INTEGRATED USE OF SOLAR ENERGY FOR CROP DRYING

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Abstract: During the drying of agricultural materials it has to be taken into account the energy saving, quality of end-products and also environmental aspects. Several new approaches in application of solar dryers and a great number of biological materials have been developed. In the paper the background of solar drying, current solar drying arrangements, and some of the recently focused biological products such as grain, fruit, vegetable, etc are selected and discussed. Additionally an integrated energy/technology approach in the sense of maximizing the solar energy use is introduced. It is implies to include a sophisticated solution for process control, as well.

Keywords: energy savings, agricultural crops, integrated systems, control

INTRODUCTION

There is a number of traditional drying methods currently available, but it is worth taking into account both the technical and economical benefits of the possibility of solar drying, along with a substantial number of commercially available solar dryers in operation today. However, for some special cases individually designed solar dryers have also been developed and used.

The scope of solar drying is to produce a solid end-product of a certain percentage of moisture content for immediate use or for further long-term safe storage. This condition should be achieved at a moderate temperature level as some of the materials to be dried may be sensitive to higher temperature. The final goal, of course, is to improve the overall energy efficiency of the drying operation.

The applicable temperature range and energy requirement for moisture removal are the most important parameters in designing a safe and cost-effective drying system.

The traditional use of solar energy for grain drying is a forced convection heated air in solar air collector. A low-temperature system can accommodate several grain types in spite of the longer processing time.

A solar cabinet type of dryer can be successfully used for drying of different fruits like apricots, peaches, apples, etc. The main parts of such dryer are solar collector, thermal storage, cabinet type of drying chamber and chimney.

In an ordinary agricultural farm, there is an impetus to maximise collection of all available energy resources, including solar, and distribute them optimally among the different energy consumers. The dryers require a fairly great portion of the total energy consumption. Therefore, this task requires an integrated energy/technology approach in the sense of utilizing the solar energy. At the same time it implies to include a sophisticated solution for process control, as well.

In the paper the background of solar drying, some solar drying arrangements, and some biological products as grain, fruit are discussed.

SOLAR GRAIN DRYING

The traditional use of solar energy for grain drying is in a forced convection heated air system. A small-scale solar dryer (Fig. 1) can be used effectively for drying of various agricultural crops (Farkas, 2008).
This dryer is designed for producing 2000 kg dried material (mostly for barley) starting at 20-40% w.b. initial moisture content. The collector structure is 36 m² and integrated into the roof, the dryer size is 3 m long by 2.5 m wide by 1 m high and the cross section of the air channel is 0.15 m² with an air flow rate is 500 l/s requiring a fan motor capacity of 1 kW.

Santos et al. (2004) proposed a design method for sizing solar assisted crop-drying systems and assessing the combination of solar collector area and auxiliary energy needs that meets the load. Two empirical correlations were compared for their use with high thermal inertia solar collectors, which are cheap and adequate in rural areas. The grain drying with partial air heating by solar energy can provide an annual economy of 30% in the fuel consumption for an 1.80 m² collector area during drying of 1,2 t of corn at 50 °C and air flow of 1526.8 m³/day.

SOLAR FRUIT RYING

There are several types and sizes of fruit that often need to be handled together during the drying process, using the same equipment. For that purpose a modular solar tray dryer was designed (Farkas, 2008). Two basic variations were considered of which one is surface dryer the other one is a batch or "overflowing" solution. A modular construction of the dryer means that the equipment does not need to contain all of its parts for operation. It can be used with or without the solar collector, with natural (without fan) or forced airflow. The dryer has four main sections (Fig. 2), a drying chamber with different trays, a photovoltaic (PV) module with the maximum power of 2x20 Wp, a 300 W capacity grid connected fan and a solar collector unit of about 1 m².

![Diagram of a modular solar tray dryer](image)

Fig. 2. Scheme of a modular solar tray dryer

With a modular construction, the dryer can be operated with natural ventilation by ambient air, artificial ventilation of ambient air with PV module, artificial ventilation of collector preheated air and combined uses as well. During the drying experiments, several types of fruit were tested e.g. grape, peach, plum, cherry and blackthorn.

Romano et al. (2009) have studied the drying behaviour of carrot and apple in the same solar dryer in order to evaluate the weight losses during the drying period, and to present the temperature and moisture content distributions in the modular solar dryer. Different size and form of the apples and carrots were measured and analysed. The initial and final moisture contents (w.b.) of fresh products were 85% and 26% for apple and 71% and 13% for carrot with an initial weight of 1.56 kg and 3 kg, respectively. The results revealed that temperature inside the chamber was strongly negatively correlated with air humidity ($R^2=0.91$) and that the length of the drying period was influenced by the weather conditions, as the cloudy weather retarded drying of carrots. It was possible to reach air drying temperature over 40 °C with a daily total solar energy incident on the collector’s surface of 857,2 kJ/(m² day) for apples and 753,20 kJ/(m² day) for carrots. The analysis of energy requirements to remove moisture from apples and carrots during the total drying period showed values of 3139,12 kJ/kg and 7428,28 kJ/kg, respectively. The amount of air to remove water from the samples was also determined at 120,7 m³ for apples and at 928,56 m³ for carrots.

A hybrid solar dryer has been constructed by Amer et al. (2006) that relied on solar energy to heat forced air flow for drying fruits. A heat exchanger placed inside the collector is used during sunny days, to heat water from the heated air and the direct solar radiation. While at night hot water flows through the exchanger to heat air in the reverse direction. Additionally, electric energy can be applied during the night to complete the heating of water in case the stored energy in the water tank is insufficient for heating the drying air during the night.

Sowti Khiabani et al. (2002) have developed a method for improving the quality of sun-dried peaches by osmotic dehydration. It has been concluded that different factors such as sample thickness and agitation conditions contribute significantly to dehydration rate in osmotic pre-concentration. Their results indicated that osmo-sun dried samples have better colour and taste properties compared to sun-dried ones.

MULTIPLE USE OF SOLAR DRYING

An attractive advantage of solar dryer is their versatile use, i.e. the same design of solar dryer can be used for different sorts of crops. A solar assisted indirect dryer may consist of a solar air collector, a heat storage unit, a drying chamber and a solar chimney and it can be used for different crops such as rice, tobacco, etc as suggested by Vlachos et al. (2002).

Topic and Topic (2006) designed a new solution of a solar, mobile, universal and ecological chamber dryer that satisfies the basic three requirements in the drying process: maximal process intensity, good quality of the dried material and minimal energy consumption.
INTEGRATED SOLAR DRYING SYSTEMS

In a typical agricultural farm, there is an impetus to maximise collection of all available energy resources, including solar, and distribute them optimally among the different consumers, including dryers, which require a fairly great portion of the total energy. This task requires an integrated solar energy/technology approach (Farkas, 2008). Setting up a solar preheating system can be economically justified if the solar energy is used throughout the year. The integration of solar energy into the farm energy system seems to be economically possible. However, the storage of the collected solar energy is a key question in such cases. The layout of an integrated solar energy/technology system including a hay dryer is shown in Fig. 3.

![Fig. 3. Layout of integrated solar drying](image)

The solar collector can be connected to the dryer, to the hot storage tank, to the hot water producing system and to the other technological heat consumer. This gives the advantage of a multipurpose use of solar energy. The Fan forces the air through drying bed, which can also be preheated by oil/gas burner if it is necessary. During night, the storage tank takes over. In this case the dryer or other technological heat consumers can be operated from the storage tank. In case of unfavourable weather conditions additional energy is needed.

Madhlopa and Ngwalo (2007) have designed, constructed and evaluated an indirect type natural convection solar dryer with integrated collector-storage solar and biomass backup heaters. The dryer was fabricated using simple materials, tools and skills, and it was tested in operation modes of solar alone, biomass alone and a combined solar-biomass.

Another type of direct solar-biomass dryer was developed by Prasad and Vijay (2005). In that case the biomass burner has a rock slab on the top part which assists in moderating the temperature of drying air. Such dryer designs have a backup heater without thermal storage of captured solar energy.

CONCLUSIONS

Several new approaches in the application of dryers and biological materials are under development in order to produce a high quality of product at competitive cost.

That includes designing of new type of solar dryers, revising of existed traditional dryers with solar preheating unit and use the multi purpose operation of solar units. Example dried material cases, such as grain and fruit were selected and reviewed in details.

An integrated energy/technology approach in the sense of utilizing the solar energy can be successfully applied in case of solar drying.

REFERENCES


