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Thermal energy storage based solar drying systems: A review

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ABSTRACT

Solar dryer based on thermal energy storage materials is quite effective for continuously drying agriculture and food products at steady state in the temperature range (40 °C–60 °C). Such dryers have globally become a potential viable substitute to the solar dryers based on fossil fuel, due to the utilization of clean energy resources and cost-effectiveness. Storage materials utilized in these dryers can store energy during the sunshine hour and deliver the stored energy during off-sunshine. It reduces the existing load on the gap between energy demand and supply, hence plays a vital role in energy sustainability. A number of studies have been done in last few decades for drying agriculture and food products with a solar dryer based on thermal energy storage concept. This paper mainly presents a review on the important contributions made so far in the field of solar drying systems based on the thermal energy storage medium, with a focus on recent updates in thermal energy storage technology available in terms of materials capable of storing heat as sensible and latent heat.

Industrial relevance:

1. Solar energy defuses in the nature and provides low grade heat. This characteristic of solar energy is good for drying at low temperature, high flow rate with low temperature rise.
2. Worldwide, there is huge demand of efficient solar dryers utilized by various food and agricultural products.
3. Solar energy based solar dryers are not only cost efficient but also can be used across the globe, specially contributing to cleaner energy resources.
4. Novel system designs and techniques related to solar dryers are being explored to increase the efficiency and performance of solar dryers, which could in turn be much more commercially utilized by the end user.
5. Phase change materials can store energy during sunshine hours and retrieve during off-sunshine hours for drying purpose, hence solar dryers embedded with such materials could be quite useful.

Contents

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1. Introduction

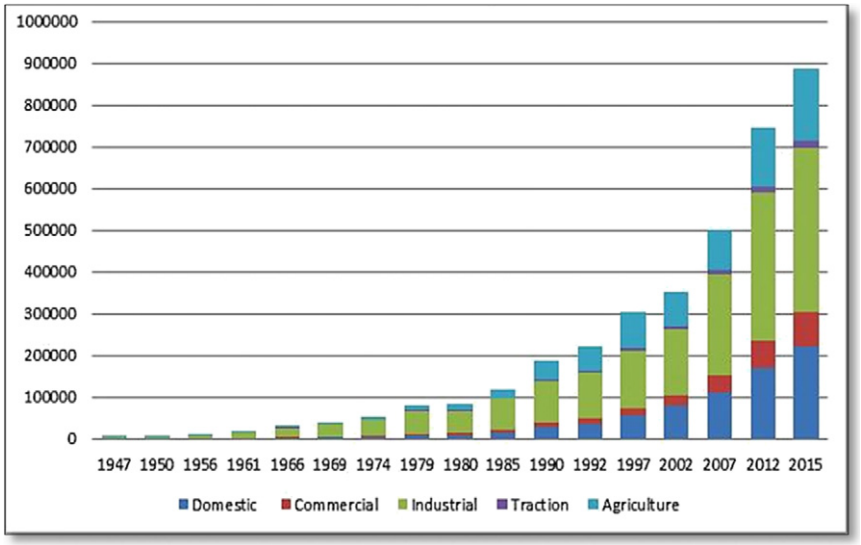
The drying is the basic process to reduce moisture from a product, which is one of the oldest techniques used for food or agricultural products storage (Augustus Leon, Kumar, & Bhattacharya, 2002). Food products, particularly fruits and vegetables require hot air in the temperature range of 45–60 °C for safe drying i.e., drying the products so as to keep their edible and nutritious properties intact. Requisite moisture content and superior quality of the product can be achieved under controlled conditions of temperature and humidity (Sharma, Colangelo, & Spagna, 1995). In the case of vegetables, which is the main nutrients product, 50% of wet (Wahidi & Rohani, 1996) (Wahidi & Rohani, 1996) (Wahidi & Rohani, 1996) (Wahidi & Rohani, 1996) (Wahidi & Rohani, 1996) (Wahidi & Rohani, 1996) vegetables (i.e., peels) are removed as unwanted items while cooking due to its higher moisture content (Wahidi & Rohani, 1996). Dried peels of vegetables can be further used for the feeding of the animals. Moreover, the transportation cost of vegetables is also reduced due to reduction in the weight and size of such dried product. It has been studied that lack of appropriate technology, inappropriate farming, fertilization, the non-existence of marketing channels, inappropriate transportation, high post-harvest losses etc., cause a food loss in the range of 10 to 40% (Esper & Mühlbauer, 1998). Hence, food preservation is the need of the hour to reduce the food loss and drying is widely accepted as an important tool in this direction, since a long time. Therefore, efficient drying technologies are required to reduce moisture content from food and vegetables for preservation. Well-designed solar dryers may provide a much-needed suitable substitute for drying of some of the agricultural crops in developing countries (Mahapatra & Imre, 1990; Sodha & Chandra, 1994; Ekechukwu & Norton, 1999; Hossain, Woods, & Bala, 2005; Zhiqiang, 2005). Application of solar energy in the agricultural area has enlarged due to fluctuation in the price of fossil fuels, environmental concerns and expected running down of conventional fossil fuels. Fig. 1 shows the drastic increase in energy consumption being experienced in the food and related sector. This is putting a pressure on very many fields related to energy production as well as energy transmission. Solar energy is the most abundant energy resource available on the regular basis (during day time) which can become the most efficient and feasible way out to deal with the increasing energy demand and supply gap. Particularly, to facilitate the drying of food and agriculture products, the solar energy is most suitable but intermittent in nature due to non-availability of solar radiation in the night. Therefore thermal energy storage facility is required to store solar energy to be used in off sunshine hours (Saxena & El-Sebaii, 2015; Shalaby, Bek, & El-Sebaii, 2014).

Solar drying technique facilitates domestic as well as industrial sector for number of food and agricultural products, so as;

— to make the preservation process much easier,
— to develop a certain product much more usable,
— to increase storage capacity and cost-effective transportation, and
— to harness direct or indirect ecological benefits.

Hence, an efficient solar dryer system could be of much use for the larger benefit of the mankind. This certainly requires the challenging task of developing novel solar dryers with efficient energy consumption for the specific product. Solar energy is considered quite effective for food drying, due to the following reasons:

- Solar energy diffuses in nature easily and provides low-grade heat. These characteristics of solar energy are good for drying food products at low temperature, high flow rate with the gradual and low-temperature rise.
- The irregular nature of solar radiation will not affect the drying performance at low temperature. Even the energy stored in the product itself will help in removing excess moisture during the period of no sunshine.
- Solar energy is available at most of the required sites of drying food products.
- The solar dryer for food products could also be put to other multiple usages, such as space heating.



Source: Central Electricity Authority 2015

Fig. 1. Sector wise electricity consumption growth in India (GWh).