Effect of Temperature Variation by Forced Air Dryer on Solar Drying of Okra

Ugwoke Emmanuel Eze[1*]; Audu Ibrahim Ali[2]; I.C. Iloani (M.Eng In View)[3]; K.C. Onyeneho[4]; and E.C Ugwuoke[5]

[1]Weather Forecasting Services, Nigerian Meteorological Agency, Nigeria.
[2]Department of Mechanical Engineering, The Federal Polytechnic, Idah, Nigeria.
[3]Institute of Management and Technology (IMT), Enugu, Nigeria.
[4]Department of Mechanical Engineering Technology, Akanu Ibiam Federal Polytechnic Unwana, Afikpo, Ebonyi State, Nigeria.
[5]Projects Development Institute (PRODA), Enugu, Nigeria.

E-mail: emmychyugwuoke@yahoo.com*

ABSTRACT

Drying is the traditional and oldest method of processing okra to reduce the water activity and improve the keeping quality. Drying may be achieved by sun or using a hot-air oven. Dehydrated foods and the dried components of many formulated or manufactured foods are now common articles of commerce and drying is becoming a standard processing operation. Its technology is now rather well-defined and it is carried out in well tested types and sizes of equipment to produce billions of pounds of dry product annually.

This research was conducted to compare different drying techniques forced air drying, solar drying and sun drying. There was rapid drop in moisture content in the forced air-drying method that the two other drying method. At 24 hours of drying time it was recorded that forced air dryer has 16% moisture content and solar dryer has 23% while sun drying recorded 35%. The comparison made on the forced air dryer at 50ºC, 70ºC, and 90ºC indicated that 90ºC has highest drying rate with faster reduction in the moisture content.

(Keywords: okra, drying, preservation, temperature, solar drying)

INTRODUCTION

Drying is a heat and mass transfer process resulting in the removal of water moisture, by evaporation from a solid, semi solid, or liquid to end in a solid state [1]. The drying technique is probably the oldest and the most important method of food preservation practiced by humans. The removal of moisture prevents the growth and reproduction of microorganisms which cause decay and minimizes many of the moisture-mediated deteriorative reactions [2]. It brings about substantial reduction in weight and volume, minimizing packing, storage and transportation costs and enables storability of the product under ambient temperatures [3]. During drying many changes take place; structural and physic-chemical modifications affect the final product quality, and the quality aspects involved in dry conversion in relation to the quality of fresh products and applied drying techniques.

Currently, hot air drying is the most widely used method in post-harvest technology of agricultural products [2]. Using this method, a more uniform, hygienic, and attractively colored dried product can be produced rapidly. However, it is an energy consuming operation and low energy efficiency, so more emphasis is given on using solar energy sources due to the high prices and shortage of fossil fuels.

Solar dryers are now being increasingly used since they are a better and more energy efficient option. The solar dryers could be an alternative to the hot air and open sun drying methods, especially in locations with good sunshine during the harvest season [4]. Among these are lack of ability to control the drying process properly, weather uncertainties, high manpower costs, large area requirements, insect infestation, mixing with dust and other foreign materials, and so on.

Drying is a complex thermal process in which unsteady heat and moisture transfer occur simultaneously [2, 3]. From an engineering point of view, it is important to develop a better understanding of the controlling parameters of this complex process. Mathematical models of the drying processes are used for the control of the drying process [2]. Many mathematical models have been proposed to describe the drying process, of which thin-layer drying models have been widely in use. These models can be categorized as theoretical, semi-theoretical, and empirical [5, 6]. Recently, there has been a lot of research in mathematical modeling and experimental studies of the drying characteristics of various vegetables and fruits. Studies on the sun drying of okra are scarce in the literature.

The use of solar driers helps to eliminate the air pollution problems caused by fossil fuel dryers [7]. The conditions in the tropical countries make the use of solar energy for drying food particularly attractive. Egypt is one of the countries which have favorable solar energy condition. It has a clear sky almost all the year around except few days during winter and spring seasons. The utilization of solar energy for drying fruits and vegetables can contribute a significant agro-industrial development. Solar drying systems must be properly designed in order to meet particular drying requirements of specific crops and give satisfactory performance with respect to energy requirement [8]

Solar Drying

Solar drying refers to the methods of use of sun energy for drying but excludes open-air sun drying [9]. Solar drying is defined as, a process whereby agricultural materials are dried not by direct exposure to the sun, but by means of solar heated air in more protected environment [10].

The justification for solar dryers is that, they may be more effective than sun drying, but have lower operating costs than mechanized dryers [11]. The introduction of solar dryers in developing countries can reduce crop losses and improve the quality of dried product significantly compared to traditional drying methods [12]. In recent years numerous attempts have been made to develop solar drying mainly for preserving agricultural and forest products.

Solar drying systems must be properly designed in order to meet particular drying requirements of specific crops and to give satisfactory performance with respect to energy requirements [13]. Solar dryers have some advantages over sun drying when properly designed. They give faster drying rates by heating the air (10ºC-30ºC) above ambient temperature, which causes the air to move faster through the dryer, reduces its humidity and deters insects. The faster drying reduces the risk of spoilage, improves quality of the product and gives a higher throughput, so reducing the drying area that is needed. Solar dryers also protect foods from dust, insects, birds and animals [9]. They can be constructed from locally available materials at a relatively low capital cost and there are no fuel costs. Thus, they can be useful in areas where fuel or electricity are expensive, land for sun drying is in short supply or expensive, sun shine is plentiful, but the air humidity is high. Moreover, they may be useful as a means of heating air for artificial dryers to reduce fuel costs [14].

Okra is a widely consumed cultivated vegetable in tropical and subtropical countries. The most important okra producing countries are India, Nigeria, Pakistan, Ghana, and Egypt [15]. This vegetable is more famously known by its rows of tiny seeds and slimy or sticky texture when cut open. It is easy to cultivate, suited to regions with moderate rainfall and is normally grown during the summer [16]. Okra is also a crop of significant nutritional value that contains a high percentage of water, averaging 85%, fat and protein in a small and varying amount, a fair proportion of carbohydrates which are present as cellulose, starch in small quantity and sugar [17]. It also contains non-cellulose, non-starch, polysaccharides [17]. It is a source of protein, vitamins C and A, iron and calcium [18] and dietary fiber [19].

The most extensive use of okra is in the home garden, on the small farm and at large agricultural enterprise level [16]. It is used in the fresh state and the product may be processed (by drying or blanching before drying) and then preserved for later use. In Nigeria, particularly, the western part, okra is commonly used for making soup (as a thickener), cooking of yam etc. Okra contains large quantities of glycans, which are responsible for the viscosity of the aqueous suspension [20] and the stringy, gum-like consistency that is particularly desirable in soups.

The okra pod which is quite slimy even after cooking is most often used in stews, soups, and gravis, giving a thickening effect in soups [21].

Sliminess property of the okra fruit is of great importance to its acceptability and food value to consumers. The more viscous or slimy okra is better and is rated as a food thickener. Okra mucilage is suitable for medicinal and industrial applications. It has medically found application as a plasma replacement or blood volume expander. Industrially, okra mucilage is usually used to glace certain papers and also useful in confectionery among other uses. Okra is highly perishable because of its high moisture content and respiratory activities; thus, it is necessary to preserve the commodity. Sometimes, processing of okra involves blanching, which is a heat treatment, given to vegetables to limit or put a stop to both enzymatic and microbial activities.

Botanical Description of Okra

The okra plant, somewhat resembles its close relative cotton, although okra has a much larger, rougher leaves and a thicker stem [9]. It is a semi woody, fibrous, herbaceous annual with an indeterminate growth habit. It grows to a height of 0.9 to 1.8 m. The plant forms a deeply penetrating taproot with dense, shallow feeder roots in the upper 46 cm of the soil. It has large, alternate, palmate leaves with small stipules. Leaf margins vary from slightly wavy to very deeply lobed. Flower buds appear in the axle of each leaf beginning above the six-to eight-leaf stage and develop into five large showy, yellow petals with a large dark maroon or royal purple colored area at the base. As okra plant develops the lowest flower bud on each stem opens soon after sunrise and closes at mid-day to late afternoon [22]. Okra is considered to be a self-pollinated crop. The upper rows of stamens are adjacent to the lower surface of stigma [23].

MATERIAL AND METHODS

The okra used in this research work was obtained from an okra farm located at Umudiaba in Igbo Eze South Local Government Area of Enugu State. The okra was planted by August 4th, 2018 and was allowed to grow to it maturity stage where enough number of the okra will be harvested for the experiment. The time for planting the okra by August 2018 was chosen in other to perform the experiment by November end where enough sun radiation will be seen. This is also to avoid disruption which may be caused by constant rainfall in the region. It was expected that during the mid year in the southern part of the country, rainfall is maximum which hindered a lot of activities.

The okra vegetable has average length of 55-75 mm and the average diameter is 12-18 mm. The color of the okra is dark green. A sharp clean knife was used to slice the okra into 4mm length which will be used for the experiment. The slicing of the okra was important in order to increase the surface area thereby hastening drying rate.

Methods

The okra was sliced to 4 mm each was measured in a weighing balanced to obtain a weight. The forced air dryer was used for the drying of the measured okra. The forced air dryer required the use of fan or blower to blow the air. The 100 g measured weight of okra was replicated into three places. Each of this weight were put in a flat plate and put in a forced air dryer which used a high-speed blower to support and facilitate the air movement in the dryer. The equal weight of the okra was subjected to different air temperature each of 50ºC, 70ºC, and 90ºC. The temperatures were at a different of 20ºC at air velocity of 1m/s ± 0.1m/s.

Also, the experiments were conducted for solar drying using atmospheric temperature and pressure. The solar drying method of okra drying was done without artificial support of air blowing machine. The is just to have the result gotten from solar drying compared with the forced air-drying method. The loss in weight was recorded after a period of 3 hours of exposure.

It was also sun-dried by putting the measured quantity of okra on a drying paper plate and exposed to sunlight. The moisture loss was recorded after 3 hours. The moisture loss of forced air dryer was also measured at 20 min interval. Also sun-drying, solar-drying and forced-air drying moisture content was measured after 3 hours for appropriate comparison.

The experiments start at 10 am and continued till 4pm where the experiment is paused to be continued the next day. The loss in weight of the okra was measured by the use of digital electronics balance.

Moisture Content Determination

The method used in determination of the moisture content of okra pods is described by AOAC (1985) [24]. A representative sample of 5 g of okra pods was taken from the okra lot to determine its initial moisture content. The okra sample was cut into slices and the sliced sample was put into an empty moisture can of known weight. The moisture can was then put inside an air-oven set at a temperature of 105^{o}C for 24 hours [9].

After the 24 h drying time the moisture can was removed from the oven and placed into a desiccator until it got cold. Then the weight of the dry okra samples and the moisture can were recorded. The loss in weight of okra samples was used in calculation of their initial moisture contents by the following equation:

$$IMC = \frac{W_2 - W_1}{W_1} \times 100 \quad [9]$$

Where,
IMC = Initial moisture content of okra pods, percent (w.b.)

W_1 = Wet weight of the okra samples, g

W_2 = Weight of the wet pods samples and moisture can, g

W_3 = Weight of the dry okra samples and moisture can, g

Ebtihal Mohammed (2000) developed a model for determining moisture ratio. The model developed from Henderson and Pabis, 1961 was used successfully to model the drying process of corn [25].

The model can be written as:

$$MR = a \exp(-kt) = \frac{M - M_e}{M_o - M_e} \quad [9]$$

Where,
MR = moisture ratio, dimensionless

M = moisture content at any time, % (d.b.)

M_0 = initial moisture content, % (d.b.)

M_e = equilibrium moisture content % (d.b.)
a and k = constants

t = drying time, h

RESULT AND DISCUSION

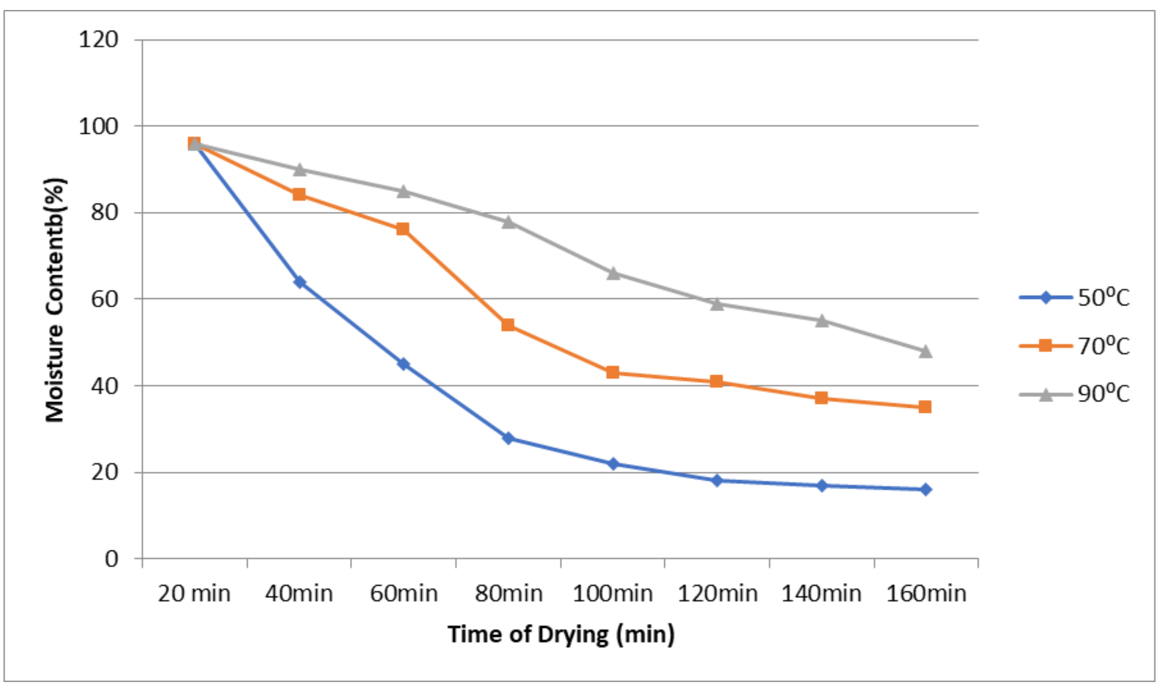

Figure 1: Forced Air-Drying Curve for Okra Slices.

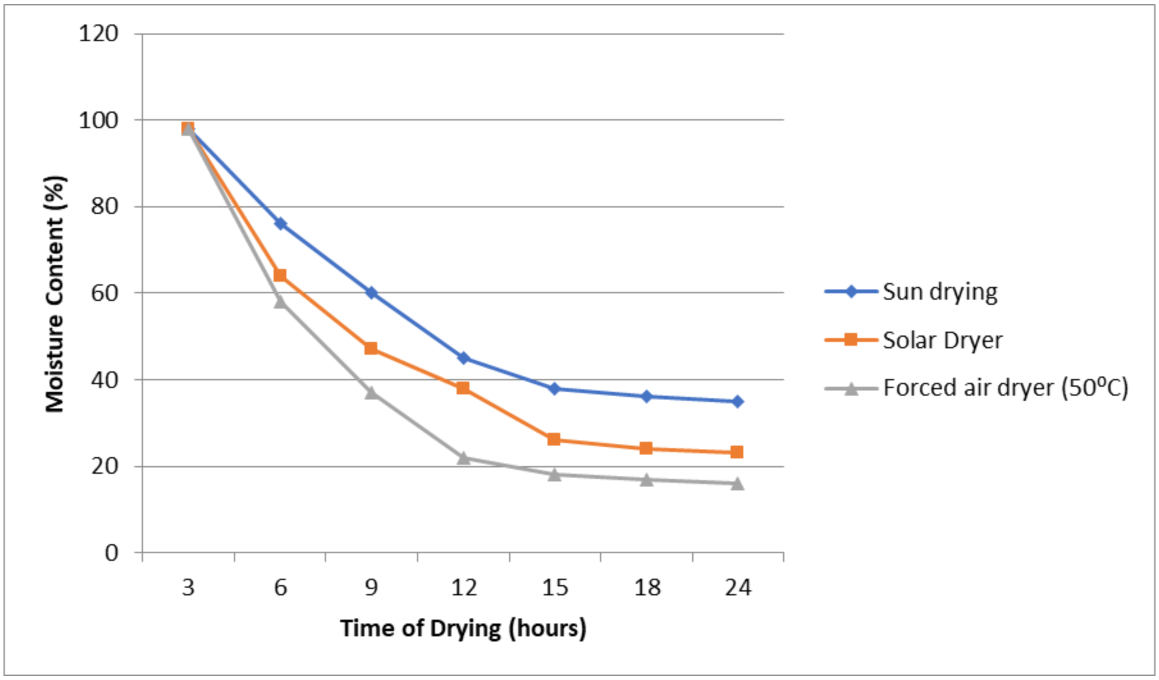

Figure 2: Drying Curve of different Drying Methods for Sliced Okra.

The results of drying of sliced okra were analyzed. The result indicated that there was general decline in moisture content as the time of drying increased. The drying time started at 20 min and ended at 160 min with 20 min interval of drying. The results also indicated that at 40º C temperature there was decreased in the moisture content of the sample from 100% to 16% at 160 min. This is similar with the result obtained by Mohammed et al. (2010) which stated that the drying time for reducing initial moisture content of pretreated okra from 792.86% (d.b) to the final moisture content of 10.41% (d.b) in the forced convection direct solar dryer with air flow rate of 0.075 m3/sec was 16 hours.

At 70ºC drying temperature the moisture content decreased from 100% to 35% and at the same time at 90ºC the moisture content decreased from 100% to about 48%, respectively, at 160min. Wankhade and Sapkal et al. (2012) gave similar results that there was a general decline in moisture content of the sample from 100 g to 15 g in all methods of drying. This showed that as the temperature of air increases the rate of drying increases, in other words the drying is faster at a higher temperature than at lower temperature.

Evaluation of sliced okra sample was done and it was discovered that the okra sample dried at 40ºC has a better quality than the one dried at 60ºC. This was similar to the results obtained by Wankhade and Sapkal (2012) which stated that dried samples obtained at 40°C, 60°C, and 90°C were evaluated for taste and color. The sample dried at 40°C was found better as compared to the samples obtained at 60°C and 90°C.

CONCLUSION

The traditional method for preserving okra involves slicing and sun drying of the fruit until they become brittle, followed by milling into powder for further use. Since it is an important constituent of Nigerian food/curries, drying of okra to enhance it's keeping quality has been practiced since time immemorial. Sun drying is inexpensive drying technique but has many drawbacks. Therefore, to overcome these problems okra is dried in solar or hot air driers more effectively.

The forced air dryer was studied under three temperature of 50ºC, 70ºC, and 90ºC. It was discovered that the 90ºC temperature difference has highest drying rate with faster moisture content reduction. The comparison made with the sun drying, solar drying and forced-air drying indicated that sun drying has lowest moisture content reduction rate.

REFERENCES

1. Wankhade, P.K., R.S. Sapkal, and V.S. Sapkal. 2012. "Drying Characteristics of Okra Slices using Different Drying Methods by Comparative Evaluation". *Proceedings of the World Congress on Engineering and Computer Science.*

2. Wankhade P.K., R.S. Sapkal, and V.S. Sapkal. 2013. "Drying Characteristics of Okra Slices on Drying in Hot Air Dryer". *Procedia Engineering*. 51: 371 – 374.

3. Sahin, A.Z. and J.I. Dincer. 2005. *Food Eng*. 71:119-126.

4. Pangavhane, D.R., R.L. Sawhney, and P.N. Sarsavadia. 2002. "Design, Development and Performance Testing of a New Natural Convection Solar Dryer". *Energy*. 27(6):579–590.

5. Ozdemir, M. and Y.O. Devres. 1999. *J. Food Eng.* 42: 225-233.

6. McMinn, W.A.M. 2006. *J. Food Eng*. 72: 113-123.

7. Mohamed, M.A., G.R. Gamea, and M.H. Keshek. 2010. "Drying Characteristics of Okra by Different Solar Dryers", *Misr J. Ag. Eng*.

8. Steinfield, A. and I. Segal. 1986. "A Simulation Model for Solar Thin Layer Drying Process". *Drying Technology*. 4: 535–542.

9. Ebtihal Mohammed Ibn Idriss. 2000. "Modelling of Thin Layer Solar Drying of Okra (*Abelmoschus esculentus* L.)". *Pods*. University of Gezira

10. Akoy, E.O.M. 2000. "Construction and Performance Testing of a Forced Convective Solar Dryer". Unpublished M.Sc. Thesis, University of Khartoum.

11. Dilip, J. 2005. "Modelling the Performance of the Reversed Absorber with Packed Bed Thermal Storage Natural Convection Solar Crop Dryer". *Journal of Food Engineering*.

12. Inci, T.T. and P. Dursun. 2002. "Mathematical Modelling of Solar Drying of Apricots in Thin-Layers". *Journal of Food Engineering*. 55: 209-216.

13. Kamil, S., K. Rahmi, and K.E. Ahmed. 2005. "Mathematical Modelling of Solar Tunnel Drying of Thin-Layer Organic Tomato". *Journal of Food Engineering*. 73: 231-238.

14. Fellows, P. 1997. *Guidelines for Small-Scale Fruit and Vegetable Processors*, FAO Agricultural Services Bulletin 127, FAO of the United Nations: Rome, Italy.

15. Eze, J.I. and P.I. Akubor. 2012. "Effect of Drying Methods and Storage on the Physicochemical Properties of Okra". *Journal of Food Processing Technology*.

16. Martin. F.W. and R. Ruberte. 1978. "Vegetables for the Hot Humid Tropics, Part 2". *Okra Abelmoschus esculentus Horticulturist and Agricultural Research*. Mayagues Institute of Tropical Agriculture, Agricultural Research, Science and Education Administration, USDA: Mayaguez, PR.

17. Fellows, P. 2000. *Food Processing Technology: Principles and Practice*. Woodhead Publishers: London, UK.

18. Ihekoronye, A.I. and P.O. Ngoddy. 1985. *Integrated Food Science and Technology for the Tropics*. Macmillan Education Ltd.: London, UK.

19. Adom, K.K., V.P. Dzogbefia, W.O. Ellis, and B.K. Simpson. 1996. "Solar Drying of Okra-Effects of Selected Package Materials on Storage Stability". *Food Res Intl*. 29: 589-593.

20. Owoeye, A.I., M.C. Caurie, N.N. Allagheny, and F.N. Onyezili. 1990. "Chemical and Physical Parameters Affecting the Viscosity of Mixed Okra and Tomato Homogenate". *J Sci Food Agric*. 53: 283-286.

21. Janick, J., R.W. Schery, F.W. Woods, and V.W. Ruttan. 1981. *Plant Science. An Introduction to World Crops.* (3rd edn). Freeman & Comp.: New York, NY.

22. Lamont, W.J. 1999. "Okra-Aversatile Vegetable Crop". *Hort Technology*. 9(2):179-184.

23. El Amin, M.A. 2002. "The Effect of Chemical Scarification, Cultivar and Seed Longevity on Germination of Okra (*Abelmoschus esculentus* (L). moench". M.Sc. Thesis, University of Khartoum.

24. AOAC. 1985. *Official Methods of Analysis, 12th ed.* Association of Official Analytical Chemists: Washington, D.C.

25. Henderson, S.M. and S. Pabis. 1961. "Grain Drying Theory. I. Temperature Effect on Drying Coefficients". *Journal of Agricultural Engineering Research*. 6:169-174.

ABOUT THE AUTHORS

Ugwoke Emmanuel Eze, works with Weather Forecasting Services, Nigerian Meteorological Agency, emmanugwuoke@yahoo.com, +2348037509782.

Audu Ibrahim Ali, is a Lecturer at Department of Mechanical Engineering, Federal Polytechnic, Idah. +23408033322061.

I.C. Iloani, is a Lecturer at the Institute of Management and Technology (IMT), Enugu, Nigeria. Telephone +2348033600163. He has several books and papers to his credit.

K.C. Onyeneho, is a Lecturer at the Department of Mechanical Engineering Technology, Akanu Ibiam Federal Polytechnic Unwana, Afikpo, Ebonyi State. His research interest is in production engineering. kconyeneho@ymail.com, +2348187458600.

E.C. Ugwuoke, is a Master's degree holder in Energy and Power Technology at the University of Nigeria, Nsukka, and he also works with Projects Development Institute (PRODA), Enugu, Nigeria. His research interest is in renewable energy. He has done a lot of research on solar water distillation systems and biogas technology. emmychyugwuoke@yahoo.com, +2348039308009.

SUGGESTED CITATION

Eze, U.E., A.I. Ali, I.C. Iloani, K.C. Onyeneho; and E.C Ugwuoke. 2019. "Effect of Temperature Variation by Forced Air Dryer on Solar Drying of Okra". *Pacific Journal of Science and Technology*. 20(2):224-230.