ/m^2

2.3. Constructing the loops of solar keep warm system

The proposed solar hot-water system attempts to provide a heater source in order to keep chicks warm during their early growth. Figure 2 illustrates those loops. Four loops and the function of each loop are described as follows.

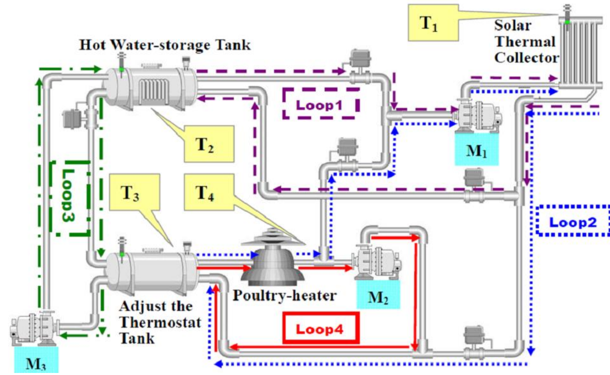

Figure 2. the loops of solar keep warm system

Loop1: Loop 1 is the main circle of the solar energy collection system. The hot water-storage tank facilitates heat exchange and storage. This loop starts to operate when the temperature (T_1) of the copper inside the solar collector is higher than 65℃, and T1 is higher than the temperature (T_2) in the hot water-storage tank water more than 5℃.

Loop2: For increasing the efficiency of the solar energy collection system, loop 2 is designed when the heat exchange is no longer sufficient in loop 1 during the daytime. After passing through the poultry heater, water can heat exchange with the solar collector by passing loop 2, resulting in absorption of more solar heat. Loop 2 operates when loop 1 and/or loop 4 is inactive. It includes that fact that temperature T1 is higher than return water temperature T4 and/or temperature T3 of the adjusting tank in the poultry heater, which must maintain the temperature between 50℃ and 55℃.

Loop3: If the adjusting tank temperature is lower than 50℃, Loop 3 is forced to operate, especially OR particularly when loop 2 no longer functions and T2 is 5℃ higher than T3. Additionally, loop 3 stops when T3 is higher than 55 ℃.

Loop4: Loop 4 is a system that keeps chicks warm. The heat source of the poultry heater uses hot water from the adjusting tank. Notably loop 2 stops functioning when this loop 4 starts to perform.

2.4. Proposed poultry heater

This work develops a poultry heater, whose shape is similar to that of the traditional tungsten lighter system. As depicting in Figure 3., installed under the poultry heater, a fin plate is embedded in copper tubes, subsequently causing the passage of hot water. Additionally, above the fin plate, a fan is installed to force convection heat transfer with the bottom-up flow, subsequently forming a thermal convection field. Moreover, to achieve heat concentration and prevent heat loss, a deflector plate is established on the bottom edge of the proposed poultry heater. Some parameters of the poultry heater in the examination are described as follows. Maximum ventilation is 19.8 CMM; thermal conductivity of the fin plate is 237 W/m·K° ; dissipation area is 3 m^2; and heat convection coefficient is 20 $W/m^2 \cdot K°$.

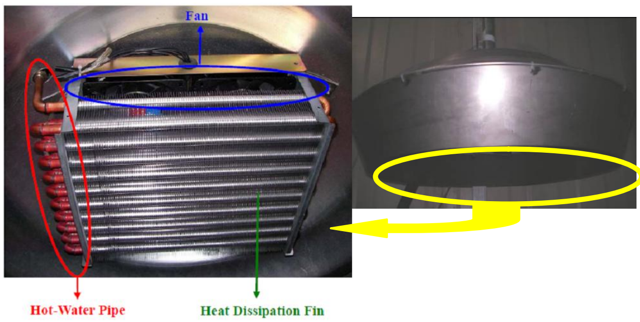

Figure 3. View of Poultry-heater structure

2.5. Experimental procedures

A circulating pump is established in the solar collectors system, allowing for water to flow through the collector and exchange; hot water is then stored in a hot water-storage tank. Temperature of the water-storage tank is recorded by using the Data Logger record, and efficiency of the solar system is calculated as well. When the temperature reaches 55℃, water is automatically sent to the adjusting tank, subsequently providing a heat source of chicks to keep them warm. To demonstrate the effectiveness of the proposed poultry heater, the experimental conditions of the system to keep the chicks warm are proceeded with in low environmental temperatures (e.g., 15, 20 and 25℃), various water temperatures (e.g., 40, 50, 60 and 70℃), and various heights (e.g., 10, 15, 20, 25, 30, 35, 40 and 45cm). A thermocouple is set at 10cm above the ground (i.e. similar to height of the chicks). Data logger records the temperature distribution. Both measurements and simulations are observed.

Reliability of the system to keep the chicks warm by using tungsten lighter is also examined to record electric consumption for a group of chicks required. Meanwhile, electrical consumption of the motor transport in the current solar-energy system is also recorded. Next, the two systems are compared with respect to the electrical consumptions. The amount of CO_2 emissions is calculated as well.

3. Results and Discussions

3.1. Efficiency of solar hot water system

Efficiency of the solar system was determined at low surrounding temperatures of around 14.31℃ on January 1, 2011. Table 1 displays the temperature and sunlight on an hourly basis. The flow rate of water through the solar collector is 5.7 kg/min, and the maximum intensity of sunshine is 329 W/m^2. After 115 liters of water were poured from the storage tank through the collector to the heat exchange, Figure 4 displays the water temperature. The highest water temperature reached 57℃. From 9:00 am to 16:00 pm, the initial temperature of water T_i was 41.22℃, and the final temperature T_f was 51.89℃. The total sunshine H_t was 1620.2 W/m^2. According to formula 1, the collection efficiency of solar hot water system was 51.5%. Figure 5 shows the cooling rate of the water with the initial temperatures of 40, 50, 60 and 70℃ without any heat source. This figure reveals that the useful time of water in the storage tank with the temperatures of 40, 50, 60 and 70℃ for maintaining the temperature of 32℃ for chick growth was 90, 140, 145 and 155 minutes, respectively.

Table 1. average temperature and sunlight

Time	Temperature (℃)	Solar Irradiance (W/m^2)	Time	Temperature (℃)	Solar Irradiance (W/m^2)
1:00	15.49	0.019	13:00	20.72	307.2
2:00	15.33	-0.475	14:00	21.73	305.6
3:00	15.18	-0.38	15:00	21.39	174.7
4:00	14.9	-0.133	16:00	21.11	115.2
5:00	15.22	-0.674	17:00	20.31	27.6
6:00	14.89	-0.465	18:00	18.92	-0.864
7:00	14.31	2.458	19:00	18.26	-1.965
8:00	14.72	47.03	20:00	17.46	-1.794
9:00	16.12	115.5	21:00	16.58	-1.414
10:00	17.77	184.6	22:00	16.45	-1.129
11:00	19.07	200.8	23:00	16.15	-0.864
12:00	19.71	216.6	24:00	16.13	-0.531

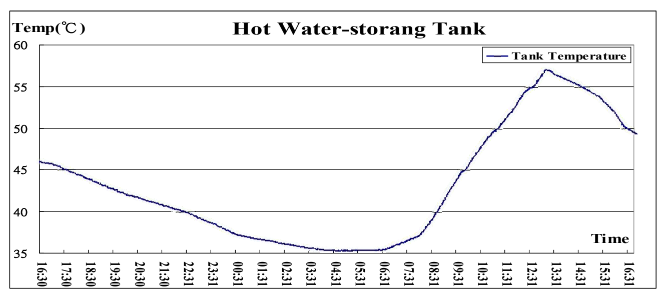

Figure 4. Temperature distribution of storage tank

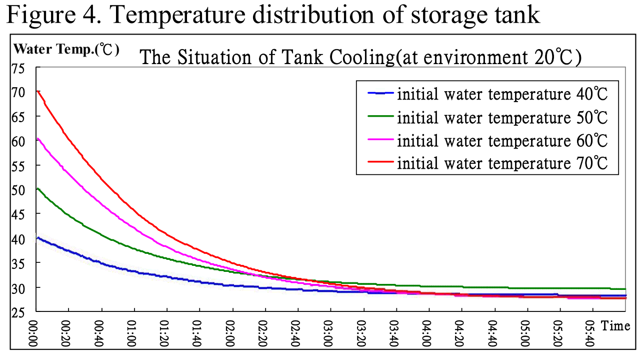

Figure 5. The cooling rate of water without any heat source

3.2. Examination of poultry heater

Figure 6 shows the region for the temperature to keep the chicks warm at various environmental temperatures (e.g., 15, 20 and 25℃) and various poultry heater heights. According to this figure, a higher heat loss of thermal convection in the poultry heater occurs at a higher environmental temperature, which is initially lower. For instance, a water temperature under 70℃ and a poultry heater height of 10cm, the heat loss with environmental temperatures at 15, 20 and 25℃ is 19.74℃, 17.19℃ and 14.84℃, respectively. However, it is a non-linear curve. This figure also clearly reveals that the height of the poultry heater may depend on the initial water temperature and environmental temperature for the region to keep the chicks warm region, which is set at 30-32 ℃. This finding suggests that height of the poultry heater can be adjusted, allowing for a constant temperature of the region to keep the chicks warm. For instance, on January 1, 2011, temperatures outdoor and those of the water storage tank are 17.4 and 45℃, respectively. Therefore, the optimum height of poultry heater should be adjusted to around 13 cm.

The temperature under the poultry heater is determined at different set heights in the experimental process. Analysis results of the statistical turnkey test analysis indicate an almost uniform temperature distribution under the poultry heater range and temperature (center ± 45cm, inside or outside of the poultry heater). Additionally, inside the poultry heater (center ± 30cm), the temperature can remain in the range of 30-34℃. However, analysis results indicate a significant difference under the poultry heater within and outside the range. Moreover, according to turnkey test analysis results the P value is 0.827 <0.05. This finding suggests that the poultry heater can supply a uniform temperature for chicks to keep warm. As for 150-200 chicks, the poultry heater range (60cm) should be sufficient for chicks activity, yet not outside the scope. Figure 7 shows the temperature distribution under the poultry heater. Temperatures of the outdoor and water storage tank are 17.4 and 45℃, respectively. Figure 7(1) shows the computer simulated figures, while Figure 7(2) shows the experimental measurements.

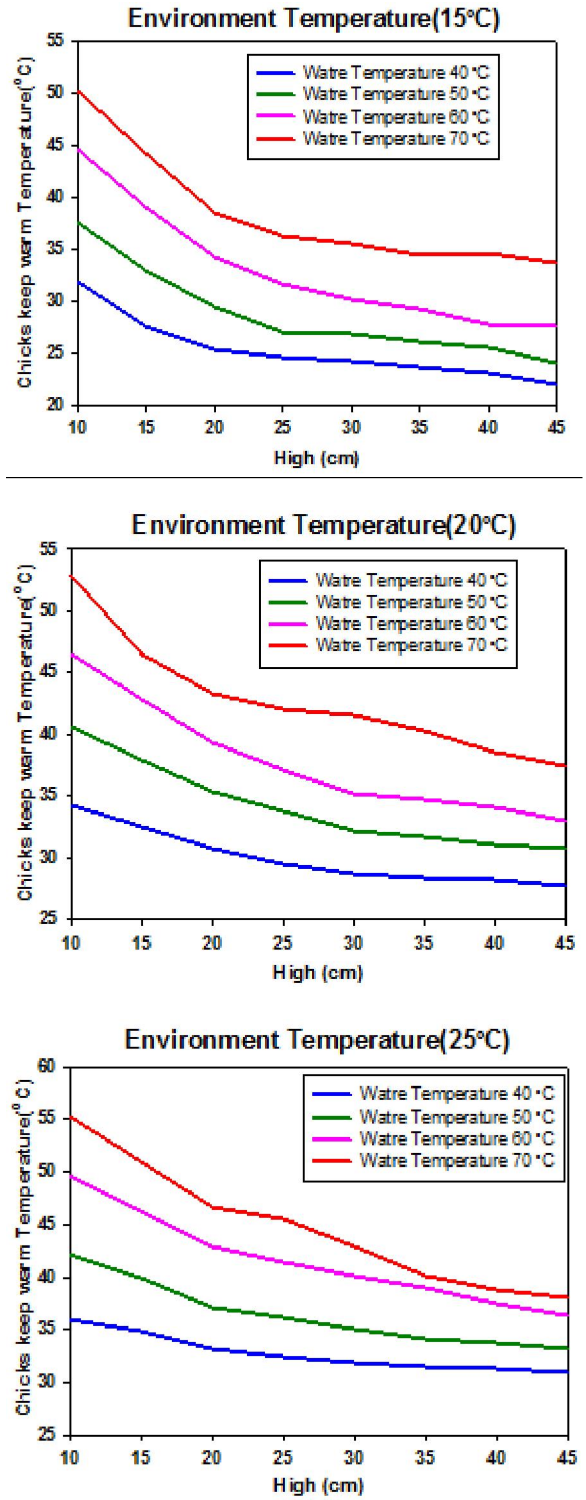

Figure 6. Chick keeping warm temperature with various heights

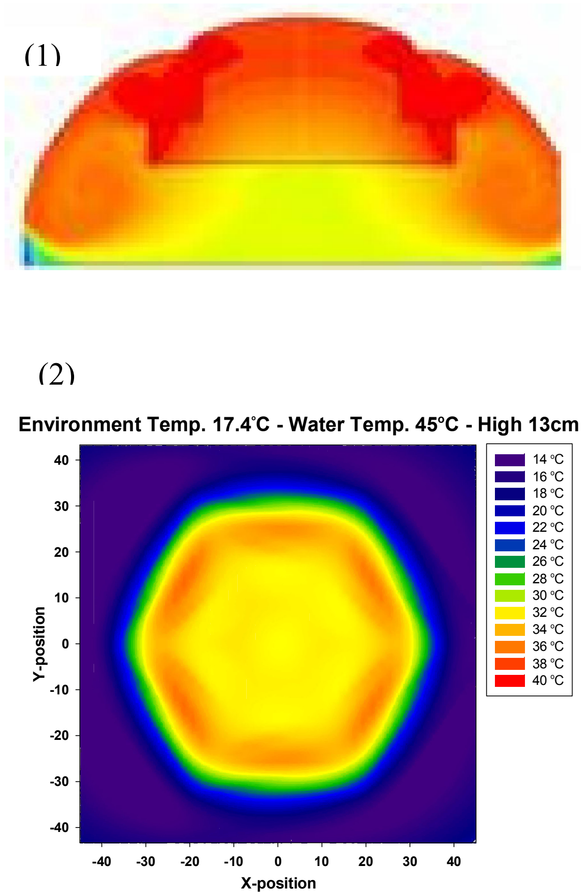

Figure 7. Temperature distribution under the poultry heater, (1) computer simulated, (2) experimental measured

3.3. Electrical consumption and carbon dioxides emissions

Table 2 shows the electrical consumption for one poultry heater to keep the chicks warm. For the traditional tungsten lighter, the electrical consumption is around 50.4 ℃ (kWh) for two weeks. The solar hot water system relies on the three motor, and each one has 1/ 4 horsepower. The motor in the current system includes the following. M1 loop motor in the solar collector loop, M2 motor between the hot water-storage tank and adjusting tank and M3 motor for the poultry heater system. Electrical consumption of these three motors is nearly 69.5 ℃. However, a motor (M3) in the solar hot water systems can provide a multi-poultry heater. Therefore, the electrical consumption in the solar system could be lower than of the traditional tungsten lighter. Moreover, while considering that the system consisted of six poultry heaters or the 1,000 chicks system, the proposed poultry heater is more effective than the tungsten lighter radiation, as well as saves about 148.6 Kg carbon dioxide emissions. This is owing to that each traditional poultry heater added consumes more than 50.4 ℃ , which is equivalent to more than 32Kg of CO_2 emissions in the air. Taiwan has nearly 100,000 chicks in one large-scale henhouse, which accumulates CO_2 emissions of more than 15 tons.

Table 2. Electricity consumption of each poultry-heater

	Tungsten Lighter System	Solar Energy System		
		M_1	M_2	M_3
Consume Electricity	50.4	9.4	7.6	52.5
Amount	50.4	69.5		

4. Conclusions

This work develops a novel poultry heater for a chick rearing system. Our results demonstrate the following.

1. The collection efficiency of the solar hot water system can be 51.5% or higher;
2. The higher heat loss of thermal convection in the poultry heater initially occurs at a higher and lower environment temperatures;
3. Adjusting the height of poultry heater can lead to a uniform temperature for the region to keep chicks warm; and
4. The proposed poultry heater is more effective than the traditional tungsten lighter system and saves about 148.6 Kg of carbon dioxide emissions for a 1,000 chicks system.

We recommend that future research examine the total amount of GHG when using the traditional poultry heater, by using electricity, natural gas and diesel or the proposed solar energy system.

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