Solar Drying of Potato using Solar Dryer

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ABSTRACT

Drying, particularly of crops, is an important human activity and globally the use of dryer products is wide spread. For preservation, quality improvement, and processing purposes, moisture must often be removed both from organic and inorganic materials. Sun drying and mechanical drying using fossil fuels are the most common technologies used. Sun drying is a low cost drying method but the final qualities is variable, while mechanical drying is an energy intensive process and contribute substantially to energy use and greenhouse gas emissions.

Many products must be dried at relatively low temperature (i.e., less than 100^{0}C) to ensure the desired product quality and solar dryers can often be used instead of sun drying or conventional dehydration systems. The experimental result indicated decreasing weight of an agricultural produce (potato) as sun radiation increases. The maximum temperature of tray obtain on day 1 was 48^{0}C while the minimum temperature recorded was 39^{0}C. The experiment was done for ten days. The weight of potato dried reduced from initial weight of 3000g to final weight of 495g under controlled drying (solar dryer). The weight reduced from 3000g to 689g under open air drying.

(Keywords: solar drying, open air drying, crops, energy, wet weight, dry weight)

INTRODUCTION

With the increasing population and industrialization, there is need to cut down the load of fossil fuels and to reduce environmental pollution [1]. Unlike conventional energy utilization, solar energy is free of connections, unlimited supply of source and also decease gas emission. Solar energy investments in developing countries are imperative to avoid an energy crisis arising from over-dependence on fossil fuels. The situation is critical because fossil fuels are finite and fast depleting (Okoro, 2004) [2].

Various industrial surveys show that up to 24 percent of all industrial heat, directly used in the processes, is at temperatures from ambient to 180°C. In several industries, 100 percent process heat requirement is below 180°C which can be supplied economically by evacuated tube collectors and solar concentrators (Garg & Prakash, 2006) [3]. From a number of studies on industrial heat demand, several industrial sectors have been identified with favorable conditions for the application of solar energy. The most important industrial processes using heat at mean temperature level are: sterilizing, extraction, pasteurizing, drying, solar cooling and air conditioning, hydrolyzing, distillation and evaporation, washing and cleaning, and polymerization. The ranges of all these processes lie between 60-280 °C (Kalogirou, 2003) [4].

Most of the agro-based industries can be operated in this medium temperature range. The use of solar energy in agriculture sector can be used to process many perishable agricultural products at farm level [5]. At present, various kinds of solar collectors are in use in the sector of agriculture and post-harvest technology, yet their applications are restricted only to drying and warming water, etc. Beyond these low temperature applications there are several potential fields of application of solar thermal energy at a medium and medium-high temperature level.

Many important developments have occurred in solar concentrating systems for diverse applications in the last decades. In particular, an important research effort has been directed towards power generation applications, chemical systems, and process heat (Estrada, 2007) [6].

Tremendous efforts have been made in areas of application of solar energy in the agricultural sector. This can be seen in areas of solar water heating for dairy and micro irrigation (Jenkins 1995) [7]. The promotion of small scale agro-based industries by using innovative solar collectors can open new landmarks in rural development especially in tropical countries.

Medicinal plants have been used for different purposes in many regions of the world since ancient times. After World Health Organizations (WHO), medicinal plants are commonly used in preventing and treating specific ailments and diseases and are generally considered to play a beneficial role in health care. Some cultivars from medicinal plant families are also used as ingredients to season or to give a pleasant flavor or smell to foods [8]. Therefore, the terms “medicinal” and “aromatic” are usually used in conjunction.

Essential oils extraction from medicinal and aromatic plants is one of the medium temperature agro-based industries. These oils are used in medicinal and pharmaceutical purposes, food and food ingredients, herbal tea, cosmetics, perfumery, aromatherapy, pest, and disease control, dying in textiles, gelling agents, plant growth regulators, and paper making (Öztekin and Martinov, 2007)[9]. A single ounce of many of these oils can be worth thousands of dollars. In the last decade, these oils remedies have gained enormous popularity in industrialized countries as well particularly in the multi-million-dollar aromatherapy business. Out of all extraction methods, the distillation methods have advantages of extracting pure and refine essential oils by evaporating the volatile essence of the plant material (Malle and Schmickl, 2005)[10].

At present, there are large and centralized distillation units mostly located in city areas. Due to their high operating costs, these are sometimes unmanageable by farmers or even groups of farmers in most of the developing countries. Further, some essential oils come from extremely delicate flowers and leaves that must be processed soon after harvesting. Thus, for functional, economic and environmental reasons, there is need of a decentralized distillation system. Due to lack of adequate facilities for the decentralized distillation systems, farmers prefer to dry their product rather to sell it at very low price. Results show that conventional drying methods such as open sun drying and conventional-fuel dryers are not suitable which deteriorate the essential oils components in the herbs. Moreover, the drying process necessitates an enormous amount of thermal and electrical energy (Fargali, 2008)[11].

The on-farm solar distillation is a decentralized approach to reduce the post-harvest losses and to prevent spoilage of essential oil components by processing the fresh herbs. Examples of the plants are peppermint, lemon balm (Melissa), lavender, cumin, cloves, anise, rosemary, patchouli, caraway, cassia, oregano, European silver fir, and fennel, etc. In order to run the distillation experiments, boiling, cooking and steam generation are the basic requirements.

Increasing awareness of the growing global need for alternative cooking fuels has resulted in an expansion of solar cooker research and development (Funk, 2000) [12]. A system for solar process heat for decentralized applications in developing countries was presented by Spate, et al. (1999) [13]. The system is suitable for community kitchens, bakeries and post-harvest treatment. The system employs a fix focused parabola collector, a high temperature flat plate collector and pebble-bed oil storage. Decreasing the area from which the heat losses occur can increase energy delivery temperatures. With higher a concentration ratio, there is an increase in temperature at which heat is delivered due to an increase in flux intensity and a decrease in the receiver area.

Modern parabola trough concentrators and central receiver towers are operated by high-tech computer programmed tracking system and are used only in large scale applications to justify the high investment costs and gross over design [14]. The conventional paraboloidal concentrators converge all the beam radiations at the focus and are selected as the bottom part of a paraboloid parallel to the directrix. With such parabolic concentrators, not only the frequent tracking of two axes is required but also the receiver is fixed at the focal point as an integral part of the reflector. Moreover, focus lies in the path of incident beam radiations.

Despite the high temperature output, such types of concentrators are rarely used for industrial applications due to frequent changes of the focus position and inadequacy of handling approach at the receiver. This limitation, however, is solved by the Scheffler fixed focus concentrator which not only provides simple and precise automatic tracking but also a fixed focus away from the path of incident beam radiations. This design also provides an opportunity to shift the receiver for indoor applications. The versatile reflector rotates along an axis parallel to polar axis with an angular velocity of one revolution per day from east to west to counterbalance the effect of earth rotation. Therefore, the relative position of the Scheffler reflector with respect to sun remains stationary and provides a fixed focus on the line of the axis of rotation (Scheffler, 2006) [15].

The reflector not only provides daily tracking but also a seasonal tracking device to ensure the focus remains at the same fixed point with changing solar declination. Nevertheless, there is a little compromise on the aperture area as compared with the conventional paraboloid concentrator but this drawback is compensated by precise automatic tracking and fixed focus with respect to Earth. Scheffler reflector provides an extraordinary opportunity that can be used for domestic and industrial applications. The automatic tracking system with a stationary focus point has made it even more attractive for decentralized industrial applications in underdeveloped areas, where there is no electricity or fossils fuels availability.

For small-scale applications, it can be used as a point source of heat, directly or indirectly by using a secondary reflector. On large scale applications and steam generation, a number of Scheffler reflectors are arranged in the form of tandems to get a common focus point in the center. It also provides an opportunity to set the reflector in a standing position or in a laying position rotating along the same axis of rotation. In addition, the balanced structure of the Scheffler reflector requires only a nominal torque to track the sun. This is done with the help of a small PV tracking system or clockwork driven by gravity.

Different sizes of the Scheffler reflectors can be constructed ranging from 2 m^2 to 60 m^2. In order to obtain direct absorption of solar energy, a parabolic dish with a receiver configuration is often used. These types of reflectors can be successfully used in distillation, baking, water distillation, solar community kitchen, etc. It is observed through comparison that the two axes tracking paraboloid dish, which always faces the sun, is the most promising design for concentrating systems justifying the use of the Scheffler concentrator for industrial process heat applications (Bhirud and Tandale, 2006). These concentrators are capable of delivering temperatures in the range of 300 °C and are technically suitable for medium temperature applications (Delaney, 2003)[16].

Scheffler (2006) [17] investigated that about half the power of sunlight which is collected by the reflector becomes finally available in the cooking vessel. The use of solar energy for the generation of steam is now an economically attractive possibility since the payback period of such a system lies between 1.5 and 2 years. These cookers are economically viable if they are used regularly (Jayasimha, 2006)[18]. For small-scale applications in agriculture, post-harvest technology and the food industry, this is a cheaper solution. A focal receiver absorbs the concentrated solar radiation and transforms it into thermal energy to be used in a subsequent process. The essential feature of a receiver is to absorb the maximum amount of reflected solar energy and transfer it to the working fluid as heat, with minimum losses (Kumar, 2007)[19].

With cultural and industrial development, artificial mechanical drying came into practice, but this process is highly energy intensive and expensive which ultimately increases product cost. Recently, efforts to improve “sun drying” have led to “solar drying”. In solar drying, solar dryers are specialized devices that control the drying process and protect agricultural produce from damage by insect pests, dust and rain. In comparison to natural “open drying”, solar dryers generate higher temperatures, lower relative humidity, and lower product moisture content and reduced spoilage during the drying process. In addition, it takes up less space, takes less time and relatively inexpensive compared to artificial mechanical drying method. Thus, solar drying is a better alternative solution to all the drawbacks of natural drying and artificial mechanical drying. The solar dryer can be seen as one of the solutions to the world’s food and energy crises. With drying, most agricultural produce can be preserved and this can be achieved more efficiently through the use of solar dryers.

MATERIALS AND METHODS

Experimental Setup

The most commonly seen design types are of cabinet form, some types are even improved making use of cardboard boxes and transparent nylon or polythene. For the design being considered, the greenhouse effect and thermos-siphon principles are the theoretical basis.

There is an air vent (or inlet) with guide ways to the solar collector where air enters and is heated up by the greenhouse effect, the hot air rises through the drying chamber passing through the trays and around the food, removing the moisture content and exits through the air vent (or outlet) near the top of the shadowed side. The hot air acts as the drying medium, it extracts and conveys the moisture from the product (or food) to the atmosphere under free (natural) convection, thus the system is a passive solar system and no mechanical device is required to control the intake of air into the dryer. “Here is an additional cabin for heat exchanging at the air exhaust door”. “There is a lot of heat wastage at the air outlet, so to accomplish that here we have one heat exchanger and it consists of copper tubes for water heating system; there is a hole at the top side of the cabin for air outlet”.

Design Consideration made on the Solar Dryer used for the Experiment

Temperature: The minimum temperature for drying food is 30°C and the maximum temperature is 60°C, therefore. 45°C and above is considered average and normal for drying vegetables, fruits, roots and tuber crop chips, crop seeds and some other crops.

Design: The design was made for the optimum temperature for the dryer. T0 of 60°C and the air inlet temperature or the ambient temperature T1 = 30°C (approximately outdoor temperature).

Air Gap: It is suggested that for hot climate passive solar dryers, a gap of 5 cm should be created as air vent (inlet) and air passage.

Glass or Flat Plate Collector: It suggested that the glass covering should be 4-5 m thickness. In this work, 4mm thick transparent glass was used. He also suggested that the metal sheet thickness should be of 0.8 – 1.0 m thickness; here a Galvanized steel of 1.0mm thickness was used. The glass used as cover for the collector was 103 ×100cm^2.

RESULT AND DISCUSION

At first day 3000 grams of potato was placed to dry in open drying system and solar (closed) drying system. The weight of potatoes were found at the first day**;** in open drying 2800 grams and in closed drying it was 2600 grams. Then this item is placed drying for next day morning and by the end of the evening it was found to be that as in open drying 2500 grams and closed drying as 2300 grams. On the third day the weight of the potato was also monitored by 6pm to 2100 grams by open drying and 1900 grams by controlled drying (solar drying).

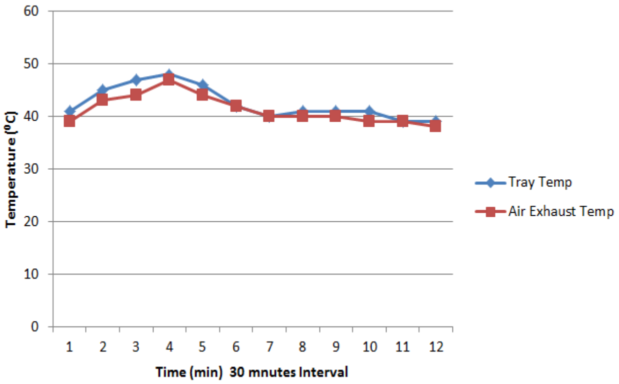

Figure 1: Temperature Variation in Dryer.

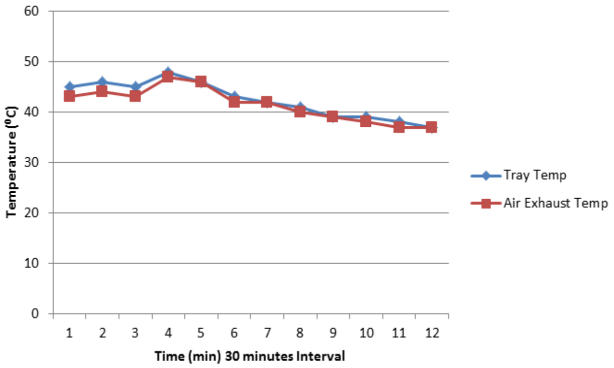

Figure 2: Temperature Variation in Dryer.

The tenth day recorded weight of open drying to be 689 grams and controlled drying to be 495 grams. Okeke et al [20] observed in there experiment that the weight of beans been dried in solar dryer reduced gradually decreased from

10Kg on day 1 to 6.0 Kg on day 10. This value indicated that solar radiation is very efficient in drying beans and other grains because the nutrient value of the beans was not altered after drying. Ugwuodo, et al. also observed that solar intensity increases the drying rate of crop drying [21].

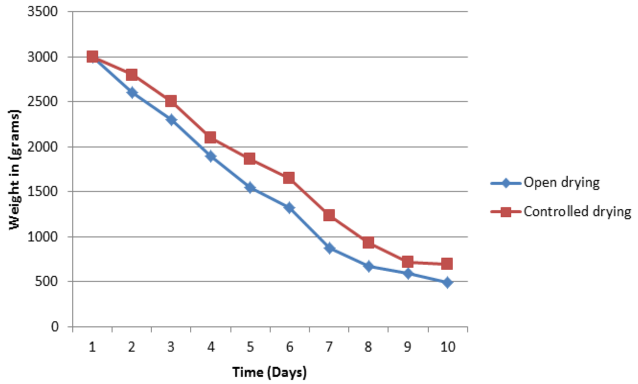

Figure 3: Open Drying versus Controlled Drying.

CONCLUSION

A solar dryer is designed and constructed based on preliminary investigations of drying under controlled conditions (laboratory dryer) [21]. The constructed dryer is to be used to dry vegetables and potatoes under controlled and protected conditions. The designed dryer with a collector area of 1m^2 is expected to dry 20 kg fresh vegetables/potatoes from 89.6% to 13% wet basis in two days under ambient conditions during harvesting period from February to March. A prototype of the dryer with 1.03 m^2 solar collector area was constructed to be used in experimental drying tests. Along with this the water heating system is also employed to the dryer to recover the waste heat getting from the dryer. Hence the practical usage of dryer is greatly increased by employing the water heating system along with dryer.

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