THE INFLUENCE OF WETTED SURFACE OF SUPER GREEN B SPONGE ON TEMPERATURE, RELATIVE HUMIDITY OF AIR AND POWER EFFICIENCY OF BLOWER AT EVAPORATIVE COOLING SYSTEM

La Choviya Hawa[•]

Abstract

Temperature and relative humidity of air were factors that influenced the evaporative rate of vegetables. The evaporative rate become higher at high temperature and low relative humidity. This is caused by the high gas partial pressure difference between air of storage and vegetables.

One method to slow down the metabolism activity of agricultural product was to decrease air temperature and to increase the relative humidity. Humidifying the air can be done by spraying water to the unsaturated air stream. The sensible heat of air was used to evaporate the water from liquid phase to gas phase, therefore result the temperature of process became lower than before. This process called evaporative cooling which its and the mechanism was heat transfer between air and water.

The objectives of this research was utilizing evaporative process and knowing the influence of wetted surface on temperature, relative humidity and power blower efficiency.

This study was performed using seven treatments at evaporative cooling system i.e. : no sponge,1 sponge layer, 2 sponge layer, 3 sponge layer, 1 sponge + water, 2 sponge + water, 3 sponge + water. The parameters measured were dry bulb and wet bulb temperatures process, air pressure of fan, temperature and relative humidity of air room, temperature of water from nozel. To analize the parameters used thermodynamic analizes without factorial design.

The result showed that the thicker wetted surface applied with spraying water the lower temperature gained and the relative humidity become higher. The greatest temperature decrease in 3 sponge + water treatment was 2.29°C, relative humidity 89.09% and the lowest temperature decrease in 1 sponge+water treatment was 1.74°C and relative humidity was 85.27%. The addition of sponge with spraying water would reduce the mass rate of air output from blower and decrease the power blower efficiency. The highest power efficiency in 1 sponge layer treatment was 62.93% and the lowest power efficiency in 3 sponge + water treatment was 22.57%.

Keyword : evaporative cooling

[•] Agricultural Engineering Department, Faculty of Agricultural Technology, Brawijaya University, Malang

PREFACE

Temperature and relative humidity of air were factors that influenced the evaporative rate of vegetables. The evaporative rate become higher at high temperature and low relative humidity. This is caused by the high gas partial pressure difference between air of storage and vegetables.

One method to slow down the metabolism activity of agricultural product was to decrease air temperature and to increase the relative humidity. Humidifying the air can be done by spraying water to the unsaturated air stream. The sensible heat of air was used to evaporate the water from liquid phase to gas phase, therefore result the temperature of process became lower than before. This process called evaporative cooling which its and the mechanism was heat transfer between air and water.

The objectives of this research was utilizing evaporative process and knowing the influence of wetted surface on temperature, relative humidity and power blower efficiency (Kulshrestha, 1989).

At evaporative cooling process, one factor that influenced the effectiveness of saturated air was wetted surface that used as medium contact between air and water. It was hoped that the existance of wetted sponge would lengthen contacting duration between water and air, therefore water can be evaporated become cool air (Wang,1990)

The objective of this research was using the evaporative process and knowing the influence of wetted surface on temperature, relative humidity and power blower efficiency.

REFERENCES

Psychrometry was a study about the properties of dry air and water vapour because atmospher was not really dry but the mixture between dry air and water vapour.

Relative Humidity (∅)

Relative humidity was a comparison of water vapour molecules fraction in wet air againts water vapour saturated molecules at the same temperature and pressure (Stoecker and Jones, 1989).

$$\phi = P_v / P_s \qquad (1)$$

Humidity Ratio (w)

Humidity ratio was a water mass in every kilograms dry air (Stoecker and Jones, 1989)

$$w = m_w / m_a \qquad (2)$$

Dalton Law said that the pressure of gas mixtures was an addition from the pressure of elements in the same volume. For moist air, total pressure was :

$$P_t = P_a + P_v \qquad (3)$$

with assumed that moist air was perfect gas, so humidity ratio was :

$$w = 0.622 \frac{P_v}{P_t - P_v} \qquad (4)$$

from Kulshrestha (1989), partial vapour pressure was :

$$P_v = P_{vb} - \frac{(P_t - P_{vb})(T_{bk} - T_{bb})}{1555.56 - 0.722\, T_{bb}} \qquad (5)$$

Enthalphy (h)

Entalphy was calor energy from matter in one temperature, so the entalphy of moist air with humidity ratio x kg at t°C temperature was calor energy needed to boiling 1 kg dry air and x kg water from 0°C until t°C and evaporating it become water vapour (Arismunandar & Saito, 1981). Entalphy of moist air was :

$$h = 1.005\ T + w\ (2501.4 + 1.88\ T) \quad \ldots.(6)$$

Sentrifugal Blower

The ideal power that needed by fan consist of two parts, were power to raise pressure and power to give kinetics energy at moved air.

Ideal power that needed to raise pressure was :

$$Power = Q_a(p_2 - p_1)\ Watt \quad \ldots\ldots\ldots(7)$$

whereas ideal power to give kinetics energy at moved air was :

$$Power = \frac{w_a V^2}{2}\ Watt \quad \ldots\ldots\ldots\ldots(8)$$

so the combination from two ideal power was :

$$Power_{ideal} = Q_a(p_2 - p_1) + \frac{w_a V^2}{2}\ Watt..(9)$$

RESEARCH METHOD

The research was held in Laboratory of Processing Engineering, Agricultural Engineering Department, Faculty of Agriculture Technology in August 1999 until September 1999.

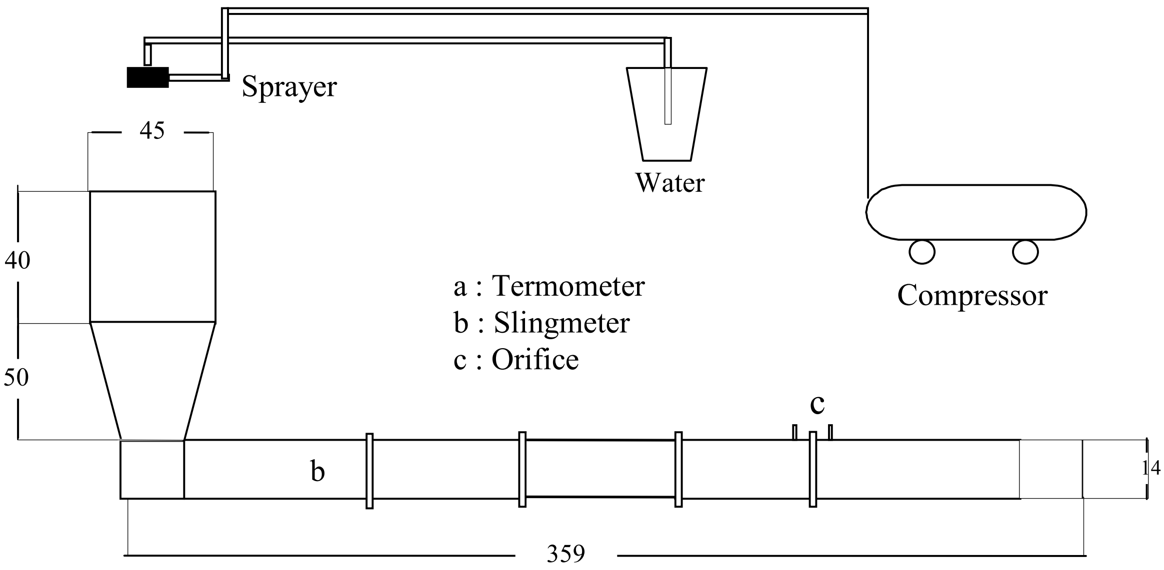
Materials use in this research were water, air, sponge type green super B, 2.5 cm in thickness. Instruments that used were manometer for measuring air pressure, sling meter for measure dry and wet bulb's temperature.

Structural design of evaporative cooling system was made from galvanized iron sheet and covered by glass wool 1 cm in thickness. This units consist of two parts. First part was cylinder with diametres 45 cm and 40 cm, and second part was a turned up cone with 14 cm in diametres and 50 cm in high. They were connected to blower using PVC pipe 14 cm in diametres. The sponge with thickness 2.5 cm and 45 cm in diametres was put on evaporative cooling unit as contact medium between air and water. The air output process had 14 cm in diametres and total length 421 cm. The fan as blower air was put on outlet in 62 cm from start duct. The picture of structural plan design can be seen at Picture 1.

Functional design of evaporative cooling system consist of compressor to push water to the nozel, one set of airflow (blower) to flow air came to the system and gas nozel modified to distribute water into sponge.

Engineering analyze were analyses in mass and heat transfer in evaporative cooling system i.e. : (1) air mass flow rate, (2) initial air condition, (3) actual result of air condition, (4) theoritical result of air condition, (5) water evaporating stream rate, (6) power efficiency of blower.

Boundary of system that used in evaporative cooling was open system, that water and air stream enter and eject through a measured point. Heat transfer process in the system being assumed only happened because of contact between water and air. To simply the analises, we have assume : water mass and air were constant, initial temperature water and air were constant, water spraying stream rate was constant.



Picture 1. Structural Diagram of Evaporative Cooling System

RESULT

Evaporative Cooling Process

The relative humidity of room when research carried out was 71.58 % with 27°C dry bulb temperature and 23°C wet bulb temperature. The result in this research presented in Table 1.

Heat and mass transfer process in evaporative cooling system happened because of the contact between unsaturated air with water. Sensible heat of air was used for evaporating water from liquid phase to gas phase (steam). The total of sensible heat that absorbed by water mass was equal with total of latent heat that needed to change water liquid to gas.

Heat transfer from air to water happened because air temperature was higher than water temperature. The average temperature on sponge surface was 18°C and initial temperature of water before getting into nozzle was 22°C. So, when water mass was pressed to flow through the nozzle, it would reduced water temperature until 4°C.

2 kg/cm^2 pressure given by compressor to water stream caused pressure reduction of water output from nozzle. It was carried out because the nozzle hole being narrow. The reduction of static pressure happened in nozzle hole will decrease water temperature.

Table 1.
Influence of Treatment in Final Air Condition

Treatment	The Increased of RH (%)	The Temperature Reduction (°C)	
		Research	Theoretical
No Sponge	4.00	0.28	1.05
1 Sponge Layer	4.00	0.28	1.05
2 Sponge Layer	4.00	0.28	1.05
3 Sponge Layer	4.00	0.28	1.05
1 Sponge + Water	11.38	1.42	1.59
2 Sponge + Water	13.67	1.73	1.79
3 Sponge + Water	17.48	2.29	2.71

Temperature

The final temperature reduction of treatment no sponge,1 sponge layer, 2 sponge layer, 3 sponge layer were constant 0.28°C. In no sponge treatment, the decreased of air temperature happened because the effect of air velocity from blower. In 1 sponge layer, 2 sponge layer, 3 sponge layer, the decreased of air temperature happened because when evaporated process, some part of water vapour from outside (environment) go inside and accumulated to the pores of sponge so that the temperature result of air became lower than before even though without water spraying.

At wet treatments (1 sponge + water, 2 sponge + water, 3 sponge + water), the highest temperature decreased happened on 3 sponge + water was 2.29°C and the lowest decreased on 1 sponge + water was 1.42°C. The result showed that the increase of sponge thickness caused the increase of final temperature reduction. This is caused by sponge could hold water and inhibit water stream rate, so the time of heat transfer from air to water became longer, causing the increase of temperature reduction. From Table 1 we can show the relationship between the temperature reduction actually and theoretically againts treatments in Picture 2.

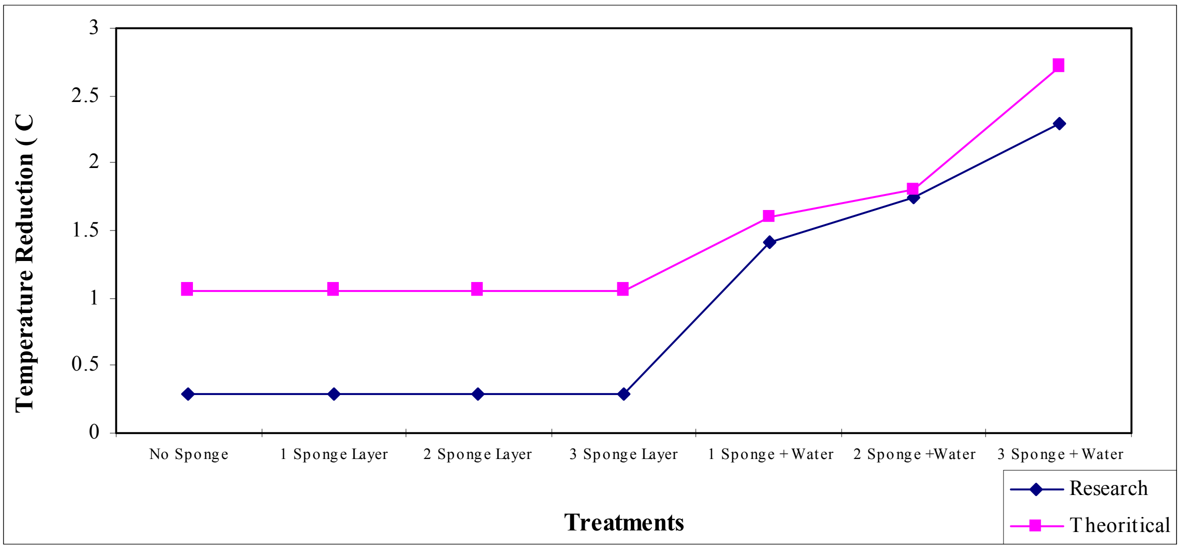
Sponge as blower's barrier made the pressure of sponge pores less than atmosphere pressure. Therefore the evaporative temperature reduction followed the termodynamics law of water. Indeed, by thickening sponge, evaporation temperature became lower and final temperature reduction will be higher than before.

In this case the temperature reduction was very low. It was caused by the input RH was 71.38%, so total of evaporated water mass was also small. This is appropriate with phisical phenomenon stated by Hall (1980). He said that the low RH caused the increased of vapour need to reach RH 90% and temperature reduction became higher.

The temperature difference rate decreased of research and theory was 0.53°C. This difference happened because there were an entalphy increased of air after compression of blower machine and temperaure measured of research carried out after blower.

Relative Humidity(RH)

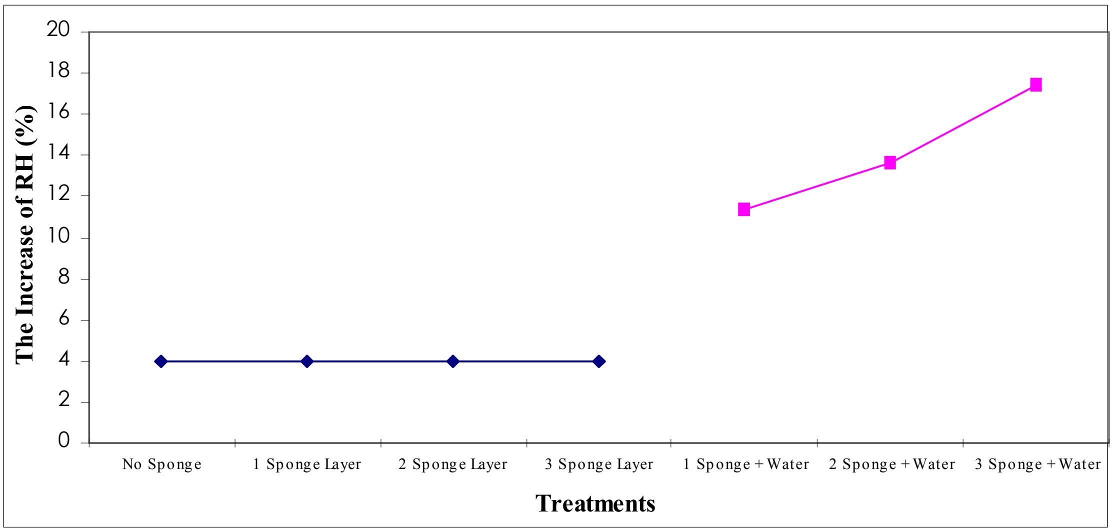
The increase of air relative humidity and evaporative rate research result presented in Table 2.



Picture 2. The Relationship between Temperature Reduction vs Treatments

Table 2.
The Increase of Relative Humidity in Evaporative Cooling System

Treatment	The Increase of RH (%)	Evaporative .Rate.(10^{-4}kg/s)		
		Research	Theory	Difference
No Sponge	4.00	1.469	0.682	0.787
1 Sponge Layer	4.00	1.236	0.849	0.387
2 Sponge Layer	4.00	1.074	0.735	0.339
3 Sponge Layer	4.00	0.912	0.625	0.287
1 Sponge + Water	11.38	2.070	1.237	0.833
2 Sponge + Water	13.67	2.269	1.616	0.653
3 Sponge + Water	17.48	1.685	1.542	0.143



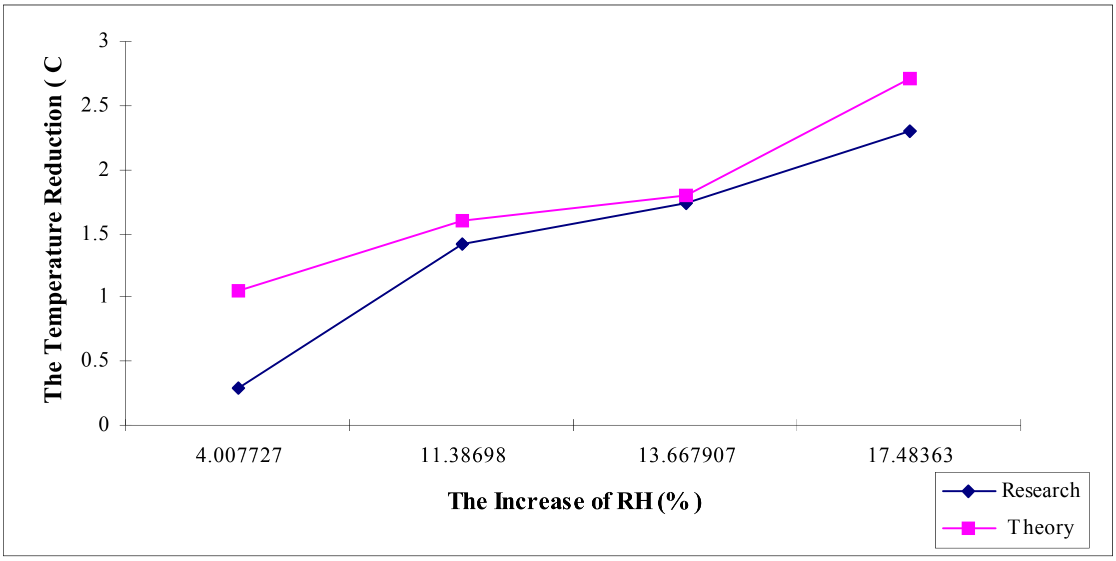
Picture 3. The Relationship between The Increase of RH vs. Treatments

From Table 2 we can made the relationship between relative humidity and treatments at Picture 3.

The final relative humidity on treatments no sponge,1 sponge layer, 2 sponge layer, 3 sponge layer were constant, 75.61%. In no sponge treatment, the increase of RH happened because of the effect of air velocity from blower. In 1 sponge layer, 2 sponge layer, 3 sponge layer treatments, the increase of RH happened because when evaporated process held, part of water vapour from outside (environment) go inside and accumulated to the pores of sponge so that the RH result of air became higher than before even though without water spraying.

At wet treatments (1 sponge + water, 2 sponge + water, 3 sponge + water)the highest RH increased happened on 3 sponge + water was 17.38% and the lowest increased on 1 sponge + water was 11.38%. This result showed that the increased of sponge thickness caused the increase of final RH. This is caused by sponge could hold water and inhibit water stream rate, so the time of heat transfer from air to water became longer, causing the increase of relative humidity.

From Table 2 we can show the relationship between the increased of relative humidity with the decrease of temperature presented in Picture 4.



Picture 4. The Relationship Between The Increase of RH vs The Temperature Reduction

Picture 4 shows that the higher the relative humidity of air stream the greater the temperature decreased. This unlinear air temperature decreased at relatively equal with the increase of relative humidity happened because the variation of water mass flow rate in to the sponge, and its influencing the rate of heat exchanger from air to water. The difference between research result and theory shown that the process carried out in an unadiabatic process which indicated with entalphy increased of air, so temperature reduction of research lower than temperature of theory at the same relative humidity point.

The relationship between the increased of relative humidity and temperature reduction could be expressed linearly as follow :

$$Y = 0.5186\ X + 0.4941 \ldots\ldots\ldots\ldots(10)$$

where correlation factor r = 0.9838, X is the increased of relative humidity (%) and Y is the temperature reduction (°C).

The actual temperature reduction predicted by reducing correction factor rate of actual air temperature and theoritically air temperature with 0.53°C. Therefore the equation become :

$$Y = (0.5186X + 0.4941) - 0.53056\ldots.(11)$$

Equation 11 only applied in relative humidity range between 45.62% - 89.09% or when research carried out.

Power Blower Efficiency

Blower efficiency was a comparison between ideal power againts actual power each treatments with comparison between ideal power againts actual power without sponge treatments. The results of pressure drop, air flow rate, ideal power of blower and blower efficiency presented in Table 3.

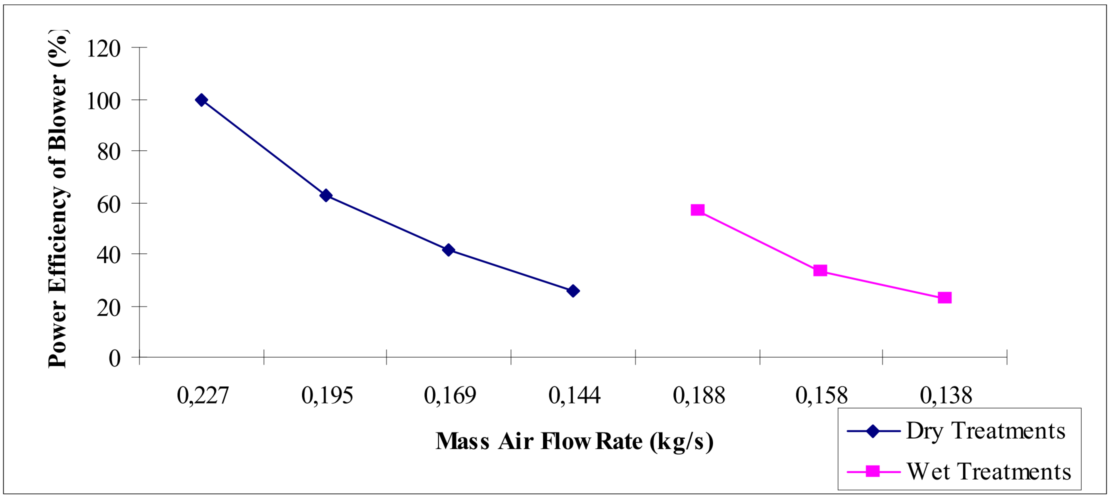
The highest blower efficiency happened on 1 sponge was 62.97% and the lowest on 3 sponge + water was 22.565%. This efficiency agreed as Wang recomendation (1993), that for forward-curved sentrifugal blower, the range of efficiency between 60 - 75%. According to Perry (1981), forward-curved sentrifugal blower has efficiency 40 - 80%.

The relationship between mass airflow rate with power blower efficiency presented in Picture 5.

Table 3.
The Result of Blower Efficiency in Evaporative Cooling System

Treatments	Pressure Drop (Pa)	Air Flow Rate (kg/s)	Ideal Power of Blower (Watt)	Efficiency (%)*
No Sponge	441.26	0.227	0.224	100.00
1 Sponge Layer	323.59	0.195	0.140	62.92
2 Sponge Layer	245.15	0.169	9.28×10^{-2}	41.50
3 Sponge Layer	176.51	0.144	5.67×10^{-2}	25.34
1 Sponge+Water	300.71	0.188	0.126	56.33
2 Sponge+Water	212.46	0.158	7.49×10^{-2}	33.52
3 Sponge+Water	163.433	0.138	5.05×10^{-2}	22.56

* Comparison of each treatments efficiency with no sponge treatment



Picture 5. The Relationship between Mass Air Flow Rate vs Power Efficiency of Blower

It shows that the existance of sponge in dry treatments (no sponge, 1 sponge layer, 2 sponge layer, 3 sponge layer) and spraying water in wet treatments (1 sponge + water, 2 sponge + water, 3 sponge + water) could reduce mass air flow rate from blower , which was indicated with a decreasing pressure measured at orifice. That two points would influence power blower efficiency. The result of power blower efficiency equal with ideal power each treatments. The lower the ideal power the lower the power blower efficiency.

.CONCLUSION

1. In 1 sponge + water, 2 sponge + water, 3 sponge + water treatments the thicker the sponge layer the greater the temperature reduction and the higher the relative humidity. The relationship between air relative humidity (X %) and temperature reduction (Y °C) was Y = (0.5186X + 0.4941) - 0.53056, for relative humidity between 75.62 % - 89.09 %.
2. The highest of temperature reduction occured at 3 sponge+water treatment was 2.29 °C and relative humidity was 89.09%. The lowest temperature reduction at 1 sponge + water was 1.74 °C and the relative humidity was 85.27%.
3. The highest blower eficiency at 1 sponge layer was 62.93% and the lowest blower efficiency at 3 sponge + water was 22.57%.

SUGGESTION

1. Further research was needed to make the temperature reduction much greater and to raise relative humidity. Those achieved by: (1) lengthen the pipe between wetted surface and blower, (2) substituting sponge with another wetted surface that easy to absorb water and easy to evaporate water, (3) and carrying out research between May - September (dry season).
2. Further research was needed to increase power blower efficiency with substituting blower that have big power input so the efficiency will increased.

REFERENCES

Arora, C.P. 1981. *Refrigeration and Air Conditioning*. Tata Mc Graw Hill Publishing Company Limited. New Delhi.

Geankoplis, C. J. 1997. *Transport Process and Unit Operations*. Prentice Hall of India. New Delhi.

Henderson S. M and R. L. Perry. 1996. *Agricultural Process Engineering*. The AVI Publishing Company, Inc. Wesport. Connecticut.

Kulshrestha, S. K. 1989. *Buku Teks Termodinamika Terpakai, Teknik Uap dan Panas*. Terjemahan Budiharjo, I Made Kartika D, Budiarso. Penerbit Erlangga. Jakarta.

Narang G. B. S and J. K. Jasna. 1980. *Refrigeration and Air Cooling*, Katson Publishing House. Incorporating Katana and Sons. Ludhiana.

Stoecker, F. W dan J. W. Jones. 1989. *Refrigerasi dan Pengkondisian Udara*. Terjemahan Supratman Hara. Penerbit Erlangga. Jakarta.

Toledo, R. T. 1980. *Fundamental of Food Process Engineering*. The AVI Publishing Company, Inc. Wesport. Connecticut.

Wang, S. K. 1993. *Handbook of Air Conditioning and Refrigeration*. Mc. Graw Hill.