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Experimental Investigation to Assess the Performance of Desiccant Integrated Chilly Dryer

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Abstract: *In many parts of India, hot and humid environmental conditions are present. In such an environment, the dry air is necessary for drying agricultural products. In this project work, an indirect forced convection desiccant integrated chilly dryer has been designed and fabricated to investigate its performance under hot and humid climatic condition of Bhopal, India. The set up consists of a module of aluminium tubes filled with wax as a phase changing material, drying chamber, chemical dehumidification type desiccant unit.*
In experimental analysis, 500 gm chillies have been taken. Flow rate has been maintained at 0.0188 m³/s. After 4 hr of drying, the moisture removal rate was found out to be 45.5 g/hr. On the other hand, same type of 500gm chillies has been taken in direct solar radiation. After 4 hr of drying, the moisture removal rate was 35 g/hr. So the experimental setup is 30 % more efficient than direct solar radiation. Drying experiment has also been performed at different flow rate to find out optimum flow rate for drying.
Keywords: *Chilly, Desiccant, Drying, Moisture removal rate, Phase changing material*

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I. Introduction

For many industrial and domestic purposes, dry air is produced by using desiccants [1-4]. Desiccants can be in liquid form or solid form. These desiccants can be used many times, but for using these desiccants again, these should be regenerated. This paper reports the results of some experiment on drying chilly from desiccant and also regeneration of desiccant which include

- To find out the moisture removal rate of chilly in drying process.
- To compare the moisture removal rate of chilly from experimental setup and with direct solar radiation.
- To find out the moisture removal rate at different flow rate of drying air.
- To compare the regeneration time of solid desiccants from experimental setup and direct solar radiation.

II. Literature Review

The brief discussion of the work done by different researcher till date is given below:

V. Shanmugam and E. Natarajan [5] have done experimental investigation of forced convection and desiccant integrated solar dryer. The system consists of a flat plate solar air collector, drying chamber and a desiccant unit. The system pickup efficiency, specific moisture extraction rate, dimensionless mass loss, mass shrinkage ratio and drying rate were discussed in this paper.

Mohammed M. Farid , Amar M. Khudhair, Siddique Ali K. Razack, Said Al-Hallaj [6] studied on phase change energy storage: materials and applications. The different applications in which the phase change method of heat storage can be applied are reviewed in this paper.

Kodama et al. [7] carried out experiments on desiccant cooling process where regeneration was done at 60°C temperature and heat was obtained from low grade energy such as waste heat or solar heat. Various solid desiccants like silica gel, activated alumina, activated charcoal and zeolite can be regenerated at low temperature by using solar energy which can be easily collected by simple flat plate and evacuated tube solar air collector.

Wisut Chramsa-ard, Sirinuch Jindaruksa, Chatchai Sirisumpunwong, and Sorawit Sonsaree [8] studied performance of desiccant bed solar dryer. From the experiment it was found that the drying time of with-dehumidification system is shorter than without-dehumidification system by 20.83 %.

Nagaya et al. [9] developed a desiccant based drying system. The drying time was found to be six time faster than conventional desiccant drying.

Thoruwa et al. [10] designed and developed a prototype dryer that provide dehumidified air at night using solid betonite $CaCl_2$ as a desiccant material. During the daytime, the desiccant was regenerated from solar radiation.

Hodali and Bougard [11] designed an adsorption unit of silica gel integrated with tunnel type crop solar dryer. The solar dryer was coupled with collector, adsorber and dryer in series. This drying system reduced the drying time by 8 hour.

Avadhesh Yadav and V. K. Bajpai [12] compared various solid desiccants for regeneration by evacuated solar air collector and air dehumidification. The air needed for the regeneration was heated in an evacuated tube solar collector with a surface area of 4.44 m^2. The desiccants were regenerated at temperature in the range of 54.3-68.3°C.

III. Experimental setup

The schematic of desiccant integrated dryer consisting of a drying chamber, desiccant bed, blower and heat storage unit is shown in the figure 1. The G. I. Sheet is used to make the drying chamber. The dimension of the drying chamber 0.304 × 0.304 ×0.304 m^3 has been taken. There are two net are provided in the drying chamber, one for sample and the other one is for silica gel as shown in the figure. The single phase continuous type blower is used to force the air. The dimension of heat storage unit is taken as 0.60 × 0.45 × 0.35 m^3 in which aluminium round pipes are arranged in staggered pattern on mild steel plate by epoxy adhesive. Aluminium pipes are filled with wax. For reducing the heat loss, all side of the heat storage system are covered with glass.

The hygrometer is used to measure the temperature and relative humidity of the inlet and outlet air. Digital anemometer is used to measure the velocity of the air for finding out its flow rate. While moisture removal rate have been found out by subtracting the initial weight and final weight and dividing this quantity by minutes.

Experiments were conducted on drying of green chilly to study the weight loss and moisture removal rate. This moisture removal rate from the setup has been compared with the moisture removal rate with direct solar radiation. Moreover the weight loss and regeneration time of solid desiccant (i.e. silica gel) is also calculated and compared with the direct solar radiation.

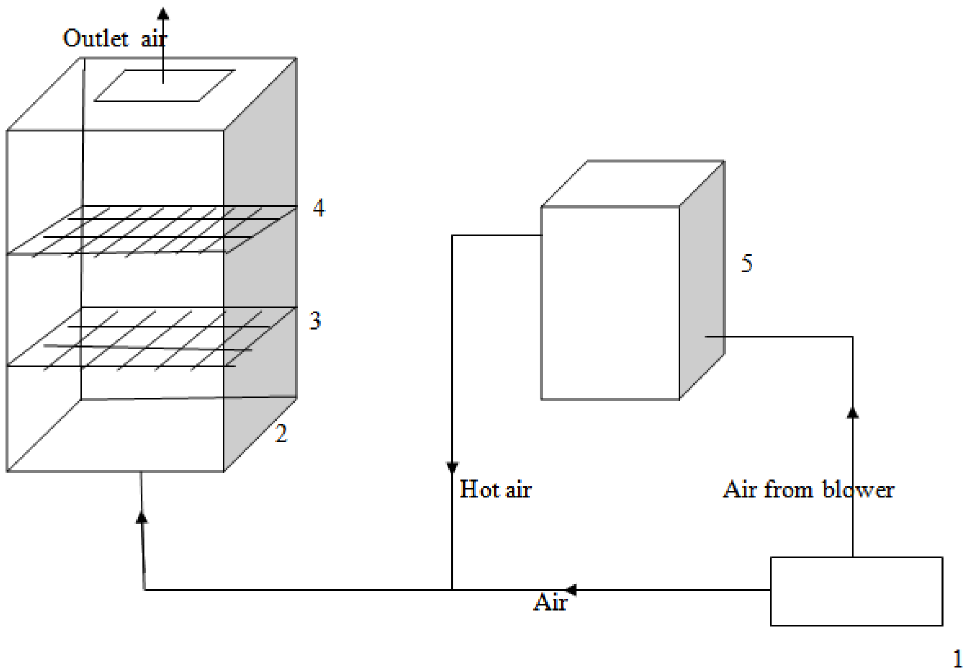

Fig.1. Schematic view of experimental setup

1 Blower; 2 Drying Chamber; 3 Net for Desiccant; 4 Net for Sample; 5 Heat Storage unit

IV. Experimental Procedure

For Drying Chilly

The experiment was conducted on 22 june, 2017 at 12 pm. Initially the blower is directly connected with the drying chamber with the help of PVC pipe. The air from the blower is forced through the desiccant and then chilly in the drying chamber. After that the air left through the exit [1-2-3-4]. The experiment was conducted on 500 gm chilly and 1.75 kg of silica gel was used. The mass flow rate of the air was maintained at 0.0188 m^3/s. To estimate the weight loss, moisture removal rate and sp. humidity of the drying product, the reading were taken at 15 minute interval. From hygrometer and psycrometric chart sp. humidity is find out. The drying

process was continued until the saturation of desiccant. (i.e. approx 3 to 4 hour). The saturation of the desiccant can be understood by changing its colour from dark blue to purplish pink.
The experiments were also conducted for different air flow rate, namely 0.028 m^3/s and 0.04 m^3/s for one hour on 24 june, 2017 to check the optimum flow rate for drying.

Fig.2. Experimental set up for drying chilly

For Regenerating the Desiccants

The regeneration of the desiccant has been done with the help of thermal storage unit. The thermal storage unit had been put in the sunlight so that it can store latent heat because of phase change of wax. The blower is directly connected with the thermal storage unit which is connected with the drying unit. In the upper net of the drying chamber 500 gm desiccant is placed [now chilly have been removed from the setup]. As blower is started, the air from the blower comes in the contact with the aluminium pipes in the heat storage unit and temperature of air increases. This hot air from the heat storage unit is forced through the drying chamber in which desiccant is placed [1-5-2-4]. The flow rate of air is maintained at 0.0188 m^3/s. After some time (approx 45 to 50 min.) equilibrium is reached, it means that further regeneration of desiccant is not possible. The weight loss of desiccant has been noted down in 15 min interval. The weight loss of desiccant from set up is compared with the weight loss of desiccant from direct solar radiation.

Fig.3. Experimental set up for regeneration of solid desiccants

V. Result and Discussion

For Drying chilly:

500 gm chillies have been taken for the experiment on 21 june, 2017 at 12pm. After drying the chillies for 4 hour in day time by solar radiation, the net weight of chillies comes as 360 gm. During this period moisture removal rate is 35 gm/hr. On the other hand same type of 500 gm of chilly has been taken for the experiment on 22 june, 2017. After drying the chillies for 4 hours by experimental setup, the net weight of chillies comes as 318 gm. During this period moisture removal rate is 45.5 gm/hr. Comparison between moisture removal rate by direct solar radiation and experimental set up are shown in the chart below:

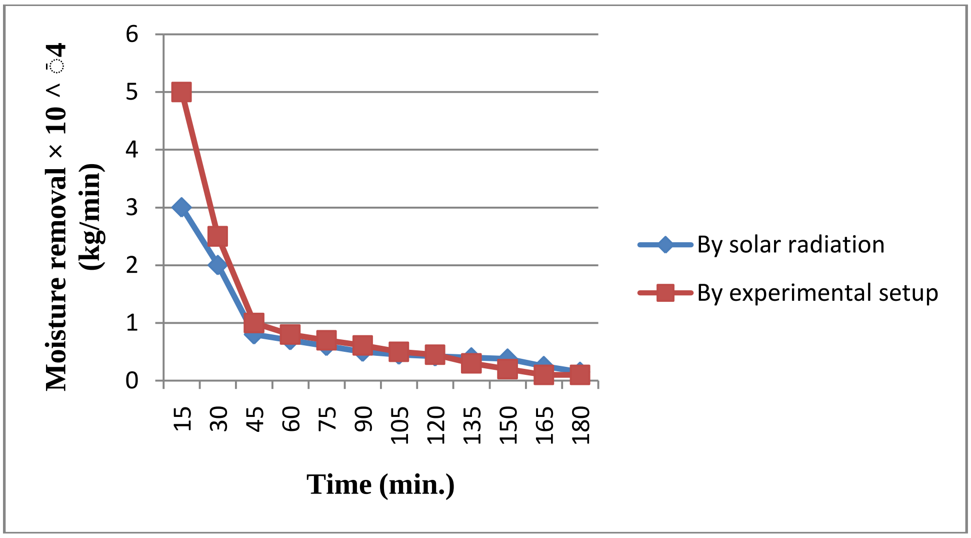

Fig.4. Moisture removal rate vs time

Above chart shows that moisture removal rate at initial is more by experimental set up than solar radiation. This is because of the fact that initially the desiccants are fully unsaturated and the moisture absorbing capacity of desiccants is high. As time passes, the moisture absorbing capacity of desiccant reduces because of saturation.

The experiments were also conducted for 500 gm chilly on 24 june, 2017 for different air flow rate, namely 0.028 m^3/s and 0.04 m^3/s for one hour to check the optimum flow rate for drying. The higher air flow rate seems to have no influence on drying because most of air passes through without contacting the desiccant. This can be easily understood by the following graph.

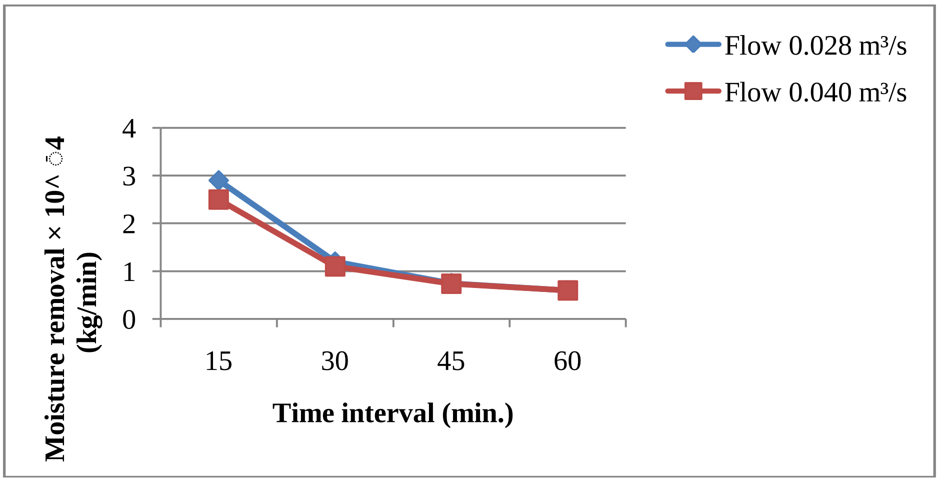

Fig. 5. Comparison of moisture removal rate at different flow rate

This graph shows the moisture removal rate at different flow rate. Moisture removal will be optimum when velocity of adsorption bed is optimum. After increasing the flow rate above the optimum range does not increases the moisture removal rate. It is found from the experiment that the moisture removal rate is more at 0.028 m^3/s in comparison to moisture removal rate at 0.040 m^3/s.

For regenerating desiccants:

500 gm saturated silica gel has been taken for the regeneration experiment. The saturated silica gel has been put in the direct solar radiation on 21 june, 2017 at 4 pm for 1 hour (equilibrium reached in approx 1 hour). The weight loss of silica gel has been noted down for 15 minute interval. Similarly 500 gm saturated silica gel has been put in the experimental setup on 22 june, 2017 at 4 pm and reading is noted down at 15 minute interval. The weight loss of silica gel is compared in the following chart.

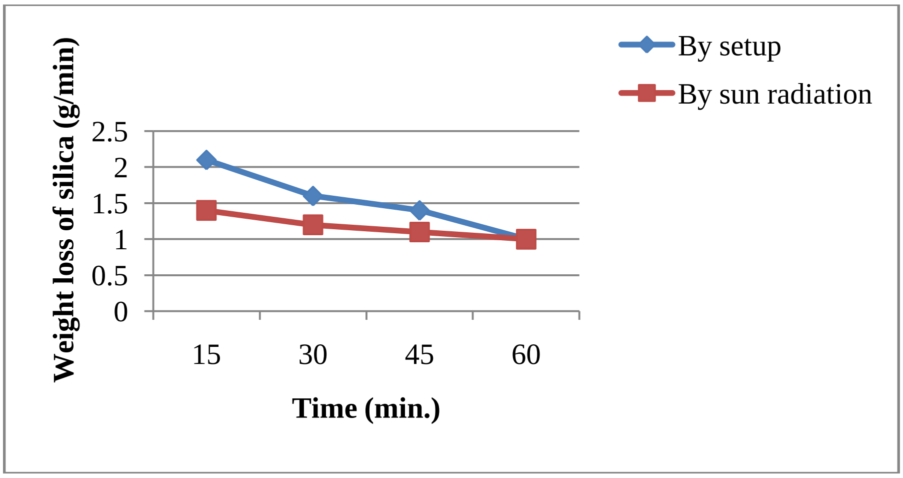

Figure 6. Comparison of weight loss of desiccant vs time

This is clear from the graph that regeneration time of silica gel is less by experimental set up as compare to sun radiation. The regeneration time is less from the experimental setup because of the high temperature forced convection air passing from through the desiccant bed. On the other hand, there is only sun insolation for regeneration from direct solar radiation.

VI. Conclusion

The main objective of the present research work was to explore the feasibility of chilly drier for typical hot and humid climates, as an alternative to the solar dryer system. The main conclusions from the present work are as follows:

From the experimental analysis, 500g chillies have been taken. Flow rate has been maintained at 0.0188m³/s. After drying 4 hour, the moisture removal rate is 45.5g/hr.

From solar radiation, 500g chillies have been taken. After drying 4 hour, the moisture removal rate is 35 g/hr.

So the experimental setup is 30 % more efficient than solar system.

From the experimental analysis, moisture removal rate has been done at different flow rate 0.028m³/s and 0.040m³/s. In both the cases maximum moisture removal has occurred at 0.028m³/s. So for higher moisture removal rate, lower flow rate has maintained.

From the experimental analysis, regeneration time of silica gel by phase change material like wax is less as compare to solar system. From the experimental analysis, regeneration time of silica gel by phase change material like wax is less as compare to solar system.

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