XVII[th] World Congress of the International Commission of Agricultural and Biosystems Engineering (CIGR)

Hosted by the Canadian Society for Bioengineering (CSBE/SCGAB)
Québec City, Canada June 13-17, 2010

DRYING OF DATES IN OMAN USING A SOLAR TUNNEL DRYER

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CSBE101658 – Presented at Section VI: Postharvest Technology, Food and Process Engineering Conference

ABSTRACT A 12 meter long by 2 meter wide solar tunnel batch dryer was designed and constructed to dry 180-200 kg of freshly harvested dates. Half of the partially air-tight tunnel base was used as the flat plate air heating solar collector and the remaining half as a dryer. The drying air was forced from the collector region (south side) to the drying region (north side) of the half circular tunnel where the product was to be dried. The drying temperature could easily be raised from 5-300ºC above ambient temperatures inside the tunnel at an air velocity of approximately 0.5 m/sec. The moisture content of 190.2 kg of freshly harvested dates was reduced by 32.8% (wet-basis) to a final average moisture content of 18.6% (wet-basis) within two days (20 hours). The results indicated that the drying was faster in solar tunnel dryer than under natural open air sun drying. It was possible to reach the moisture content level for safe storage within less than two days (20 hrs) with a solar tunnel dryer and 5-7 days in open air natural sun drying. The improvement in the quality of dates in terms of color, brightness, flavor, and taste and food value was distinctly recognizable.

Keywords: Solar dryer, Tunnel, Dried dates.

INTRODUCTION Drying is very important because it is the cheapest, easiest and most common method of preserving and storing of perishable agricultural products. Dried products are becoming highly alternative to marketing than the freshly harvested products because of many advantages.

Annual production of dates in Oman is estimated about 200,000 tones [1]. Most of the dates are still dried by traditional method of open air natural sun drying. A successful new solar tunnel drier that have been successfully tested under field conditions in about 30 countries under different climatic conditions in drying various agricultural products [2], [3], [4], [5], [6], [7] and [8]. Unfortunately, solar tunnel dryer has not yet been tested here in Oman where solar energy is abundant and can be used for drying of dates and other agricultural products.

The original designed of the dryer (20 × 2 m) however with a capacity that is suitable for use in a large farm. In order to adapt its design for small and medium scale rural farmers of Oman, a scaled down (12 × 2 m) prototype of the tunnel dryer was designed and fabricated for the detail experiment at the Department of Soils, Water and Agricultural Engineering, Sultan Qaboos University, Oman.

MATERIALS AND METHODS

The prototype solar tunnel dryer consists of a flat plate air heating solar collector and drying tunnel, fabricated as a single unit (Figure 1). The tunnel is 2.0 m wide, with a collector and dryer length of 6.0 m, respectively. The light weight aluminum frames were used as the upper structure for the entire tunnel to support the transparent plastic cover. The tunnel was placed on concrete block substructures 700 mm above the ground surface. The ply wood planks (0.9 × 2.0 m) of thickness 4 mm were used as the bed both for the dryer and collector parts of the tunnel to make the base of the tunnel almost air tight. Over the wooden base, black painted metallic sheets (0.9× 2.0 m) of thickness 0.25 mm was used as the absorber plate in the collector section of the tunnel. The steel wire mesh net was spread over the wooden dryer base to dry the desired product. A 0.2 mm thick UV stabilized colorless polyethylene sheet was used as the transparent cover over the entire tunnel (collector and dryer area). The entire tunnel became almost air-tight except the inlet opening (south side) for fixing a fan and the exit side (north side) for the moist air. The light weight (30 × 1 mm) aluminum flat bars were cut into pieces of each having a length 3140 mm and were bend to half-circles before fixing with the wooden base of the tunnel. A solar powered fan of 40 watt capacity was installed at the holes made on the wooden cover plat, 150 mm above the

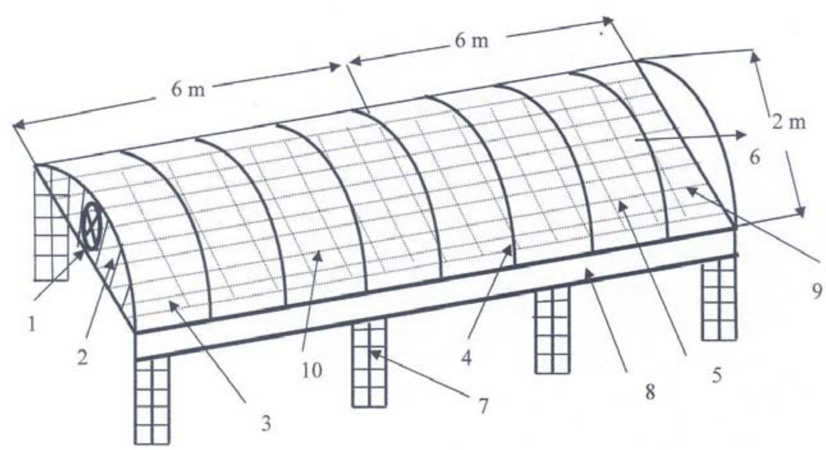

Figure 1 A rough sketch of a solar tunnel dryer used in this study without plastic cover and part of wooden base of the tunnel *(1- Air inlet to the collector, fan, 2- South side wooden cover, 3- Collector part (12 m^2), 4- Light weight aluminum frame, 5- Dryer part (12 m^2) 6- Air outlet from the dryer, 7- Concrete block sub-structures, 8- Wooden frame to support bends and base of the tunnel; 9- Metallic wire mesh net over wooden base in the dryer part, 10- Absorber plate (black painted metallic sheet over wooden base, not visible in figure, 12 m^2*)

absorber metallic sheet at the air input side of the tunnel. Thus the drying air was forced from the collector region to the dryer region where the product is to be dried. The fan has an air handling capacity of 7.3 m^3/min against a maximum static pressure of 157 Pa (16 mmH_2O). Prior to the operation of the dryer thermocouples were installed to record the temperatures at different locations within the tunnel. Nine thermocouples were connected within the tunnel, three at each of the mid-point of the collector, dryer and as well as the whole tunnel.

The moisture content of whole dates was determined by using oven drying method. The sample of whole dates was kept at 100^0C for 20 hours [9].

RESULTS AND DISCUSSION

No-load tests (test without product)

The no-load tests with and without fan were conducted to know the temperature and air flow characteristics at different weather conditions and also, the temperature gradient both in the collector and dryer regions of the tunnel. Figure 2 shows the variations of ambient, collector and dryer temperatures with time of the day. The drying air temperature could be easily raised by some 5-30^0C above the ambient temperature at an air flow rate of 0.5-0.6 m/sec. The difference between the drying air temperature and ambient temperature gradually increased from morning till mid-day then gradually fall in the afternoon (Figure 2). The highest temperature 69^0C was observed at around 1 PM. This indicated that solar tunnel dryer can be easily used to dry dates. In no load tests the maximum difference between the average temperatures of the dryer and collector parts was about 2^0C. This indicated the uniformity of temperatures inside the entire tunnel except at entrance side of the collector.

There was almost no temperature gradient in the vertical direction of the whole tunnel (Figs. 3 and 4). A no-load test was also conducted without using fan. It was also observed that the highest temperature inside the tunnel became 75^0C when the fan was not in operation. The difference between

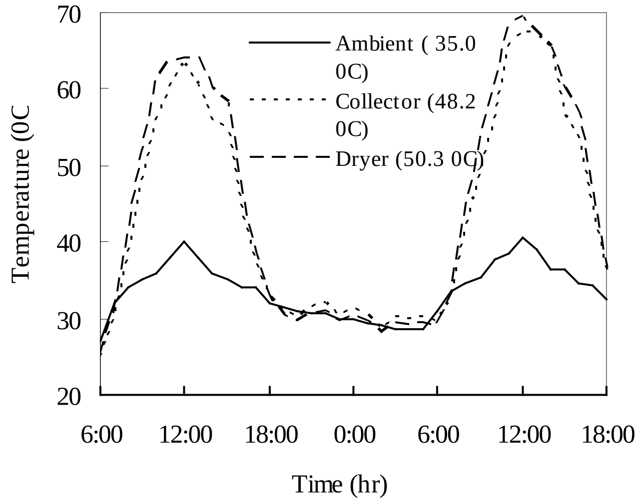

Figure 2 Variations of ambient, dryer and collector air temperatures with time of the day (August 8-9, 2008) under no load condition.

the average temperatures inside the tunnel without and with fan was about 10^0C. This indicated the operation of the dryer without fan would cause over drying of the product particular during 11:00 AM-3:00 PM. The average solar irradiance was about 500 w/m^2

Test with Freshly Harvested Dates

The full load test with 190.2 kg freshly harvested dates (khalas variety) was conducted to study the dryer performance on July 27-28, 2009. The average initial moisture content of the freshly harvested dates collected from the Agricultural Farm of the University, was 32.8% (wet-basis). The dates were spread on a wire mesh net in a single layer thickness placed over the plywood bottom of the drying section of the tunnel. The drying was started at 6:30 AM and continued till 6:30 PM. The approximate sun rising and setting time was 6:00 AM and 7:00 PM, respectively. After termination of first day drying, the product was kept

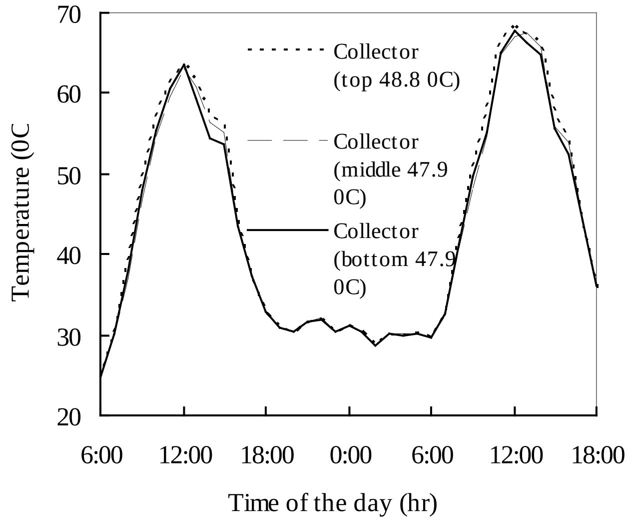

Figure 3. Temperature profile in vertical direction of collector section of the tunnel.

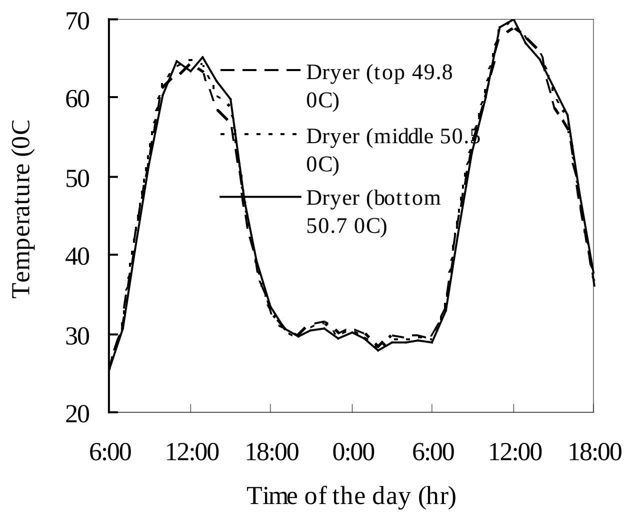

Figure 4. Temperature profile in vertical direction of dryer section of the tunnel.

undisturbed in the dryer closing both sides of the tunnel by polyethylene sheet so that air could not passed through the tunnel. The moisture content was reduced to 21.5% from initial 32.8% wet-basis in 12 hours drying on the first day. The next day drying was started at 6:30 AM and continued till 5:00 PM when the products reached their final moisture content 18.5 % (w.b.). Samples were collected for moisture content determination at the end of drying and it was found around 18.5% (wet-basis).

The variations of the dryer and collector air and the ambient air temperatures with drying time (6:00-19:00 hr/day) in two days have shown in figure 5. The variations of solar radiation with drying time is shown figure 6. The average drying air and ambient temperatures were 52.0^{0}C and 36.2^{0}C, respectively, and the average total radiation on a horizontal surface was 490.9 w//m^2. The average temperature in the collector part was lower than the average temperature in the dryer part because of the presence fan at the air entrance side of the collector.

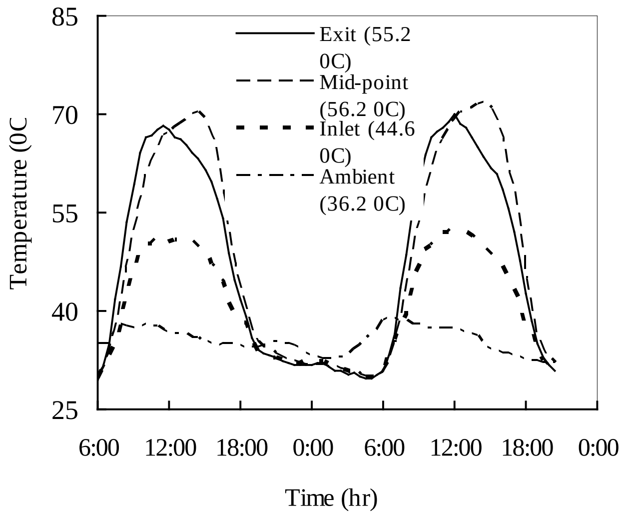

Figure 5. Variations of ambient, dryer and collector temperatures with time of the day (July 27-28, 2009,) in drying freshly harvested dates.

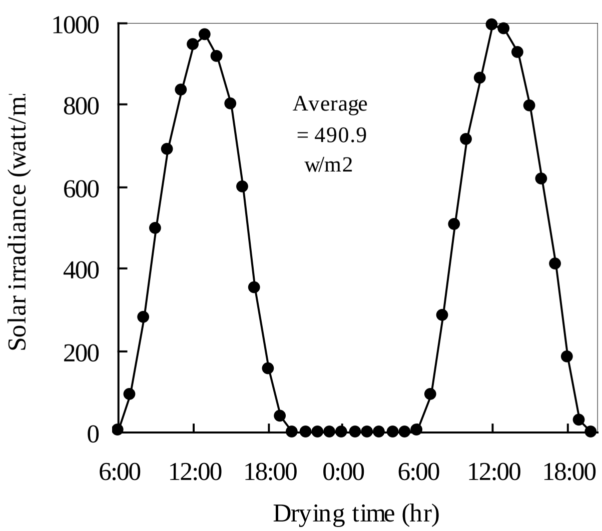

Figure 6. Variation of solar radiations in drying dates on 27-28 July 2009.

To compare the drying rates of solar tunnel dryer and natural convection open air drying, two separate tests was conducted with about 100 gm samples under the same weather conditions. The samples from the tunnel dryer and open air drying were taken at one hour interval for the first four hours of drying starting from 6:30 AM and then at two hours interval till 6:30 PM to measure the moisture content against the drying time. The variations of moisture contents in solar tunnel drying and natural open air sun drying with time has shown Figure 7. The moisture removal rate was much high in solar tunnel dryer than the open air natural sun drying (Figure 7).

CONCLUSIONS

This paper describes the design, construction and experimental investigation of a solar tunnel dryer. The no-load tests clearly indicated that the drying temperature can be easily raised to 5-30^{0}C above the ambient temperature while the average air flow velocity inside the tunnel was 0.5 m/s. The average drying air temperature could be easily attained 50-55^{0}C .

The experiments were carried out with 190.2 kg freshly harvested dates and the performance of the dryer was compared to open air natural sun drying. A considerable reduction in drying time in comparison with natural open air sun drying was obtained. The thermal efficiency of dryer was found to be 36.4% approximately.

These investigations show that solar tunnel dryer can be used for low temperature drying of dates and other agricultural products in the rural areas of Oman where electricity is not available.

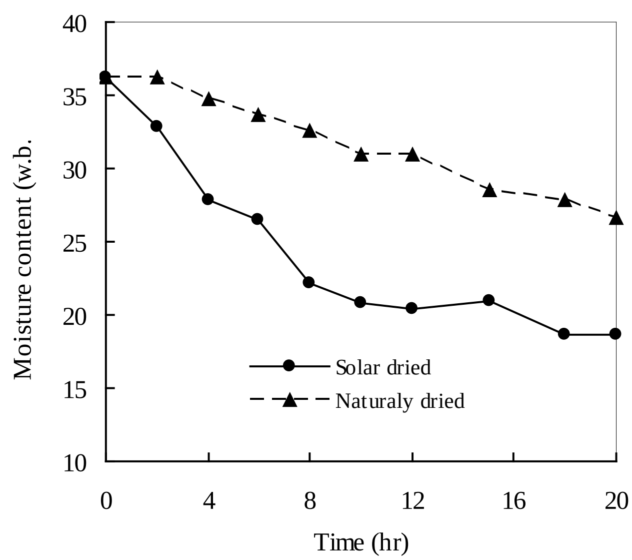

Figure 7. Variations of moisture content with drying time with solar tunnel dryer and natural open air sun drying

ACKNOWLEDGEMENT

The financial support by the IG/AG/SWAE/08/01 for this study at the College of Agricultural and Marine Sciences, Sultan Qaboos University is greatly acknowledged.

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