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Design, Implementation and Testing of an Indirect Solar Potato Dryer

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ABSTRACT

This paper reports the design, implementation and testing of an indirect solar potato dryer. Indirect solar drying is the new technique of product drying. It is very efficient method than the direct type of solar drying. In this method the atmospheric air is heated in flat plate collector. This hot air then flow in the drying cabinet or drying chamber where potatoes slides are stored. Therefore moisture from the potatoes slides may lost by convection and diffusion. This method of drying is used to avoid direct exposing to the solar radiation. This method mainly reduces the disadvantages of direct solar drying. The experimental set up used for testing the performance of an indirect solar food dryer and determining the influence of various drying methods on the drying behavior of fresh potatoes slides. Evaluation of the dryer was centered on the moisture content reduction and temperature variations. 2 kg of fresh potatoes slides was used for evaluation. Temperatures of the drying chamber (drying cabinet), solar collector and ambient air were taken daily using digital sensors on an hourly basis from 9:00 am to 5:00 pm. Moisture content was taken at the beginning and at the end of each drying day. The test results gave temperature above 65 ^{o}C in the flat plate collector (solar collector), 50 ^{o}C in the drying cabinet, and the moisture content of 2 kg of fresh potatoes slides reduced to about 66.1 % in five days of drying.

Introduction

Drying is the reduction of moisture from the products and is a most important process for preserving agricultural products since it has a great effect on the quality of the dried products. The major objective in drying agricultural products is the reduction of the moisture content to a level which allows safe storage over an extended period [1-3].

Solar drying is the oldest method of products drying. Open air solar drying method is used frequently to dry the agricultural products. But this method has some disadvantages. Therefore to avoid disadvantages it is necessary to use the other solar drying methods. Different solar drying methods are direct solar drying, indirect solar drying, and mixed mode solar drying. Solar dryer is the simple devices used to collect the solar radiations and transfer that radiation in the form of heat energy and this heat energy then transfer to product for drying [4-7].

The aim of this research work therefore, is to design, implement and test an indirect solar potato dryer to dry at least 2 kg of potato slides. The design consists of three major sections: the solar flat plate collector upon which solar energy is incident, transmitted and absorbed to heat air which is passed by forced convection to the drying cabinet; the drying cabinet and the drying racks. The experimental set up used for testing the performance of an indirect solar food dryer and determining the influence of various drying methods on the drying behavior of potato slides.

Evaluation of the dryer was centered on the moisture content reduction and temperature variations. 2 kg of fresh potatoes slides were used for evaluation. Temperatures of the drying chamber, solar collector and ambient air were taken daily using digital sensors on an hourly basis from 9:00 am to 5:00 pm. Moisture content was taken at the beginning and at the end of each drying day.

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Material and Method

The solar dryer considered in this research paper is an indirect forced convection solar dryer. In this method the atmospheric air is heated in flat plate collector or concentrated type solar collector. This hot air then flow in the drying cabinet where products are stored. Therefore moisture from the product may lost by convection and diffusion. A typical indirect solar dryer is made up of the following basic units:

(a) Flat plate solar collector

The heat absorber of the solar air heater was constructed using 5 mm thick galvanized plate, painted black, the surface facing sunlight was painted with black paint. The solar collector was insulated on all sides. The solar collector assembly consists of air flow channel enclosed by transparent cover (glazing). The glazing is a single layer of 4 mm thick transparent glass sheet. The collector has been rigidly fixed to the dryer at an angle approximately 17^{o} to the horizontal to obtain approximately perpendicular beam of sun rays to avoid damage in transit as shown in Figure 1.

(b) Drying chamber or drying cabinet

The designing of the drying chamber depends on many factors such as the product to be dried, the required temperature and velocity of the air to dry food material, the quantity of the dried product and the relative humidity of the air passing over the food material. The drying chamber houses three drying racks, between a tray and another tray is 10 cm as shown in Figure 1. The drying chamber was also lined with foam insulation material 5 cm thick to prevent loss of heat.

(c) Drying beds or drying racks

Three trays or drying racks were fabricated from an aluminum wire of dimension (0.8 x 0.30 x 0.08 m) as shown in Figure 3. Metal handles were attached on each tray for ease of handling and sliding the trays inside the drying cabinet through the produce to be dried. Figure 1 shows the main components of an indirect solar dryer. The dryer has three main features namely: the absorber solar air collector, the drying cabinet and the drying racks.

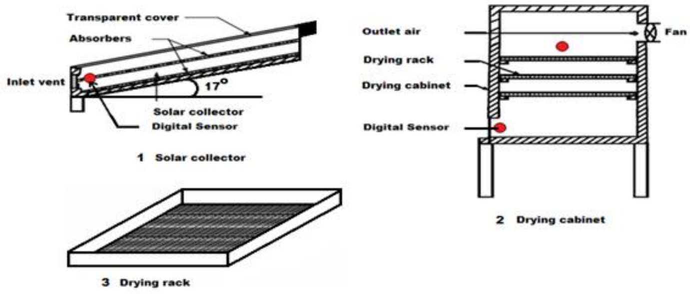

Fig 1. Main component of an indirect solar food dryer
1. Solar collector 2. Drying cabinet 3. Drying beds or drying rack

Design Specification

The testing of the solar potato dryer was done in the month of April for five days starting from 9:00 am to 5:00 pm. The solar Dryer was placed outside with the collector facing the direction of the sun. The collector has been rigidly fixed to the dryer at an angle approximately 17^{o} to the horizontal to obtain approximately perpendicular beam of sun rays to avoid damage in transit. Slides of fresh potato were arranged on the drying bed in a single layer to avoid moisture being trapped in the lower layer. The dryer chamber door was closed and seals placed in position.

- Total mass of freshly potato = 2 kg
- Drying period required =9 hrs x 5 days = 45 hrs
- Average ambient temperature (T_a) = 32 ^{o}C (305 K)
- Relative humidity (RH) = 70 %

Evaluation of the Dryer

Evaluation of the dryer was centered on the moisture content reduction and temperature variations. 2 kg of fresh potato was used for evaluation.

Temperature

Temperatures of the drying chamber, solar collector and ambient air were taken daily using digital sensors on an hourly basis from 9:00 am to 5:00 pm.

Relative Humidity

Relative humidity may be defined as the ratio of the water vapor density (mass per unit volume) to the saturation water vapor density, usually expressed in percent:

$$Relative\ Humidity\ (RH) = \frac{Actual\ Vapour\ Density}{Saturation\ Vapoud\ Density} \times$$

Relative humidity of the drying chamber, solar collector and ambient air were taken daily using digital sensors on an hourly basis from 9:00 am to 5:00 pm.

Moisture content

Moisture content was taken at the beginning and at the end of each drying day using the oven drying method and calculated using the following equation:

$$Moisture\ content = \frac{M_i - M_f}{M_i} \times 100$$

Where:

M_i = Mass of potato slides before drying

M_f = Mass of potato slides after drying

Testing

The testing of an indirect solar potato dryer was done in the month of April for five days starting from 9:00 am to 5:00 pm. Evaluation of the dryer was centered on the temperature variations and moisture content reduction. 2 kg of fresh potato was used for evaluation. The result obtained for hourly reading is tabulated in tables 1-5.

Results

Discussion of results

Variation of Temperatures with Time

Variations in temperature were observed as shown in Tables 1 – 5 and Figures 2 – 6. Lower temperatures were recorded during the morning and evening hours with the morning hours recording the lowest temperatures. At 9:00 am, the ambient temperature was about 32 ^{o}C, while the solar collector recorded about 42 ^{o}C and the solar drying cabinet had about 35 ^{o}C. At 5:00 pm, the temperatures were about 36 ^{o}C, 53 ^{o}C and 44 ^{o}C for ambient, solar collector and drying cabinet respectively.

It is observed from Tables that, the temperatures in the solar collector and drying cabinet were higher than the ambient temperatures, with the solar collector recording the highest temperature at each reading followed by the drying cabinet. The highest temperatures were recorded during noon. At 2:00 pm, the ambient temperature was about 39 ^{o}C while the solar collector recorded 62 ^{o}C and the solar drying cabinet had 52 ^{o}C.

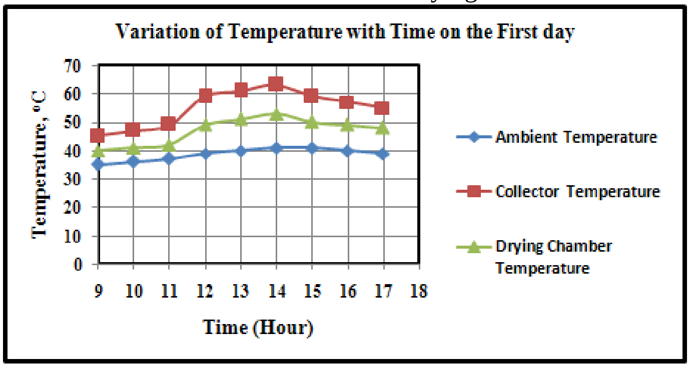

Fig 2. Variation of Temperature with Time on the First day

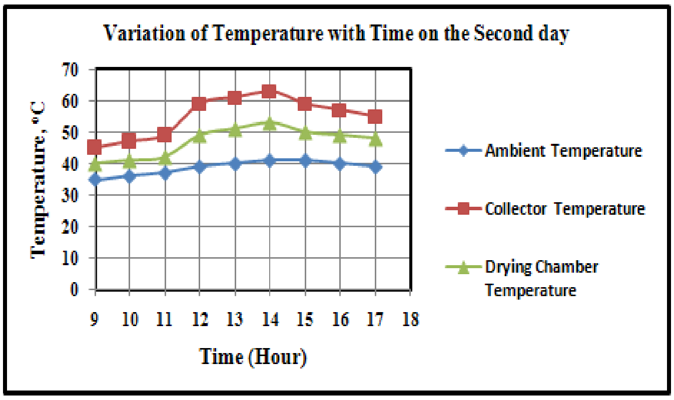

Fig 3. Variation of Temperature with Time on the Second day

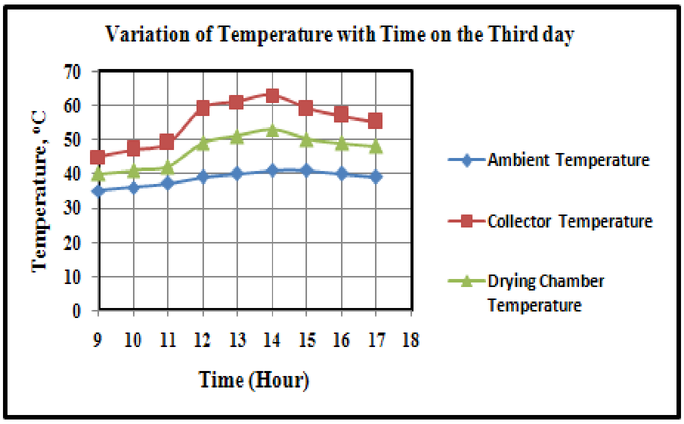

Fig 4. Variation of Temperature with Time on the Third day

Results on 12 April 2015

Table 1. Variation of Temperature with Time on the First day

Day 1									
Time	**9 am**	**10 am**	**11 am**	**12 am**	**1 pm**	**2 pm**	**3 pm**	**4 pm**	**5 pm**
Ambient (^{0}C)	32	34	36	38	40	39	38	37	36
Collector (^{0}C)	42	45	50	58	61	62	58	54	52
Drying cabinet (^{0}C)	37	39	41	48	51	52	52	46	44
Mass of Potato (g)	2000								1620

Moisture removed = 2000– 1620 = 380 g   Total moisture loss = 19 %

Results on 13 April 2015

Table 2. Variation of Temperature with Time on the Second day

Day 2									
Time	**9 am**	**10 am**	**11 am**	**12 am**	**1 pm**	**2 pm**	**3 pm**	**4 pm**	**5 pm**
Ambient (^{0}C)	34	35	36	38	40	42	40	37	36
Collector (^{0}C)	45	48	52	58	60	62	62	58	53
Drying cabinet (^{0}C)	39	40	41	48	51	52	52	46	44
Mass of Potato (g)	1620								1350

Moisture removed = 1680 – 1350 = 270 g   Total moisture loss = 16.7 %

Results on 14 April 2015

Table 3. Variation of Temperature with Time on the Third day

Day 3									
Time	**9 am**	**10 am**	**11 am**	**12 am**	**1 pm**	**2 pm**	**3 pm**	**4 pm**	**5 pm**
Ambient (^{0}C)	34	36	37	40	42	43	38	36	35
Collector (^{0}C)	44	47	49	60	63	65	56	53	51
Drying cabinet (^{0}C)	39	41	42	50	53	55	50	45	43
Mass of Potato (g)	1350								1160

Moisture removed = 1350 – 1160 = 190 g   Total moisture loss = 14.1 %

Results on 15 April 2015

Table 4. Variation of Temperature with Time on the Fourth day

Day 4									
Time	**9 am**	**10 am**	**11 am**	**12 am**	**1 pm**	**2 pm**	**3 pm**	**4 pm**	**5 pm**
Ambient (^{0}C)	35	36	37	38	40	42	42	39	37
Collector (^{0}C)	46	47	49	58	61	64	60	56	53
Drying cabinet (^{0}C)	41	41	42	50	51	52	50	48	46
Mass of Potato (g)	1160								1020

Moisture removed = 1160 – 1020 = 140 g   Total moisture loss = 12.1 %

Results on 16 April 2015

Table 5. Variation of Temperature with Time on the Fifth day

Day 5									
Time	**9 am**	**10 am**	**11 am**	**12 am**	**1 pm**	**2 pm**	**3 pm**	**4 pm**	**5 pm**
Ambient (^{0}C)	35	36	37	39	40	41	41	40	39
Collector (^{0}C)	45	47	49	59	61	63	59	57	55
Drying cabinet (^{0}C)	40	41	42	49	51	53	50	49	48
Mass of Potato (g)	1020								915

Moisture removed = 1020 – 915 = 105 g   Total moisture loss = 10.3 %

Table 6. Variation of Moisture Removed and Moisture Loss with Time for 5 days drying

Day	**Moisture removed (g)**	**Total Moisture Loss (%)**
1	380	19
2	270	16.7
3	190	14.1
4	140	12.1
5	105	10.3

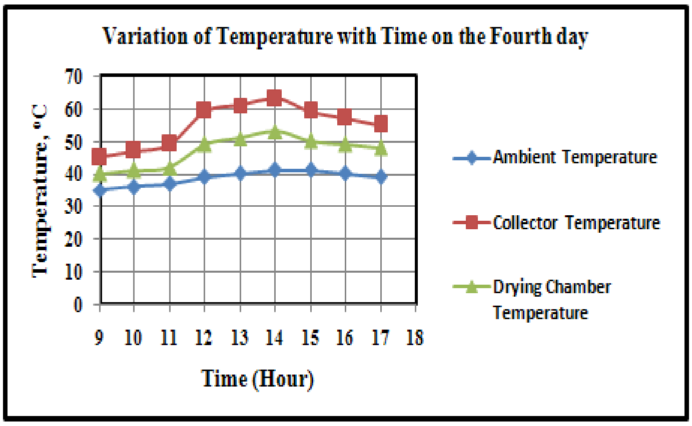

Fig 5. Variation of Temperature with Time on the Fourth day

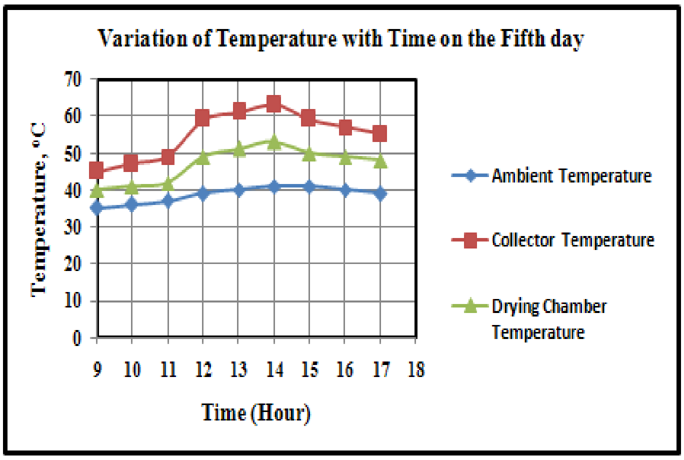

Fig 6. Variation of Temperature with Time on the Fifth day

Figures 2 - 6 show the variation of the temperatures in the solar collector and the drying cabinet compared to the ambient temperature. The dryer is hottest about mid-day when the sun is usually overhead. The temperatures inside the dryer and the solar collector were much higher than the ambient temperature during most hours of the daylight. The temperature rise inside the solar collector was up to 22 °C approximately. The temperature rise inside the drying cabinet was up to 12 °C approximately for about three hours immediately after 12.00 h (noon). This indicates prospect for better performance than open-air sun drying.

Variation of Mass of the Potato and Moisture Loss with Time

Tables 1 – 5 and Figures 7 & 8 show the variation of mass of the potato and moisture loss in an indirect solar food dryer. It was observed that the drying rate increased due to increase in temperature between 12.00h and 14.00h but decreased thereafter, which shows the earlier and faster removal of moisture from the dried item.

Based on the results obtained during the test, temperature above 50 °C was recorded. This high temperature in the drying chamber causes *380 g* of moisture to be removed on the first day, *270 g* on the second day, *190 g* on the third day, *140 g* on the fourth day and finally *105 g* on the fifth day. At the end of the five days of drying process, the mass of *2000 g* of potato was reduced to *915 g*. Total amount of moisture removed was *1085 g* and total moisture loss was 54.25 %, which is the required amount of moisture to be removed for safe drying of potato slides. Variations in moisture removed and moisture content for the five days of drying were observed as shown in Table 6 and Figures 7 & 8.

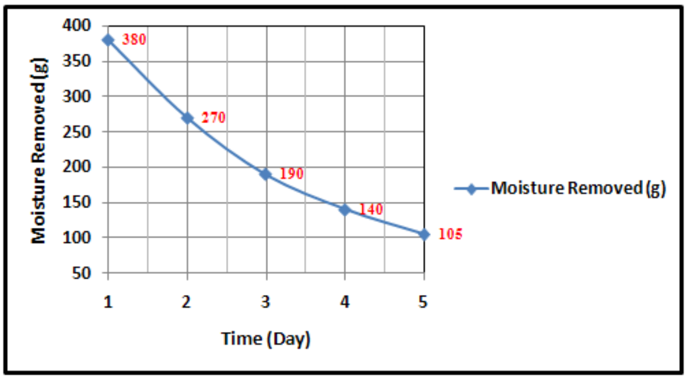

Fig 7. Variation of Moisture Removed with Time for the period of drying (5 days)

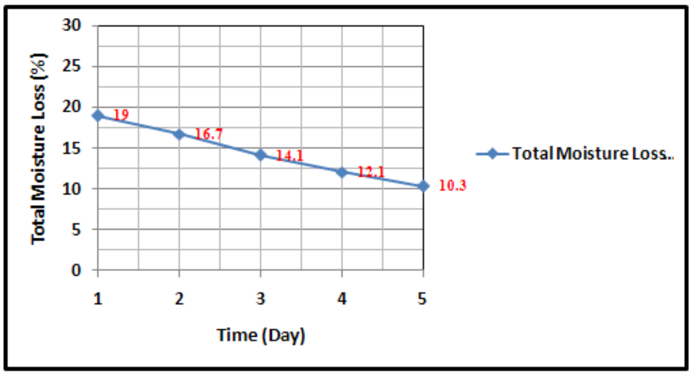

Fig 8. Variation of Total Moisture Loss with Time for the period of drying (5 days)

The moisture content of the freshly potato slides was 19 % at the end of drying for the first day at about 5:00 pm, 16.7 % at the end of drying for the second day, 14.1 % at the end of drying for the third day, 12.1 % at the end of drying for the fourth day and finally 10.3 at the end of drying for the fifth day. It was observed that the drying rate increased from the end of one day to another, which shows the earlier and faster removal of moisture from the dried item.

Conclusions

From the test carried out, the simple and inexpensive indirect solar potato dryer was designed and implemented using locally sourced materials. The variations of the temperatures inside the drying cabinet and solar air heater are much higher than the ambient temperature during the most hours of the day light. The temperature rise inside the solar collector was up to 22 °C for about three hours immediately after 12.00h, while the temperature rise inside the solar cabinet was up to 12 °C. It was observed that the drying rate increased due to increase in temperature between 12.00h and 14.00h but decreased thereafter, which shows the earlier and faster removal of moisture from the dried item. Finally, the dryer exhibited sufficient ability to dry food items reasonably rapidly to a safe moisture level and simultaneously it ensures a superior quality of the dried product.

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