International Journal of Environmental Biology Research Vol. 2 (3) pp. 081-087, March, 2015. Available online at www.Internationalscholarsjournals.org

Full Length Research Paper

Assessment of the drying rate steady, drying productivity, supplements and tactile characteristics of dried vegetables utilizing sun powered dryer and outside sun drying techniques

Onuoah Young Chidera

Department of Home Science, Nutrition and Dietetics, University of Port Harcourt, Port Harcourt, Nigeria.
E-mail: chidera.young@hotmail.com

Accepted 7 January, 2015

Utazi (*Gongromena ratifolia)* and Nchuanwu (*Occimum americanus*) were dried using solar dryer and open- air sun drying methods. 200 g of each sample was used. The weight losses were used to determine the reduction in moisture content. Drying was assumed to have taken place in the falling-rate period, which enabled the use of only one drying rate constant, K. Graphs of ln(M_0-M) versus time were used to obtain the drying rate constants, K for the two drying conditions. All analyses were done using standard procedures. The drying rate constants for the solar dryer and open- air sun dried Utazi were 0.8 and 0.7, respectively. Similarly, the values for Nchuanwu were 0 2 and 0.3, respectively. Moisture versus time graphs of both samples showed that the assumption of one falling- rate period is justifiable. The solar dryer was more efficient and would be more appropriate to industrial application. Both the nutritional and sensory qualities of the dried products were enhanced by the process.

Key words: Drying, solar dryer, drying rate constant, drying efficiency, nutrients, open-air drying.

INTRODUCTION

Drying has been recognized as the most useful processing technique for prolonging the keeping quality of solid foods including vegetables (Dissa et al., 2011). Utazi (*Gongromena ratifolia)* and Nchuanwu (*Occimum americanus***)** are both vegetables and belong to the class of agricultural food products often referred to as perishables. Their common feature is that they are abundant during the peak of their respective season but thereafter, become quite scarce (Onoja et al., 2012).

They are well cherished spices especially in sub-Saharan Africa where they are widely used in preparations of various soups. They play quite significant role in our diets of the population because they are major sources of essential macronutrients, micronutrients and vitamins. Due to their seasonal nature and high moisture content, there is need therefore, to develop an appropriate technology for their preservation so as to guarantee their availability all year round (Eze and Chibuzor, 2008). Over

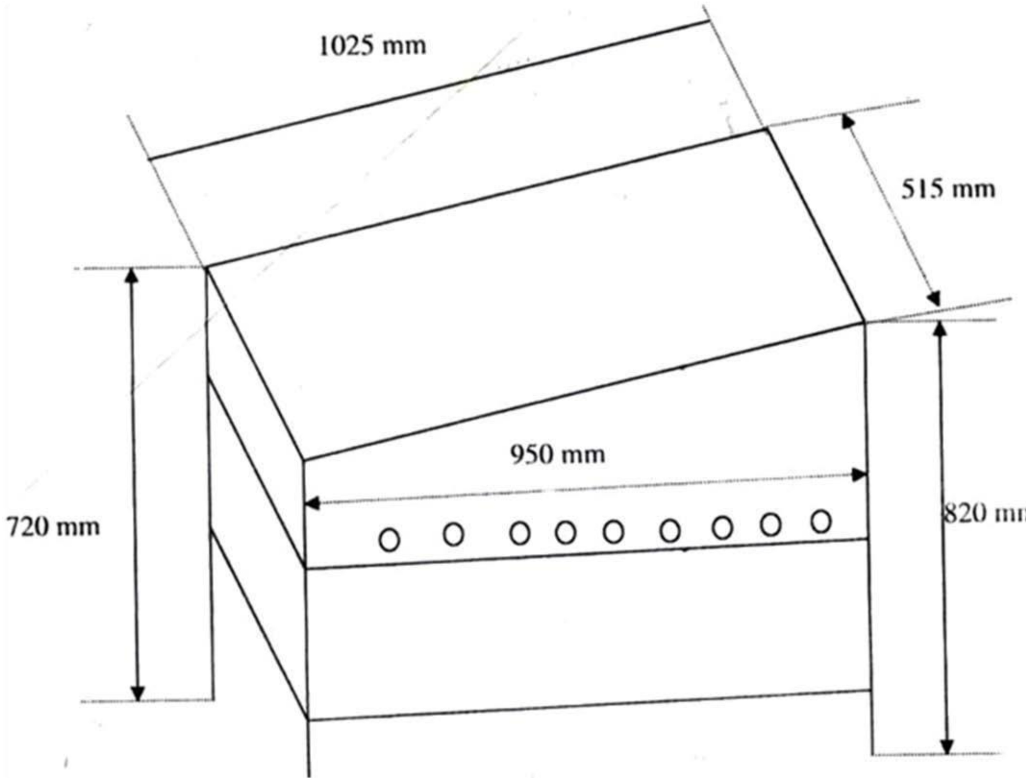

Figure 1. A schematic diagram of the passive solar dryer (National Centre of Energy Research and Development (NCERD), University of Nigeria, Nsukka).

the centuries, agricultural foodproducts including vegetables and spices are dried in the open- air sun or in certain parts of the chimneys designated for the purpose (Scanlin et al., 1997). Whitefield (2002) identified different types of drying techniques including electrical drying, open- air sun drying, firewood/fuelwood drying and solar dryer method. On comparative basis, open-air sun drying ranks first in terms of cost benefit but the poorest when variables such as protection against dust, rain and wind, insect infestation, microbial attack and nutrients retention are considered (Eze and Chibuzor, 2008; Anyanwu and Okonkwo, 2008; Oparaku, 2008).

Solar drying is an appropriate technology for a sustainable environment because it has the potential for high product quality (especially for such heat labile nutrient like ascorbate), it is inexpensive and most importantly, it is environmental friendly (Ekechukwu, 1989; Yaldiz and Ertekyn, 2001). A number of complex theoretical models to describe the heat and mass transfer phenomena in the drying of agricultural products have been described (Tongrul and Pehlivan, 2004; Doymaz, 2004; Mwithiga and Olwal, 2005; Sacilic et al., 2006; Anyanwu and Okonkwo, 2008)). These researchers have studied the kinetics of solar drying of agricultural products and observed that the process occurs in the falling rate period for most fruits and vegetables. The knowledge of drying rate constant is imperative for accurate prediction of drying rates according to the falling rate model. This information is very important to peasant farmers and industrial applications alike since specified levels of moisture content could be linked with a specified time in the process equation. The objective of the study was to compare the drying efficiency between solar dryer and open-air sun drying of agricultural products.

MATERIALS AND METHODS

Utazi (*Gongromena ratifolia)* and Nchuanwu (*Occimum americanus***)** used for the study were purchased at Ogige market, Nsukka. Each sample was divided into two equal batches of 200 g. One batch was subjected to open-air sun drying while the second batch was charged into a passive solar dryer supplied by the National Centre of Energy Research and Development (NCERD), University of Nigeria, Nsukka. The solar dryer measuring 1025 mm × 515 mm with glass cover uses natural convection principle (Ekechukwu, 1989; Anyanwu and Okonkwo, 2008) . Its North end is 845 mm high while the south end is 720 mm high. The glass cover is inclined at an angle of 7° corresponding to the local latitude. The sides of the dryer are made of plywood perforated at intervals for effective air flow. Inside the solar dryer were lined thin perforated trays in layers (Figure 1).

Determination of proximate composition

The proximate composition of the samples was determined using standard techniques (AOAC, 1990). The ambient and drying chamber temperatures during the drying operations ranged between 22 to 35°C and 37 to 48°C, respectively. Samples were evenly spread during the drying operations to ensure effective drying in consonance with the thin layer model which describe the drying phenomena in a unified manner regardless of the controlling mechanism in the drying of agricultural products (Tongrul and Pehlivan, 2004;) . The initial moisture contents of the samples were 72.4 and 65.4% for Utazi and Nchuanwu, respectively. They were weighed at intervals of two hours and the moisture content was calculated from the weight loss until a constant weight was obtained when the weighing was then terminated. The samples had to be carried to a sheltered place each time it rained. Samples were kept in desiccators at nights to prevent moisture re-absorption. The drying of each sample was done in triplicate.

Assumptions and mathematical consideration

In this study, we have assumed that drying occurs mainly in the falling rate period (Uretir et al., 1996; Karathanos and Blessiotis, 1997; Lashsasni et al., 2004; Anyanwu and Okonkwo, 2008). This enabled us to use the falling rate model (Equation 1). Moreover, it has been assumed throughout this work that the drying process was continuous and took place in one falling rate period, hence we employed only one rate constant. Couson and Richardson (1977) and cited by Anyanwu and Okonkwo (2008) observed that natural convection drying in the falling rate period can be represented by the following model:

$$dM / dt = e^{-kt} \quad (1)$$

Where, M = moisture content (%) at time, t (h); t = time; K = drying rate constant.

From the above it is obvious that:

$$dM = e^{-kt} dt \quad (2)$$

Integrating using appropriate limits we arrive at:

$$\int_{m_o}^{m} dM = \int_{t_o}^{t} e^{-kt}\, dt \quad (3)$$

Since the negative power of e shows that $M_0 > M$ and because $t_0 = 0$, we can write:

$$(M_0 – M) = e^{kt} \quad (4)$$

Where, M_0 is the initial moisture content (%) of the samples.

Applying the natural logarithms we arrive at:

$$\ln (M_0 – M) = Kt \quad (5)$$

Sensory evaluation

A -five point Hedonic scale where 5 represented the highest score and 1 the lowest was employed to evaluate the products (soups made from the dried vegetables) for taste, flavour, texture, colour and general acceptability. A 20- taste panel randomly selected from students and lecturers of the Department of Home science, Nutrition and Dietetics, University of Nigeria, Nsukka, participated in the tasting sessions. The tasting was carried out at the department. Each judge (panel member) was seated in an individual compartment free from noise and distraction. The soups were properly coded and served to the panelists.

Statistical analysis

The Statistical Package for Social Sciences (SPSS, version 17) was used to analyze the data. Means ±(SD) were calculated and Analysis of variance (ANOVA) were used to test the significance of the difference . The significance was accepted at $p<0.05$. (Cochran and Cox, 1992)

RESULTS

The results showed that while the percentage moisture loss by the open-air and solar dried samples were very close at the second day, the gap widened by the end of the third day. At the end of fourth day, it could be seen that the solar dried samples had lost virtually all its expellable moisture content as against the open-air sun dried samples. Moreover, the open-air samples had to be carried into a sheltered place each time it rained. However, this did not entirely prevent its weight from fluctuating as a result of the rainfall which occurred thrice during the period of the study. This is clearly visible from the graphs (Figures 2 to 6). Furthermore, analysis of the plots of $\ln(M_0 - M)$ against time (Figures 3 and 4) indicates that the rate constant for the solar dried samples are approximately 0.8 and 0.2 units per day while the open-air sun dried samples are approximately 0.7 and 0.3 for Utazi leaf and Nchuanwu leaf, respectively. With these values, it is quite possible to link a given level of moisture content with a specified drying time. This could be achieved either graphically or analytically using Equation

(5).

The dry basis moisture content (X) versus time (t) graphs of both the open-air dried and the solar dried samples are also presented in Figures 5 and 6. Moisture content was calculated using Equations (6) and (7).

$$X = x^* x_t \quad (6)$$

Where x^* is the equilibrium moisture content (%). x_t is the moisture content corresponding to time, t.(h)

Ekechukwu (1999) and cited by Anyanwu and Okonkwo (2008) observed that x_t can be derived from the equation:

$$x_t = \frac{W - W_s}{W_s} \quad (7)$$

Where W = weight (g) before drying and W_s = weight (g)after drying.

The results also showed that drying resulted in improved proximate composition but decreased ascorbate and minerals of the samples (Tables 1 and 2).

The sensory attributes of the soups made from the dried samples were also enhanced (Table 3).

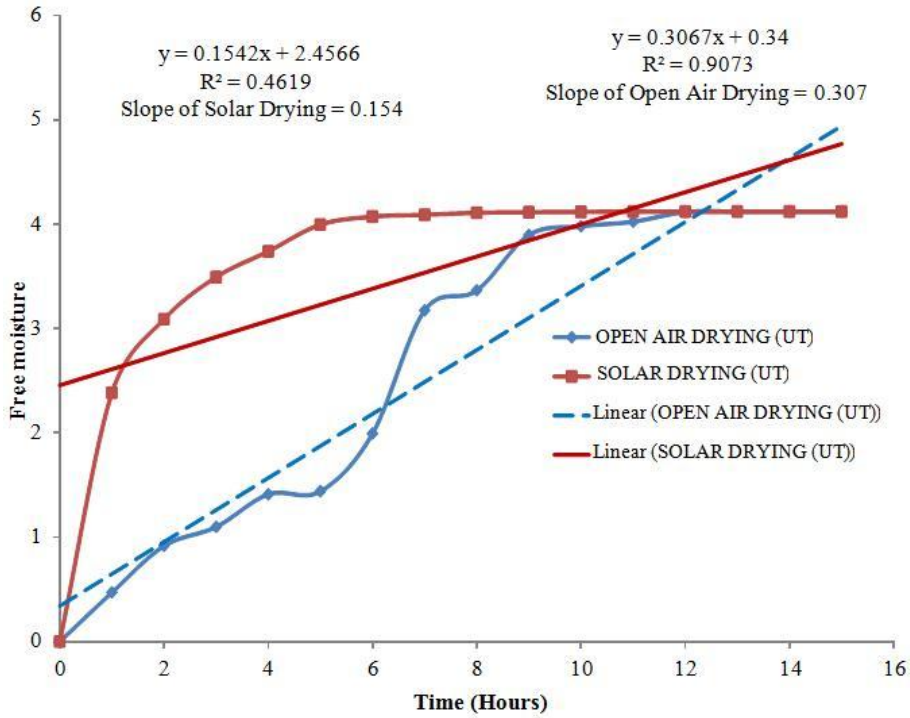

Figure 2. ln(Mo-M) versus time(t) graphs for utazi sample.

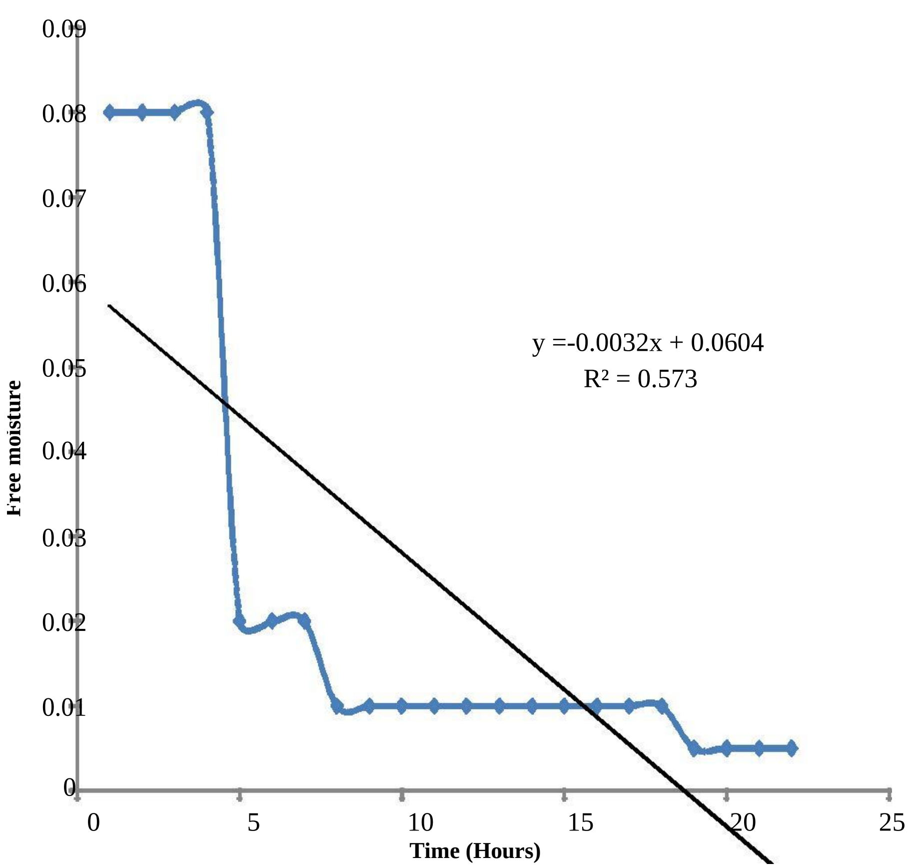

Figure 3. Solar drying of Utazi leaf.

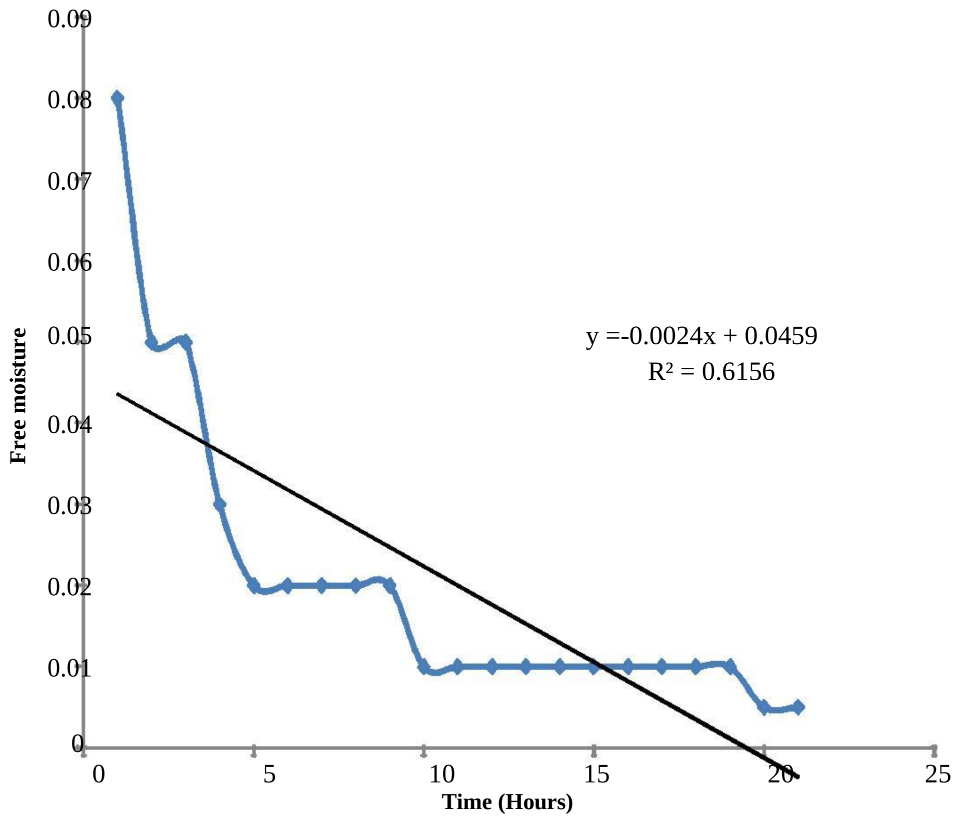

Figure 4. Open-air drying for Nchuanwu leaf.

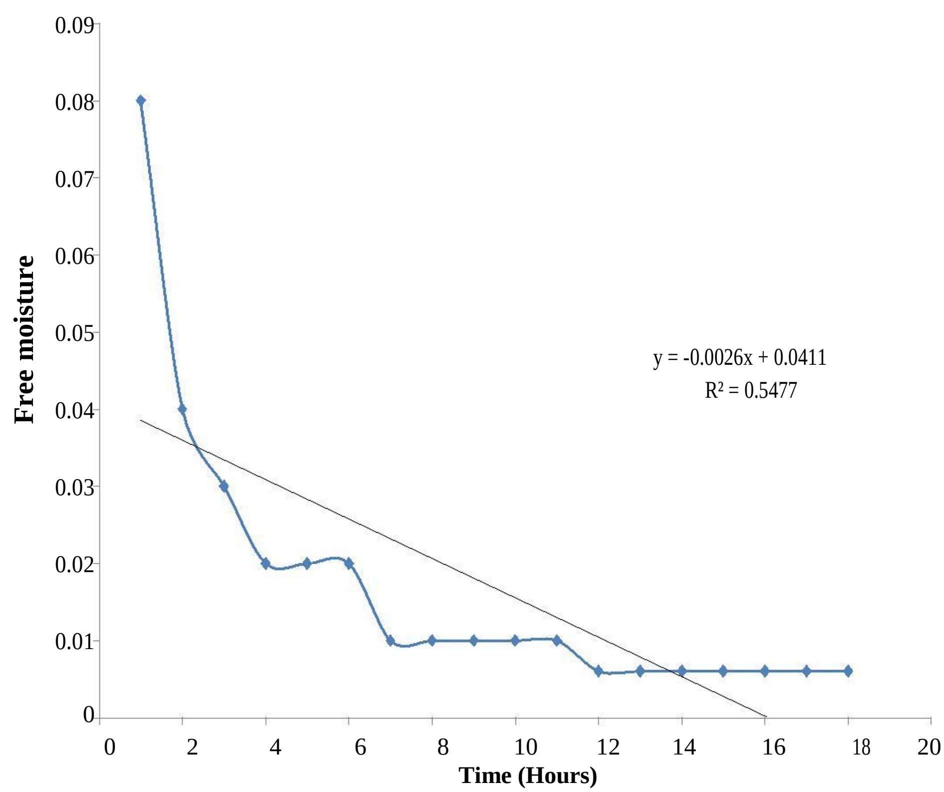

Figure 5. Solar drying for Utazi.

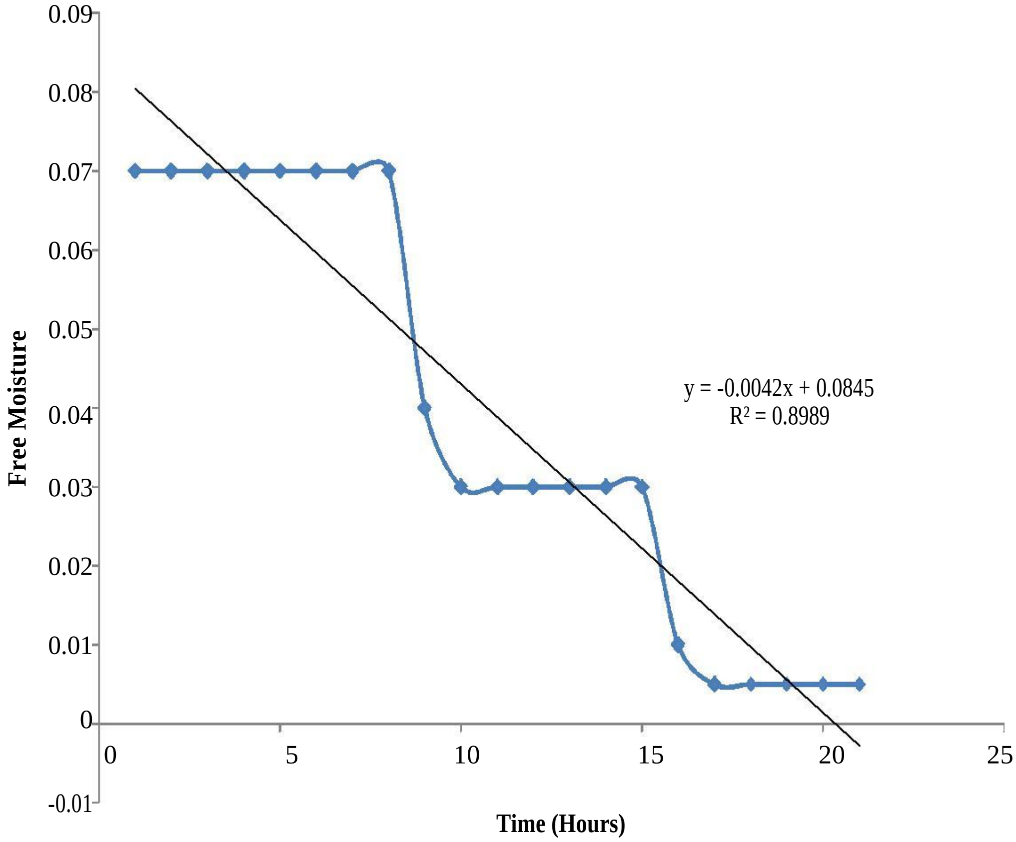

Figure 6. Open-air sun drying for Utazi.

Table 1. Proximate composition (%)* of fresh and dry samples.

Moisture	Fresh (mean)	Dry (mean)	t-value	p-value
Utazi	72.16	13.82	7145.162	0.0000
Nchuanwu leaf	71.86	11.97	4639.059	0.0000
Protein (%)				
Utazi leaf	0.66	3.10	0.6287.840	0.0000
Nchuanwu leaf	0.46	2.20	7.136	0.0000
Ash (%)				
Utazi leaf	10.97	14.68	453.156	0.0000
Nchuanwu leaf	10.86	16.61	16.325	0.0000
Fat (%)				
Utazi leaf	0.30	0.42	944.278	0.0000
Nchuanwu leaf	0.26	0.31	31.498	0.0000
Crude fibre (%)				
Utazi leaf	11.50	2.90	164.762	0.0000
Nchuanwu leaf	10.26	3.60	384.377	0.0000
CHO (%)				
Utazi leaf	67.30	35.90	6295.389	0.0000
Nchuanwu leaf	48.48	38.50	2.595	0.0000

CHO: Carbohydrate. *The standard AOAC method was used to determine the proximate values of both the fresh and the dry samples.

Table 2. Mineral composition* of the different samples.

Ascorbic acid (mg/100 g sample)	Fresh (mean)	Dry (mean)	t-value	p-value
Utazi leaf	96.87	23.50	57.124	0.0000
Nchuanwu leaf	28.27	6.30	12.908	0.0020
Iron (mg/100 g sample)				
Utazi leaf	5.10	8.15	4.432	0.0110
Nchuanwu leaf	9.87	4.61	52.169	0.0000
Copper (mg/100 g sample)				
Utazi leaf	2.64	0.10	6.644	0.0030
Nchuanwu leaf	6.31	0.11	13.211	0.0000
Calcium(mg/100 g sample)				
Utazi leaf	41.92	20.85	13.610	0.0000
Nchuanwu leaf	33.83	16.94	38.249	0.0000
Zinc(mg)				
Utazi leaf	0.05	ND	-	-
Nchuanwu leaf	ND	ND		

ND = Not Detected. *mg/100 g for both fresh sample and dry sample.

Table 3. Sensory evaluation of the cooked soups*.

Taste	Treatment 1** (mean±SD)	Treatment 2*** (mean±SD)	Control (mean±SD)
Utazi leaf	5.13±2.391	6.25±2.176	6.50±1.461
Nchuanwu leaf	6.13±1.668	6.81±1.377	6.44±2.308
Texture			
Utazi	4.25±2.082	4.63±2.277	5.63±1.147
Nchuanwu leaf	5.31±1.991	6.38±1.708	6.50±1.673
Flavour			
Utazi leaf	4.94±1.806	5.25±2.176	5.69±1.401
Nchuanwu leaf	5.94±2.081	6.31±1.352	6.38±1.784
Colour			
Utazi leaf	4.50±1.897	5.19±2.562	5.63±1.708
Nchuanwu leaf	6.25±1.693	5.75±2.145	6.50±1.713
General acceptability			
Utazi leaf	4.81±2.536	5.06±2.670	6.13±2.029
Nchuanwu leaf	5.88±2.062	6.31±1.580	7.25±1.291

* These vegetable samples are used for soup preparation;** Statistical treatment for fresh sample
*** Statistical treatment for dry sample.

DISCUSSION

From the free moisture time graphs it is evident that there appeared to be multiple falling rate periods for each sample. However, the first rate period lasted for less than five hours in both drying techniques, an indication that the original assumption of one rate period is quite justifiable (Anyanwu and Okonkwo, 2008; Dissa et al., 2011). The above information is critical to peasant farmers and industrial applications because specified levels of moisture content could be linked with a specified time in the process equation.

CONCLUSION AND RECOMMENDATIONS

The study revealed the quantification of the drying rate constants, K, the drying efficiency and the nutrients and sensory qualities of the vegetable samples dried under the two drying conditions. The free-moisture versus time graphs showed that the drying took place at the falling rate period. Solar dryer was more efficient and has potential to give higher product quality than the open-air sun drying. However, solar dryer would be more costly than the open- air sun drying technique but when quality and safety are considered, the former should be better in the drying of vegetables. Also, the study showed that drying resulted in improved nutrients and sensory qualities of the samples. The process if adopted would ensure steady availability of these vegetables all the year round.

Conflict of Interest

The authors have not declared any conflict of interest.

REFERENCES

AOAC (1995). Association of Analytical Chemists. Official Methods of Analysis, 15th edn. Washington, D.C

Anyanwu CN, Okonkwo WI (2008). Experimental determination of the drying rate of chilly yellow pepper (Capsicum anuum). Nig. J. Solar Energy 19(1):18-24.

Cochran WG, Cox GM (1992). Experimental Designs, 2nd edn. New York: Wiley.

Coulson JM, Richardson JF (1977). Chemical Engineering, vol. 1 3rd Ed, A. Wheaton & Co, Exeter, GB.

Dissa AO, Desmorieux H, Bathiebo J, Koulidiati J (2011). A comparative study of direct and indirect solar drying of mango. Global J. Pure Appl. Sci. 17(3):273-294.

Doymaz I (2004). Drying kinetics of white mulberry. J. Food Eng. 74:341-346. http://dx.doi.org/10.1016/S0260-8774(03)00138-9

Ekechukwu OV (1989). Performances of a large integral type passive solar energy dryer for rural application. Natl. Centre Energy Res. Dev. J. 1:173-176.

Eze JI, Chibuzor EE (2008). Evaluation of the drying efficiency of solar cabinet dryer using okra and tomato. Nig. J. Solar Energy 19(1):25-33.

Karathanos VT, Belessiotis VG (1997). Sun and artificial air drying kinetics of some agricultural products. J. Food Eng. 31: 35- 46. http://dx.doi.org/10.1016/S0260-8774(96)00050-7

Lashsasni S, Kouhila M, Mahrouz M, Jaouhari JT(2004). Drying kinetics of prickly pear fruit (Opuntia ficus indica). J. Food Eng. 61(2):173-179. http://dx.doi.org/10.1016/S0260-8774(03)00084-0

Mwithiga G, Olwal JO (2005). The drying kinetics of kale (Brassica oleracea) in a convective hot air dryer. J. Food Eng. 71:373-378. http://dx.doi.org/10.1016/j.jfoodeng.2004.10.041

Onoja US, Iroegbu JC, Eze JI (2012). A comparative study of the drying rate constant, drying efficiency, nutrients and sensory qualities of dried vegetables using solar dryer and open-air sun drying methods. Global J. Pure Appl. Sci. 18(3-4):125-133.

Oparaku NF (2008). Development and performance evaluation of medium-scale solar fish dryer. Nig. J. Solar Energy 19-1:34-39.

Sacilic K, Elicin AK, Unal G (2006). Drying kinetics of Uryani plum in a convective hot air dryer. J. Food Eng. 76:362-388. http://dx.doi.org/10.1016/j.jfoodeng.2005.05.031

Scanlin D, Renner M, Domermuth D, Moody H (1997). The design, construction and use of an indirect through-pass solar food dryer. Home Power 57:62-72.

Tongrul IT, Pehlivan D (2004). Modeling of thin layer drying kinetics of some fruits uder open-air sun drying process. J. Food Eng. 65(3):413-425. http://dx.doi.org/10.1016/j.jfoodeng.2004.02.001

Uretir G, Ozilgen M, Katnas S (1996). Effects of velocity and temperature of air on the drying rate constant of apple cubes. J. Food Eng. 30:339-350. http://dx.doi.org/10.1016/S0260-8774(96)00056-8

Whitefield D (2002). Solar Dryer Systems and the internet: Important Resources to Improve Food Preparation. Conference Paper, International Conference on Solar Cooking, Kimberley, South Africa.

Yaldiz O, Ertekyn C (2001). Thin layer solar drying of some different vegetables. Drying Technol. 19(3&4):583-597. http://dx.doi.org/10.1081/DRT-100103936