Performance evaluation and demonstration of direct solar potato dryer

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Abstract

The study was conducted to evaluate the performance of two models of direct solar potato dryers and to demonstrate the best drier to farmers in major potato producing areas in the Amhara region. Type 1 (wooden box) dryer and Type 2 (tent) dryer models were evaluated. Both were compared with open sun drying methods. Temperature, relative humidity, and rate of moisture removal as expressed by loss-in-weight were recorded and analyzed. Results showed that on average there was a 10-20 ^{0}C temperature difference between ambient condition and the drying chambers. Besides, the weight of sliced potato which was initially 0.9 kg was reduced to about 0.19 kg within two days of drying. There was an overall reduction in drying time by 2-3 hours compared to open sun drying. This result, however, was not perceived to be large enough under existing testing condition. But, considering other benefits of the driers like protecting the material against contaminants, dust, and insects and maintaining better quality product, this result is acceptable. Of the two driers, Type 2 dryer was found better in creating more conducive drying environment with higher temperature and lower relative humidity. Moreover, considering manufacturing costs and simplicity in design and construction, type 2 dryer is still better than Type 1 dryer. Demonstration and practical training on the use of solar dryers and methods of food preparation out of the dried potato slices was provided for a group of farmers. This dryer is suitable for drying small quantities (10-15 kg) of granular materials and is recommended for use at household level.

Key words: Potato, solar drier.

Introduction

Drying as a means of preserving agricultural products has been practiced since ancient times. It is one of the postharvest operations for biological materials as quality of these materials is influenced by drying. Crops such as fruits, vegetables and cereals can be well preserved after removing free water by means of drying. Moreover, the main purpose of drying agricultural product is to store for longer periods, minimize storage and packaging spaces and reduce weight to handle and transport. Open sun drying with the application of traditional knowledge is still widely practiced throughout the world and largely unchanged since ancient times. This method employs spreading the crop on the ground and turning regularly until the product is sufficiently dried. However, it has inherent limitations in that it requires large amount of space and extended drying time. The crop will also be damaged because of the hostile weather conditions, will be contamined with foreign materials, and will be degraded by overheating. Besides, products will be subjected to series insect and fungal infestation and also might be susceptible to re-absorption of moisture. In such conditions, solar operated crop dryers appear to be viable alternative to the traditional open sun drying where quicker and controlled drying process can be attained and crops can be well protected during drying.

Solar thermal technology is a technology that is rapidly gaining acceptance as an energy saving measure in agriculture application. It is preferred to other alternative sources of energy such as wind, because it is more abundant, inexhaustible, and non-polluting (Akinola and Fapetu, 2006). In many parts of the world there is a growing awareness that renewable energy has an important role to play in extending technology to farmers in developing countries to increase their productivity (Waewsak *et al.*, 2006). But the performance of solar dehydration process can be affected by many variables such as amount of sun light, relative humidity, air movement and type of crop to be dried. In this regard, different types of dryers have been developed and used to dry agricultural products to improve shelf life (Esper and Muhlbauer, 1996). Most of the dryers in use to date utilize electric power which is expensive and unavailable for smallholder farmers in Ethiopia. Simple natural convection dryers can suit better to dry fruits and vegetables in remote areas of the country.

Potato is one of the most widely grown tuber crops in Amahara region. Recent survey results reveal that more than 71,325 ha of land in Amhara region were covered by potato in the year 2001/02. It accounts 90% of the total land coverage by root and tuber crops and about 68% of the volume of root crop production. Out of this produce, about 70% was used for household consumption (CSA, 2003). In spite of its wide adaptation, it is perishable which often results in high postharvest losses. Drying potato using simple natural convection dryer may be a viable option to reduce postharvest loss and assist farmers to prepare a variety of potato based food products. The objective of this study was, therefore, to determine the performance of two models of direct solar dryers in drying potato and thereby demonstrate better performing dryer to potato producing farmers in Amhara region.

Materials and methods

Description and construction of the direct solar dryers

The exact manufacturing drawing of the solar dryers was prepared using reveres engineering. Two types of direct solar dryers were manufactured for evaluation at Bahir Dar Agricultural Mechanization and Food Science Research Centre.

Figure 1 (left and middle) shows the essential features of the Type 1 solar box dryer. The drying chamber is made of a simple wooden box with its outer dimension of 1.81 m X 0.83 m X 0.82 m. The upper part of the dryer is covered with a single layer of 4 mm thick glazing transparent glass sheet; with a surface area of 1.72 m by 0.86 m. But the effective area of the glazing collector is 1.17 m. The solar collector (mirror) is oriented facing South and tilted at 21.27^o to the horizontal so as to receive maximum solar radiation during the desired season of use. The best stationary orientation is due South in the Northern hemisphere and due North in Southern hemisphere. This is approximately 10^o more than the local geographical latitude (Bahir Dar is located at 11.37^{o}N).

The drying chamber has partition in the middle where each partition has three shelves and a total of six sliding trays are inserted for placing the dried products. Each tray is 10 mm deep with wire mesh in the bottom and its effective area was 0.44 m^2. The relative positions of these trays are: the bottom tray (T3), the middle tray (T2) and the top tray (T1) which are located at 32 cm, 21 cm and 10 cm, respectively above the interior bottom floor of the dryer.

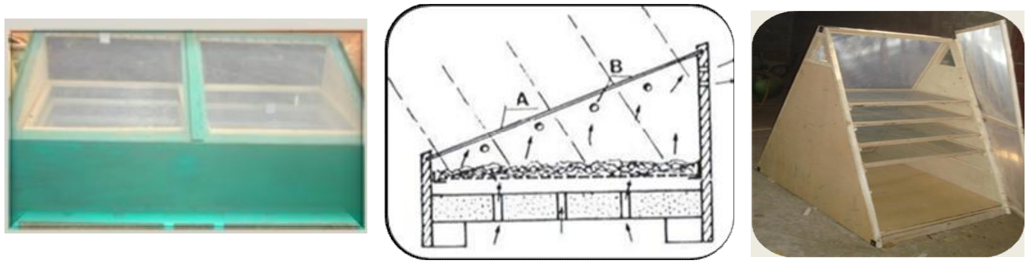

Figure 1. Complete and sectional view of Type 1 solar dryer (left and middle) and Type 2 dryer (right) .

The drying trays inside the drying box are constructed from a double layer of fine chicken wire mesh with a fairly open structure to allow drying air to pass through the drying stuff. The solar dryer has a total of 80 air inlet and outlet vents at the bottom with a diameter of 12 mm. Inlet vents located at the bottom and outlet vents provided towards the upper end at the back and at both sides of the cabinet to facilitate and control the convection flow of air through the dryer. Access door to the drying chamber is also provided at the back of the cabinet. The material used for the construction of the direct absorption dryer is wood, chipboard, 4 mm mirror and sawdust between 5 cm thick walls as insulating materials. These materials are easily available at the local market. Its weight was 75 kg and production cost was about ETB 2075.

The right side photographic view in Figure 1 depicts the Type 2 solar dryer. This dryer has 1.70 m X 1.48 m X 1.10 m overall dimensions. The front and back sides of the dryer are covered with a transparent plastic sheet; the effective area of the collector glazing is 3.28 m^2. The dryer has four shelves with sliding trays where the products to be dried are placed. Each tray is 10 mm deep with wire mesh in the bottom and their effective area for tray 1, 2, 3, and 4 are 0.59 m^2, 0.74 m^2, 0.89 m^2, and1.05 m^2, respectively. The relative positions of these trays are: the bottom tray (T4) located at 48 cm, the next tray (T3) located at 62 cm, the middle tray (T2) located at 77 cm and the top tray (T1) located 90 cm above the internal bottom floor of the dryer. The drying trays are placed inside the drying box which is constructed from a double layer of fine chicken wire mesh with a fairly open structure to allow drying air to pass through the material to be dried.

This dryer has one rectangular shape air inlet and two triangular shaped outlet windows. The inlets have a total area of 0.048 m^2 while the outlets have an area of 0.055 m^2. Inlet vents are located under the edge of the door, whereas the outlet vents are located on the upper end at both sides of the cabinet to facilitate and control the convection flow of air through the dryer. Access door to the drying chamber is also provided at the front of the cabinet (Figure 1, right). The materials used for the construction of this solar dryer were wood, plywood, and plastic sheet. These materials are easily available in the local market. Its weight is 20 kg and production cost is about ETB 568.72. The design of Type 2 dryer is simple, can be disassembled easily during transporting time and its cost is low.

Dryer performance evaluation

Fresh potato of unknown variety purchased from the local market was used for the experiment. Before drying, the potatoes were washed, peeled, cut into slices of 58 mm average diameter and 28 mm average thickness. The samples were blanched for about 10 minutes in 87 ^{O}C water, and then the surface water was removed using wire mesh filter. Finally, the samples were placed on the drying tray in a single layer in each dryer. Open sun drying was used as a check.

The performance of dryers was evaluated at the Bahir Dar Agricultural Mechanization and Food Science Research Centre. Air temperature and relative humidity of both ambient and dryer environment were recorded using temperature and relative humidity sensors which were placed at different locations inside the dryer. The sensors (Model 100 WatchDog data logger of SpecWare ^{TM}) were configured to record data at 10 minute interval. The hourly weight difference of the sample was recorded for two consecutive days between 4:00 and 9:00 local time. Conventional air and sun radiation were used to dry potato slices. The test was conducted with dryer inlets and outlets fully opened.

Results and discussion

Two tests were conducted between May and Jun 2010. This paper reports the results of one of the tests. The two dryers were compared with open sun drying between 12 to 14 May 2010 without loading potato slices. The three consecutive day time average temperature value at the peak time (20:03 hr) were found to be 29.36, 44.00 and 61.93 ^{O}C for open sun, Type 1 and Type 2 dryers, respectively (Figure 2). The overall day time (12:00–24:00) average temperature was found to be 27.3, 38.0 and 48.1 ^{O}C for open sun, Type 1 and Type 2 dryers (Figure 2). Type 1 and Type 2 dryers had 10.7 to 20.8 ^{O}C higher temperature values than open sun drying, respectively. The solar dryers were well energized during day time to a temperature of 38 to 60 ^{O}C, which is suitable for drying fruits and vegetables. During night time the temperature inside the dryers lowered and was almost equal to the ambient condition. On both dryers, temperature in the upper tray was higher than the trays in the middle. The reason is that the direct sun radiation fully falls first on the top tray and then through time expands to the rest of the trays.

The day time (12:00–24:00) relative humidity for the open sun drying, Type 1 and Type 2 dryers was 36.6%, 24% and 13.1%, respectively (Figure 3). The night time relative humidity was higher than the day time values. A fairly lower value was obtained in Type 2 dryer both during day time and night time which shows that the potential of the drying air helps to remove from the potato slices.

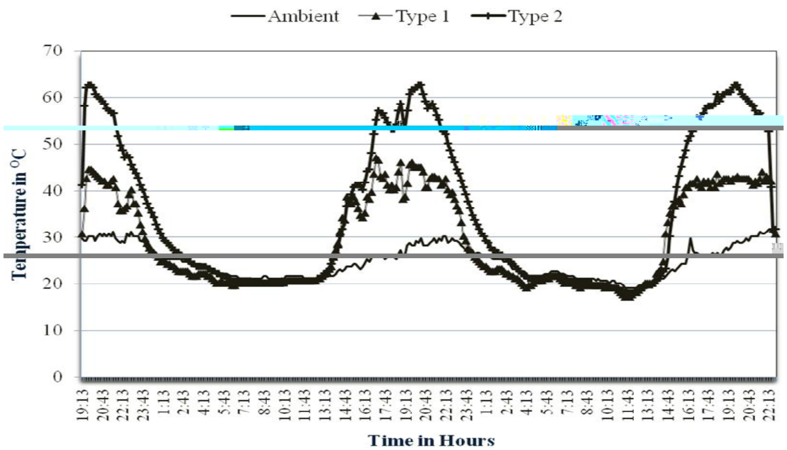

Figure 2. The inlet and outlet air temperature for Type 1 and Type 2 dryers and ambient condition. (Without loading potato slices in the dryers from 12 to 14 May 2010).

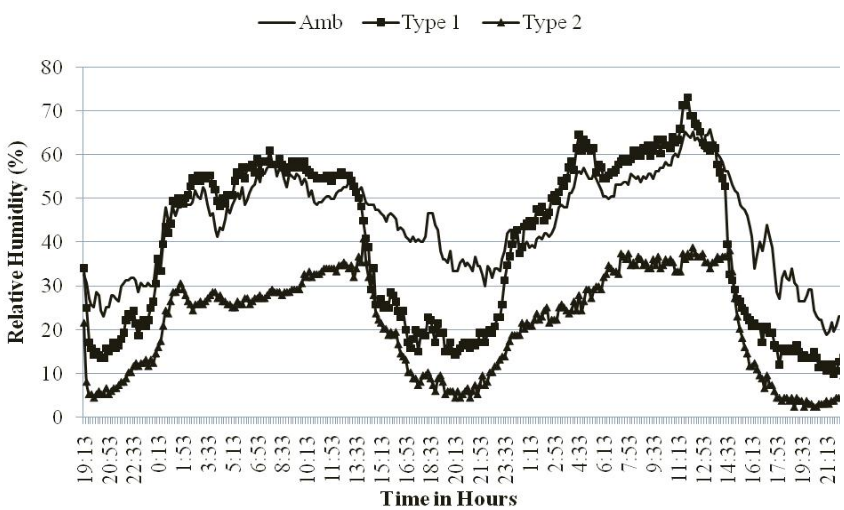

Figure 3. Relative humidity in Type 1 and Type 2 dryers and ambient condition (Without loading potato slices from 12 to14 May 2010).

The driers were also compared with open sun drying while potato slices were loaded. The results of average temperature difference between the dryer trays while fully loaded with potato slices are shown in Table 1. The results on the moisture content of potato slices showed that in Type 1 dryer the upper tray (Tray 1) exhibited the most rapid drying (Figure 4). In the first day, after 4 hours of drying the moisture content of the potato slice dropped from 78.9% to about 68.4%, 69.7%, 72.3%, and 75.7% (wet basis) for Tray 1,Tray 2, Tray 3 and open sun, respectively.

During the second day, the moisture content decreased gradually to 17.2%, 24.9%, 28.0% and 40.6% for respective tray locations. The final moisture content for the above respective trays was 8.2%, 17.0%, 18.1% and 20.8% on wet basis. These moisture contents indicated that the first tray drying time was faster than the other trays. The moisture content for potato in the open sun tray showed slow drying time requiring 2 to 3 hour to get a stable dried material.

Table 1. Average temperature (^{O}C) record for each tray for Type 1 and type 2 solar dryers between 9 to 10 June 2010.

	Type 1 solar dryer		Type 2 solar dryer	
Driers	Time:12:00 - 24:00	Time:00:00 - 12:00	Time: 12:00-24:00	Time:00:00 - 12:00
Ambient	25.3	20.1	25.5	20.0
Tray 1	35.6	20.0	43.5	21.5
Tray 2	34.0	19.7	41.1	21.5
Tray 3	35.2	20.5	37.8	21.5
Tray 4	34.1	20.7	37.5	22.2

The results of the drying rate analysis indicated that Tray 1 expectedly had the highest drying rate during the first 3 hours (Figure 5). However, as it got dried its drying rate decreased from 1.07 up to 0.167%. The drying rate of the potato on the other trays was less than Tray 1 after hours because the drying air absorbed less moisture from the trays.

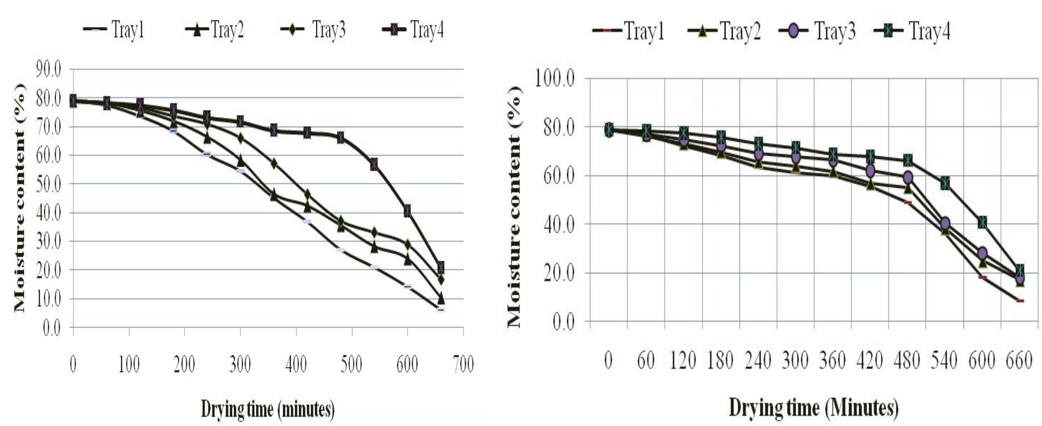

Figure 4. Moisture content of potato slices on different trays of Type 1 (left) and Type 2 (right) dryers.

Figure 5 plays the variation of air temperature with vertical distance from the bottom of the drying chamber. The major drawback of the shelf-type dryer is uneven drying. As a result of the migration of the drying front, the materials at the upper trays dried first, while the middle trays delayed in drying resulting in uneven drying.

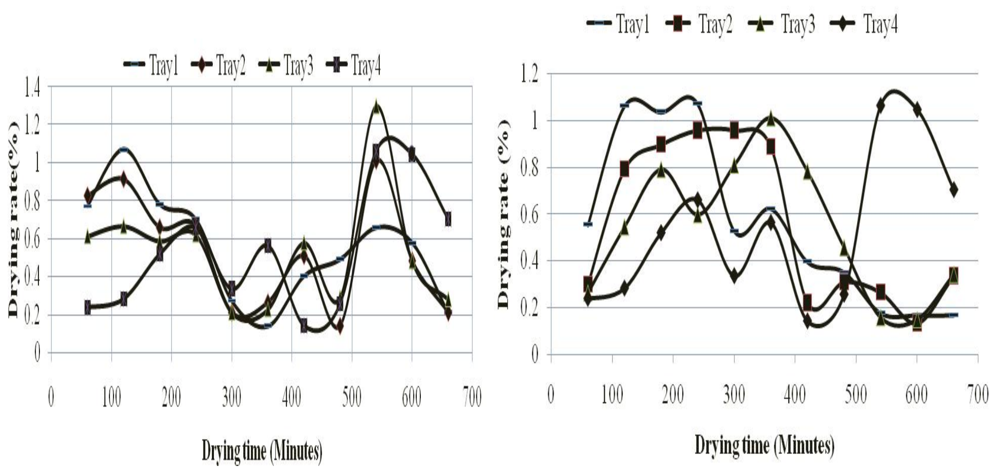

Figure 5. Drying rate curves for potato on a dry weight basis in Type 1 (left) and Type 2 (right) dryers.

Demonstration

Due to its better performance, simplicity and other parameters Type 2 dryer was selected for demonstration. Demonstration was carried out in *Adet* woreda at *Inawera* kebele. The dryer along with different methods of potato processing using dried and undried potato was demonstrated for various potato producing farmers. Both men and women households were involved during the demonstration. It was then observed that most farmers showed interest in using the dryer together with the new methods of home processing of potato. However, they strongly suggested modification for the technology. For making it easy for handling and transport the drier should be detachable.

Conclusion and recommendation

Based on the technical test results and farmers opinions during demonstration the following conclusions and recommendation are made:

- The design of Type 2 dryer is simple and its cost is low. It is suitable for drying small quantities (10-15 kg) of granular materials and is suitable for household level drying.
- Drying time reduced up to 2-3 hour compared to open sun drying, but this difference is not large enough under existing weather condition; however, the dried material is protected from contamination by dust and insects. As a result, the product quality will be high.
- Uneven draying was seen among different trays on both dryer types. The problem of shelf-type dryer on uneven drying can be alleviated by rotating the drying shelves.
- Farmers gained knowledge on processing potato where they were able to use potato slices to prepare different sorts of food.
- From the production cost, weight, transportation, and manufacturing simplicity point of view Type 2 dryer is preferable than Type 1 solar dryer. Farmers said that they can produce Type 2 dryer from local materials and using their own skill.
- The dryer temperature during night time was almost similar to ambient condition which results in lengthening the drying period. Future works to conserve day time temperature and evaluation of other types of dryers with different agricultural products needs to be addressed.

References

Akinola, A.O. and Fapetu, O.P. 2006. Exergetic Analysis of a Mixed-Mode Solar Dryer.

Esper, A. and Muhlbauer, W. 1996. Solar tunnel dryer. Plant Res. and development 44(4):16-64.

Waewsak, J., Chindaruksa, S. and Punlek, C. 2006. A mathematical modeling study of hot air drying for some agricultural products. Thammasat Int. J. Sci. Technol. 11(1):14-20.

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