Influence of Desiccant on the Performance of Solar Dryer

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Abstract— The primary purpose of this report is to present the design of a solar dryer cum solar cooker and also the investigations carried out in order to evaluate the influence of incorporating a desiccant on the drying efficiency of the solar dryer. The findings obtain in this project through experimentation reveal that the incorporation of a desiccant can help improve the drying efficiency. The use of silica gel as a desiccant was made. The study also describes the conditions that led to the selection of silica gel as a desiccant.
Key words: Solar Dryer, AUTOCAD Model of Dryer

I. INTRODUCTION

Food drying is a very basic fundamental requirement and simple & ancient skill. It requires a safe place to spread the food where dry air in large quantities can pass over and beside thin pieces. Sun is often used to provide the hot dry air. Dry, clean air including dry cold air from any source will dehydrate food. Solar dryers use the energy of the sun to heat the air that flows over the food in the dryer. As air is heated, its relative humidity decreases and it is able to hold more moisture. Warm, dry air flowing through the dryer carries away the moisture that evaporates from the surfaces of the food.

Solar dryers used in agriculture for food and crop drying ,for industrial drying process, dryers can be proved to be most useful device from energy conservation point of view. It not only save energy but also save lot of time, occupying less area, improves quality of the product, makes the process more efficient and protects environment also. Solar dryers circumvent some of the major disadvantages of classical drying. Solar drying can be used for the entire drying process or for supplementing artificial drying systems, thus reducing the total amount of fuel energy required.[2]

People have been drying food for hundreds of years, by placing the food on the mats in the sun. This simple method however allows the food to be contaminated by dust and insects. Furthermore, we can't do that in humid climate too. Solar food dryers represent a major improvement up on this ancient method.

II. OBJECTIVE

To investigate the effect of using a desiccant in solar drying applications on the performance of solar dryer and to compare the results with those obtained from conventional dryers. The Solar dryer to be fabricated will be compatible with an existing solar cooker so that the two can be used inter-changeably as per the need.

III. MODELING

A. Design

As stated in the objective of the project, a solar dryer that can be used along with an existing solar cooker was to be fabricated. This fixed up the dimensions of the solar dryer as follows:

Length (L): 448 mm
Breadth (B): 446 mm
Height (H): 598 mm

The following Fig1 is the model of the Solar Dryer in Auto-CAD and PRO-E

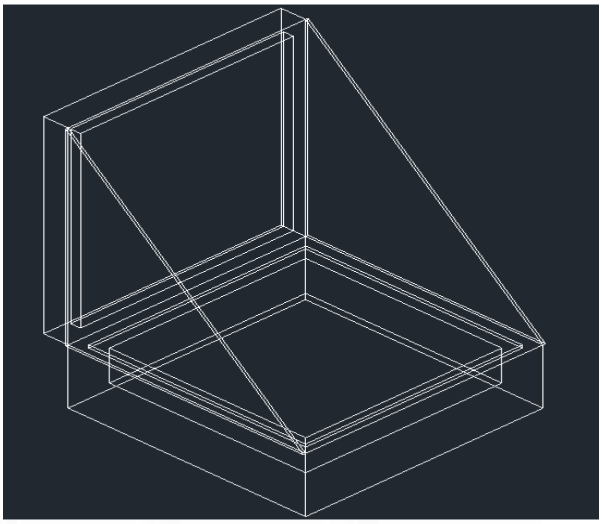


Fig. 1: AUTOCAD Model of dryer

B. Fabrication of Actual Model

The fabrication work involved the manufacturing of a solar dryer that could fit into the existing solar cooker. The use of polycarbonate sheets was made to make the solar dryer. 3 mm thick sheets were joined using araldite solution. Araldite not only acts as an adhesive but it also helps to form a leak-proof, thermally insulated joint which will trap the heat inside the dryer cabinet. The use of polycarbonate was made as it has excellent strength against its light weight. It is also opaque to the low wave-length radiation reflected back from the surface of the solar cooker and hence aids in achieving rapid rise in temperatures as compared to acrylic sheets or other glass types. Holes were drilled on the two sides of the dryer, one at the top on one side and other at the bottom, on the other side. These will help in natural circulation of air and also to facilitate the insertion of probes for the purpose of temperature measurement.

A desiccant is a hygroscopic substance that induces or sustains a state of dryness in its local vicinity in a moderately-well sealed container. Commonly encountered pre-packaged desiccants are solids, work through absorption or adsorption of water, or a combination of the two. Desiccants for specialized purposes may be in forms other than solid, and may work through other principles, such as chemical bonding of water molecules. Pre-packaged desiccants are most commonly used to remove excessive humidity that would normally degrade or even destroy certain products which are sensitive to moisture. Some commonly used desiccants are: silica gel, activated charcoal, calcium sulphate, calcium chloride, montmorillonite clay and molecular sieves.

The following Fig2 shows the solar cooker and the modified solar cooker + solar dryer:

Fig. 2: Complete Model of Dryer attached with cooker

C. Desiccant

1) Montmorillonite Clay:

It is a naturally occurring porous adsorbent. The mined clay is activated for use as a desiccant through careful drying. This clay will successfully regenerate for repeated use at very low temperatures without substantial deterioration or swelling. However, this property causes clay to give up moisture readily back into the cabinet as temperature rises. Clay is inexpensive and effective within normal temperature and relative humidity ranges (Table 1). Some variance in performance can be seen due to its source as a naturally occurring material.

2) Silica Gel:

It is a partially dehydrated form of polymeric colloidal silicic acid. Silica gel has an amorphous micro-porous structure with a distribution of pore opening sizes of roughly 3-60 angstroms. These interconnected pores form a vast surface area that will attract and hold water by adsorption and capillary condensation, allowing silica gel to adsorb up to 40% of its weight in water. Silica gel is extremely efficient at temperatures below 77°F (25°C) (see Figures 3 and 4), but will lose some of its adsorbing capacity as temperatures begin to rise, much like clay (Figure 5). Much of silica gel's popularity is due to its non-corrosive, nontoxic nature and its having received US government approval for use in food and drug packaging.[1]

3) Molecular Sieve (Synthetic Zeolite):

These adsorb moisture more strongly than either silica gel or clay. This can be seen by the high initial slope of the adsorption isotherm for molecular sieve as compared to the other desiccants (Figure 4). This can also be seen in comparing their heats of adsorption for water. The heat of adsorption is the sum of the latent heat of vaporization of water and the heat of wetting. The heat of wetting will vary as a function of the saturation level of the desiccant. For purposes of comparison, the heat of adsorption for water on molecular sieve is about 1800 BTU/lb. of water adsorbed, as compared to 1300 BTU/lb. of water adsorbed on silica gel. Clay is roughly similar to silica gel in this respect. What does this mean? Where a very low relative humidity is required, molecular sieves are often the most economic desiccant because of their high adsorption capacity at low relative humidity. Also, molecular sieves will not give up moisture into the package as readily as silica gel or clay as temperatures rise (Figure 5). This is particularly important to packaged products which can potentially see a wide variety of environmental conditions.

Molecular sieve contains a uniform network of crystalline pores and empty adsorption cavities, which give it an internal adsorptive surface area of 700 to 800 sq. m per g (1/2 the total volume of the crystals). Because of its uniform structure, molecular sieve will not give up moisture into the package as readily as silica gel or clay as temperatures rise. Being synthetic rather than naturally occurring, molecular sieve is higher in cost per unit, but due to its extremely large range of adsorptive capabilities, it might often be the best value. Lack of government approval has limited a more widespread use of molecular sieve, presumably due to the industry's unwillingness to fund an expensive government study. Independent testing suggests that molecular sieve does meet all government requirements.

Calcium oxide: It is calculated or recalculated lime having a moisture adsorptive capacity of not less than 28.5% by weight. The distinguishing features of calcium oxide (also known as Quick Lime) are: it will adsorb a much greater amount of water at low relative humidity than other materials (Figure 4); it is effective in retaining moisture at high temperatures; and it is relatively inexpensive as compared to many other desiccants.

Calcium Sulphate: It is an inexpensive alternative available in suitable packaging forms. Calcium sulphate is created by the controlled dehydration of gypsum, acting as a general-purpose desiccant geared mainly toward laboratory use. It is chemically stable, non-disintegrating, nontoxic, non-corrosive, and does not release its adsorbed water when exposed to higher ambient temperatures. The low cost of calcium sulphate must be weighed against its equally low adsorptive capacity: it adsorbs only up to 10% of its weight in water vapour (Figure 4). Calcium sulphate also has regeneration characteristics that tend to limit its useful life. Although available, it is not normally sold in package form.

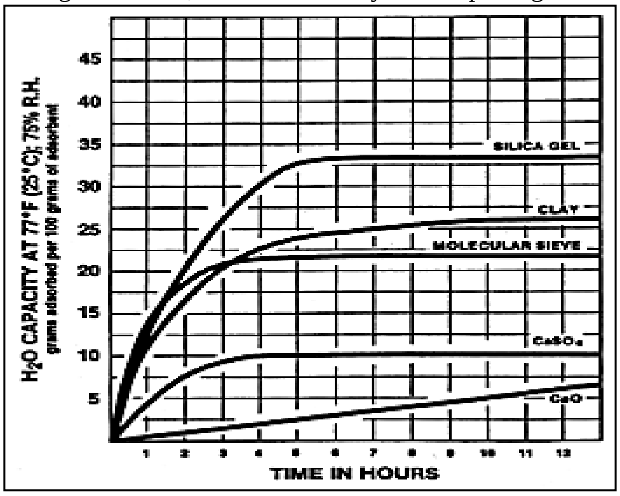


Fig. 3: Adsorption rate of various adsorbents

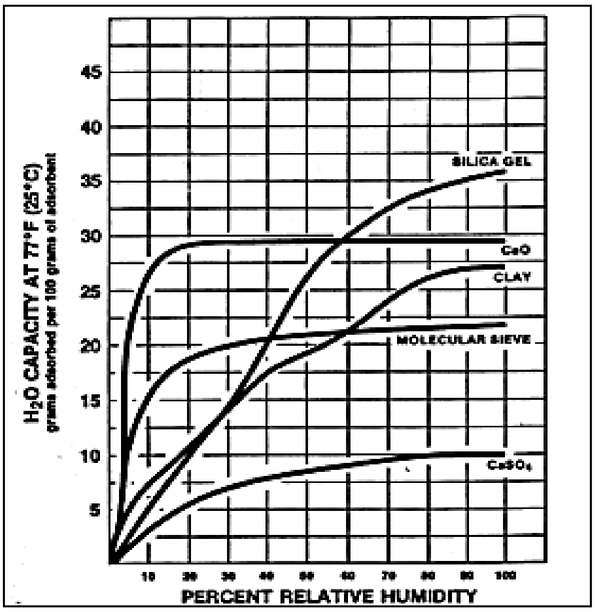


Fig. 4: Equilibrium capacity of various adsorbents

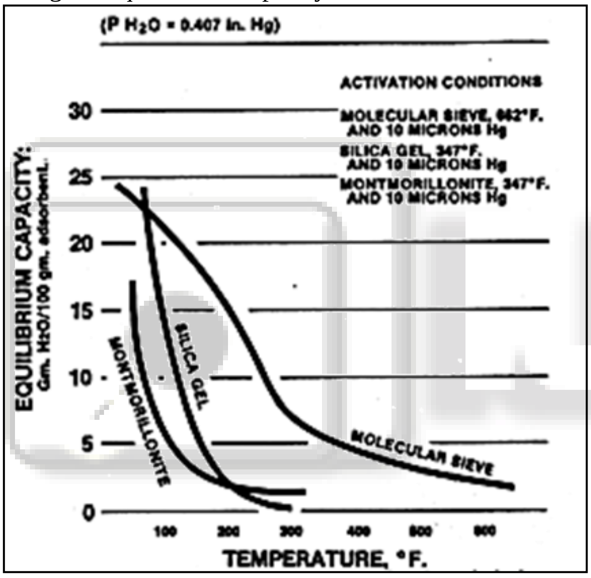


Fig. 5: Equilibrium H2O capacity

Property	Molecular Sieve	Silica Gel	CaO
Adsorptive Capacity at low H20 Concentrations	Excellent	Poor	Excellent
Rate of Adsorption	Excellent	Good	Poor
Capacity for Water @77° F, 40% RH	High	High	High
Separation by Molecular Sizes	Yes	No	No
Adsorptive Capacity at Elevated Temperatures	Excellent	Poor	Good

Table 1: Properties of Adsorbents

From the above comparison made for the various desiccants, it is quite clear from the graphs that silica gel is the most suitable desiccant. This is so because the application of drying involves higher relative humilities and higher temperatures. Silica gel has excellent adsorption characteristics at higher relative humilities and also the rate of adsorption of water is high as compared to other desiccants. The only demerit with the use of silica gel is the reduction in moisture adsorbing capacity with the increase in temperature. In this regard, molecular sieves would serve best. But these do not satisfy other requirements as stated above and as such they are toxic and so cannot be used for food drying applications. Hence the best choice for solar drying application is of silica gel.

D. Regeneration

When a desiccant is used to absorb moisture from the product, it gets saturated after taking up certain amount of water depending on the temperature, absolute and relative humilities. In order to reuse the saturated desiccant, it is required to remove the moisture from it. This process is called regeneration. In case of silica gel, it is required to heat it up to 150° C in order to regenerate. This can be achieved by employing any kind of solar concentrator. This will render the reuse of silica gel.[3]

Time	Intensity of Radiation(w/m²)							
	Without silica gel				With silica gel			
	02/04/13	03/04/13	05/04/13	07/04/13	10/04/13	12/04/13	14/04/13	16/04/13
09:00	623	620	600	613	520	610	615	608
10:00	673	679	667	664	560	667	656	647
11:00	767	757	740	771	610	764	733	748
12:00	785	793	788	797	620	789	779	788
13:00	800	803	807	809	640	803	815	809
14:00	764	759	749	762	612	759	765	754
15:00	742	737	735	731	557	710	717	726
16:00	649	653	629	647	542	646	665	654
17:00	543	538	548	557	503	548	559	556
18:00	441	432	419	420	434	428	445	443
Avg	678.7	677.1	668.2	677.1	559.8	672.4	674.9	673.3

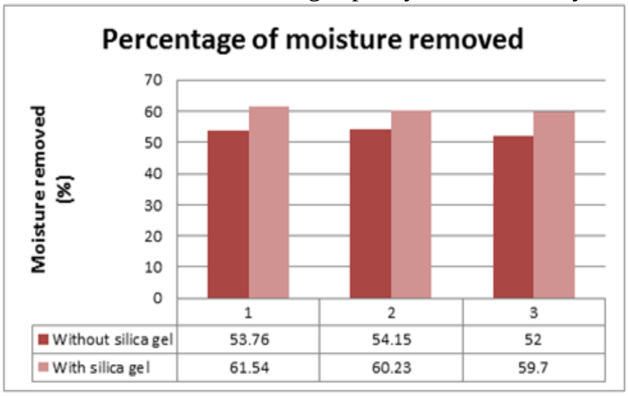
Table 2: Comparison of Intensity on Different Days

Here, comparison is made for moisture removed in the above two cases for the days having nearly the same average intensity of radiation.

No.	Date	Radiation Intensity (w/m2)	Moisture removed (%)
1	05/04/13	668.2	53.76

	12/04/13	672.4	61.54
2	03/04/13	677.1	54.15
	16/04/13	673.3	60.23
3	07/04/13	677.1	52.00
	14/04/13	674.9	59.70

Table 3: Moisture removing capacity of the solar dryer



As seen from the above column chart, percentage of moisture removed is more when silica gel is employed. On an average, 7% more moisture is removed by incorporating silica gel.

IV. CONCLUSION

The design and fabrication of a solar dryer that can be used interchangeably with an existing solar cooker was done. Also, the experimentation work was carried out in order to evaluate the effect of desiccant on the performance of solar dryer.

The incorporation of silica gel as a desiccant for solar drying application leads to improvement in the performance of solar dryer. The results show that, on an average, the capacity of solar dryer is increased by 7% upon incorporation of silica gel.

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