DRYING CHARACTERISTICS OF KEREWA TOMATO UNDER INFRARED DRYING

[1]Dairo, O. U[*], [1]Adeosun O, J., [2]Adeleke, E. A, [1]Omotainse, P. O., [1]Abimbola M., [1]Yusuf B., [1]Dada Omolara, and [3]Dairo R. B

[1]Department of Agricultural Engineering, College of Engineering, Federal University of Agriculture. Abeokuta. Ogun State, Nigeria

[2]Mechanical Engineering Department, Faculty of Engineering, Federal University Oye Ekiti, Ekiti State, Nigeria

[3]Department of Nutrition & Dietetics, Federal University of Agriculture Abeokuta. Ogun State, Nigeria

[*]Corresponding author: dairoou@funaab.edu.ng

ABSTRACT

In Drying characteristic for infrared drying of tomato slices were investigated. The drying experiments were carried out using Kerewa local varieties of tomato at five infrared drying power (150, 250, 300, 400 and 500 W) with slice thickness of 10 mm. For all drying powers there was a reduction in moisture content with increased drying time, the drying took place in the falling rate period. The drying time reduced as the infrared heating power increased from 150 to 500W. The diffusivity obtained for the tomato slices were within the range specified for fruits and vegetables with a value of 5.6132 x 10^{-7} m/s^2. Blanched tomato varieties had better rehydration capacities than all unblanched samples.

Keywords: Infrared, Kerewa, Tomato, Drying, Diffusivity,

Introduction

Tomato *(solanum, lycopersicum)* is one of the most scientifically investigated vegetable, because of its commercial importance, its highly perishable and post harvesting losses reach 25 – 50%, with high water content of 93-95%. In tropical countries, there is a loss of 20-50% from harvesting to consumption. It is low in calories and rich in vitamin A, C, and E and minerals such as calcium, potassium and phosphorus. Tomatoes grow in lowland and highland areas, but they cannot survive for a long period of time after harvested. After three days in storage, tomatoes respiration and transpiration will cause increase of CO^2 and H_2O content. This triggers the growth of bacteria that cause rotting of tomato (Cahyono, 1998). The quality of tomatoes depends on its freshness while low water content in tomatoes discourages the growth of bacteria. In order to make the tomatoes last longer after harvesting, preservation method is needed to drying tomatoes while retaining flavor. Drying is an important process to preserve raw food materials. The drying process occurs when water vapour is removed from its surface into the surrounding space, resulting in a dried material with an extended shelf life and reduced water activity of food products. During drying, the moisture content can be reduced to a level ranging from 1 to 5%, which avoids microbial spoilage and undesirable enzymatic reactions. In addition to substantial reduction in weight and volume, it minimizes packaging, storage and transportation costs (Fumagalli and Silveira, 2005; Falade and Solademi, 2010). Drying can be carried out by the application of heat either by conduction, convection or radiation. It involves both heat transfer (application of heat) and mass transfer (removal of water).

The use of artificial drying to preserve agricultural products has expanded widely, creating a need for more rapid drying techniques and methods that reduce the large amount of energy required in drying processes. New and or innovative techniques that increase drying rates and enhance product quality have achieved considerable attention. New drying techniques and dryers must be designed and studied to minimize the energy cost in the drying process (Kocabiyik and Tezer 2009).

Several methods are used in the drying industry such as sun drying, hot air, microwave, vacuum and infrared radiation. Infrared Drying (IR) drying is based on the action of infrared wavelength radiation from a source, which interacts with the internal structure of the sample and thus increases its temperature and favors the evaporation of its moisture content. IR drying technique is particularly valid for products with significant moisture content, for which long wave radiation (over 3μm) is almost totally absorbed by moisture, while dry material is highly permeable to such radiation. IR heating presents some advantages with respect to conventional drying: decreasing drying time, high energy efficiency and lower air flow through the sample product (Togrul, 2005).

IR drying has been investigated as a potential method for the drying of numerous foodstuffs, including fruit, vegetables and grains, and of some derived sub products, as described in the works on the IR drying of cashew kernel (Hebbar and Rastogi, 2001), of carrot (Togrul, 2006), of onion (Sharma *et al.,* 2005) and of wet olive husk (Ruiz Celma *et al*., 2008).

Until recently, one of the most commonly used drying techniques was the convective hot air drying. However, in this drying technique, food material are exposed to elevated temperature, which leads to an increase in shrinkage and toughness, reduction in both the bulk density and rehydration capacity of the dried product, and it also causes serious damage to flavor, colour and nutrient content. There is scarce literature on infrared drying of the local Kerewa tomatoe variety; hence the main objective was to investigate the effect of infrared power on drying characteristics (moisture ratio, drying rate, and diffusivity and activation energy) of Kerewa tomato slices

Materials and Methods

The Yoruba-Kerewa tomato variety used for the experiment was procured at local market in Ogun state. Tomatoes that appeared damaged was removed by hand picking. Red, fresh and ripe tomatoes with the same grade were sorted out and wash with water to remove dirt and soil. The fresh ripe tomato samples were stored in a refrigerator until drying experiment was conducted. The tomato was washed and sliced into 10 mm thickness using a stainless steel knife. The direction of cut was perpendicular to the vertical axis of the tomato. A micrometer was used to check the thickness and uniformity of each slice at three different locations, and acceptance was being based on mean value and deviation from the desired thickness of 10mm.

All tomatoes varieties were divided into two batches; one batch was blanched in water at 80^{o}C for three minutes and drained for five minutes. This was regarded as blanched samples while the other batch was used fresh without any pre-treatment and was referred to as raw or unblanched samples. Each batch slices of tomato were subjected to drying at five infrared energy levels (150W, 250W, 300W, 400W and 500W).

The weight change was recorded at every 5 minutes from the LED display of the digital balance. The initial moisture content of the tomato samples was determined using AOAC (1990) standard oven drying method at an air temperature of 105 ± 2^{o}C until there will be no appreciable weight change as reported by Dairo *et al.,* (2017). The drying experiment was terminated be when there is no appreciable change in weight.

Equipment setup and drying procedures

The drying setup used by Dairo *et al* (2017) consisting of a rectangular infrared drying chamber box (500 mm x 500 mm x 300 mm) made of 12 mm thick plywood was used as the infrared drying. The inner chamber of the box was lined with aluminum sheet to prevent heat loss. Three outlets (one at each end and one at the center) were provided at the underside of the chamber top for installation of infrared bulbs which converts electrical energy to infrared energy. Two Infrared Bulbs (150 and 250 W, Philip Bulbs) were arranged both as combination and singly to provide 150, 250, 300, 400, and 500W of heat source from the infrared bulbs. A front door with a viewing glass for loading and offloading of sample was also provided. A fan was attached to one side of the chamber while an exit for moist air was provided at the opposite end. A digital infrared thermometer was used to monitor the chamber temperature. A tray covering the length of the cabinet was provided at about 150mm below the bulb end for drying of samples.

Three sample trays (10 cm in diameter and 1 cm deep made of steel wire mesh) containing the sample were arranged on the horizontal tray within the radius of each infrared bulb rays to allow good absorption of the infrared energy. The change in mass during the microwave drying was recorded by removing the sample from the cabinet and weighed on a digital balance (Model PE1600, Mettler Instruments Corporation, Zurich, Switzerland) with a resolution of ± 0.01g at 5 min intervals of drying time until there was no appreciable change in weight for three consecutive readings. All experiments were carried out in triplicates for both blanched and unblanched samples and the mean value was used for analysis. The samples were uniformly arranged on the tray as a thin layer and moisture loss was recorded at 5mins intervals during the drying process in order to determine the drying curves. The drying process was continued until no moisture content was recorded. Samples were thus completely dried in order to carry out the mathematical modelling of kinetics of the drying process.

Experimental data from the different drying runs were expressed as moisture ratio versus drying time, drying rate versus drying time and drying rate versus moisture content. The change in moisture content of tomato slices was calculated and moisture ratio was obtained from equation 1

$$M = \frac{M}{M} \quad (1)$$

Where Mt and Mo are the moisture content at any given time and the initial moisture content, respectively, since in IR drying, samples may be dried as much as dry matter content.

Determination of Rehydration ratio (RR)

The rehydration characteristics of a dried product are widely used as indicators of quality. Rehydration is a complex process that is influenced by both physical and chemical changes associated with drying and the treatments preceding dehydration. The rehydration ratio of dried tomato was determined as reported by (EL-Mesery and Mwithiga, 2012) by immersing of dried sample in water at a temperature of 100ºC and after 20 minutes, samples were drained and weighed. The rehydration ratio (RR) was calculated as the ratio of the mass of the rehydrated sample to that of dry sample using equation (2)

$$R = \frac{M_a}{M_i} \quad (2)$$

Where M_a is mass of sample after rehydration and M_i is initial mass of sample before rehydration

Determination of effective Diffusivity

Diffusivity is used to indicate the flow of moisture out of the material being dried (Cui, *et al.*, 2005). Moisture diffusivity is influenced mainly by moisture content and temperature of the material. Fick's second law of diffusion equation was used to fit the experimental drying data for the determination of diffusivity coefficients.

$$\frac{¢M}{¢t} = D_e \quad \nabla^2 M \quad (4)$$

The diffusion equation (Eqn 3) was solved for infinite slab assuming uni-dimensional moisture movement, volume change, constant temperature and diffusivity coefficients, and negligible external resistance (Crank, 1975):

$$MR = \frac{M-M_e}{M_o-M_e} = \frac{8}{\pi^2}\sum_{n-1}^{\infty}\frac{1}{(2n-1)^2}\left(\frac{-(2n-1)^2\pi^2 D_e \quad t}{4H^2}\right) \quad (4)$$

Where D_{eff} is the effective coefficient (m^2s^{-1}), H is the thickness of the slab (m) and *n* is a positive integer. Only the first term of eqn 3 as presented in Equation 4 can be used with a small error (Doymaz, 2005)

$$MR = \frac{8}{\pi^2} e \quad \left(\frac{-\pi^2 D_e}{4H^2}\right) \quad \mathbf{(4)}$$

The slope is determined by plotting (MR) against time according to eqn (4) and the diffusivity determined from Equation 5

$$Slope = \frac{\pi^2 D_e}{4H^2} \quad \mathbf{(5)}$$

RESULTS AND DISCUSSION

The drying curve for Kerewa tomato variety of 10 mm thickness at all infrared power (150, 250, 300, 400, and 500W) are presented in Fig. 1 and 2 for blanched and unblanched samples respectively. The average Kerewa 94.63 % (w.b.) was reduced to an average of 14.8, % (w.b.) after infrared drying. The average time of drying ranges between 55 min to 240 min with 150W infrared power having the longest drying period.

The drying curves showed that there was a reduction in drying time with increased in infrared drying power of 150 to 500W. This could be attributed the increase in available energy to dry the tomato slices. It was observed that an increase in infrared power output led to reduction in drying time. This is in corroboration with findings by El-Mesery and Mwithiga (2014)

Drying curves for infrared drying tomato slices showed that the rate of moisture removal was higher as infrared power increased. This shows that infrared power output had significant influence the rate of moisture removal. This is in line with findings of Sorour and El-Mesery (2014), Kozabiyik and Tezer (2009). The drying curve revealed that moisture ratio decreased with time. Drying rate increased with increase in infrared output power, indicating that infrared power has effect on drying rate of the crop. This is in line with research findings by Kocabiyik and Tezer (2009)

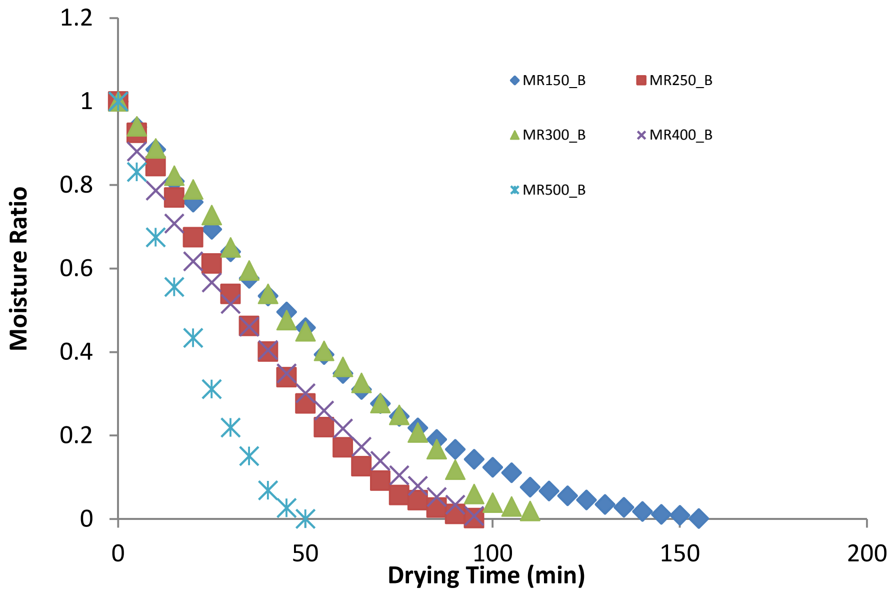

Fig. 1: Drying Curve for Blanched Kerewa tomato variety at different infrared Power

.

Drying rate curves (Fig.3) shows the higher drying rate was observed at initial phase of drying, this may be due to the high moisture content of the crop at initial phase of drying. As moisture reduced with time, the drying rates began to decrease. Drying rate increased with increase in infrared output power, indicating that infrared power has effect on drying rate of the crop. This is in line with research findings by Gabel *et al*. (2006). Drying rate at 500W

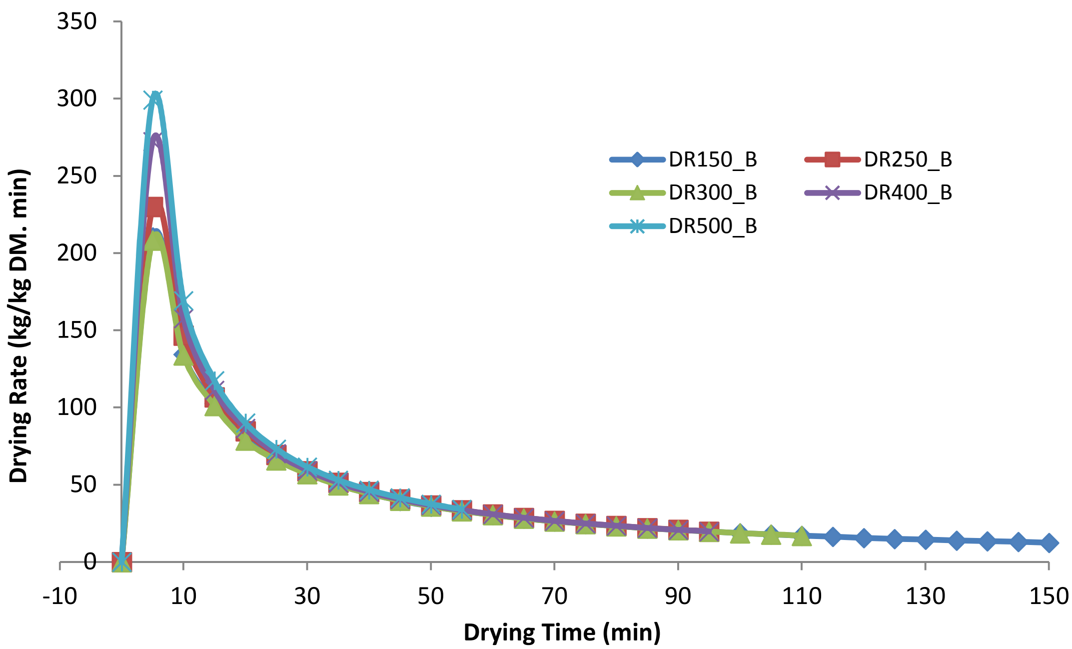

Fig. 3: Drying Rate Characteristics of Blanched Kerewa under different Infrared Power

output power had the highest drying rate of water removal with the shortest drying time while the 150W infrared power had the longest drying time with the lowest drying rate. The blanched samples had a slightly higher drying rate than fresh unblanched samples

Diffusivity of Infra-red Drying

The variation of Ln (MR) against drying time for blanched Kerewa using infra-red power of 150, 250, 300, 400 and 500 W is presented in Fig. 4. It was observed that the plot of In (MR) against time followed a straight line with negative slopes, where the effective diffusivity (*Deff*) was obtained from these values. The slope was found to increase with increase in infra-red power while the effective diffusivity *Deff* also increased with the infra-red power for both unblanched and blanched samples indicating increased drying rate with increase in infra-red power.

The range of *Deff* for both blanched and unblanched of kerewa slices was between 1.844 E-7 and 4.08324E-7 the values for blanched samples were consistently higher than corresponding blanched samples indication that drying would be accomplished faster with blanched samples as evident in the drying curves

CONCLUSION

From the study conducted the following could be concluded.

i. For all drying powers there was a reduction in moisture content with increased drying time and drying took place in the falling rate period.

ii. The drying time reduced as the infrared heating power increased from 150 to 500W

iii. There were no significant differences in drying times but the pre-treated samples always had a slightly lower drying times than the raw or fresh tomato slices.

iv. The diffusivity obtained for the tomato slices were with the range specified for fruits and vegetables with value of 5.61319 E -7 m2/s

v. Blanched tomato varieties had better rehydration capacities than all unblanched samples.

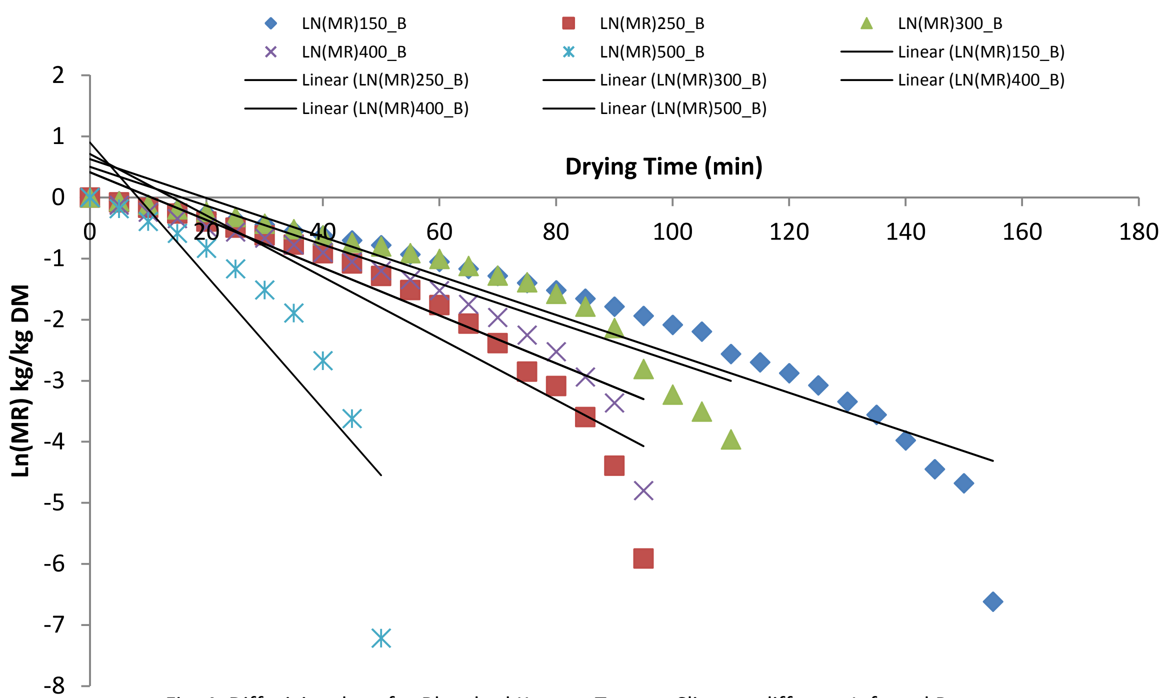

Fig. 4: Diffusivity chart for Blanched Kerewa Tomato Slices at different Infrared Power

REFERENCES

Alaei, B., Chayjan, R. A. (2015). Modelling of nectarine drying under near infrared - Vacuum conditions. *Acta Sci Pol Technol Aliment. 14(1):15-27. doi: 10.17306/J.AFS.2015.1.2*

AOAC (1990). Official method of analysis (12th ed.) association of official analytical chemist, Washington ,Dc , moisture content in plant, I,949

Cahyono L. (1998). Tomat – Usaha Tani dan Penanganan Pasca Panen, Kanisius, Yogyakarta.

Crank, J. (1975). Mathematics of Diffusion, 2nd edn. London: Oxford University Press

Cui, Z. W., Xu, S.Y., Sun, D.W., Chen, W., 2005. Temperature changes during microwave-vacuum drying of sliced carrots. Drying Technology. 23, 1057-1074.

Dadali, G., Apar, D.k., & Ozbek, B. (2007). Microwave drying kinetics of okra. *Dry technol. 25, 917-924.*

Dairo, O. U, Bassey, E. J., Olayanju, T. M. A., Sobukola, O. P (2017). Microwave Drying and Energy kinetics of Nigerian white onion (Allium cepa) variety slices as affected by microwave power. Journal of Technology, Mathematics and Education (JOSTMED). 13(2):125 – 145.

Darvishi, H., Khoshtaghaza, M. H., Najafi, G., & Nargesi, F. (2013). Mathematical modeling of green pepper drying in microwave-convective dryer. *Journal of Agricultural science and technology, 15(3), 457-465*

Doymaz I. (2005). Sun drying of figs: an experimental study. *Journal of Food Engineering* 71: 403–407.

EL-Mesery, H.S., G. Mwithiga, 2012. The drying of onion slices in two types of hot-air convective dryers. *Afr. J. Agric. Res., 7(30): 4284-4296.*

Falade, K.O. and Solademi, O.J. 2010. Modelling of air drying of fresh and blanched sweet potato slices. *Int. J. Food Sci. Technol. 45*, 278–288.

Fumagalli, F. and Silveira, A.M. 2005. Quality evaluation of microwave-dried Packham's triumph pear. *Drying Technol. 23*, 2215–2226.

Hebbar, H.U. and Rastogi, N.K., 2001, Mass transfer during infrared drying of cashew kernel. *Journal of Food Engineering, 47: 1–5.*

Kocabiyik, H. Tezer, D. (2009).: Drying of carrot slices using infrared radiation, *International Journal of Food Science and Technology 2009, 44, 953–959*

Ruiz Celma, A., Rojas, S. and Lopez-Rodriguez, F., 2008, Mathematical modelling of thin-layer infrared drying of wet olive husk. *Chemical Engineering and Processing, Process Intensification, 47: 1810–1818.*

Sharma, G.P., Verma, R.C. and Pathare, P.B., 2005, Thin layer infrared radiation drying of onion slices. *Journal of Food Engineering, 67: 361–366*

Sorour, H., El-Mesery, H. (2014). Effect of microwave and infrared radiation on drying of onion slices. International *Journal of Research in Applied, Natural and Social Sciences*. 2 (5): 119-130.

Togrul, H., 2005, Simple modelling of infrared drying of fresh apple slices. *Journal of Food Engineering, 71: 311–323.*

Togrul, H., 2006, Suitable drying model for infrared drying of carrot. *Journal of Food Engineering, 77: 610–619.*