SOLAR DRYING OF PINEAPPLE USING SOLAR TUNNEL DRIER

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Abstract Field level experiments on solar drying of pineapple using solar tunnel drier were conducted at Bangladesh Agricultural University, Mymensingh, Bangladesh. The drier consists of a transparent plastic covered flat plate collector and a drying tunnel connected in a series to supply hot air directly into the drying tunnel using two dc fans operated by a solar module. This drier has a loading capacity of 120-150 kg of pineapple and a total of 8 drying runs were conducted. In all the cases the use of solar tunnel drier leads to considerable reduction of drying time in comparison to sun drying. The pineapple being dried in the solar tunnel drier were completely protected from rain, insects and dust, and the quality of the pineapple dried in the tunnel drier was of quality dried products as compared to sun dried products. Proximate analysis also indicates that the pineapple dried in the solar tunnel drier is a good quality dried product for human consumption.

Keywords: flat plate collector; forced convection; pineapple; solar module.

INTRODUCTION

Agriculture is the main source of livelihood for the people in Bangladesh. Fruits such as, mango and pineapple are produced here in large quantities and the incomes derived from these products are normally minimal due to inadequate conservation and storage facilities and lacking marketing structures. Drying of agricultural products is still the most widespread preservation technique and it is becoming more and more an alternative to marketing fresh fruits since the demand of high quality dried fruits is permanently increasing all over the world (Esper and Mühlbauer, 1996).

Drying of fruits in Bangladesh is normally done by sun drying. Although sun drying offers a cheap method, it often results in inferior quality due to its dependence on weather conditions and vulnerability to the attack of insect, pests, microorganisms and dust. Each year a huge amount of pineapples of different varieties is produced in Bangladesh. This fruit is highly perishable and seasonal. If the excess fruits in the season were preserved by any means ensuring the quality, consumers would have the taste of this seasonal fruit all the year round and also these processed fruits could be exported to earn foreign currency.

Solar drying can be considered as an elaboration of sun drying and is an efficient system of utilizing solar energy (Bala, 1997a & 1998, Zaman and Bala, 1989 and Mühlbauer, 1986). Sharma *et al.* (1995) reported solar drying of tomatoes, chillies and mushrooms.Karathanos and Belessiotis (1997) conducted drying experiments of fruits such as sultana grapes, currants, figs, plums and apricots. Karathanos and Belessiotis (1999) also reported that the Page equation was successful for modeling of fresh fruits, but it failed to predict the drying behaviour when the drying was continued for moisture contents below 15% (d.b.).

Natural convection dryer is low cost, can be locally constructed and does not require any power and energy from electrical grid or fossil fuels. But the natural convection solar dryers suffer from the limitations due to extremely low buoyancy induced airflow inside the dryers (Bala and Woods, 1994 & 95). The high weather dependent risk and drying limitations due to extremely low buoyancy induced air flow of natural convection solar dryers stimulated Mühlbauer and his associates at the Institute of Agricultural Engineering in Tropics and Subtropics, University of Hohenheim to develop solar tunnel drier in which a fan is providing the air flow required to remove the evaporated moisture. The electric power requirement of the fan is very low and can be operated by one photovoltaic module independent of electric grid. Numerous tests in regions of different climatic conditions have shown that fruits, vegetables, cereals, grain, legumes, oil seeds, spices and even fish and meat can be dried properly in the tunnel dryer (Mühlbauer and Muller, 1993, El-shiatry *et al.*, 1991, Schirmer *et al.,* 1996, Esper and Mühlbauer, 1993,1994&1996, Bala,

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1997b, 1999a&b, and 2000, Bala *et al.*, 1997&1999, and Bala and Mondol 2001). The purpose of this research was to study the performance of the solar tunnel drier for drying of pineapple slices under Bangladesh condition.

MATERIALS AND METHODS

Solar Tunnel Drier

The drier consists of a flat plate air heating collector, a tunnel drying unit and a small fan to provide the required air flow over the product to be dried. These are connected in series as shown in Fig.1. Both the collector and the drying unit are covered with plastic. Black paint is used as an absorber in the collector. The products to be dried are placed in a thin layer on a plastic net in the tunnel drier. Glass wool is used as insulation material to reduce

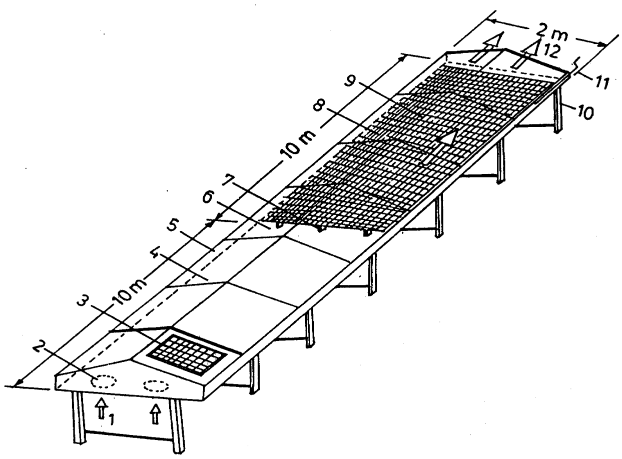

Fig. 1 Solar Tunnel Drier:
1. air inlet, 2. fan, 3. solar module, 4. solar collector, 5. side metal frame, 6. outlet of the collector, 7. wooden support, 8. plastic net, 9. roof structure for supporting the plastic cover, 10. base structure for supporting the tunnel drier, 11. rolling bar, 12. outlet of the drying tunnel

the heat loss from the drier. The whole system is placed horizontally on a raised platform. The air at required flow rate is provided by two dc fans operated by one photovoltaic module. As the air is passed over the product rather than through the product in the drier, the power requirement to drive a fan is low. To prevent the entry of water inside drier unit during rain, the cover is fixed like a sloping roof. Solar radiation passes through the transparent cover of the collector and heats the absorber. Ambient air is forced through the collector. Heat is transferred from absorber to air in the collector and heated air from collector while passing over the products absorbs moisture from the products. Solar radiation also passes through the transparent cover of the drier and heats the products in the drier. This enhances the drying rate and the temperature in the drier rises in the ranges of 34.1 °C to 64.0 °C.

Experimental Procedure

The solar tunnel drier was installed at Bangladesh Agricultural University, Mymensingh, Bangladesh. The drier was placed on raised platform and it was not shaded by trees or building during 8.0 am to 4.0 pm. Three sets of full scale experimental runs on solar drying of pineapple were carried out in the month of October, 1998, September, 1999 ,and July and August, 2000.

Important parameters affecting the performance of the drier were measured. The k-type thermocouple was used to measure the drying air temperature along the flow direction of the air inside the drier and a pyranometer (photovoltaic solar cell type) was used to measure the global radiation at the inlet of the drier. The relative humidity and temperature of the ambient air were measured with a digital thermometer and relative humidity meter (Lutron HT-3003). The velocity of drying air was measured with an anemometer (Taylor 3132) at the outlet of the drier. Weight loss of the product during drying period was measured with an electronic balance. The sun dried control samples were weighed as well. All these data were recorded at one hour interval. The moisture contents of the pineapple were measured at the starting and end of each run of experiments by air oven method.

Experimental solar drying runs were conducted on one variety of pineapple. This variety was Giant Kew. Pineapple slices of thickness 10 mm were treated with sulfur dioxide by burning sulfur in a sulfuring box and 40 mg of elemental sulfur was burnt per kg of fresh pineapple slices. The sulfuring was continued for about 0.5 hour. Pineapple slices were then spread on plastic net in a thin layer. For each of the experimental runs the drier was loaded to the full capacity of 150.0 kg of pineapple. The drying was started usually at 9.0 am and discontinued at 4.0 pm. for each day. To compare the performance of the tunnel drier with that of the sun drying, control samples of pineapple slices were placed on trays in a single layer on a raised platform beside the drier. Both experimental and control samples were dried simultaneously under the same weather condition.

RESULTS AND DISCUSSION

Experimental Results

The variations of solar radiation and generated voltage for a typical experimental run during drying of pineapple are shown in Fig.2. During drying of pineapple for 8 experimental runs the solar radiation varied from 0 W/m^2 to 580 W/m^2 while the generated voltage varied from 0.0 V to 14 V.

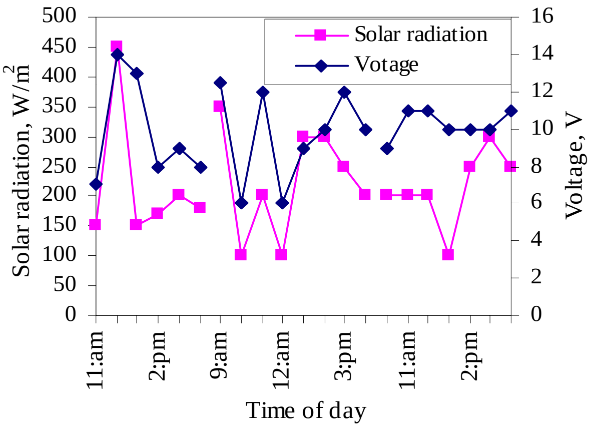

Fig.2 Variations of solar radiation and generated voltage with time of day for a typical experimental run during solar drying of pineapple.

Fig.3 shows the variations of the ambient air temperature and relative humidity of a typical experimental run during solar drying of pineapple. The ambient relative humidity decreases with the increase in the ambient temperature.

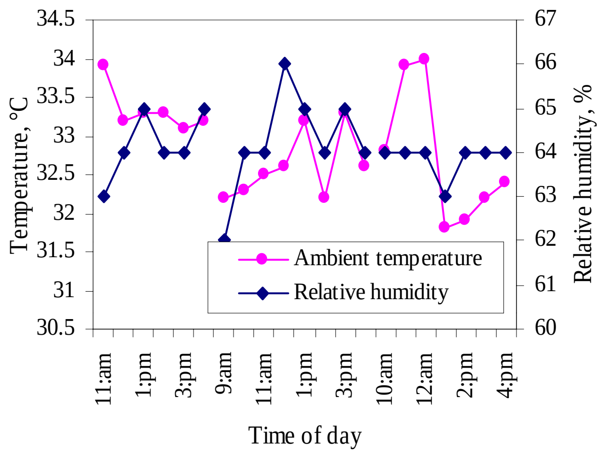

Fig.3 Variations of ambient air temperature and relative humidity with time of day for a typical experimental run during solar drying of pineapple.

The variation of the air flow rate helped to regulate the drying temperature. During high insolation period more energy was received by the collector which was intended to increase the drying air temperature, but it was compensated by the increase of the air flow rate. While during low solar insolation period less energy was received by the collector and airflow rate was low. Hence the decrease in temperature due to low solar insolation was compensated by the increase in temperature due to low airflow rate. This resulted minimum variation of the drying air temperature throughout the drying period. The patterns of temperature changes of the drying air at the collector outlet and airflow rate of a typical experimental run are shown in Fig.4.

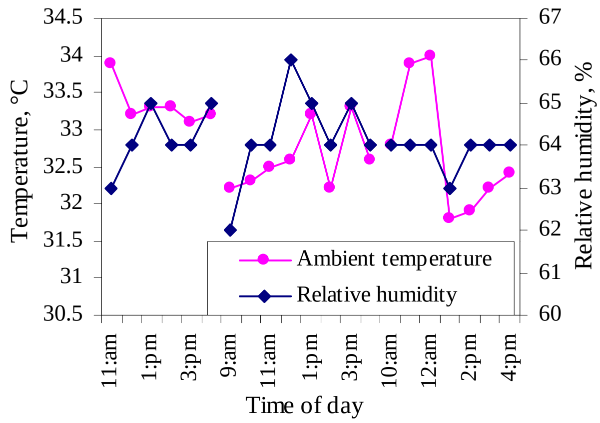

Fig.4 Variations of collector outlet temperature and air flow rate with time of day for a typical experimental run during solar drying of pineapple.

Fig.5 shows the variation of the air temperature along the length of both collector and drier for different solar radiation for a typical experimental run. The temperature inside the collector increases along the length of the collector from the inlet of the collector while the drying air temperature is almost constant throughout the drier length. As a result the pineapple slices were uniformly dried along the length of the drier.

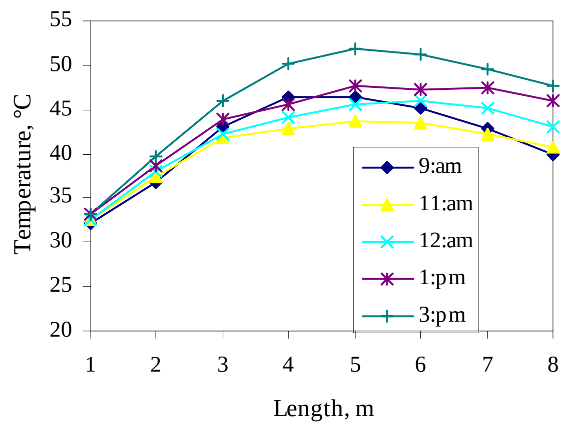

Fig.5 Variations of air temperature along the length of the solar tunnel drier for a typical experimental run during solar drying of pineapple.

Comparison of the moisture contents of pineapple in the solar tunnel drier with those obtained by the traditional method for the variety Giant Kew for a typical experimental run during drying is shown in Fig.6. The moisture content of sulfur treated pineapple (variety: Giant Kew) of a typical experimental run reached to 14.13% (w.b.) from 87.32% (w.b.) in 3 days of drying in the solar tunnel drier while it took 3 days of drying to bring down the moisture content of similar sample to 21.52% (w.b.) in traditional method. The faster drying of pineapple slices inside the solar tunnel drier is due to the fact that the pineapple in the drier received energy both from the collector and from incident solar radiation, while the control samples received energy only from incident radiation and lost significant amount of energy to the environment.

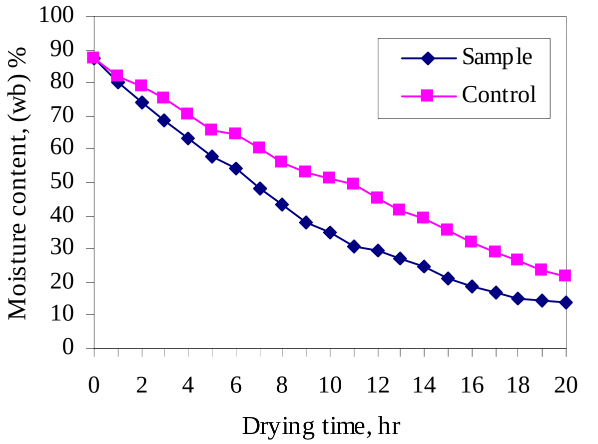

Fig.6. Variations of moisture content with time for a typical experimental run during solar drying of pineapple (variety: Giant Kew).

Proximate analysis of both fresh and dried pineapple was conducted and solar dried pineapple contains higher amount of protein and vitamin-C. Chemical compositions of the dried pineapple represent that the pineapple dried in the solar tunnel drier was a good quality product for human consumption. In all cases the quality of pineapple dried in the tunnel drier was of quality dried product as compared to sun dried pineapple. Thus, this study demonstrated the potentiality of the solar tunnel drier for drying of pineapple slices in Bangladesh.

CONCLUSIONS

Three sets of full scale field level drying runs for drying of pineapple slices were conducted and the temperature of the drying air at the collector outlet varied from 34.1 ^{0}C to 64.0 ^{0}C during drying. This drier can be used to dry up to 150 kg of fresh pineapple. The pineapple dried in the solar tunnel drier was completely protected from rain, insects and dust, and the dried pineapple was a high quality product.

This drier is simple in construction and it can be constructed using locally available materials by the local craftsman. The solar tunnel drier can be operated by a photovoltaic module independent of electrical grid. The photovoltaic system has the advantage that the temperature of the drying air is automatically controlled by the solar radiation. The photovoltaic driven solar tunnel drier must be optimized for efficient operation.

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