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Drying Characteristics of vermicelli in a Slant height greenhouse Dryer

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Abstract: *Drying is the process of moisture removal from the product. The greenhouse dryer operates in the two different modes, namely, natural convection and forced convection modes. In the present study greenhouse dryer is designed and fabricated to evaluate their performance under forced convection mode to drying the vermicelli of different thickness. A slant height greenhouse dryer have been fabrication of 120×80 cm² size. Various experiments have been conducted for drying the vermicelli with diameter 3 mm, 2 mm, and 1.25 mm to dry inside the slant height greenhouse dryer. Many parameters such as moisture ratio, drying rate (g/min), and moisture content on dry basis (%) have been evaluated to determine the performance of given greenhouse dryer. The drying rate has been observed to decrease with the increase in vermicelli thickness during its drying in slant the greenhouse dryer. A linear regression analysis has been conducted to investigate the accuracy of prediction of five selected thin layer drying models. Five mathematical models, namely, Lewis, Page, Modified Page, Henderson and Pabis, and Wang and Singh models have been fitted to the experimental data of moisture ratio for vermicelli dried in slant greenhouse dryer under forced convection mode. It has been observed the Wang and Singh model shows the best agreement between experimental and theoretical values of moisture ratio.*
Keywords: *Mathematical modeling, moisture content, slant greenhouse dryer, vermicelli*

I. INTRODUCTION

Vermicelli is a popular snack food item and its demand is steadily growing. It is generally prepared at household level by extruding the dough with a cylindrical hand extruder whose diameter generally varies from 1.25 mm to 3 mm. It is liked by people from all walks of life, irrespective of age. With changing life style, greater awareness about health and preference for instant food items have made vermicelli very popular and an item of mass consumption. They are easily affordable, tasty and easy to make. There are some established brands like Maggi and Bambbino, but the market is very large and growing. A small scale unit can compete with these brands in the local market on the price front because of low overheads, less transportation costs and reasonable advertisement budget. It is expected to increase further in future. Different names of vermicelli around the globe are: minutelli in Venice, fermentini in Reggo. It get various names like in India also: shemai in Bengali, seviyan in Hindi and Urdu, shavige in Kannada, sevalu or semiya in Telagu and semiya in Tamil [1-2].

Greenhouse solar driers use regular greenhouse structures where the product is placed in trays receiving the solar radiation through the plastic cover, while the moisture is removed by natural convection or forced convection modes. The uses of greenhouse dryers improve the quality of the product, prevent the contamination by insects, microorganisms and bacteria, and lead to reduction of drying time interval [3-4].

The usage of greenhouse for vermicelli drying is a new approach in the vermicelli preservation. This may pave a new path in the field of food industry. In the present study two greenhouse dryers were design, analysis and comparative to evaluate their performance under forced convection mode to drying the vermicelli of different thickness.

The drying behavior of different materials were studied by many authors and several mathematical models were proposed such as for ginger [5], roselle [6], kiwifruit slice [7], lemon [8], chilli [9], tomato [10], stone apple [11], alfalfa [12], eggplant [13], canola [14], mulberry [15], grenade peel [16], banana [17], chilli pepper [18], bread [19], gooseberry [20], dill leaves [21], pork [22], carrot [23], red chili [24], sultana grape [25], seaweed [26], apples [27], sour cherry [28], bitter melon [29], Barberry [30], pumpkin [31], Cuminum cyminum [32], amaranth [33] etc. All these factors make mathematical modeling of drying more complicated. To the best of present authors' knowledge, no significant work on the drying characteristics of vermicelli and its mathematical modeling was reported in the literature. Therefore, the objectives of the present work are:

1. Fabrication and design of forced convection slant-height greenhouse dryer.
2. To study the drying characteristics of vermicelli inside slant height dryer.

II. MATERIALS AND METHODS

2.1 Experimental Set-Up And Instrumentation

The greenhouse dryer is made of the PVC pipes and UV film (200 microns).A slant height greenhouse of 120×80 cm² effective floor area was fabricated of PVC pipe and a UV film covering of 200 microns. The central height and the walls were maintained as 60 cm and 40 cm respectively. A fan of 225 mm sweep diameter and 1340 rpm with a rated air velocity of 5 m/s was provided on the sidewall of the greenhouse for the forced convection experiments. The schematic view for slant height greenhouse dryer under forced mode is shown in Figure 1 and its photograph of the experimental setup is shown in Figure 2.

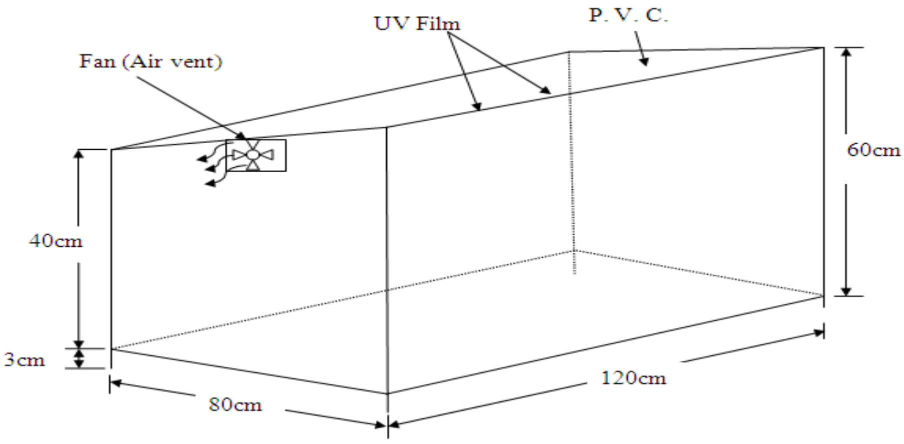

Figure 1 A schematic view of slant height greenhouse dryer under forced convection mode

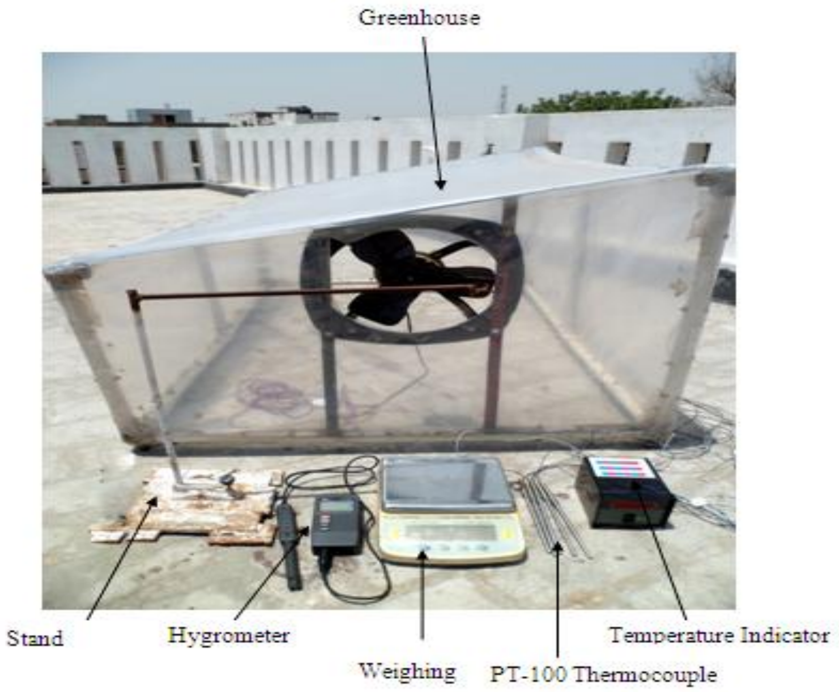

Figure 2 A photographic view of slant height greenhouse dryer under forced convection mode

2.2 Cost Analysis of Greenhouse Dryer

Cost analysis has been done for the slant height greenhouse dryer under forced convection mode for the size 120×80 cm². The cost analysis of slant height green house dryer under forced mode has been given in Table 1.

Table 1 Cost analysis of slant height greenhouse dryer under forced mode

S. No	Items	Quantity	Rate (Rs.)	Cost (Rs.)
1.	PVC pipe	1106cm	30.00 per feet	332
2.	UV film	3 kg	130.00 per kg	390
3.	AC fan	1	700	700
4.	Nut and bolts	376 g	0.375 per g	141
5.	Total			1563

2.3 Measuring Instruments

- Five thermocouple (PT-100 sensor)
- Temperature indicator
- A digital hygrometer (model Lutron HT-305)
- A digital weighing balance (capacity 6 kg; Scaletech, model TJ-6000)
- An eight channel temperature indicator (0-199.9°C, least count of 0.1°C)
- A rectangular shaped wire mesh tray of dimension 160 × 10 cm²
- An electronic digital anemometer (model AM-4201, made in Taiwan).
- A cylindrical hand extruder

2.4 Sample Preparation And Experimental Observations

Vermicelli has been freshly prepared by taking semolina flour mixed with 30 % of water content per kg of vermicelli weight. The flour has purchased locally, and that fraction of flour which passes through a 40-mesh sieve (610 microns) has used for making vermicelli. Dough has been made and rolled in circular shape and extruded in cylindrical extruder. The bottom of extruder is attached with steel die plates of 57 mm diameter having holes of 3 mm, 2 mm, and 1.25 mm diameters respectively. The freshly prepared vermicelli of 37.5 gram of 3 mm, 21.2 gram of 2 mm, and 16.2 gram of 1.25 mm thickness respectively have been used for each run of the greenhouse drying mode.

Experiments have been performed during the month of April-May 2014 at Hisar. The orientation of the greenhouse during the experimentation has been kept in east-west because sunlight availability is more in comparison to north-south. Experimental setup has been located on the open floor of a two-floor building to have a good exposure to the solar radiation. Each observation was taken for vermicelli drying after ten minutes time interval. The vermicelli sample was kept in the wire mesh tray over the digital weighing balance. All experiment has been repeated three times on slant greenhouse. The drying rate, moisture content and moisture ratio were calculated by taking the difference of mass of vermicelli diameter 1.25 mm, 2 mm, 3 mm readings.

III. MATHEMATICAL MODELING OF DRYING CURVE

The thin layer drying models selected for fitting experimental data of vermicelli are expressed in the form of moisture content, drying rate and moisture ratio of sample during drying and it is expressed as:

$$M\ (\%\ \text{dry basis}) = \frac{W_w - W_d}{W_d} \times 100 \quad (1)$$

$$M\ (\%\ \text{wet basis}) = \frac{W_w - W_d}{W_w} \times 100 \quad (2)$$

$$DR = \frac{\text{inital weight} - \text{final weight}}{\text{time interval}} \quad (3)\backslash$$

Where, M is the vermicelli moisture content (dry basis % and wet basis %), W_w is the wet weight and W_d the dried weight of the sample [34]. The drying rate has been calculated by using Equation (3) [35].

IV. DRYING CHARACTERISTICS OF VERMICELLI

Drying tests have been conducted on the vermicelli in slant height greenhouse dryer under forced convection mode. Drying rate (g/min) of the sample has been calculated. The drying rate is observed to decrease with the increase in drying time. The drying rate variation w.r.t. time are illustrated in Figures 3.

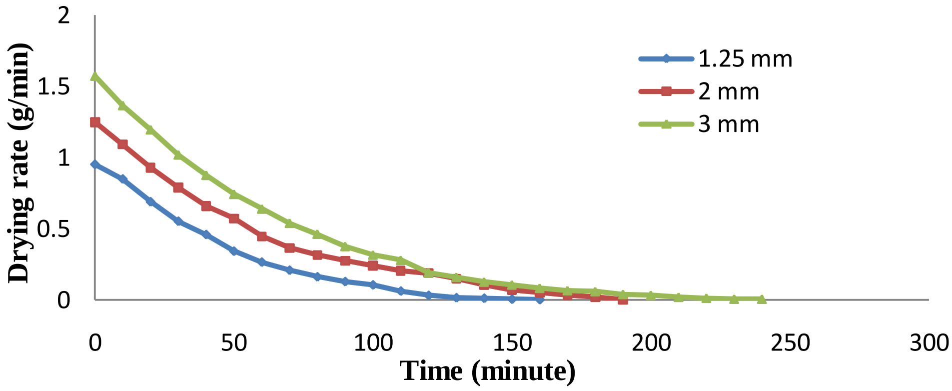

Figure 3 Variation of the drying rate with the drying time of vermicelli with thickness 1.25 mm, 2 mm, and 3 mm in the slant height greenhouse

From Figure 3 it is observed that drying rate decreases with the increases in thickness of vermicelli during its drying in the slant height greenhouse dryer under forced convection mode. The drying rate is observed to decreases with the increases in drying time.

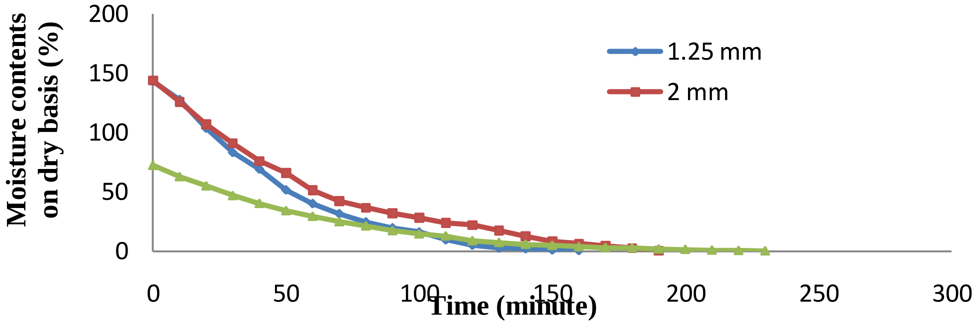

Fig. 4. Variation of the moisture contents on the dry basis (%) with the drying time of vermicelli with thickness 1.25 mm, 2 mm, and 3 mm in the slant height greenhouse

From Figure 4 it is observed that moisture content on the dry basis (%) decreases with increases in thickness of vermicelli during its drying in the slant height greenhouse dryer under forced mode. It can be observed that the moisture content on the dry basis (%) decreases with respect to increases in drying time.

V. CONCLUSION

In this study, the drying behavior of vermicelli has been investigated under the forced convection mode inside slant height greenhouse dryers. The experiments have been conducted in the month of April to May 2014. From the present work the following conclusions have been drawn:

1. The drying rate is found to be decreasing with respect to increasing drying time.
2. It has been found that the moisture content on the dry basis (%) decreases with respect to increases drying time.

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