Study, design and realization of an indirect solar dryer

Abstract

The post-harvest losses of agricultural products in developing countries are estimated of the order of 40% of global production, and maybe, under the obtained conditions, reach up to 80%. The main cause is the lack of means of conservation. Drying is an efficient and not cost method, which would recover the surplus, thereby reducing losses and helping to increase significantly the availability of food in these countries. Traditional drying (open-air), the simplest and cheapest method of preserving food, is the most common in developing countries. However, it poses many problems, such as exposure to dust and rain, availability of a large surface, long time, difficulty in controlling the drying process, and generally a loss of moisture, color and nutritional values of the product.

To overcome these inconveniences, the use of solar dryers seems to be an attractive solution. These systems are good for the environment and represent a promising application of solar energy. In addition, solar drying will improve financial opportunities for farmers compared to traditional drying methods. Indeed, solar dryers generally made with local materials with low cost and are easy to use, will reduce crop losses, and improve the quality of the dried product. Many researchers report the advantages of solar dryers over the open-air drying method.

In the region of Adrar (Algerian Sahara), farmers cannot manage the surplus of tomato and henna crops and suffer huge losses every year. Also, the objective of our work is to develop an indirect solar dryer with natural convection for drying agro-food and/or medicinal products from these Saharan regions. This type of dryer is simple to make and capable to dry a large amount of product for a short period of time while preserving the product quality.

To achieve that, a new design of indirect solar dryer is proposed with significant changes to the conventional dryer. In order to improve the performance of the proposed solar dryer, the collector was provided with two absorbers, one vertical and the other horizontal. Furthermore, to allow the dried air to dry homogenously large quantities of products, the drying chamber was relatively large (2 m × 1 m × 1 m) with an appropriate height.

The chosen dryer is handcrafted in design. It is made from local materials, without using sophisticated techniques, which are very expensive, or specialized labor.

The new indirect solar dryer with natural convection was designed, built, and tested in the climatic conditions of the Adrar region. The construction and experimentation phases were preceded by modeling of the dryer. The heat balances of its main components, drying chamber and solar collector, were established, and the resulting equations were solved by the 4th order Range Kutta method. The effect of many parameters on the drying kinetics was examined. In order to validate on the one hand the numerical results and to demonstrate on the other hand the efficiency of the proposed prototype, measurement companions of many parameters (solar radiation, temperatures of the horizontal and vertical absorbers of the solar collector, temperatures in and at the outlet of the latter, temperature, and humidity of the drying air, water content of tomato and henna products), were carried out on January 19, March 08, July 07 and October 07, that is, one day per season (winter, spring, summer and autumn). Analysis of the results obtained led to the following observations:

- The temperatures of the vertical absorber can reach 64 °C, 52 °C, 84 °C and 71 °C respectively, on the days of January 19, March 08, July 07 and October 07. The maximum temperatures of the horizontal absorber for these days are respectively 66 ° C, 72 ° C, 89 ° C and 72.5 ° C. Thus in winter when the weather conditions are unfavorable, the vertical absorber will help improve the efficiency of the solar dryer.

- The maximum air temperatures at the outlet of the collector, of 45 °C, 47 °C, 71 °C and 52 °C, respectively on the days of January 19, March 08, July 07 and October 07, greatly exceed (from near 24 °C, 20 ° C, 31 °C and 18 °C), the maximum values of the ambient temperatures recorded, during these days. These values demonstrate that the temperature of the drying air is largely sufficient and adequate for the drying of the products studied, even in winter, for the henna leaves.

- The proposed indirect solar dryer allows, compared with drying in the open air, to reduce the drying time of henna leaves by 52% (day of January 19) 36% (day of March 08) and 12% (day of 07 July) and 17% for drying of tomato, while preserving the quality (color and cleanliness) of the products.

- The drying time and the quality of the dried product depend on the type of dryer used. It has been confirmed that when drying time is reduced in the case of a direct solar

dryer, the quality of product is affected or even deteriorated due to high temperatures of the drying air, which reached up to 100 °C. In the indirect dryer the temperature reached 65°C, although the drying time is little longer, the quality of the product is much better preserved.

The results obtained strongly encourage the installation of the proposed indirect solar dryer in the Saharan environment. Such a device will undoubtedly make it possible to conserve the surplus crops of agro-food products and medicinal plants, limit or even eliminate the significant losses recorded each year. Such a device will undoubtedly make it possible to conserve the surplus crops of agro-food products and medicinal plants, limit or even eliminate the significant losses recorded each year. The device will undoubtedly contribute to the socio-economic development of these desert regions.

The comparison of the numerical results obtained with those of other authors and with our experimental results made it possible to validate our model.

The work undertaken as part of this thesis opens the way to many other avenues of research (energy storage system to be used at night and or in the absence of solar radiation, organoleptic properties and their changes during drying etc.).