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Studies on Air-Dry Processing of Onions (*Alium cepa*)

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Abstract: The drying process of hot air oven drying was evaluated and compared with open sun and solar drying. Onion slices were dried using the open sun, solar dryer and hot air oven dryer. The results show that hot air oven drying of onions elicited higher mass and heat transfer coefficients than open sun and solar drying thereby resulting in a higher drying rate leading to a faster drying time. The effects of temperature and sample size on the dry rates and drying time of sliced onions were determined. Drying rate curves were characterised by a constant phase followed by a falling rate phase. Drying rate generally increased with increasing temperatures and decreasing sample sizes.

Key words: Drying, drying curves, drying rates, optimum conditions

INTRODUCTION

Fruit and vegetables such as onions, pepper, pawpaw, etc. are perishable products that deteriorate some few days after harvest. However, keeping these food products for some months in their fresh states (so as to retain the actual nutrients, taste and colour as when freshly or newly harvested) has remained a problem yet unsolved[1]. Since the discovery of the basic vitamins and their many forms, efforts have been made to retain them in foods during post-harvest handling, commercial processing, distribution, storage and preparation[2]. Therefore, dried fruit and vegetables are preferable to the fresh product because of lower water activity that extends the shelf life, reduces microbial growth an enzyme activity[3].

The traditional method of drying fruits and vegetables that has been practiced over the centuries throughout the world is the open sun drying. This method was used to study the drying kinetics, physico-chemical and nutritional characteristics of *Kindimu*, a fermented milk-based sorghum flour[4]. This frequently results in poorly dried and infested products due to contamination by dust, microorganisms, insects, birds, animals, and result in spoilage and quality deterioration[1].

In most developing countries, there is an increased emphasis on rural development that will undoubtedly necessitate increased energy demands in these rural areas. The use of solar dryers for drying agricultural products in both rural and urban areas is becoming important in the sense that it makes use of cheap and renewable source of energy (solar energy) rather than electrical or wood powered source[5].

Drying is dependent on two fundamental processes-heat and mass transfer. Heat has to be transferred into the fresh product, which is then followed by the removal of moisture from the product[6]. The drying rate depends on the drying conditions (dry bulb temperature, relative humidity, air velocity and the rate of heat transfer); the food properties (moisture content, surface-volume ratio, area of cut surface, surface temperature and the rate moisture loss)[7]. In the selection of the appropriate drying conditions, the drying rate should preferably be as high as possible[6,7]. Hence, when drying fruits and vegetables, parameters are sought that exhibit high drying rates[8]. Long drying times leads to final products of poor quality, due to caramelisation, mailard reactions, enzymatic reactions, pigment degradation and ascorbic acid oxidation[9] as well as high energy requirements for the drying process. No literature is available on the effect of different conditions of temperature and size of sample on the drying rate of onions.

The objective of the present study is to evaluate the drying process using a hot air oven drying and compare it with the traditional open sun drying and solar drying. This method was used to study the drying kinetics, physico-chemical and nutritional characteristics of the

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Kindimu, a fermented milk-based sorghum flour[4]. The study includes the comparison of heat and mass transfer properties. The effects of temperatures and sample size on the drying rate and thus, drying times of Nigerian cultivated onion was also examined.

MATERIALS AND METHODS

Preparation of material: Fresh onions (*Alium cepa*) were purchased at Ogbomoso local market in Nigeria. They were sorted, washed, peeled and cut into slices of 0.020 m diameter before being displayed on the drying trays.

Drying equipment: The drying experiments were conducted in a tray placed in the open sun, solar dryer, and oven dryer, respectively. The solar dryer used was fabricated and consists essentially of a solar collector and drying chamber constructed with wooden planks with cross-sectional areas of 1.0 m^2 x 1.5 m^2, respectively. Transparent polythene, framed in wood, served as the top cover for both the collector and the drying chamber. A laboratory oven dryer (Uniscope SM-9053 A, Surgfriend Medicals, England) was used for the hot air drying.

Drying

Open-sun drying: 0.05 kg of sliced onions were spread on a metal tray and then placed in the open sun between 0800-1800 hours every day. At the end of each day, samples were weighed and recorded. This was done until an approximately 5 % moisture content was obtained for the onions. The temperature and relative humidity of the drying environment was measured and recorded at different time intervals between 0900-1700 h.

Solar drying: 0.05 kg of sliced onions were spread on a metal tray and loaded into the solar dehydrator. The solar dehydrator was left in the open sun environment. . The temperature and relative humidity within the drying chamber was measured and recorded at different time intervals between 0900-1700 h. At the end of each day, the samples were weighed and recorded. This was done until an approximately 5 % moisture content was obtained for the dried onions.

Hot air drying: 0.05 kg of sliced onions were spread on a metal tray and loaded into the laboratory oven dehydrator (Uniscope SM-9053 A, Surgfriend Medicals, England). At hourly intervals, samples were withdrawn and weighed until an approximately 5 % moisture content was obtained for the dried onions. Drying was carried out at a temperature of 50°C. However, the experiment was repeated for different combinations of dry bulb temperature (60, 70 and 80°C) and sample sizes (5, 10 and 15 mm).

Moisture determination: Moisture content determination of fresh and dried onion samples was carried out according to standard method[10].

Heat and mass transfer determination: The heat and mass transfer coefficient were determined according to the classical approach of psychrometry. The rate of drying is described by

$$R_d = -\left(M/A\right)\left(\frac{dx}{dt}\right) \quad (1)$$

When the heat transfer is in the convection mode, and considering the simultaneous heat and mass transfer, the constant rate of drying is given as[11].

$$R_d = K_{M_a}\left(H_a - H_s\right) \quad (2)$$

For water in vapour-air mixtures, the ratio h / K_{Ma} is approximately equal to its enthalpy

$$h/K_{M_a} = (1.005 + 1.88H)\,x10^3 \quad (3)$$

where M = mass of product (kg)
A = drying area of sample (m^2)
x = free moisture content (kg kg^{-1} ds) t = time(s)
K = mass transfer coefficient (Kmol/m^2s)
h = heat transfer coefficient (W/m^2K)
M_a = molar mass of air, 28.96 kg/Kmol
H_a = humidity of drying air (kg^{-1} air)
H = saturation humidity of drying air (kg^{-1} air)

The drying rate (R_d) was determined by using Eq. 1. The drying curves were plotted Fig. 1-3 using these R_d values against moisture content values. The R_d values at the constant drying period were obtained from the drying curves at critical moisture content where the slope of the drying curve changes from falling rate period to constant rate period. Mass transfer coefficient (K) was determined using Eq. 2. The H_s value was obtained from the psychrometric charts at known surface temperatures (T_s) of the product. From the values of *K*, the heat transfer coefficient (h) was determined using Eq. 3. The values obtained are shown in Table 1.

Application of regression models: Multiple linear regression models were performed on the drying data to

Table 1: Heat and mass transfer coefficients

Drying conditions	Drying time (h)	Drying rate kg/m²s (R_d)	Mass transfer coefficient (KmoL/m²s)	Heat transfer coefficient (W/m²K)	Temperature of drying (°C)	Relative humidity
Open Sun	240	0.11 E-4	0.181 E-3	5.41	32.7[a]	44.7[c]
Solar	192	0.14 E-4	0.210 E-3	6.28	35.2[b]	44.0[d]
Hot Air	12	2.0 E-4	1.53 E-3	46.2	50.0	26.4

[a, b, c] and [d] are mean values

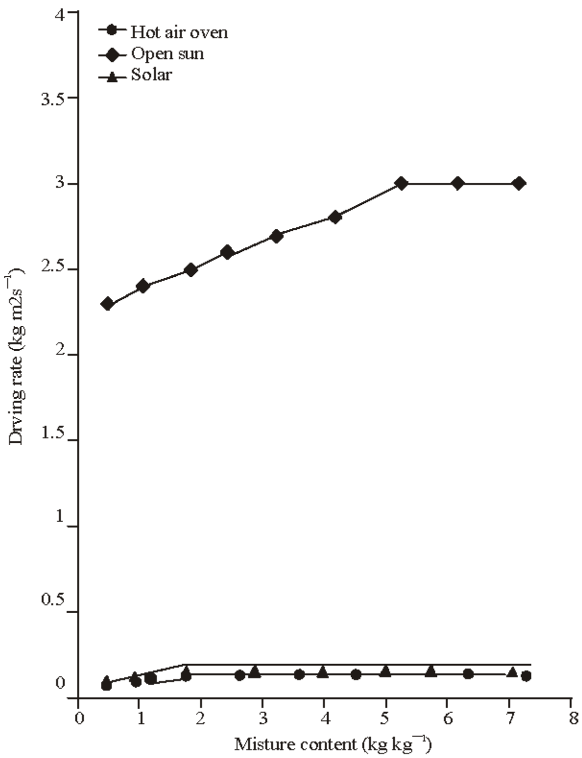

Fig. 1: Companison of three dying system for 20 mm sized sample

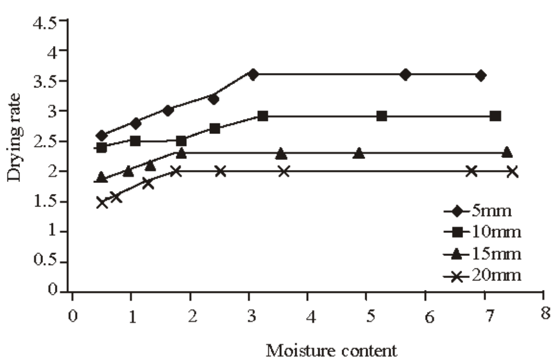

Fig. 2a:Effect of moisture content on dying rate at 50°C

establish a statistical relationship between drying time, temperature and sample size in the form:

$$Y = b_0 + b_1x_1 + b_2x_2 + \mu \quad (4)$$

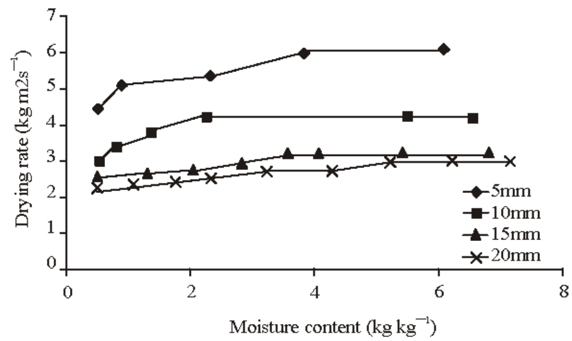

Fig.2b: Effect of moisture content on dying rate at 80°C

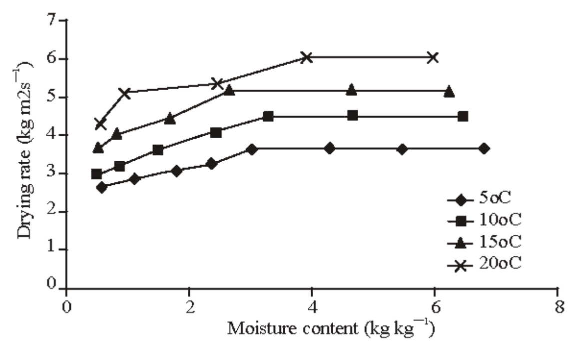

Fig. 3a: Effect of moisture content on dying rate atdifferent temperatures for 5 mm size

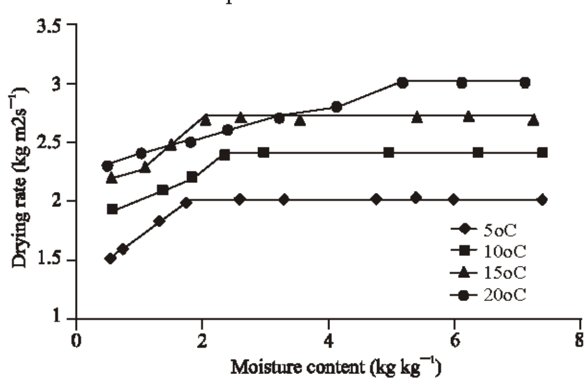

Fig. 3b: Effect of moisture content on dying rate at different temperatures for 20 mm size

where Y = drying time
x_1 = drying temperature
x_2 = sample size
b_0 = regression constant

b_1, b_2 = respective coefficients due to temperature and sample size on the drying time. Hence, the empirical values of b_0, b_1 and b_2 were computed using Eq. 4 such that the data could be used for the prediction of drying time of onions for the optimization of process operations.

RESULTS AND DISCUSSION

The initial moisture content of the onions was 8.2 kg^{-1} (dry basis) and drying was programmed to terminate at 0.5 kg^{-1} (dry basis).

Both constant and falling rate periods were presented during the drying of the onions Fig. 1. The mass transfer coefficients varied from 0.181 E-3 to 1.53 E-3 Kmol/m^2s and the heat transfer coefficients from 5.41 to 46.2 W/m^2K, the higher values referring to the hot air oven dried products Table 1. The differences in mass and heat transfer coefficients of the hot air oven drying process and the other two drying processes open sun and solar drying are very high. These higher transfer coefficients under hot air drying leads to faster drying than the traditional open sun and solar drying. Although the differences in heat and mass transfer coefficients of both open sun and solar drying processes are marginal, the general trend indicates higher transfer coefficients under solar drying. This leads to faster drying than the traditional open sun drying.

The experimental values of the transfer coefficients were comparable to those published in the literature: the coefficients for red pepper were 0.94 E-3 Kmol/m^2s and 57.3 W/m^2K[12] and for ethyloleate-treated grapes were 0.48 E-3 Kmol/m^2s and 49.1 W/m^2K[13].

The effect of dry bulb air temperatures on the drying rates of the sliced onions with 0.005 m and 0.02 m diameters, respectively is shown in Fig. 2a and 2b. These were the extreme sizes used for the investigation. Drying rate data for the sample sizes 0.01 m and 0.015 m is not presented here because similar trends to drying at 0.005 m and 0.02 mm were obtained.

Figure 2a and 2b show that higher drying rates were achieved for onions at higher temperatures (70 and 80°C) and smaller sample size (0.005 m). As sample size increased from 0.005 m Fig. 2a to 0.02 m Fig. 2b, differences between the drying rates at the given temperatures become more pronounced. This is evident from the drying rate maxima that range from (2.6-6.0) E-4 kg/m^2s. The drying rate of green bell peppers was shown[14] to increase substantively with increasing temperatures from 55 to 75°C. It was also shown[15,16] that the drying rate of red pepper, okra and bitterleaf increase with increasing temperature from 35 to 75°C.

Drying rates close to resembling constant and falling rates drying were observed during drying at 50°C to 80°C Fig. 2a and 2b. A constant rate drying for red peppers was observed at 55 and 65°C as well as falling rate drying at 60, 70 and 75°C[14]. During constant drying rate, the surface of the product remains saturated with water due to the fact that migration of water from within the product to the surface takes place at the same rate as that of evaporation from the surface. The rate of drying during this period is thus dependent only on the rate of heat transfer to the drying surface[17]. This is determined by solid configuration and geometry of the product as well as the heat transfer coefficient and the temperature differential[18]. The rate during the falling rate period was higher at 80°C than at the other temperatures in the case of drying the 0.005 m sample size Fig. 2a. During the falling rate period, the drying rate depends on the rate of moisture migration from the interior of the product to the surface.

Figure 3a and 3b show the effect of different sample sizes on the drying rate at 50 and 80°C. The maximum drying rates at 50°C decreased as sample size increased. The observed effect of sample size in this study is in agreement with theoretical considerations[7,18] and also with the observation of[19] in their study of the air drying behaviour of fresh and osmotically dehydrated banana slices.

Multiple linear regressions that were performed on the drying rate data resulted in the following relationship;

$$\text{Drying Time} = 13.3 - 0.125x_1 + 0.2833x_2$$

where x_1 = drying temperature
x_2 = sample size
$R^2 = 0.981$

Both the drying temperature (dry bulb temperature) and sample size were found to be highly significant ($p<0.05$). It is evident from the empirical equation that increasing the drying temperature (dry bulb temperature) from 50 and 80°C at a constant sample size results in a decrease in the drying time. At the same time, increasing the sample size from 0.005 mm to 0.02 m at constant dry bulb temperature increases the drying time. Conditions leading to shorter drying times (i.e., elevated temperatures) would tend to increase the energy requirements for the production of a unit dry product [20]. Nonetheless, the unit cost of producing a dry product is also determined by capital investment. This contribution to the total product cost will be minimised at the shortest drying time because of higher throughput. The relationship between drying temperatures, sample size and drying time should enable dryer operation to minimise production costs.

CONCLUSION

The present study indicates that there is significant difference in the transport properties (heat and mass transfer coefficients) between the drying process under hot air oven drying and conventional drying (traditional open sun and solar drying). Drying rates, and thus drying times, were affected by different drying temperature and sample sizes. Increasing drying temperature at constant sample size resulted in decreasing drying times while increasing sample size at a constant temperature resulted in increased drying times. Drying rates are generally higher at elevated drying temperatures (at constant sample size) and lower at greater sample size (at constant temperature). The optimum drying conditions required to achieve a high drying rate and short total drying time are thus conditions of high temperature and small sample size.

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