Bulletin UASVM Agriculture, 67(1)/2010
Print ISSN 1843-5246; Electronic ISSN 1843-5386

Solar Energy Use in Dryers as an Alternative Energy Source in Agriculture

Mirela MILITARU, Elena POSTELNICU, Mihai CHIŢOIU, Valentin VLĂDUŢ

National Institute of Research-Development for Machines and Installations Designed to Agriculture and Food Industry – INMA, 6, Ion Ionescu de la Brad Street, sect. 1, Bucharest,
e-mail: militaru_mirela1985@yahoo.com, fax: +40212693273

Abstract. Solar energy represents one of the future energy sources with a high potential, used as an alternative to conventional methods, especially during summer. The advantages of using solar energy are multiple, this type of energy being virtually endless and free, and its use has no negative effects on the environment, being regarded as a clean energy source.

Solar energy has multiple applications in agriculture, one of its benefits being that it is used for dryers as an alternative energy source, especially in regions with a high solar potential. In this paper different types of fruits and vegetable dryers, nationally and abroad are presented, as well as results obtained from different methods of solar dryers.

Keywords: agriculture, dryer, energy, fruit, vegetable, solar.

INTRODUCTION

Using different products is a known method for centuries and used by our ancestors for conservation purposes. In the drying process dehydration appears – water evaporates, so this method is based on removing a certain percent of moisture from the product, through different processes: without affecting the nutritional value or the qualitative attributes as taste, smell, aroma, etc. The product volume gets smaller through drying by 2.5÷8.5 times for fruits and by up to 25 times in the case of vegetables.

Solar drying is considered as one of the most promising techniques for food preservation (Sodha *et al.*, 1987; Sagar and Suresh, 2009). Drying of farm produce is an energy intensive operation, and improving energy efficiency by only 1% could increase the profits by 10% (Beedie, 1995). Escalating price of petroleum products and the shortage of fossil fuels have led to increased emphasis on using solar energy as an alternative energy source especially in developing countries like India. Apart from the rise in energy costs, legislation on pollution and sustainable and ecofriendly technologies has created greater demand for energy efficient drying processes in the food industry. The food processing industries can have economic savings by avoiding wastage of costlier energy. Post-harvest losses in the developing countries are estimated to be 30–40% in the case of fruit and vegetables (Jayaraman and Gupta, 1995). The solutions involving solar energy collection devices or solar dryers have been proposed to utilize free, renewable and non-polluting energy source provided by the sun. Solar dryers can reduce crop losses and significantly improve the quality of the dried product (Sodha *et al.*, 1985).

The preservation of fruits and vegetables through drying dates back many centuries and is based on sun and solar drying techniques. The poor quality and product contamination lead to the development of alternate drying technologies (Bezyma and Kutovoy, 2005).

The use of air as a working fluid in a solar collector eliminates the need for a heat exchanger, generally employed to transfer heat from liquid to air in a liquid flat plate collector. The air heated in a solar collector can be used more effectively for controlled drying. A solar air heater may supply hot air to a conventional dryer, or a special design may combine the heater and a drying cabinet (Garg and Prakash, 2002; Bansal and Uhlemann, 1984).

Dehydration is achieved through water evaporation that reaches to product surface until the value of aw < 0.7, to which microorganism spreading is stopped. After the nature of heat adding, the drying can be:

- convective- from agent to product;
- conductive- through product;
- through radiation – from exterior sources;
- dielectric heating (high frequency current drying, microwaves);

The way in which vapors are removed, the dryers are:

- air drying;
- vacuum drying;
- atmospheric pressure convective drying (mostly used in industrial practice), that can be achieved in the following ways;
- foam layer drying – liquid material brought in mash state is mixed with emulator substance and transformed in a foam of inert gas under pressure (nitrogen);
- dispersion drying – liquid products, mashes, pasta – not applied for solids. It is done at ambient temperature in a dehydration room with the help of dry gas (N_2) in a closed circuit. Nutritive principles and sensorial properties of initial product are kept;
- pulverization drying, with variant;
- conduction drying at atmospheric pressure – is realized through product contact with a hot surface, thus leading to water evaporation. The dryers are type rotation tambour, and the products that can be dried are in a liquid concentrated state with granular structure;
- pressure drying – is realized in foam layer and a thin layer, has the following advantages: nutritional and sensorial superior qualities for products because of the lower drying temperature and lack of oxygen;
- infrared radiation drying;
- microwave drying;
- azetrop drying;
- partial osmotic drying.

Fruit and vegetable drying is the technological process through which the natural content of water is reduced until a level that stops microorganism activity, without damaging tissue or depreciate product value. The phenomena that take place during drying leads to dried substance concentration, volume shrinkage, weight unit value increase and physical-chemical modifications more or less profound in the membrane state and cellular components, that influence through rehydration capacity limits.

Dehydration represents the process through which fruit and vegetables lose a certain quantity of water that leads to a physical chemical favorable state for maintaining their nutritive and qualitative values: taste, smell and aroma.

Drying differs from dehydration by the lack of temperature, relative humidity and air movement adjustments; also it is used in expressions as natural drying, opposed to dehydration, which is artificial.

MATERIALS AND METHODS

Aktaşa *et al.*, (2009) conducted extensive research regarding apple drying characteristics determination in a solar dryer, which was composed out of a hot air collector, air channels, a vent, an air flow rate adjustment system and a drying room.

In the heat pump dryer, air drying temperature was maintained between 39÷41°C using a temperature adjustment system with a PT-100 thermocouple type and process control equipment. The adjustment algorithm was implemented with the help of the heat pump. In order to measure the temperature and humidity a thermo hygrometer was used that could measure with a ÷0.5°C precision at a 5÷95% (÷3%). Before the drying process, the apples were kept in an oven for 8 hours that was preheated to 70°C.

At the end of two consecutive measurements in the case in which the weight difference was smaller than 1%, the apples were then accepted as being dried. The average temperature of air in the dryer was 40°C.

Rathore and Panwar, (2010) conducted experiments regarding grape drying with the help of a cylinder dryer (Fig. 1). Studies have shown the fact that chemically untreated grapes needed 7 days to dry up to 16% humidity content. The temperature inside the dryer was approximately 10÷28°C during a sunny day, which is sufficient for the agricultural industry.

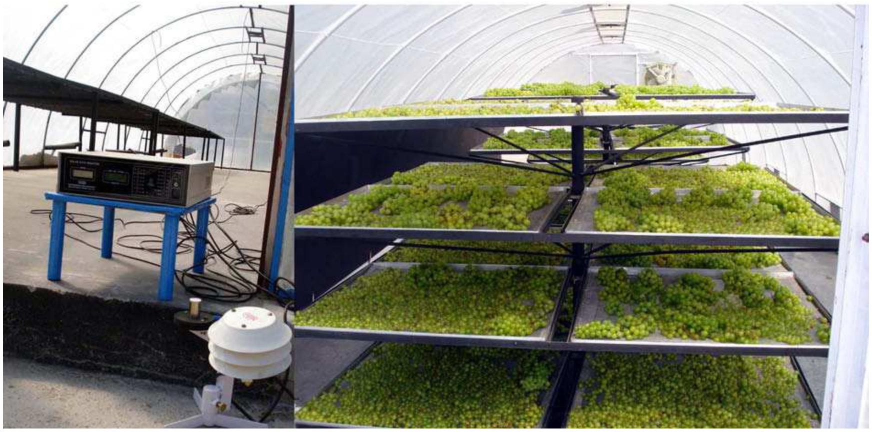

Fig. 1. Instrumentation during no load and inside view of tunnel dryer with product (Rathore and Panwar, 2010)

Aghbashlo *et al.*, (2009) has done numerous researches regarding drying performance analysis of carrot slices in a semi-industrial dryer with continuous band (Fig. 2). Experiments were made on sliced carrots with width of 5 mm at air temperatures of 50, 60 and 70°C, air flow ratio being at 0.61, 1.22, and 1.83 kg/s and feeding rates $2.98x10^{-4}$, $3.48x10^{-4}$, $4.16x10^{-4}$ kg/s. Drying variable effects have been evaluated according to the weight drop in dried product, energy consumption, energy use ratio, energy loss and efficiency.

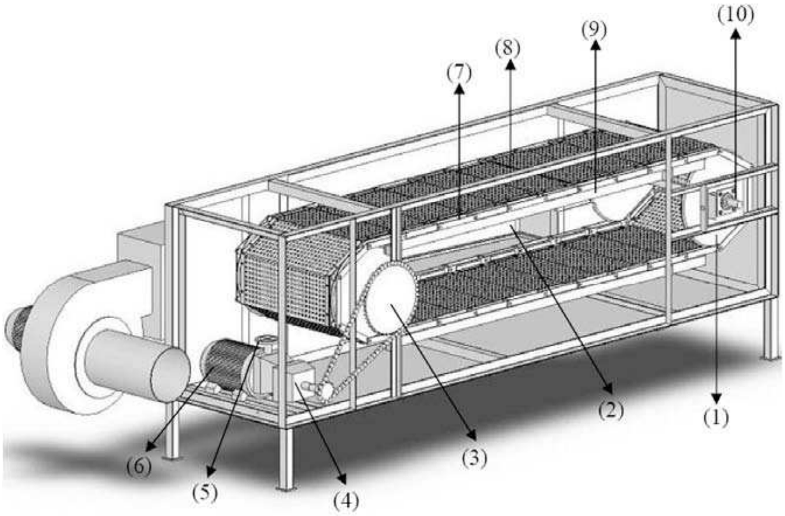

Fig. 2. Schematic view of the dryer (Aghbashlo *et al.*, 2009)
sprocket (1); location of major temperature sensor (2); large scale gear (3); gearbox (4); manual rotational speed controller (5); electrical motor (6); chain (7); perforated bands (8); chain guide (9) and shaft and bearing (10)

Pop *et al.*, (2003) established experimental researches regarding the fruit dehydration automated installation, having the drying capacity of 1700 kg/24h (Fig. 3). Researches regarding fruit drying were done in Romania, at INMA an experimental model of an automated fruit dehydration installation being conceived.

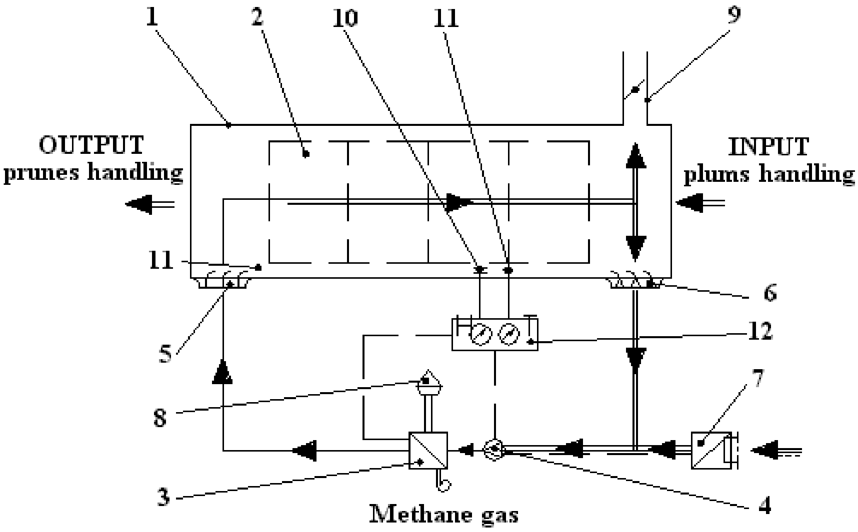

Fig. 3**.** Automated installation technological scheme (Pop *et al.*, 2003)
1- drying chamber, 2- conveyer belt, 3- hot air generator, 4- axial fan, 5- hot air distributor, 6- recycled air adjust register, 7- fresh air adjustment for register, 8- smoke pipe, 9- key chimney, 10,11 - humidity and temperature sensor, 12- electric automatic installation

RESULTS AND DISCUSSION

Following determination of apple drying characteristics in a solar dryer (Aktaşa *et al.*, 2009) using the energy from the heat pump the following results came through: drying air average temperature in the dryer with the heat pump was 40°C. In the case of solar dryer, air temperature varied between 30°C and 16°C.

Air relative humidity modification in both systems according to drying period (Fig. 4), shows that the moment at which recycled air rate was 0.90 in both cases

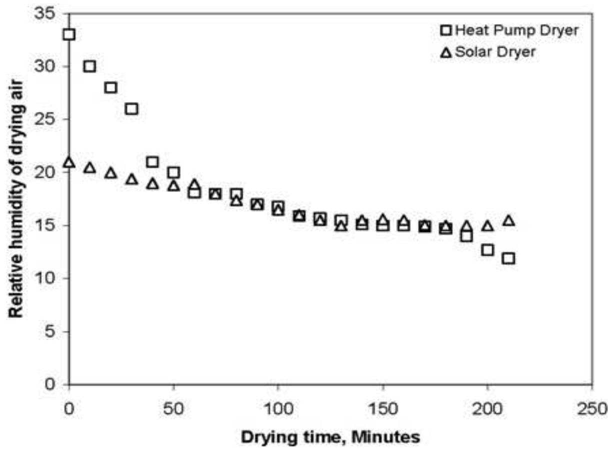

Fig. 4. Relative humidity variation of the drying air, according to apple drying time (Aktaşa *et al.*, 2009)

The cylinder solar dryer (Rathore *et al.*, 2010) used for grape drying was tested during 7 days period for temperature behavior analysis inside the dryer. This was analyzed for three days and results were presented as a graph.

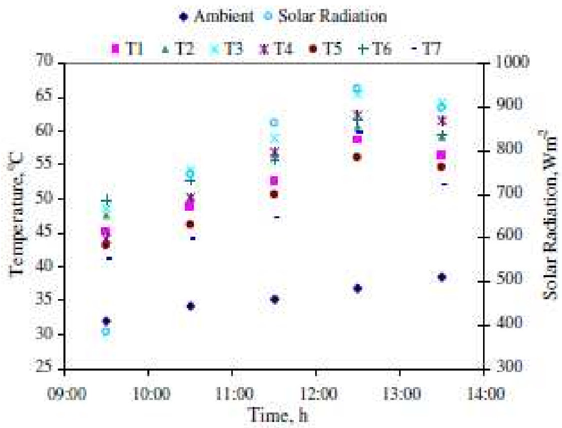

Fig. 5. Temperature variation at day 1

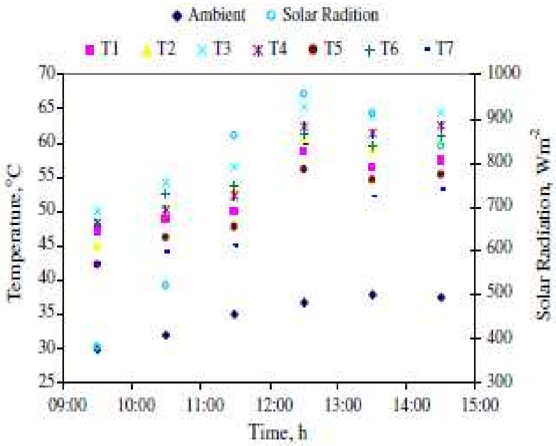

Fig. 6. Temperature variation at day 4

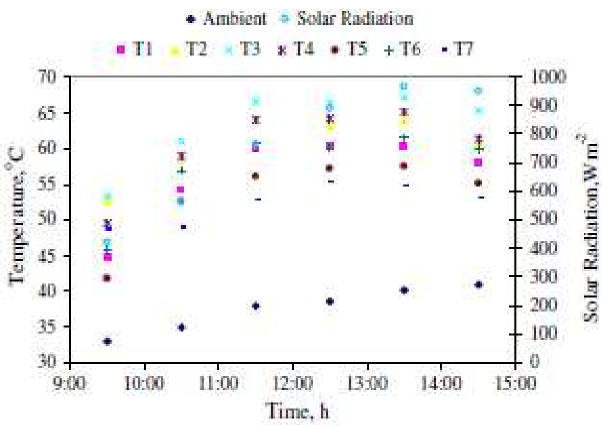

Fig. 7. Temperature variation at day 7 (Rathore *et al.*, 2010)

Following carrot slices drying performance in a continuous conveyer industrial dryer (Aghbashlo *et al.*, 2009) important results were found. Variation analysis proved that weight drop rate grew together with drying air flow rate for all air temperatures and feeding rates.

Maximum weight loss value was 84.4% al drying temperatures of 70°C at air flow rate of 1.83 kg/s and feeding rate $2.98 x 10^{-4}$ kg/s. Air temperature effect and drying air flow rate effect were more important than feeding rate on weight loss for carrot slices.

Results regarding solar dryer technical and financial feasibility from Bhutan where the following (Lhendup, 2005), the solar dryer was modeled with the help of TRNSYS system. Simulation was done for chilly at 60°C with air flow speed of 0.75%. In order to determine the necessary time to lower humidity from 57% (db) to 10% (db) a long term simulation was made to establish when humidity content reached to less than 10 kg, a ka value gave acceptable results. At this value the drying time was 18 hours (Fig. 9).

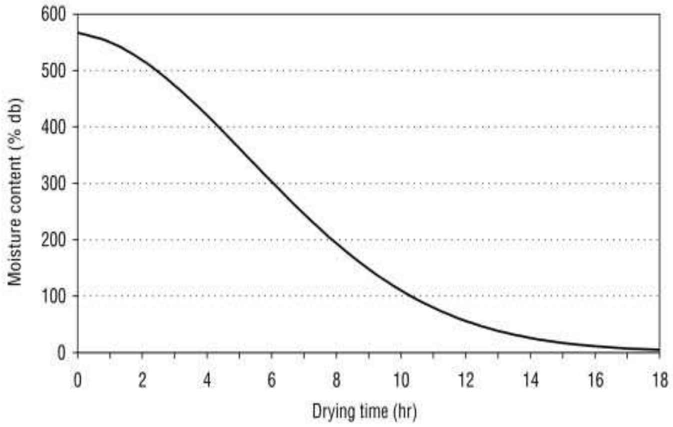

Fig. 9. Chilly drying curve (Lhendup *et al.*, 2005)

Experimental researches regarding automated installations for fruit dehydration have been conducted by (POP *et al.*, 2003), in order to define an optimal working technology, of necessary functional parameters for a software program according to the specific properties of fruits subjected to drying process. The air temperature is maintained constant through adjusting the two burner flames. Results have shown that the experimental model corresponds with the demands, function and actual possibilities. Materials chosen behaved well as a thermal isolation and also their weight permitted an easier manipulation of the dryer. Convective drying in h-x diagram is represented by the used air recirculation.

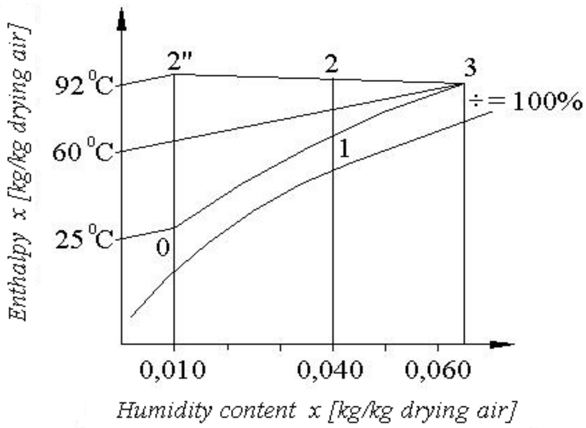

Fig. 10. H-x diagram of convective drying with recycled used air (Pop *et al.*, 2003)

CONCLUSIONS

Fruit and vegetable drying is a worldwide issue, and for this reason numerous experiments are and will be necessary to conduct for drying process optimization. Each product that needs drying has certain properties. Because of this there is a necessity regarding particularly designed dryers for each product. Cheaper and efficient methods are still studied in order to obtain necessary quality.

Aktaşa *et al.*, 2009; Rathore *et al.*, 2010; Lhendup, 2005, studied solar dryers, regarding their use for fruit drying (apples, grapes, chilly, etc.) concluding that the optimal temperature of drying is between 30÷70°C.

The problem of carrot drying with the help of a conveyer belt dryer was studied by (Aghbashlo *et al.*, 2009.), leading to the fact that drying variable effects ware evaluated according to the weight drop of the product, and energy consumption.

Product drying through solar methods proved to have a high potential, and future investigations will lead to fruit and vegetables drying process perfecting, and to drop down costs. The solar method is best fitted to areas with warm climate, but is useful in temperate climate areas as well.

REFERENCES

1. Aghbashlo, M., H. M. Kianmehr and A. Arabhosseini. (2009). Performance analysis of drying of carrot slices in a semi-industrial continuous band dryer. Journal of Food Engineering. 91: 99–108.
2. Aktaşa, M., C. İlhan and S. Yilmazb. (2008). Determination of drying characteristics of apples in a heat pump and solar dryer. Desalination. 239: 266–275.
3. Bansal, N. K. and R. Uhlemann. (1984). Development and testing of low cost solar energy collectors for heating air. Solar Energy. 33(2): 197–208.
4. Beedie, M. (1995). Energy savings-a question of quality. South Afr. J. Food Sci. Technol. 48(30): 14–6.
5. Bezyma, L. A. and V. A. Kutovoy. (2005). Vacuum drying and hybrid technologies. Stewart Post- harvest Rev. 4: 6–13.
6. Garg, H. P. and H. Prakash. (2002). Solar energy fundamentals and applications. New Delhi. Tata McGraw-Hill.
7. Jayaraman, K. S. and D. K. Gupta. (1995). Drying of fruits and vegetables. In: Handbook of industrial drying. Marcel Dekker. Inc: 643–90.
8. Lhendup, T. (2005). Technical and financial feasibility of a solar dryer in Bhutan. Energy for Sustainable Development. IX: 17-24.
9. Pop, A., T. Fader, G. Anghel and D. Mnerie. (2003). Experimental Research Regarding An Automated Installation For Dehydrating Fruits. International Conference. Integrated Systems For Agri-Food Production. Timişoara. Romania.
10. Rathore, N. S. and N. L. Panwar (2009). Experimental studies on hemi cylindrical walk-in type solar tunnel dryer for grape drying. Applied Energy. 45: 269-273.
11. Sagar, V. R. and P. Suresh Kumar. (2009). Recent advances in drying and dehydration of fruits and vegetables. A review. J Food Sci Technol (2010). 47(1): 15–26.
12. Sodha, M. S., N. K. Bansal, A. Kumar, P. K. Bansal and MAS. Malik. (1987). Solar crop drying. 1. Boca Raton. FL. CRC Press.