Experimental study the effect of CaCl2 solution temperature variation as a liquid desiccant on regeneratorhumidifier performance

by Efilta Yohana

Experimental Study the Effect of $CaCl_2$ Solution Temperature Variation as A Liquid Desiccant on Regenerator/ Humidifier Performance

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Abstract. In the food and beverage industry, drying is one of the most important factors in maintaining the durability of these foods. The technology that is often used is to use the spray drying method which converts the extraction of food and beverages into solid powder. In spray drying, air is used as the drying medium. So that air conditions are the main focus. One of the most frequently used air conditioning techniques is dehumidification, which is by reducing the moisture content in the air by using a liquid desiccant as the working medium. Calcium chloride ($CaCl_2$) solution was chosen because it is safe for food. During the dehumidification process, over time the $CaCl_2$ solution will reach a saturation point where it loses its ability to absorb water vapor in the air. Therefore a regeneration process is needed to restore its ability, namely by using a regenerator or humidifier which in this study uses a counter flow type of flow. This study aims to examine the effect of temperature variations of $CaCl_2$ on humidifier performance as read from changes in air temperature and humidity and the data obtained have been validated by previous research. From this study it was found that the higher the temperature of $CaCl_2$, the higher the addition of moisture in the air, which means that more water vapor is lost in the $CaCl_2$ solution.

INTRODUCTION

The shelf life of food and beverage ingredients will increase significantly when converted into dry powder form, through a drying process that uses a lot of spray drying technology in the industrialized world [1]. Spray drying is a unique process in which the extraction of food and beverage ingredients is converted into solid particles through an atomization process using a sprayer and into individual droplets that come into contact with the drying medium in the form of hot and dry air, resulting in fast evaporation of water [2].

Humid air can inhibit the drying process of a food and will trigger the growth of bacteria that can be harmful to consumers. But air that is too dry will also cause some problems, such as case hardening, an event where the outside of food is dry but the inside is still wet. This will cause the growth of mold on the food. In addition, if the drying is carried out, the air temperature is too high, it will damage the contents of the food, such as nutrients, vitamins and others. Therefore, the temperature of the drying air must be controlled so as not to damage the food.

There is an alternative air conditioning system, namely the dehumidification process with "desiccant" as the working fluid. Desiccant has hygroscopic properties, which is able to absorb water vapor contained in the air. This selection is due to the advantages of being able to achieve low humidity, energy saving and environmentally friendly [3] [4] [5].

The dehumidification process is the process of reducing water vapor contained in the air. As it is known that air consists of various elements and compounds, one of which is water vapor (H_2O). Moisture content in the air will affect the humidity level of the air. If the humid air comes into contact with the liquid desiccant that is sprayed on the dehumidification tower and there is a partial vapor pressure difference between the liquid desiccant and air, there will be a mass transfer in the form of water vapor displacement [6].

Liquid desiccant used in air conditioning systems must have characteristics, have a high absorption capacity, are not easily changed structurally or chemically, do not contain toxins, and are not flammable. And the ones most often used in dehumidification technology are lithium chloride (LiCl), lithium bromide (LiBr), calcium chloride ($CaCl_2$), triethylene glycol and other salt mixtures. $CaCl_2$ is an alternative that has the advantage of being cheap and safe for food, but its stability depends on the intake air conditions and the concentration of $CaCl_2$ solution itself [7] [8].

During the process of absorption of water vapor in the air, over time the $CaCl_2$ solution will reach its saturation point where it loses its ability to absorb water vapor in the air. Therefore a regeneration process is needed to restore its ability, namely by using a regenerator or humidifier. Its working principle is to remove moisture in the liquid desiccant. [9].

The regeneration process occurs in the humidification tower, using a counter flow type with air flow from bottom to top and the liquid desiccant is sprayed with a downward pressure nozzle which has previously been heated on the heater to reach a certain temperature which aims to increase the partial pressure of the liquid desiccant which will later causes mass transfer from the liquid desiccant to the air that it contacts during the regeneration process. After the liquid desiccant is free from moisture content, the liquid desiccant is ready to be used again in the dehumidifier so that the process can run continuously [10] [11].

In the operation of this regeneration system, several things need to be considered in order to get maximum results, namely: the properties of the liquid desiccant such as the concentration of $CaCl_2$ solution and several process parameters such as heating temperature, desiccant liquid flow rate and air flow rate.

Therefore, this study was conducted to test the effect of heating temperature variations of $CaCl_2$ solution as a liquid desiccant on the humidifier performance which will be read from changes in temperature and humidity in the sample house and data validated by previous studies.

MATERIALS AND METHODS

Humidifier Description

Humidifier is one of the important components in air conditioning system that uses a liquid where the liquid desiccant is in direct contact with air and a process of heat and mass transfer occurs between the two fluids. As seen in Figure 1, in the humidifier, the liquid desicant that has been used for the dehumidification process contains water which will come into contact with drier air, so that the liquid desicant concentration can return to normal and can be reused in the dehumidification system.

FIGURE 1. A series of research tools

Development Model

If air flows over a wet surface, there will be a simultaneous transfer of sensible heat and latent heat. If there is a temperature difference between the air (T) and the wet surface (T_w) then the heat will be removed. If there is a difference in the partial pressure of water vapor in the air (p_v) and the pressure in water (p_w), mass transfer (water) will occur. This mass transfer also causes transfer of heat energy, because when water vapor condenses, latent heat must be removed from the water. Conversely, if a certain amount of liquid evaporates from the water layer, the heat of evaporation must be applied to the evaporating water.

The rate of sensible heat transfer from the surface of the water to the air (Q_s) can be calculated by the convection equation,

$$dQ_c = h_c\, dA(T_w - T) \tag{1}$$

The rate of mass transfer from the surface of the water to the air is proportional to the pressure difference $p_w - p_v$. The moisture ratio is almost proportional to the vapor pressure, so that an equilibrium relationship can be made,

$$\text{Mass transfer rate} = h_D dA(m_w - m) \tag{2}$$

Since displacement to or from water causes heat transfer (as a result of condensation or as a result of evaporation), then

$$dQ_L = h_D dA(m_w - m) h_{fg} \tag{3}$$

It seems difficult to determine an exact value for the convection coefficient h_c for special circumstances, so more data are needed to determine the convection coefficient of sensible heat transfer than the mass transfer coefficient of proportionality (h_D). Fortunately, the displacement mechanism on the surface of the water regulates the rate of sensible heat transfer in the same way that it regulates the mass transfer rate. So, there must be a comparable relationship between h_D and h_c. This balance is expressed by

$$h_D = \frac{h_c}{c_p} \tag{4}$$

The specific heat of wet air is based on 1 kg of dry air so that it is the sum of the specific heat of dry air and the specific heat of water vapor

$$c_p = c_{pa} + m c_{pv} \tag{5}$$

Experiment Setup

In this study, a research tool scheme was used as shown in Figure 2, consisting of a tower dehumidifier and humidifier, a pump with a capacity of 50 GDP (2,191 x 10-6 m^3/s), a nozzle with a jet diameter of 0.2 mm, a concentration of 50% $CaCl_2$ with a temperature of 10°C in the dehumidifier and temperature variations in the humidifier, namely 50, 60, 70, and 80 °C, and an air flow rate of 2.35 m^3 / minute. During this process there is a change in humidity and air temperature in the sample house which will be read by the DHT 11 sensor installed on 4 sides (inlet, wall, floor and outlet).

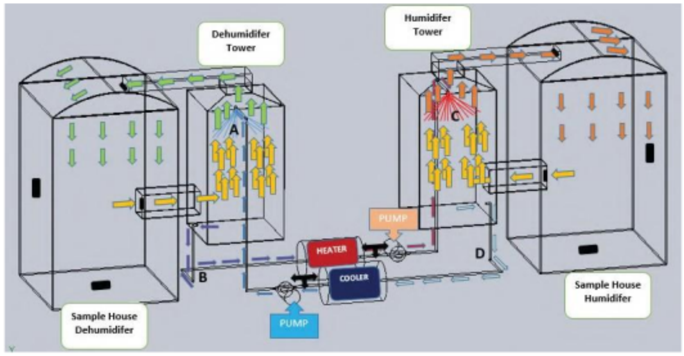


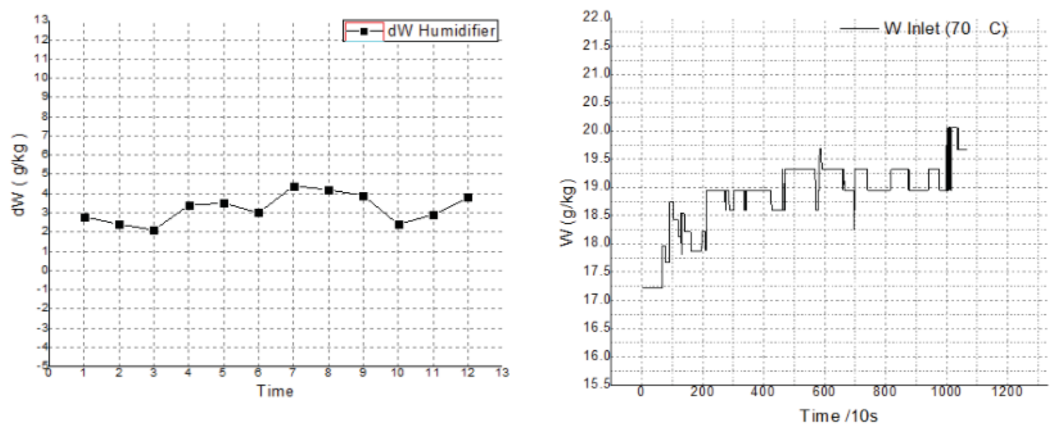
FIGURE 2. A Research schematic diagram

RESULTS AND DISCUSSION

Comparison with Previous Research

The research results obtained are then compared with previous studies, to ensure that the tool functions properly before various variations of testing are carried out. In this case, Jun Liu, et al from Tsinghua University Beijing China in 2015 analyzed the results of dehumidification and regeneration research made from thermally conductive plastic using drying desiccant.

In his research, Jun Liu used lithium bromide (LiBr) as a liquid desiccant with a concentration of 39.1 - 42.6% at a temperature of 20.6 - 25.1°C. Jun Liu also uses an additional component in the form of an internal cooled, namely by using a water flow pipe that is used for the cooling medium which passes through the humidifier so that the temperature of the incoming air becomes 15.1 - 19.1 °C. Jun Liu's research data, taken from the 12 most stable data, can be seen in the absolute humidity increase graph in Figure 3.1.a



(a) (b)

FIGURE 3. Comparison of absolute humidity increase (a)Jun Liu, et al. (2015) and (b) This study.

The graph in Figure 3 shows that Jun Liu's research has the average ability to increase the absolute humidity value by 3.2 g/kg and in this study the ability of the humidifier to increase the absolute humidity by 2.84 g/kg at a temperature of 70°C $CaCl_2$ solution.

It should be noted that in the research of Jun Liu, et al., The regeneration used is open system, which is to take free air from the environment and after the regeneration process the air drying liquid is thrown back into the environment, so that in the regeneration process the conditions for entering and leaving the air can tend to be stable as Figure 3.a shows the difference in absolute humidity values at the entry and exit sides in the y-axis statement.

Whereas in this study, the researcher wants to be able to see the ability of air to capture air vapor during the regeneration process using a closed system so that the maximum capability of the process can be seen in Figure 3.b. once the air reaches its maximum, its ability will automatically decrease.

Effect of Moisture Change

the regeneration process using a humidifier to restore the function of the $CaCl_2$ solution as an absorbent medium in the dehumidification process, the temperature of the $CaCl_2$ solution also affects the regenerator performance as said Rafique et al. (2016)[7], seen in Figure 4, each of the four graphs shows the change in absolute humidity during the regeneration process with the treatment temperature of each $CaCl_2$ solution.

The y-axis represents the change in absolute humidity conditions during the regeneration process and the X-axis represents the data collection time every 10 seconds. The red, green, blue lines are the slopes to make it easier to read the chart.

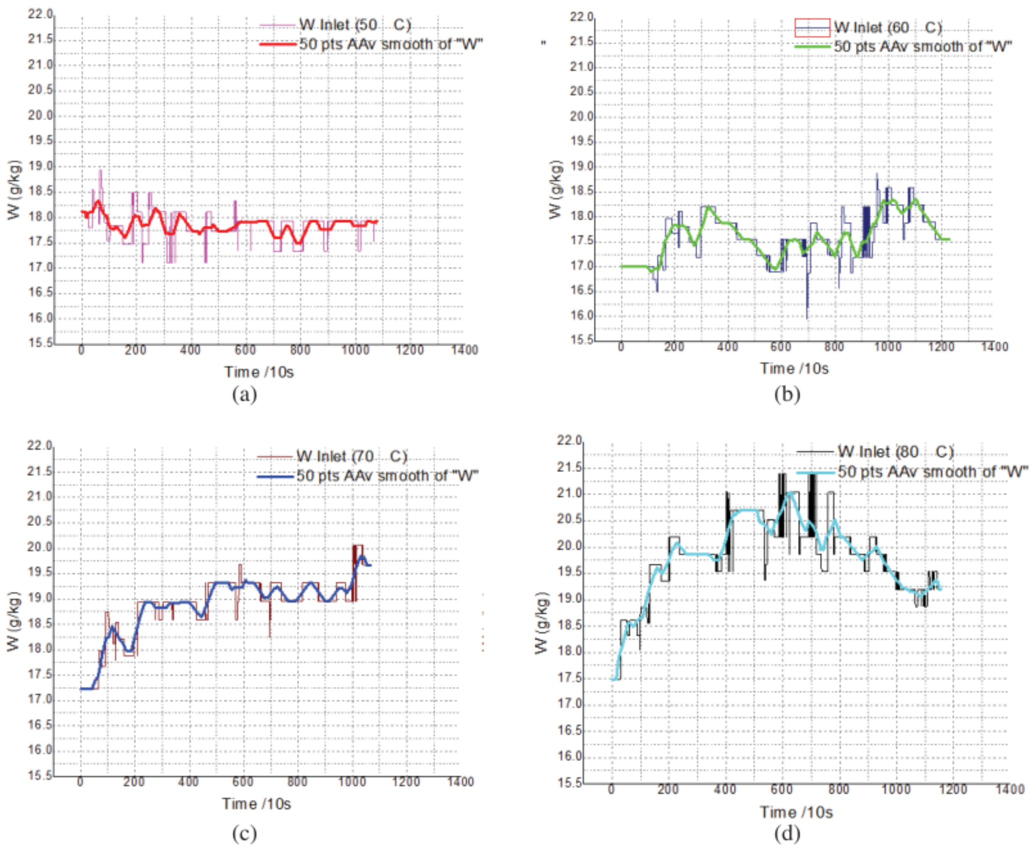


FIGURE 4. Effect of changes in temperature of $CaCl_2$ solution on air humidity during the regeneration process, (a) at 50°C, (a) at 60°C, (a) at 70°C, (a) at 80°C

All graphs in Figure 4 show an increase in humidity during the regeneration process except at the temperature of the $CaCl_2$ solution of 50°C which tends to be stable at an absolute humidity of 17.93 g/kg even though the initial humidity is 18 g/kg. This shows that the partial pressure in the $CaCl_2$ solution is still less high than the partial pressure in the air so that water vapor does not want to move into the air.

Similarly, in the research of Koronaki, et al., (2013)[6], which examined the effect of liquid desiccant temperature on dehumidifier performance, the higher the difference in partial pressure between $CaCl_2$ solution and air, the greater the ability of the humidifier to regenerate $CaCl_2$ solution. This can be seen from the graphs of 60°C, 70°C, and 80°C, each of which was able to increase air humidity by an average of 1.58 g/kg, 2.84 g/kg, and 3.9 g/kg, which means the water content in the $CaCl_2$ solution. successfully transferred to air because of the difference in partial pressure and to increase the partial pressure it can also be done by increasing the temperature of the $CaCl_2$ solution.

Effect of Temperature Changes

The air that enters the humidifier meets the $CaCl_2$ solution with a higher temperature causing the air temperature coming out of the humidifier to increase, plus friction of the particles during the absorption process. This is in accordance with research conducted by Jun Liu, et al. (2015)[3], that the air temperature increases overnight in the regeneration process. As seen in Figure 5, it can be seen that in the regeneration process with $CaCl_2$ temperatures of 50, 60, 70 and 80 °C, respectively, the air temperature increases during the regeneration process by 5, 5, 6, 4 °C. and it should be noted that by knowing the conditions of air temperature and absolute air humidty, we can find out what the relative humidity (RH) is by using a psychrometric diagram.

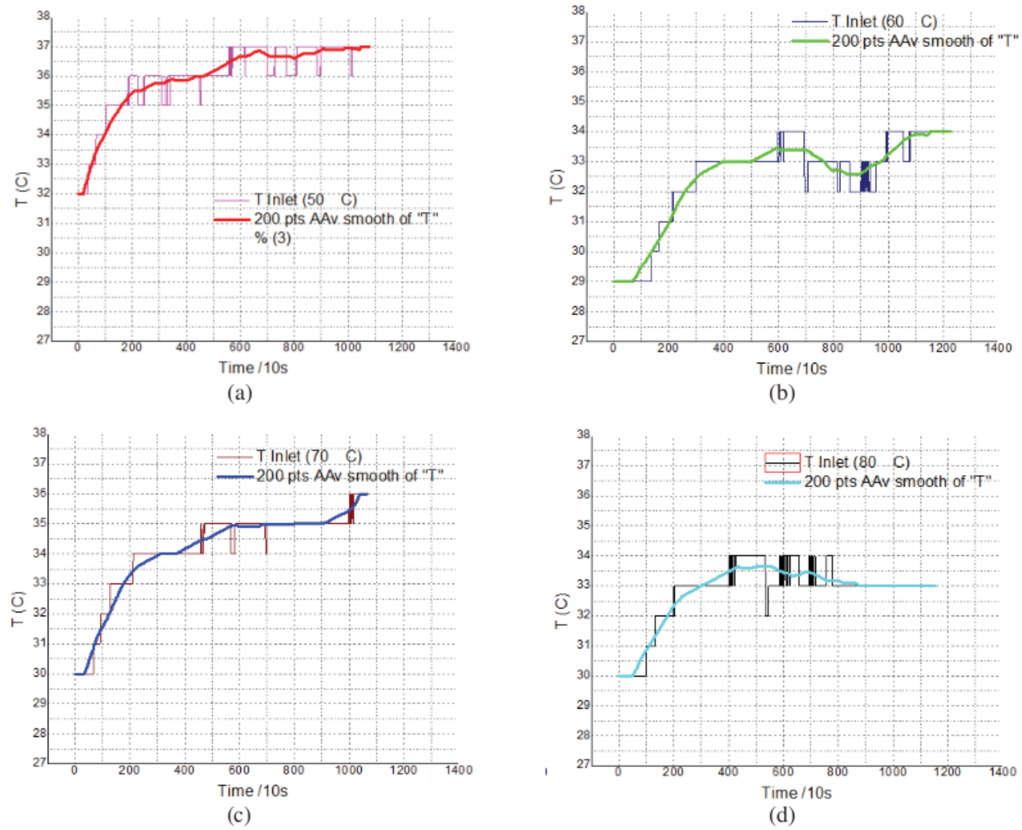


FIGURE 5. Effect of changes in temperature of $CaCl_2$ solution on air temperature during the regeneration process, (a) at 50°C, (a) at 60°C, (a) at 70°C, (a) at 80°C

CONCLUSION

Regenerators can be used to store $CaCl_2$ solution as a liquid desiccant in the dehumidification process and can continue to be used as an absorbent medium, by moving water vapor that has been captured by $CaCl_2$ solution then the water vapor is transferred to air media on the other side. During the regeneration process, the temperature of the $CaCl_2$ solution greatly affects the performance of the regenerator, namely the higher the temperature of the $CaCl_2$ solution, the more water vapor will move to the air which is indicated by an increase in air humidity after passing through the regenerator.

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