PERFORMANCES STUDY OF AIR TUNNELED-EVAPORATIVE COOLING PAD IN MINIMIZING BROILER HEAT STRESS LEVEL AND SUPPORTING LOCAL FOOD SECURITY PROGRAM

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ABSTRACT

The aims of this study is to investigate the performances of air tunneled-evaporative cooling pad system in reducing broiler heat stress level and providing an effective cost cooling system for local broiler breeders and also in general supporting local food security in Bali region. The research would be conducted in laboratory scale, in which the size and cooling load of real broiler cage would be miniaturized. Real broiler cage volume 240 m^3 with 1250 broilers and cooling load 45 kW with inner and outside cage temperature respectively 36^{o}C and 31^{o}C is then miniaturized into volume 2.4 m^3 and 450 W cooling capacity. The thermal comfort standard for the broiler in dry climate is at temperature of 11-26^{o}C and relative humidity of 60-70%. The air tunneled evaporative cooling pad with three fan speed variation of 1440 rpm (2.6 m^3/s), 1470 rpm (4.1 m^3/s) and 1500 rpm (5.7 m^3/s), would be applied on the miniature broiler cage. Air tunnel is constructed in rectangular shape with 2 m length, and 0.9 m width, 0.3 m height and in cylinder shape with 2.0 m length and 0.59 m diameter in which for those two air tunnel 65 holes is made in the bottom side of air tunnel with hole diameter of 0.05 m. While for the cooling load, it used four 100 W light bulbs and one 50 W light bulb for total 450 W cooling load. The evaporative cooling pad uses kerosene stove wick as a pad material, which is wetting by 10^{o}C wetting water temperature and wetting water discharge of 1949.94 ml/min. The experiment is carried out for two repetitions for each fan speed variation, and for each of two different air tunnel shape , in which the dry and wet bulb of incoming and discharge temperature of cage is recorded. As a result of this research is found that at 1500 rpm fan speed (5.7 m^3/s air volume rate), using rectangular air tunnel, it is reached a reasonable performances of evaporative cooling pad (ECP) including indoor cage temperature of 24^{o}C and relative humidity of 67%, and produce a cooling effectiveness of 1.24, 3.2 kW cooling capacity, 38.7 Energy Efficiency Ratio, and evaporation rate of 0.001 liter/hr. So then it can be stated that the air tunneled evaporative cooling pad can be considered to be an effective cooling system for broiler cage in dry hot climates region and it would be provide a good supporting to the local food security program.

Keywords: Air Tunneled Evaporative Cooling Pad, Broiler Heat Stress Level, Local Food Security Program, Miniaturized Cage.

1. Introduction

In hot and arid climate country, the uses of evaporative cooling pad for broilers cage and or broiler houses is considerable as it can provided thermal comfort for the broilers, in which it could cooled the indoor cage air temperature and at the same time increase the cage relative humidity. This comfort cage environment would allow the broilers to release its body heat effectively and reduce the possibility of experiencing heat stress for the broiler that in turn would keep the high broiler performances. Many studies has been conducted in investigating the performances of the evaporative cooling pad (ECP) for broiler cage and/or broiler house. According to T.Yanagi,Jr and H.Xin [1], the suitable thermo neutral zone for adult laying hens is about 21^{o}C to 25^{o}C, the higher indoor environment condition would lead to the laying hens performances reduction and increase the mortality. In this study, the caged laying hens is cooling using a partial surface wetting method and it found that the air vapor pressure deficit is directly proportional to the evaporation rate. Yahav [2] studied that at the indoor cage temperature higher than 35^{o}C ± 1^{o}C, the broiler and/or hens would experienced heat stress and reduce its feed intake for about 16%. It obviously that to improve or keep the broilers performances, the cage cooling system is desirably required to discharge accumulated heat from the cage and relief the broiler from heat stress. Gates and Timmons [3] found that the ECP is a cost effective cooling system for broilers cage. H. Xin and I.L.Berry et.al [4] investigated the indoor environment of broiler houses in term of its temperature and humidity profiles, it found that for conventional house would reach the daily cage temperature of about 22.2 to 34.7^{o}C (mean 29.3^{o}C) with 56% of relative humidity (RH) and for tunneled house would be 24.9 to 29.6^{o}C (mean 28.1^{o}C) within RH of 64%. This study as well as reported that it is unlikely to keep the birds too cool as it would increase feed consumption to maintain bodies heat but result in poor feed conversions and when left the birds too warm, it would reduce feed intake and inhibits growth rate. Li Rong et.al [5] studied on dynamic performance of ECP using wind tunnel has found that when the control time cycle is arranged longer and the supply air velocity is bigger, the temperature drop between inlet and outlet ECP would be larger. This results would produce a higher cooling capacity for ECP as there is an adequate time and capacity for air supply to evaporate larger amount of water on the pad material surface, so then it would remarkable decreases the inlet air temperature and end to the quite low exhaust air temperature. Another study by Willits [6] found that by limiting the increase of supply air velocity and using an appropriate cooling technology, the cage indoor environment can be maintained properly. Liao and Chiu [7] studied that the desired cage indoor environment can be stably provided using the ECP as it was the least expensive technology which can bring the dry-bulb temperature to the convenience temperature range for the broilers accordingly. Furthermore Dagtekin et.al [8] investigated the ECP cooling efficiency results as the effect of implementing different parameters on the ECP has found that when the outside relative humidity lower than 50%, the 9^{o}C temperature different through cooling pad can be achieved and the cooling efficiency would gain to 70-72%. This study also suggested that to achieve the highest cooling efficiency for the ECP , the suction air speed passing through the pad should be in the range of 0.5 – 1.5 ms^{-1} and the highest cooling efficiency would be achieved at 1.0 ms^{-1} air speed. But another study by Kocaturk and Yildiz [9] found that the highest cooling efficiency would be reached at the air speed range of 0.5 – 2.0 ms^{-1}. This is then argued by Dactekin, that at the air speed less than 0.5 ms^{-1}, it would occurred the laminar flow and at the air speed higher than 1.5 ms^{-1}, the air residential time would be too short to evaporate water at the pad material surface and maintain mass transfer between air and water to have a proper relative humidity for the broiler cage. In investigating the ECP performances, the indoor air temperature changes should be considered, otherwise it would impact on the broilers performances. Koskela [10] in his investigation on the cage indoor air temperature found that the fluctuation of the indoor air temperature should be less than 5.0^{o}C within a few minutes; otherwise the broilers would experience a cold air-provoked respiratory syndrome, which then could cause a dropping of egg production. While other study on indoor air temperature fluctuation for broilers house in Beijing equipped with ECP by Tan [11] reported that when the indoor air temperature is adjusted not higher than 30^{o}C and not lower than 29^{o}C, it could be keep stable the indoor air temperature changes at 4^{o}C, by turning on/off the ECP pump. The same study by Han [12] concluded that when the outdoor air temperature > 30^{o}C and humidity < 50%, the indoor air temperature would decrease over 5^{o}C in a few minutes by using the ECP. Further research results in indoor environment profiles of broilers house by H.Xin et.al [13] reported that the use of ECP in the tunnel house for summer days could reduce about 8 to 12^{o}C of the incoming air temperature, and there is no birds dead related to the heat stress effect, also it was not found the birds crowding in any location in the tunnel house. Based on those all investigation, it obviously that the heat stress occurred in the broilers house/cage in hot and arid region could be minimized by keeping indoor cage temperature and RH stable. Consequently, to keep indoor cage environment stable, it is required to distribute cold air equally to the cage and maintain its residential time in the cage. For this purposes, it is necessary for the author to investigate the additions of hollowed air tunnel to the ECP in the shape of rectangular and cylinder, this would maintain cold air distribution equally to the cage space. The cold air residential time in the cage would be longer as the cold air distributed equally and in turn it would maintain the indoor cage environment low, the lower indoor temperature occurred would provide higher broilers performance and reduce the heat stress impact. The ECP has reached some remarkable results in cooling the broilers house when it equipped with air tunnel, so then the author is likely to conduct further investigation on the more specific uses of the ECP which is equipped by hollowed rectangular and cylinder air tunnel for broilers cage cooling system in hot and arid region and studied more the indoor temperature and RH occurred and its influences to the ECP performances including dry bulb temperature drop, cooling capacity, cooling effectiveness , energy efficiency ratio (EER), and evaporation rate (ER). In this research, the 240 m^{3} volume of a commercial real broilers cage is miniaturized into laboratory scale cage of 2.4 m^{3} in the form of testing box, in which the accumulated of incoming heat and indoor heat generated of 45 kW has been designed to be 450 W. The ECP is equipped with the rectangular and cylinder air tunnel, as the pad material is used kerosene stove wick which is wrapped into 23 PVC pipe in staggered arrangement.

The objective of the study are: (1) to investigate the influence of using the hollowed rectangular and cylinder air tunnel to the ECP performances; (2) to compare inlet and outlet air temperature distribution for each air tunnel type; (3) to provide knowledge information of applying the air tunnel ECP for commercial broilers cage.

2. Materials and methodologies

2.1. Experimental facilities

This experiment is conducted using the ECP hollowed air tunnel system as can be seen in **Figure 1**. The ECP frame is made of wood with 23 cooling pad pipe that is installed perpendicular to the ECP air suction direction. As material pad is used the kerosene stove wick which is wrapped in 1.0 m length of ¾” PVC pipe, with 12 mm thickness of kerosene stove wick and it arranged staggered along the wood frame. The pads is wetted with 10^{o}C wetting water in a stable wetting water discharge of 1949.94 ml/min by passing the water through a hollowed glass consisting 69 holes within diameter of each hole about 23 mm, as can be seen in **Figure 2**. The air suction is supplied by a mechanical fan in which the velocity is arranged in three levels including 1440 rpm (2.6 ms^{-1}); 1470 rpm (4.1 ms^{-1}) ; and 1500 rpm (5.7 ms^{-1}) which is respectively produced air volume rate of 0.416 m^{3}/s ; 0.656 m^{3}/s and 0.912 m^{3}/s.

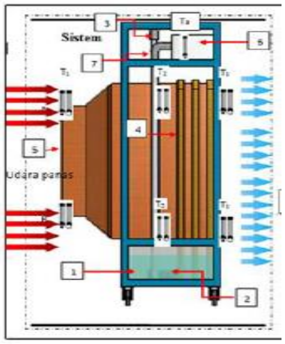

Figure 1: Evaporative Cooling Pad

1. Water Tank
2. Pump
3. Water Distribution Line
4. Pads
5. Fan
6. Wetting Water Reservoir
7. Overload Pipe

Water Discharge
1949,94 ml/min

Figure 2: Wetting water discharges arrangement

Figure 3 showed the construction of the hollowed air tunnel in the shape of rectangular and cylinder, which is installed in the front of cooled air discharge after passing through the cold wet pad , by then it is distributed into the broilers cage (testing box) and supplying lower air temperature. The rectangular hollowed air tunnel construction have 2.0 m length by 0.9 m width by 0.3 m height dimensions whithin 65 Ø 0.05 m holes that purposed to equal the cold air distribution into the broilers cage. While the dimension of the cylinder hollowed air tunnel is 2.0 m length with diameter of 0.59 m, which is had the same amount and diameter hole as the rectangular air tunnel.. These two hollowed air tunnel is installed along the testing box, so then the air distribution would be equal either in the location near to the cooling pad or far from the cooling pad.

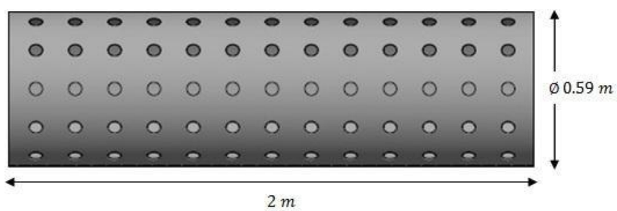

Figure3 (a): Cylinder hollowed air tunnel

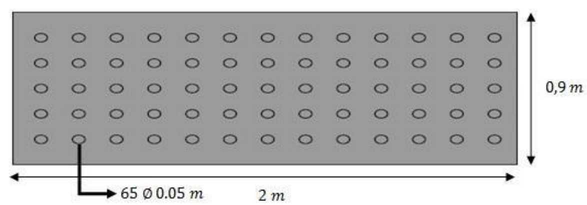

Figure3 (b): Rectangular hollowed air tunnel

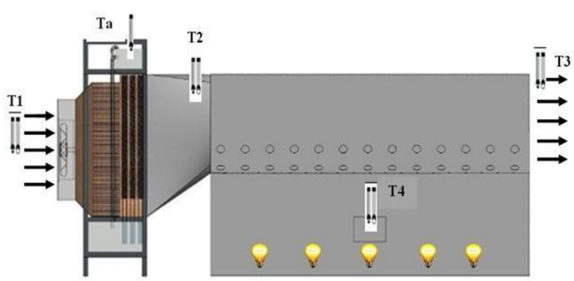

Fig.4. The ECP hollowed air tunnel experiment arrangement

2.2. Experiment procedures

The experiment is conducted as it shown in **Figure 4**, there are three levels of air velocity would be applied in this experiment including 2.6 ms^{-1} (rpm1=1440 rpm) ; 4.1 ms^{-1} (rpm2=1470 rpm) ; 5.7 ms^{-1} (rpm3=1500 rpm) and there would be two repetitions for each air velocity , for rectangular air tunnel and cylinder air tunnel respectively. Furthermore, for each experiment , it would be measured the dry and wet bulb of inlet air temperature before passing through to the cooling pad (T_1), cooling pad discharge air temperature or incoming air temperature to the air tunnel (T_2), air tunnel discharge air temperature (T_3) and indoor air temperature (T_4). For every single experiment is carried out in 60 minutes time. The wetting water temperature is kept stable for 10^{o}C (Ta). It is used data logger to record the air temperature. The cooling load is provided by four of 100 W light bulb and one 50 W light bulb. The volume of testing box that represented the 2400 m^3 real broiler cage is 2.4 m^3 and the real accumulated cooling load of 45,000 W is represented with 450 W cooling load of the testing box. The wetting water temperature is kept stable at 10^oC and discharge of 1949.94 ml/min. The operations of this ECP hollowed air tunnel experiment, as shown in Fig.4 is firstly the local ambient air temperature would pass through to the wet pad with stable 10°C water temperature (Ta) by the fan within the first air velocity of 2.6 ms^{-1} (1440 rpm), with cylinder air tunnel and it measured the dry and wet bulb air temperature as T_1 (Tdb_1 = 32°C and Twb_1= 24.8°C respectively). Cooling pad discharge air temperature is then measured as Tdb_2 and Twb_2, this discharge air would have a lower temperature and higher relative humidity than suction air temperature T_1, as it absorbed moisture and then lowering temperature of the suction air. This discharge air is then passed through to the testing box and absorbed the heat generated by the light bulb which is measured as T_4, after then it would discharged to the environment as T_3. The different between T_2 and T_3 would be used as temperature drop in this ECP system and in turn it would influence the performances of the ECP system. Then the experiment would be continued for the second and third air velocity respectively, with the same procedures as the first air velocity experiment and using the rectangular air tunnel. The experiment data would be recorded for two repetitions for each air velocity and each air tunnel type.

2.3. Mathematical equations

In this research, the ECP performances would be presented in air temperature different between inlet and outlet of the ECP system (Δ TdB), cooling effectiveness, cooling capacity, energy efficiency ratio (EER), and evaporation rate (Er). Considering this, some equations would be applied to calculate all of those performances above.

Temperature difference between inlet and outlet of the ECP system can be determined using Eq. (1):

$$\Delta TdB = TdBi - TdBo \quad (1)$$

Where T*dBi* denotes the inlet dry bulb air temperature,°C; T*dBo* is the outlet dry bulb air temperature, °C. This temperature difference is the most influential factor in determining the ECP performances. In this research, T*dBi* is measured at T*dB2* as inlet air temperature, as it can be seen in Figure 4, and T*dBo* is represented by T*dB3* as the cooling pad is equipped by the hollowed air tunnel to absorb heat from the testing box (cage), it can be described that the cooling process take place in the air tunnel. The cooling effectiveness is determined for the whole ECP system including its hollowed air tunnel.

The cooling effectiveness which described the characteristic of the ECP system is determined using Eq. (2):

$$\epsilon = \frac{T_{dB,i} - T_{dB,o}}{T_{dB,i} - T_{wB,i}} \quad (2)$$

Where T*dB,i* – T*dBo* is the dry bulb temperature different between inlet and outlet the ECP system; T*wB,i* denotes the inlet wet bulb air temperature.

The sensible cooling capacity of the ECP system by then it could be determined using Eq. (3) as the following:

$$q_s = Q \rho C_p (T_{dB,i} - T_{dB,o}) \quad (3)$$

In which qs denotes cooling capacity, kW; Q is air volume rate, m3/s; ρ is air mass density, kg/m^3; Cp is air specific heat, kJ/kg.K

Energy Efficiency Ratio (EER) described the comparison between the sensible cooling capacity and the input energy consumption for the ECP cooling system, it then could be determined using Eq. 4 as the following:

$$EER = \frac{Q \rho C_p (T_{dB,i} - T_{dB,o})}{P_t} \quad (4)$$

Evaporation rate (Er) can be determined by dividing the height water level different in the reservoir with apparatus mass before and after the experiment is conducted, it can be calculated using Eq.5 as written below:

$$Er = \frac{(\Delta ma) / \rho_{air}}{t} \text{ (liter/s)} \quad (5)$$

In which Er denotes evaporation rate, liter/hr; Δ *ma* is the apparatus mass different, kg; ρ water is water density, kg/m^3; t is experiment time, hour.

3. Results and discussions

3.1. The decreasing of dry air temperature in the ECP air tunnel

The decreasing of dry air temperature is the temperature difference between the inlet dry bulb air temperature and the outlet dry bulb air temperature of the ECP system. In hot and arid region, the inlet dry air temperature tend to have a higher temperature and lower relative humidity than the outlet dry bulb air temperature, as the inlet air passed through the pads, it would evaporate water contained in the pad, so that this air would have a larger amount of moisture (higher relative humidity) and lower temperature. The effect of the use of different type of air tunnel in the variety of air velocity could be seen in **Figure 5**

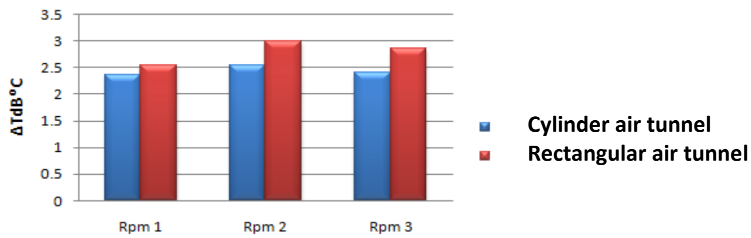

Figure 5: The dry air temperature decreasing

As shown in **Figure 5**, the rectangular air tunnel has a larger decreasing temperature different as it has a wider circumference area compare to the cylinder air tunnel, which then it can remove more heat when the cooling process occurred. The rectangular air tunnel has also a larger diagonal diameter, so that it has a larger Reynold number (Re) and in turn, this would make the air flow in the rectangular air tunnel become more turbulence and would keep the cold air even longer in air tunnel. In rectangular air tunnel, the higher the air velocity would give a higher air temperature decreasing, as the higher the air velocity, the more moisture would be conceived by the air and consequently this could lowering the air temperature significantly.

3.2. Effect of air velocity and air tunnel type to the cooling effectiveness

The cooling effectiveness described the characteristic of the ECP system, it influenced by the air temperature different between inlet and outlet side of the ECP which is equipped with hollowed air tunnel and the air temperature different is affected by the suction air velocity that passed through to the cooling pad. The effect of suction air velocity and air tunnel type to the cooling effectiveness, it can be seen in **Figure 6**;

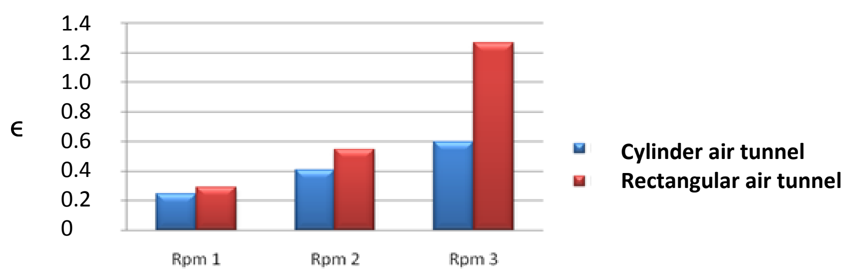

Figure 6: Cooling effectiveness characteristics

At a higher fan speed of rpm3 (5.7 ms^{-1} air velocity), the rectangular air tunnel has produced the highest cooling effectiveness at 1.239, this is caused the rectangular air tunnel has the wider cross-sectional area compared to cylinder air tunnel, then contact time between air tunnel and the cold air become longer, it would give the higher air temperature decreasing between inlet and outlet of the air tunnel. The higher the air temperature decreasing would result a higher cooling effectiveness. The evaporative cooling process in the air tunnel is described quite different to the evaporative cooling process on the pad. This would produce different air temperature decreasing between inlet and outlet of the pad and air tunnel evaporative cooling process. So that, this experiment has reached a different cooling effectiveness as previous study by Dagtekin et.al (2011), which concluded that highest cooling efficiency occurred at the lowest air velocity. In the pad, outside warm air would evaporate water in the pad surfaces, while in the air tunnel, the wet-cold moisture in the air tunnel would absorb the heat or cooling load generated in the testing box (as broilers cage).

3.3. Effect of air velocity and air tunnel type on cooling capacity

The cooling capacity become higher when the air velocity increases, in which the higher the air velocity would increase air flow rate passed through to the pads, the more heat would evaporate the cold water in the pad surfaces, in turn this would cause the air temperature different between inlet and outlet air tunnel increase and then increase the cooling capacity. It can be seen in **Figure 7**, the highest cooling capacity was occurred at the 5.7 ms^{-1} air velocity (rpm3) at about 0.4755 kW, and the lowest cooling capacity of 0.1725 kW is occurred in the cylinder air tunnel.

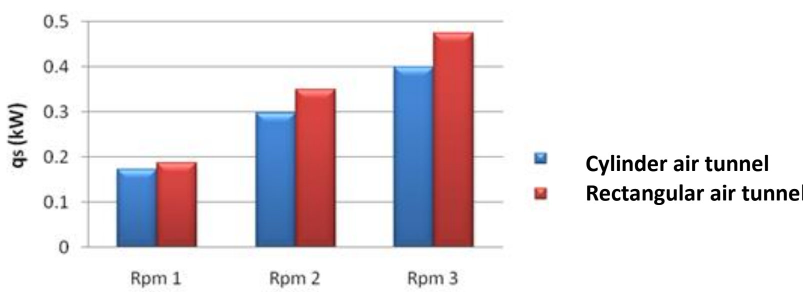

Figure 7: Cooling capacity on cylinder and rectangular air tunnel

3.4. Effect of air velocity and air tunnel type on Energy Efficiency Ratio (EER)

Energy Efficiency Ratio (EER) described the ratio between cooling capacity and cooling energy consumption, while cooling capacity is associated with the air temperature different in inlet and outlet side of air tunnel. The highest EER is given by the highest air velocity of 5.7 ms^{-1} (rpm3), this shows when the high velocity air passing through the pad, it would evaporate more water in the pad surfaces and consequently it would lowering the pads discharge air temperature, then the temperature air different would increase. The increasing of the temperature air different would increase the cooling capacity and the EER would also become increase. As it can be seen in **Figure 8**, the EER of 5.729; 4.222; and 2.255 is occurred in rectangular air tunnel with air velocity of 5.7 ms^{-1} (rpm3), 4.1 ms^{-1} (rpm2); and 2.6 ms^{-1} (rpm1) respectively. The highest EER is occurred at the highest air velocity in rectangular air tunnel, due to the wider cross-sectional area of the rectangular air tunnel that would turbulence the air flow.

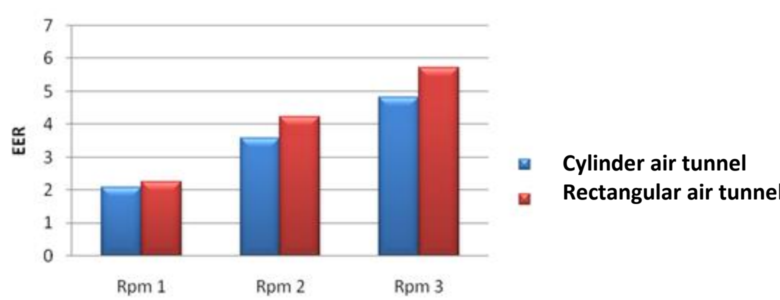

Figure 8: Energy Efficiency Ratio occurred

3.5. Effect of air velocity and air tunnel on evaporation rate

Evaporation rate (Er) described the rate of water evaporated from the pad due to the latent heat of the suction air temperature passed through to the pad and this would increase air humidity.

Table 1: Air temperature in cylinder air tunnel

Cylinder Air Tunnel		Rpm I	Rpm II	Rpm III
T1 ^{0}C	TdB 1 ^{0}C	31.35	29.65	29.1
	TwB 1 ^{0}C	24.5	24.2	23.9
T2 ^{0}C	TdB 2 ^{0}C	25	24.35	23.8
	TwB 2 ^{0}C	23.1	23.1	23
T3 ^{0}C	TdB 3 ^{0}C	27.35	26.9	26.2
	TwB 3 ^{0}C	24.5	24.35	24
T4 ^{0}C	TdB 4 ^{0}C	38.65	38.35	38
	TwB 4 ^{0}C	32	31.65	31.9

Table 2: Air temperature in rectangular air tunnel

Rectangular Air Tunnel		Rpm I	Rpm II	Rpm III
T1 ^{0}C	TdB 1 ^{0}C	31.8	31	29.65
	TwB 1 ^{0}C	24.8	24.35	23.65
T2 ^{0}C	TdB 2 ^{0}C	25.1	24.35	23.8
	TwB 2 ^{0}C	23.35	23.25	23.35
T3 ^{0}C	TdB 3 ^{0}C	27.65	27.35	26.65
	TwB 3 ^{0}C	24.35	24.35	24.35
T4 ^{0}C	TdB 4 ^{0}C	39.35	37.9	37.35
	TwB 4 ^{0}C	32.65	31.2	31.65

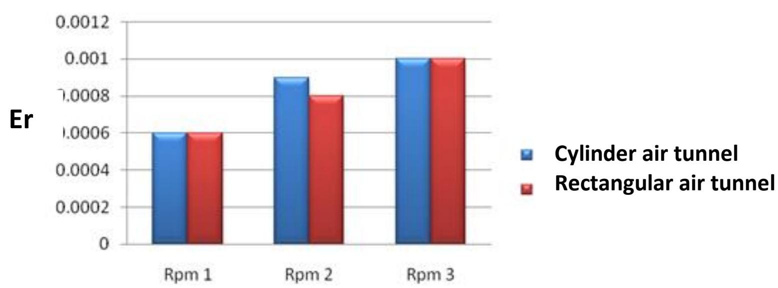

Figure 9: Evaporation rate achieved

From **Figure 9**, it shows that there is no a significant different of the evaporation rate between the cylinder and rectangular air tunnel , only at 4.1 m^3/s air velocity (rpm2), there is a slightly different on the evaporation rate of 0.0009 and 0.0008 liter/min for the cylinder and rectangular air tunnel respectively. At the highest air velocity of 5.7 ms^{-1} (rpm3), the two air tunnel shape have had the same evaporation rate of 0.001 liter/min, this would simultaneously increase the air humidity and decrease the air temperature at the same time. As it can be seen at **Table 1** and **Table 2**, the suction air temperature in the cage would decrease from 31^{o}C to 24.35^{o}C using rectangular air tunnel, and when using cylinder air tunnel the suction air temperature decreased to 24.0^{o}C. The higher evaporation rate, the more water in the pad would be evaporated by the latent heat of the suction air, as the more heat of the suction air is used, the lower air temperature would be reached in the testing box (cage).

3.6. Effect of air velocity and air tunnel on relative humidity.

Relative Humidity (RH) is determined using the psychometric chart that represented by the dry and wet bulb air temperature. It described the ratio between the moisture actual partial pressure and moisture saturated partial pressure at a certain dry bulb air temperature. The relative humidity reached by using the hollowed cylinder and rectangular air tunnel on the ECP system can be seen in **Table 3** and **Table 4** as follows,

Table 3: Air temperature distribution using air tunnel

Air Temperature (^oC)				
Air Tunnel		Rpm 1	Rpm 2	Rpm 3
Cylinder	TdB	38.65	38.35	38
	TwB	32	31.65	31.9
Rectangular	TdB	39.35	37.9	37.35
	TwB	32.65	31.2	31.65

Table 4: Relative humidity using air tunnel

Relative Humidity (%)			
Air tunnel	Rpm I	Rpm II	Rpm III
Cylinder	63.019	62.615	65.4
Rectangular	63.147	62.368	67.11

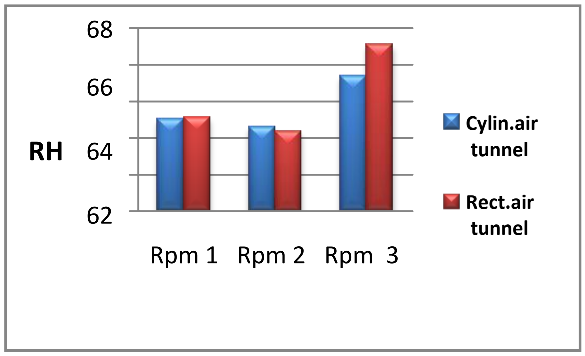

Figure 10: Relative Humidity distribution

According to this results, **Figure 10** showed that the highest RH of 67.11% can be achieved at the 5.7 ms^{-1} air velocity using the rectangular air tunnel. Due to at the higher air velocity in the rectangular air tunnel, there would be contained more moisture compare to the lower air velocity of 4.1 ms^{-1} and 2.6 ms^{-1} air velocity that give RH of 62.368% and 63.147% respectively, as it can evaporate more water from the pad surface and within the wider circumference area of the rectangular air tunnel, it would absorb more heat from the cooling load, so then the indoor box air temperature would be much lower into 24^{o}C. It also found in this research that in the cylinder and rectangular air tunnel , the incoming air become cooler and dehumidify in which there would be slightly increase of air temperature and dehumidified the incoming air as the indoor heat is absorbed by the cold humid incoming air.

3.7. The study contributions to the food security program

In this stage, the study on the ECP system using cylinder and rectangular air tunnel can be a good prospect to the breeder especially in Bali which generally has a hot and arid climates. This ECP system can provide a more distributed cold and humid air of about 24^{o}C and 67% RH to the broilers cage, so that it could be expected to minimize heat stress level of the broilers in the cage, which is in turn it probably could reduce mortality level of the broiler. This results has satisfied the thermal comfort standard for the broilers. The cage with the broilers at the age of more than 15 days should has indoor air temperature of 24-25^{o}C and RH of 60-70%.[14] also for the broiler and laying hens would has a better production when it has the indoor cage air temperature of 11-26^{o}C [15]. As an additional information, this study is based on the real broiler cage which is located in Kerambitan village, Tabanan, Bali with the real cage volume of 2400 m^3 and 1250 broilers. With the outside cage temperature of 31^{o}C and indoor cage temperature of 36^{o}C, 50% RH and only uses mechanical fan as a cooling system, it can be stated that the broilers has a high heat stress level , in which this cage has a mortality level of 3-4% (200 – 300 broilers). Further more the high mortality percentage would impact on the breeder production and in turn would decrease the security of food. So then, it probably would be worthed to use the hollowed air tunnel ECP system to provide thermal comfort for the birds, by distributing the cold and humid air more equally to the cage, it could provide 24^{o}C and 67% RH cold air to the cage at the air velocity of 5.7 ms^{-1}. At the end,this cooling system could be expected to reduce the heat stress level and the mortality level of the birds and improve the food security program.

4. Conclusion

The performances study of the hollowed air tunnel ECP system has found that the lowest cage indoor air temperature of 24^{o}C and the highest relative humidity of 67% has been resulted at a higher air velocity of 5.7 ms^{-1} (1500 rpm fan speed) and using the hollowed rectangular air tunnel and this results has been satisfied the thermal comfort requirement for the birds. It found that the higher the air velocity, the higher ECP performance would be achieved. This results as well indicated that the hollowed air tunnel ECP system could be used to distribute the cold and humid air more equally and reduce heat stress level from initial indoor cage environment of 36^{o}C and 50% RH to the lower heat stress level of 24^{o}C and 67% RH and it could satisfied the birds thermal comfort requirement . Other hollowed air tunnel ECP performances has been resulted including cooling effectiveness of 1.24 ; cooling capacity of 3.2 kW ; Energy Efficiency Ratio of 38.7; and Evaporation rate of 0.001 lt/min, these results has occurred at the highest air velocity of 5.7 ms^{-1} (1500 rpm fan speed) and using hollowed rectangular air tunnel.

ACKNOWLEDGMENT

This research has been funded by Research and Community Service for Prosperity of Udayana University (LPPM-UNUD) Denpasar, Bali, Indonesia in the research scheme of Udayana Superior Research Grant for 2017 Academic Year. We convey our sincere appreciation to LPPM UNUD, as well as for Energy Conversion Laboratory in Mechanical Engineering Department, Faculty of Engineering of their kind helpful in assisting this work accomplished properly.

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