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Effect of size of mushrooms on drying rate in a natural convection solar dryer

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Abstract

The effect of drying air temperature on drying characteristics of oyster mushrooms were investigated in this study. Different sizes of mushrooms were used to evaluate the effects of size of the mushrooms on drying processes in natural convection solar dryer. Full and half mushrooms were dried in a natural convection solar dryer until the samples reached desired moisture content of 8.2%. Air temperature inside and outside the dryer, wind velocity, relative humidity and moisture loss were also measured at every two hours interval until the samples reached desired moisture content. The moisture loss from the samples was measured at every one-hour interval. The experimental results show that the size of the mushroom has considerable effects on the moisture removal. In this study, average moisture content, average drying rate and drying duration values of full mushrooms were found to be 3.79 %, 0.2 g $min^{-1}$and 22 hours. Average moisture content, average drying rate and drying duration values of half mushrooms were found to be 5.2 %, 0.214g min^{-1} and 16 hours respectively. The results revealed that among different sizes of mushroom, half mushrooms produced better quality product than full mushrooms during the drying process in the natural convection solar dryer.

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Keywords: Convection; Mushroom; Relative humidity; Solar dryer; Wind velocity

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1. Introduction

Fresh mushrooms are highly perishable commodity, with short shelf life under ambient environment, temperature and humidity and their commercialization becomes difficult. They start deteriorating immediately within a day after harvest. After harvesting moisture loss, shrinkage rapid spoilage, in terms of colour and texture takes place. In view of their highly perishable nature, the fresh mushrooms have to be processed to extend their shelf life for off season use. Mushroom can be processed in many other ways to extend their shelf life such as drying, pickling, etc. Drying is a comparatively cheap method (Rama and Jacob John, 2000) and dried mushrooms, packed in airtight containers can have a shelf life of above one year (Bano *et al*, 1992). And also drying is the most commonly used method for long term preservation of agricultural products including mushrooms, because it extends the food shelf-life, preserving all of their features (Tulek, 2011; Pandey, *et al.*, 2000). Dried mushrooms had the high content of dietary fibre, Fe, Cu, Mg, K but low of fat, Na and Ca. Dried mushrooms satisfied the maximum permissible level standards concerning toxic metals. The results of the research suggest that dried shiitake and oyster mushrooms can be used as additives in food products. The flavour of a dried mushroom is slightly more concentrated than the fresh kind. It's what makes them spectacular for adding depth to broths, stews, and soups.

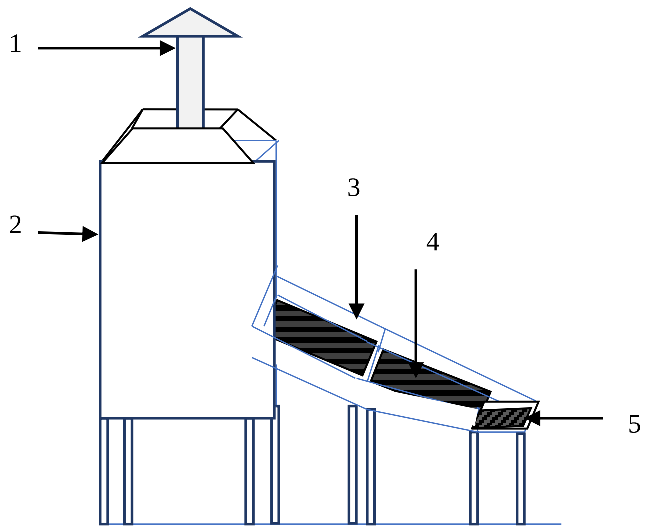
The shelf life of mushroom is only about 2 to 5 days depending on the variety. After harvesting moisture loss, shrinkage and rapid spoilage in terms of colour and texture takes place. Though sun drying has been used for drying mushroom, the quality of mushrooms may be seriously affected due to long drying times that may have adverse effect on the product quality. Drying at higher temperatures may cause serious damage to the flavour, colour and nutrients of the dehydrated product.

There are many types of dryers available in the market for drying agricultural commodities. However, the natural convection dryer is the simple and uses natural convection of air for the drying of the product which enables a cost effective drying. Therefore, the performance under ambient conditions need to be evaluated to achieve better quality dried product. Therefore, the objective of this study was to study the drying characteristics of mushrooms in natural convection solar dryer.

2. Materials and Methods

2.1Drying experiments

The experiment was conducted in a natural convective solar dryer developed in the department of Agriculture Engineering, Eastern University, Sri Lanka (Figure 1). The dryer has a drying chamber, fitted with glass between the inlet and the drying chamber for the penetration of sunlight. The chimney of 10 cm height was fixed at the top of the dryer. Fresh mushrooms were purchased and initial moisture content was measured by using oven drying method. Mushroom samples were dried as full as well as half mushrooms in the natural convection solar dryer until moisture content of the mushroom samples attained their equilibrium moisture content. The inside and outside temperature of natural convection solar dryer, wind velocity, relative humidity and moisture loss were measured at every one hour interval.



1. Chimney – Hot air passage.
2. Drying Chamber
3. Transparent glass
4. Black painted corrugated tin sheet
5. Inlet – Fresh air passage

Fig 1. Components of the natural convection solar dryer

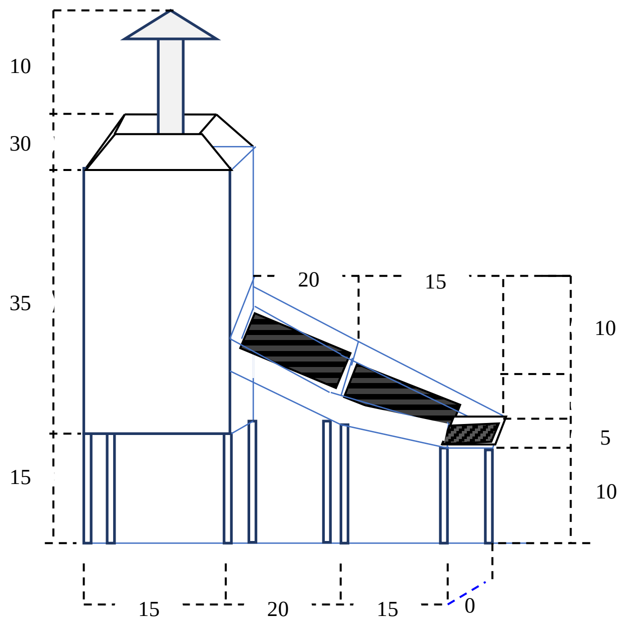


Fig 2. Dimensions of natural connections solar dryer (Not to scale)

2.2 Rehydration ratio

The rehydration ratio of dried mushroom was determined as the ratio of rehydrated mass to the initial dehydrated mass, which was given a measure of the ability of dried mushrooms to reabsorb water. A sample of 5 g of the dried mushroom was placed in a 250 ml beaker containing 150 ml of boiling distilled water. The contents were boiled for 5 minutes to allow the mushroom to rehydrate.

$$\text{Rehydration ratio} = \frac{Wr}{Wd} \qquad (1)$$

Where,

W_r - weight of rehydrated sample (g)

W_d - initial weight of the sample before rehydration (g)

2.3 Determination of moisture content

The sample was weighed using a digital electronic balance and dried in electric oven at 105 °C for 8 hours to determine the moisture content. The difference between the original mass and the final mass of the sample was expressed as a percentage of the original mass on a dry weight basis.

$$\text{Moisture content} = \frac{Wi - Wf}{Wf} \times 100\,\% \qquad (2)$$

Where,

Wi - Initial weight of samples

Wf – Weight of oven dried samples

2.4 Moisture ratio

The moisture ratios (MR) of mushrooms with time were calculated by using the following equation.

$$MR = \frac{Mt - Me}{Mi - Me} \qquad (3)$$

Where,

MR - Moisture ratio

Mt - Moisture content at any time

Mi - Initial moisture content

Me - Equilibrium moisture content

3. Results and Discussion

3.1 Variation in mushroom temperature

The drying temperature, relative humidity and wind velocity varied continuously during the drying period of 9:00 to 16:00 hour. It was also observed that the product temperatures were mostly higher than that of ambient air temperature due to the absorption of solar radiation by the mushrooms. However, the product temperatures were highly influenced by the weather parameters.

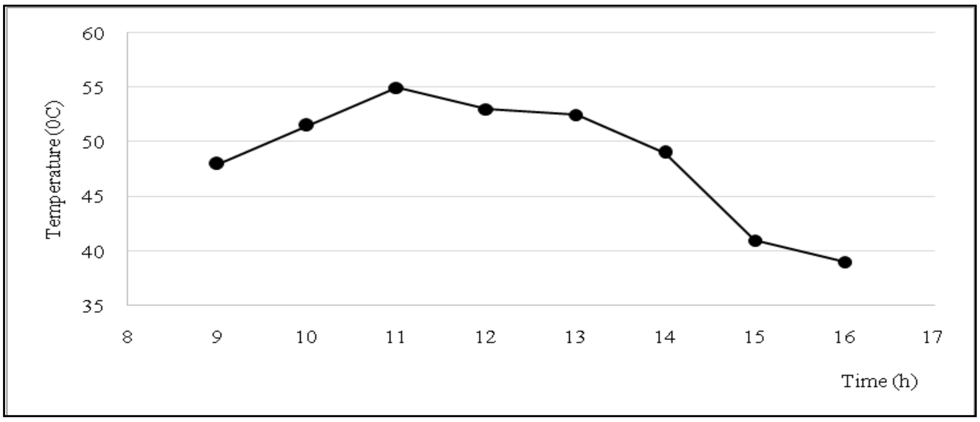


Fig 3. Temperature of mushrooms during drying in natural convection solar dryer

Figure 3 shows the product temperature within the natural convection solar dryer during the study period. It has been observed that the temperature varied from 39 °C – 55°C. During the experimental period, the average daily variations of wind velocity, ambient relative humidity and air temperature ranged from 0.72 to 0.09 m/s, 40.7 to 86 % and 25 to 32 ºC respectively at the experimental site, EUSL. When drying mushrooms, the maximum temperature and minimum relative humidity recorded inside the drying chamber were 55 ºC and 40.7 % when the corresponding ambient temperature and relative humidity were 41.5 °C and 86 %, respectively. For full mushrooms and half mushrooms, the maximum product temperatures in solar dryer were found to be 56 °C and 40 °C respectively.

The temperature was found to be higher within the solar dryer than the ambient air. The temperature changed with time due to solar radiation. It was 34 °C within time of 8 am to 9 am and it increased up to 55 °C with time from 9 am to 11 am followed by which the temperature reduced up to 39 °C during 11 am to 4 pm. The drying of mushroom was found to be greater at the time when the temperature was high. Normally in solar dryer high temperatures were observed during 11 am to 12 am whereas it was observed that low temperatures were recorded between 3 pm to 4 pm.

Higher temperature inside the natural convection solar drying chamber was due to two reasons: i) better absorption of solar energy by the product as most of the solar energy entering the solar dryer is trapped inside the dryer facilitating absorption, ii) the collector (black surface) gives away of its energy to the product by conduction heating. iii) the chimney facilitates the removal of moisture by natural circulation of atmospheric air. This explicitly indicates that the drying rate mushrooms in the natural convection solar dryer will be higher than that of oven drying experiment.

3.2 Effect of size on drying rate of mushrooms

Figure 4 illustrates that the half mushrooms dried faster than the full mushrooms. The half mushrooms attained equilibrium moisture content in 16 hours and the full mushroom attained equilibrium moisture content in 22 hours. Drying rate was high in half mushrooms compared to full mushrooms content in 22 hours. Drying rate was high in half mushrooms compared to full mushrooms.

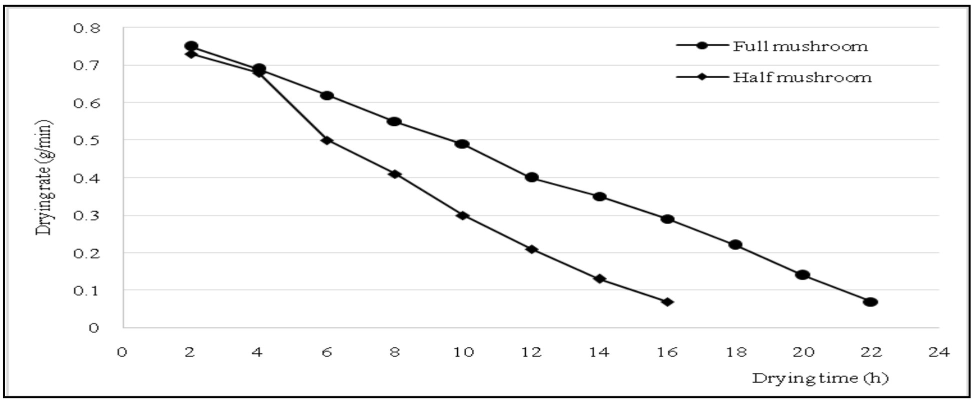


Fig 4. Drying rate with mushroom size in natural convection solar dryer

The drying time reduced significantly as per the size of the mushrooms in natural convection solar dryer, because the resistance to moisture movement is relatively higher in full mushrooms slices than in smaller ones. This resistance is known to decrease the drying rate, which resulted in increased drying time of full mushrooms. Generally, it is observed that the time required to reduce the moisture content of mushrooms to any required moisture level was dependent on the drying conditions that are influenced by weather parameters. Similarly, Sacilik *et al.* (2006) also observed that the drying characteristics of tomato slices in solar tunnel and open sun drying methods were highly influenced by weather parameters.

3.3 Effect of size on moisture loss of mushrooms

The change in moisture content of mushrooms with drying time in natural convection solar dryer is depicted in Figure 5. It was observed that the total drying time for full and half mushrooms were 22, and 16 hours respectively in natural convection solar dryer. For half mushrooms, the natural convection solar dryer required shorter drying time of 6 hours when compared to drying of full mushrooms which had taken 16 hours to become the equilibrium moisture content. In other words, drying time was reduced to about 27.27 % for half mushrooms in natural convection solar dryer when compared to drying of full mushrooms.

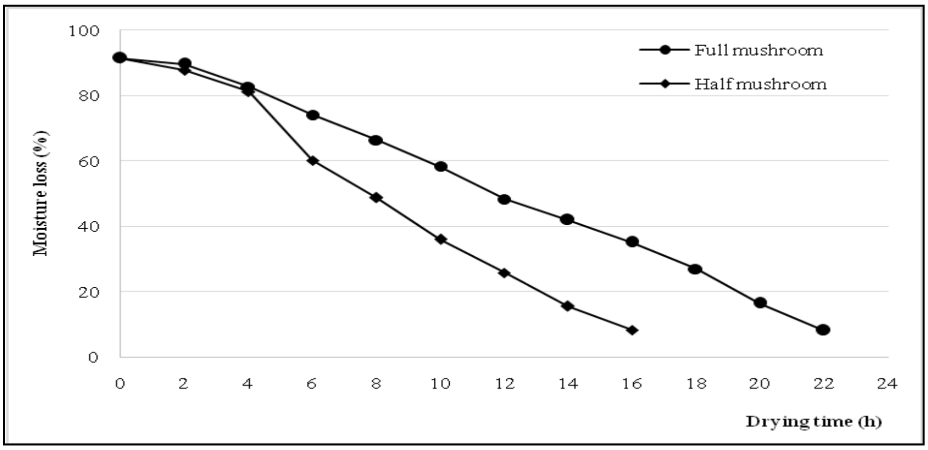


Fig 5. Effect of size on moisture loss of mushrooms in natural convection solar dryer

During the first stage of drying, the rate of moisture reduction increased as temperature increased from 41.5 °C to 43.5°C. Moisture content reduced from 82.75 to 74.03 % during the period of 2 hours. The mushrooms were therefore exposed to a shorter period of drying. The fast rate of drying is consistent with the fundamental drying theory, which expects a higher heat transfer flux to the mushrooms with higher temperature. It could also be due to the high heat and mass transfer rates between the air and the mushrooms due to the high air velocity 0.72 m/s Other researchers such as Patil and Ward (1989) explained that the high drying rate at the high initial moisture contents of rapeseed is due to the availability of more moisture at the surface of the grain. They also reported that the faster rate of drying was due to the greater sensible heat in the drying air. At lower initial moisture content, the moisture has to be transferred from the interior of the grain to the surface (Meas, 1999). As the grain moisture content reduced, the rate at which it lost moisture also reduced.

3.4 Rehydration ratio of mushrooms

Rehydration ratio of half mushrooms were 2.5 and that was 2.4 for full mushrooms. The rehydrated half mushrooms had good appearance, even though they did not recover the same appearance of fresh mushrooms.

4. Conclusions

Among natural convective solar dried samples, average moisture content, average drying rate and drying duration values of full mushrooms were 3.79 %, 0.2 g $min^{-1}$and 22 hours respectively. Average moisture content, average drying rate and drying duration values of half mushrooms were 5.2 %, 0.214g min^{-1} and 16 hours respectively. When compared to the drying parameters of full mushrooms with half mushrooms, half mushrooms dried better than full mushrooms during the drying process. The results revealed that drying process of mushroom was affected by the size of the mushrooms in the natural convective solar dryer.

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