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DEVELOPMENT OF A TRAY DRYER FOR FRUITS AND VEGETABLES USING ZIG-ZAG AIR FLOW CONFIGURATION

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ABSTRACT

Post harvest losses in fruits and vegetables in developing countries like Nigeria is high due to poor storage and processing facilities. The use of cabinet dryer for dehydration of fruits and vegetables to improve their shelf life has a draw back of non-uniformity in drying along the length of trays. Hence an effort was made to solve this problem by using a zig-zag air flow pattern configuration. A cabinet dryer of capacity 21kg/batch was designed and developed. The dryer was tested with okra slices using zig-zag air flow pattern configuration. At an air flow rate of 8.8m^3/s and 60^{o}C it took about 9 hours to reduce the moisture content from 79.55% (w.b) to 6.03% (w.b).Results obtained showed that drying of the okra slices took place in the falling rate period. The drying efficiency of the dryer was found to be 70%.

Keywords: Tray dryer, zig-zag air flow, dehydration, drying efficiency, okra slices.

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INTRODUCTION

Drying is one of the most important and widely used methods of food preservation. It is essentially the removal of water from food materials up to certain level at which microbial spoilage and deterioration chemical reaction are greatly minimized. (KroKida and marinos-Kouris 2003). The wide variety of dehydrated foods and the increasing concern for meeting quality specifications and conserving energy emphasize the need for a thorough understanding of the drying operation and problems related to the design and operation of dryers. The design of dryers to produce good quality products at an affordable costs by processors has become an increasingly challenging problem to equipment design engineers.

The application of direct solar radiation for drying food materials is common in tropical countries. However, due to contamination of product from dust, insects and spoilage due to rains, use of sun drying is limited. Fruits and vegetables are not only high in moisture but also rich in nutrients. These nutrients restrict the temperature to which the product can be raised during drying. The rate of drying also affects the quality of the dried product. Thus to overcome the above mentioned constraints tray driers are most suitable for drying fruits and vegetables. Tray dryers constitute an important family of convective dryers where the drying medium is hot air or combustion gases coming a furnace. They are adaptable to the drying of almost any material that can be put in a tray. In general batch or semi batch operation is used. Holdsworth (1971) reported that the drying of grapes in cabinet dryers gave better quality than sun -dried grapes. High capacity electrically heated dryers for fruits and vegetables have been reported by Brown et al (1973) and Luh et al (1975), however, these are beyond the reach of small scale processors who are in the majority.

Singh (1994) developed a small scale capacity dryer and evaluated its performance with cabbage, cauliflower and Onion. The drying time ranged from 11h to 14h and overall efficiency was 28.21- 30.83% at 55-650C. Kiranoudis (1998) modeled design of batch-grape dryers considering all probable factors which affect the dryer performance Das et al (2001) developed a recirculating tray dryer for high moisture biological materials. It was tested with blanched potatoes chips. At a constant air flow rate of 1.5m/s3 650C temperature it took 3h to reduce moisture content from 856.94%(dry basis) to 9.98%(dry basis). The heat utilization factor (HUF) and thermal energy efficiency (THE) of the developed dryer were found to be 18.94% and 22.16% respectively.

Olajide et al (2003) designed a cabinet dryer for small and medium scale food processors It was tested with yam slices. The performance test showed moisture removal and air heater efficiencies of 83.75% and 77.07 % respectively. In most developing countries like Nigeria the major and most common food preservation methods employed is traditional open sun drying and hot air drying. Tray or cabinet dryers are by far the most common types of dryers used in food industry. They are relatively inexpensive and can be used to dry different types of products. Presently, horizontal and vertical airflow patterns are being used in cabinet dryers. These patterns of air flow do not lead to uniform drying of food materials in the dryers. The different air flow patterns are as shown in Figure1a-1c.

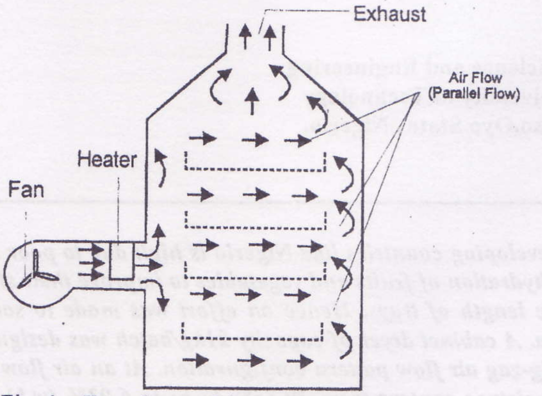

Fig. 1a: Tray dryer with Parallel Flow Configuration

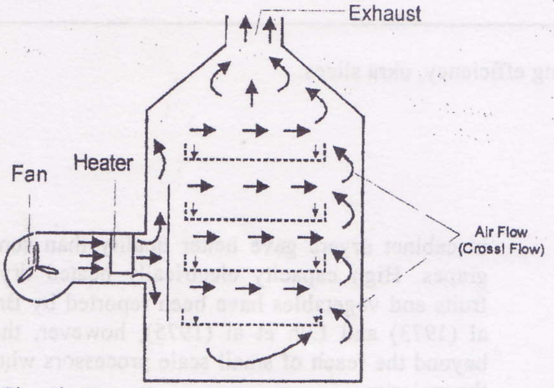

Fig. 1b: Tray Dryer with a Cross-Flow configuration

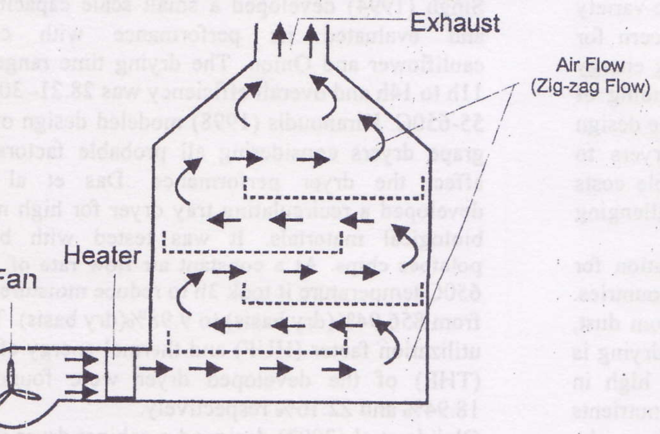

Fig. 1c: Tray Dryer with Zig-zag Air-Flow

The non-uniformity in drying of products and allows microorganisms to grow better in foods with high moisture, such products tend to spoil at a short period of time. This present study was undertaken to introduce a zig-zag air flow into a cabinet dryer design so as to reduce the problem of non – uniformity in drying thereby increasing the shelf- life of food products

Design procedures

The developed tray dryer consists of the following components as shown in Figs 2a and 2b:

(1) Drying Chamber
(2) Heating Chamber
(3) Air Blower
(4) Air discharge(Exhaust)
(5) Control Panel

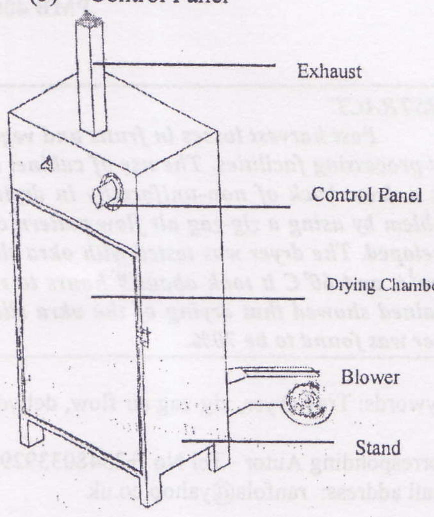

Fig 2a: Components of the Developed dryer

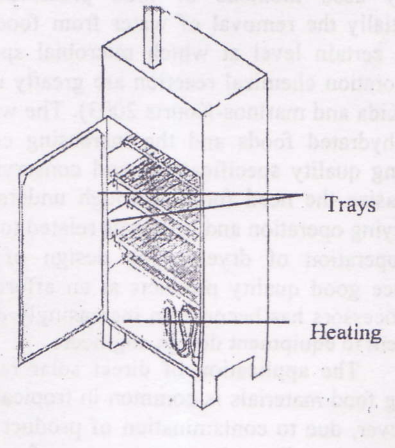

Fig 2b: Inner section of the cabinet dryer.

Drying Chamber

The drying chamber is made of gauge 16 (2mm) thick mild steel sheet. It is a double wall chamber lagged with fiber glass. The dimension of the chamber is 1070 x 610 x 46 mm^3. The drying chamber is equipped with five (5) perforated trays (485x375x25mm^3) sitting on tray racks. The space between trays is maintained at 200mm which are arranged in a zig-zag manner for good air flow.

Air blower

In selecting a blower for the dryer, the pressure which is to be delivered and direction of air is considered. To force air through the drying chamber over the trays at an air velocity of 8.8m/s a minimum blower capacity of 6.89KW is required from design calculation. A 7KW blower was selected.

Heating chamber

The chamber heating is also made of mild steel sheet and a 5.6KW heater was installed to heat the incoming fresh air from ambient temperature to 80°C. The heater capacity was calculated to take care of losses to the environment. A digital temperature controller fitted over the control panel controls the heater.

$$\text{Heater capacity} = \frac{\text{mass flow rate of air x specific heat of air.x rise in temperature}}{\text{heater efficiency}}$$

Air discharge

At the top of the tray dyer is located the discharge duct (chimney). The hot air after passing through the chamber is discharged through the chimney at the top. The discharge duct (Chimney) is rectangular in shape and has a cross-section of 350x50mm2.

Control panel

The control panel consists of switches, digital temperature controller and digital temperature indicator.

Testing of the dryer

The testing of the dryer was conducted under two conditions:

(1) No-loading condition
(2) Loaded condition

No – loading testing

(1) The air velocity above the trays ranges from
(2) The temperature of the air can be raised to 80°C from ambient temperature of 25°C.

Testing under load

The developed dryer was tested to dry okra slices of uniform thickness (4mm) at temperatures of 50°C, 60°C and 70°C. Undamaged medium scale okra size were procured from a local market. The okra were manually cleaned to remove impurities. The initial moisture content of the okra was determined and found to be 79.55% wet basis. The cleaned okra was then cut into slices of 20mm thickness.

The sliced samples were spread on the trays and dried in the dryer. The moisture content of the product was determined every 1hr. the product was dried to a final moisture content of 6.03%.

$$\text{Drying efficiency} = \frac{\text{Rate of water removal x latent heat of vaporization}}{\text{Heat available for drying}} \times 100$$

RESULTS AND DISCUSSION

The total weight of the dryer is approximately 85kg. It was mounted on a stand 130mm to accommodate the blower and the heating section. The effect of three temperatures on the drying curve of okra is as shown in Fig 3.

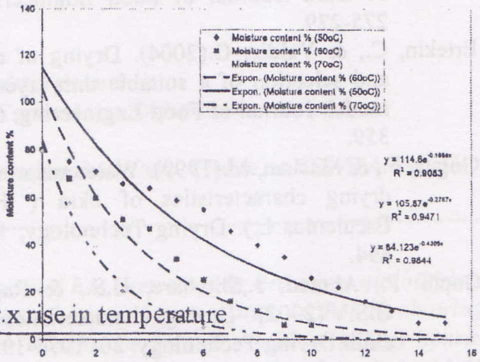

Figure 3: Drying rate curve for Okra

It can be seen that there is no constant rate drying period in the drying of okras. All the drying in the case of okra takes place in the falling rate period .This is an indication that diffusion is the dominant physical mechanism governing moisture movement in the okra samples. Similar results were obtained by Doymaz (2005) for Okra, Gupta et al.(2002) for red chilli, Gogus and Maskan (1999) for okra and Rosello et al (1997) for green pea. It can be observed from Fig 3 that increase in the drying temperature caused an increase in the drying rate , thus the drying time is reduced. The drying time taken to reduce the moisture content of okra from the initial 79.55% (w.b) to a final 6.03% (w.b) 13, 10 and 7 hr at 50°C, 60°C and 70°C respectively. Increase in drying rates when higher temperatures were used for drying some vegetables were also reported by Doymaz(2005) for okra, Ertekin & Yadiz(2004) for eggplant, Madamba et al (1996) for galic, and Doymaz (2004a) for carrot.

The efficiency of the dryer ranged from 68.4 % to 70.0 %. These values were high compared to those values reported by Das et al.(2005) which may be due to the usage of parallel air flow patterns.

CONCLUSION

The efficiency of the dryer (68.4% to 70%) when compared to (18.94% to 22.16%) as reported by Das et al (2005) using parallel air flow pattern is relatively high. This is an indication that usage of zig-zag airflow pattern in cabinet dryer can be used to minimize the problem of non-uniformity in drying along the length of trays and also improve dryer's performance.

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