International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 4 Issue 6, September-October 2020 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Influence of Blanching on the Drying Characteristics of Convective Hot Air Dried Aerial Yam

Nwadike, E. C[1]; Nwabanne, J. T[2]; Azaka O. A[1]; Abonyi, S. E[1]

[1]Department of Mechanical Engineering, Nnamdi Azikiwe University, Awka, Nigeria
[2]Department of Chemical Engineering, Nnamdi Azikiwe University, Awka, Nigeria

ABSTRACT

A research on the drying characteristics of aerial yam using convectional hot air was done. The raw unblanched and blanched samples were dried using convectional hot air. Fan speed, temperature and slice thickness were varied to determine the change in moisture content. The Fourier transform infrared (FTIR) and scanning electron microscopy (SEM) were done to determine the functional groups and surface morphology respectively for each sample. FTIR results revealed the presence of some important functional groups such as esters, ethers and nitro-compounds, and shows that drying at this temperature (40-70oC) does not alter the nutrient components of this variety of yam. The SEM results showed that important cells were not destroyed at the drying temperature. Batch studies on the drying process also showed that increase in temperature and air speed increased the drying process, but decreases with increase in slice thickness. Effect of drying rate on the sample showed that drying rate increase with increase in temperature and air speed but decrease with increase in slice thickness. After 90 minutes of drying, the drying rate of the 2 mm slice thickness was 0.353 g/g.min for drying of aerial yam while for 4 mm and 6 mm slice thickness, the drying rate were 0.261 and 0.169 g/g.min respectively, for effect of drying rate on sample thickness. It showed also that blanched aerial yam samples had a higher drying rate than the unblanched aerial yam sample at the same conditions. Therefore, the economic advantages of this yam species can be optimized by blanching.

***KEYWORDS:** Un-blanched, blanched, Hot air, aerial yam*

How to cite this paper: Nwadike, E. C | Nwabanne, J. T | Azaka O. A | Abonyi, S. E "Influence of Blanching on the Drying Characteristics of Convective Hot Air Dried Aerial Yam" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-4 | Issue-6, October 2020, pp.1146-1154, URL: www.ijtsrd.com/papers/ijtsrd33577.pdf

IJTSRD33577

Copyright © 2020 by author(s) and International Journal of Trend in Scientific Research and Development Journal. This is an Open Access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0) (http://creativecommons.org/licenses/by/4.0)

Research and Development
ISSN: 2456-6470

1. INTRODUCTION

Nutrition is a critical and essential aspect of quality of human life. Among the three basic needs of man, food is regarded as the most important of them. Most food crops are harvested only during a certain period of the year, there is, on the one hand, a temporary surplus during harvest and thereafter a shortage. Postharvest spoilage is still very common, ranging from 20% [1], 50% [2] to 60% [3], depending on the type or nature of the produ3ct and storage time.

Drying play an important role in preservation of agricultural products from common food spoilers. Drying of agricultural products has been of great importance for the preservation of food. According to Dincer and Sahin, [4], Soysal, [5], drying is an energy intensive process and involves removal of moisture from a crop until it's moisture content is in equilibrium with the surrounding air. Drying is a process comprising simultaneous heat and mass transfer within the materials and between the surface of the material and the surrounding media [6]. Drying is one of the most common techniques used to reduce microbiological activity and to improve the stability of moist material by decreasing their moisture content to a certain constant level. The main goal of drying agro-products is to reduce the moisture content to a level that halts or controls microbial growth and to reduce deteriorative chemical reaction in order to extend the shelf life of food. Furthermore, by reducing the amount of water, drying reduces the losses encountered in crops, improves the quality of dried products and facilitates its transportation, handling, and storage requirements.

Aerial yam (*Dioscoreabulbifera*) is also known as air potatoes. It is a member of the yam species often considered as a wild species of yam native to Africa and Asia. Aerial yam is a member of the Dioscoreaceae family which consist of several varieties found in Africa and South Asia [7]. Nigeria is a major producer of yam, but Ghana is leading in production of aerial yam [8]. Aerial yam is among one of the most underutilized food crops in Nigeria and other parts of the world where it grows and appears in both the wild and edible forms. It has a long vine and it produces tubers (bulbis) which grow at the base of its leaves. This species of yam is not popular among farmers or consumers and does not enjoy the patronage that some of the other edible yam species enjoy. Despite its underutilization, aerial yam has been shown to possess a myriad of compounds that are said to have several health benefits [9].

The discoloration of yam upon peeling is a major limitation. This reduces the consumer's acceptability of the products by developing off-flavors and off-colors. According to Sanful,[10], for most yam species, the most common cause of discoloration is enzymatic browning which results mainly from the action of polyphenol oxidase and peroxidase. Beside chemical treatment which involves anti-browning agents, there are some methods that are employed traditionally to inhibit enzymatic browning. Thermal treatment such as blanching has been considered as a means of controlling enzymatic browning in a variety of food produce [11]. This type of browning can be prevented by blanching; putting the product in hot water for a short period of time to deactivate the enzyme. Blanching is a common practice before drying of yam [12]. In this study, the aerial yam (Dioscoreabublifera) undergo this thermal treatment before drying process to improve product quality, increase yield, preserve colour, remove trapped air and also reduce microbial contamination. Blanching can have deleterious effects at high temperature and extended time of treatment resulting in reduced nutritional value from leaching nutrients, thermal degradation or alteration of starch profile and properties.

Processing aerial yam to flour, can help to reduce the over dependent on other flour such as wheat flour for our baked products and post – harvest losses. Therefore, there is a need to study the drying characteristics of this aerial yam with a view to obtaining information which will help in the design of dryers suitable for commercial production of aerial yam flour.

2. Materials and methods-

2.1. Collection and preparation of aerial yam and water yam sample

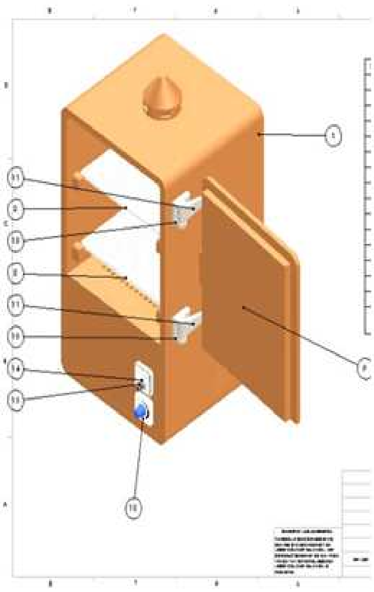
The aerial yam sample was collected from Afor Opi market in Nsukka local government area of Enugu state. It was identified in the crop science department of NnamdiAzikiwe University, Awka. The yam was washed with clean water and spread in open air to avoid spoilage.

2.2. Convectional hot-air drying

The convectional hot air dryer (Fig 1) is made up of an oven-like body consisting of blower (for air circulation), heating element (for heat supply), airspeed regulator, thermocouple, temperature control knob and trays. Hot air is forced through the material with the help of fan or blower and which aid the moisture diffusion process that result in the drying. This experiment was carried out at the Chemical Engineering laboratory, NnamdiAzikiwe University Awka. The method employed in convectional hot air drying was according to Daniel et al., [13]. The un-blanchedaerial yam was dried with convectional hot-air dryer (Fig. 3.1) at the following conditions: temperature (40, 50, 60 and 70^oC), air speed (2.0, 2.5, 3.0, 3.5 and 4.0 m/s) and sample thickness (2.0, 4.0 and 6.0mm). 2.0 mm of the samples was cut and 100g each of the samples weighed with electronic weighing scale (Model TDUB-63V09, from Netzgerat) into the dryer tray. The temperature and air speed of the dryer were set at 40^oC and 2.0 m/s, respectively. The losses in weight of the samples was taken at an interval of 5, 10, 20, 30, 60, 90…. mins., until there was no significant change in the weight of the sample. The experiments were repeated for various temperatures while keeping air speed and thickness constant and thereafter repeated for various air speeds with temperature and slice thickness kept constant. Also, the thicknesses of the sample were varied with temperature and air speed kept constant. The moisture contents of the sample at time t, was calculated using equation (1).

$$MC = \frac{M_1 - M_2}{M_1} \times 100 \qquad (1)$$

Where; MC is the moisture content of the sample after drying, M_1 is the initial mass before drying and M_2 is the mass after oven drying. The whole procedures were repeated for water yam



ITEM NO	PART NAME	QTY
1	Chamber	1
2	Sampling Trays	2
3	Base Damper	1
4	Blower Housing	1
5	Blower shaft	1
6	Fan Blade	1
7	Heater stand	2
8	Heating Coil	1
9	Chamber door	1
10	Hinge	2
11	Hinge 2	2
12	Switch Hub	1
13	Switch Knob	1
14	Temperature Gauge	1
15	Temperature Knob	1
16	Temperature Gauge Timer	1

Fig 1: A Schematic diagram of convectional hot air dryer used

2.3. Blanching of the Samples

This experiment was carried out at the Chemical Engineering laboratory, NnamdiAzikiwe University Awka. The aerial yam was dried with convectional hot-air dryer (Fig. 3.1) at the following conditions: temperature (40, 50, 60 and 70^oC), air speed (2.0, 2.5, 3.0, 3.5 and 4.0 m/s) and sample thickness (2.0, 4.0 and 6.0mm). In blanching, 2.0 mm of the sample was cut and 100g of the sample weighed into a bowel containing boiled water at 80^oC. The sample was left in the hot water for 10 minutes. The water was removed and the new weight of the sample taken. The sample was put in the dryer (convectional and solar) and allowed to dry to constant weight with the weight taken at interval as done with un-blanched samples. The whole procedure was repeated for the other thickness, airspeed and temperature of dryer.

2.4. Instrumentation characterization
The functional groups present in the sample was determined using a Fourier transform infra-red (FTIR) machine, Cary 630 model from Agilent Technologies, USA. The surface morphology of the sample was analyzed by scanning electron microscopy (SEM) machine, ProX model from Phenom World, Eindhoven Netherlands.

3. Results and discussion
3.1. Fourier Transform Infra-Red Spectroscopy
Figure 2 shows FTIR spectrum of raw aerial yam. The absorption bands in the 3500-2500 cm^{-1} is due to O-H stretching of carboxylic acids group; in the region of 2140-2100 $cm^{-1}$is due to C≡C stretching of alkynes group; in the region of 1655-1590 cm^{-1} is due to N-H bending of amides group while in the region of 1050-1035 cm^{-1} is due to C-O stretching of alcohols group. However, Figure 3 shows FTIR spectrum of aerial yam dried at 50^{o}C. The absorption bands in the 3500-2500 cm^{-1} is due to O-H stretch of carboxylic acids group; alkanes and alkyls occurred in the 3000-2850 cm^{-1} region of C-H stretching; amides occurred in the 1655-1590 cm^{-1} region of N-H bending; alkyl halides occurred in the 1350-1000 cm^{-1} and 850-750 cm^{-1} regions of C-F and C-Cl stretching; arenes occurred in the 885-860 cm^{-1} region; alcohols occurred in the 1260-1035 cm^{-1} region of C-O stretching while alkenes occurred in the 990-910 cm^{-1} region of =C-H bending. Fig. 4.6 showed that some functional groups became more visible in the dried sample. It showed that alkanes, alkyl, alkyl halide and alkenes were all very visible after drying. This added compounds where more likely been masked by high moisture content in raw aerial yam (Fig. 2).It shows that drying at this temperature does not alter the nutrient components of this variety of yam which is one of the goals of food preservations and processing.

yam which is one of the goals of food preservations and processing.

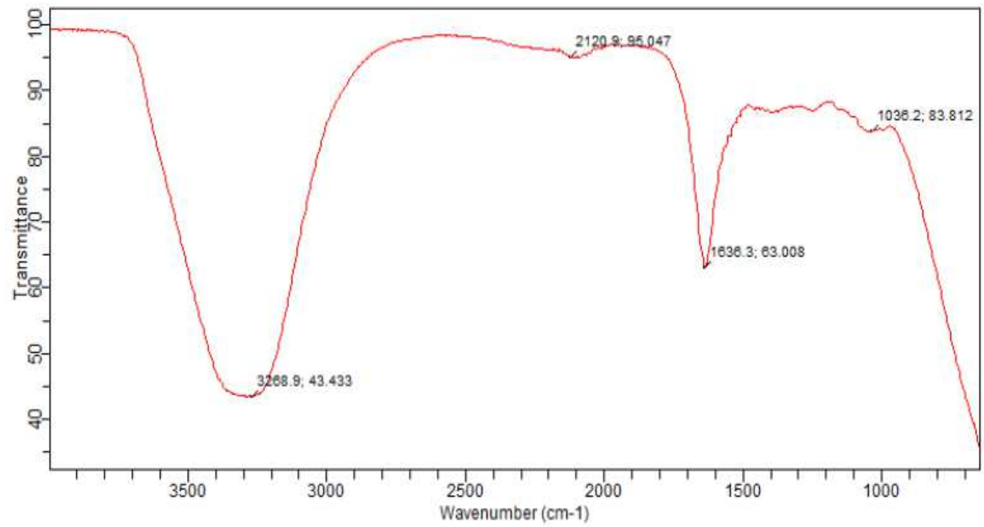


Figure 2: FTIR spectrum of raw aerial yam

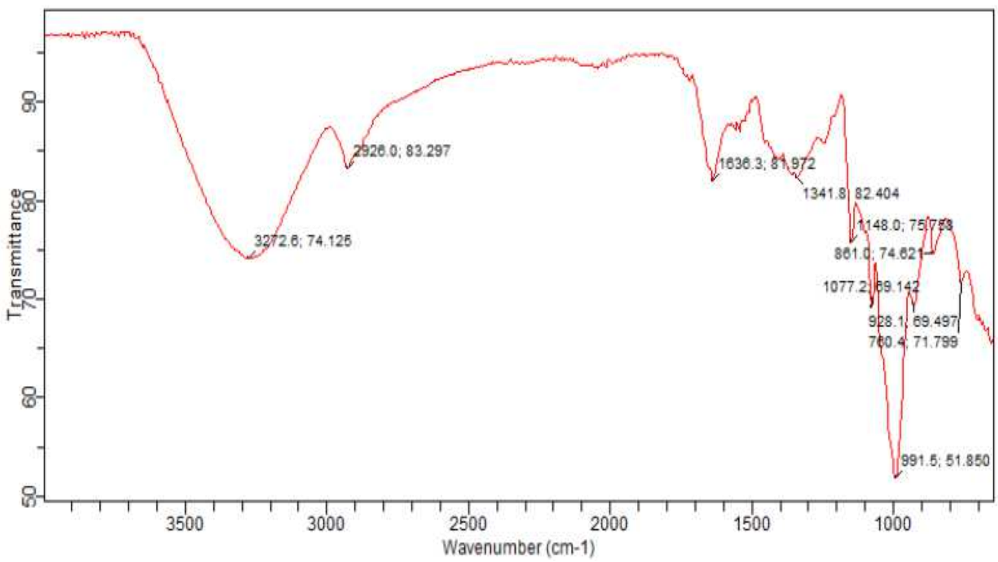


Figure 3: FTIR spectrum of dried aerial yam

3.2. Scanning electron microscopy of the aerial yam sample.
Figure 4 shows the SEM micrograph of raw aerial yam sample. It shows well arranged microtubule, parenchyma and sclerenchyma in its micro structure. Figure 5, shows that the tuber was highly degraded leaving the cells with just sheets of parenchyma and sclerenchyma cells. Fiber was seen evidently remaining after the drying process was completed, the micro tubules were seen disintegrated and fallen apart by the effect of drying, and relapse of cells were clearly seen, these could be as

a result of intensive heat or a chemical reaction as a result of heating. The major role of the micro tubules was for water and electron transport. However, excessive heat leads to the denaturing and fallen apart of these cells as clearly seen in Figure 5.

The Phloem and the xylem, comprise the major part of Anatomy in tuberous plant, with little patches of plasmodesma which explains why tuberous plant contains a lot of fluid in them. These core part of the anatomy of this plant plays a vital role in electron and water transport when tuberous plant like yam are heated or dried, this cell denature and exposes the sieve tubes with sheets of parenchyma and sclerenchyma cells exposed to the surface of the stem. The SEM image of this sample from Fig. 5 shows that the dominant ruminant after exposure to heat is the sieve elements, the definitive callus disintegrates and this account for weight and water loss of about 50% of the initial weight before processing. The fiber which is always ever present remain in small quantity, thermal degradation have little action on the fiber content in yam.

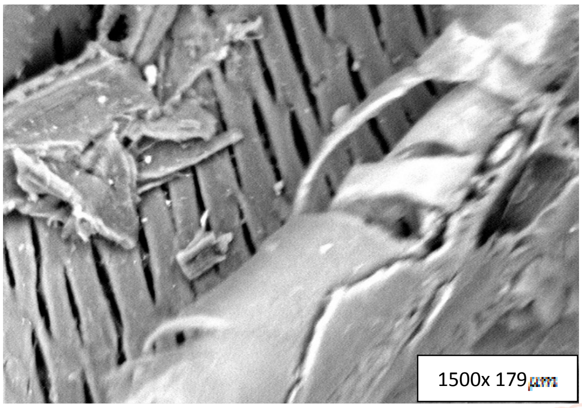


Fig. 4: SEM image of raw aerial yam

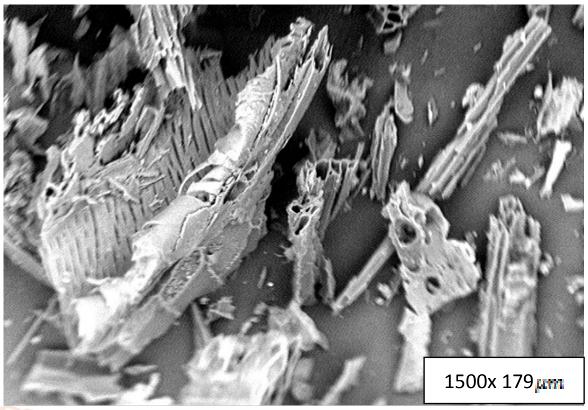


Fig. 5: SEM image of dried aerial yam

3.3. Effect of slice thickness on moisture content

Slice thickness is one of the main factors affecting the drying characteristics of food materials. The variation of the slice thickness with the moisture content was evaluated by drying different slice thickness of the yam samples as shown in Figs. 6 and 7for unblanched and blanched aerial yam respectively at constant air speed (2.5 m/s). The slice thicknesses used were 2.0mm, 4.0mm and 6.0mm. The rate of moisture content decrease was found to be dependent on the thickness of the sample. This is because, after the same time interval, the moisture content of the 2.0mm samples was found to be much smaller than the moisture content of 4.0mm and the 6.0mm samples. Hence, the rate of moisture content removal decreased as the slice thickness increased. This is because, at low slice thicknesses, the free moisture can be easily removed from the surface. The thicker the slice, the slower the approach to equilibrium moisture content and the slower the drying rate [14].

Mohammad et al, [15] reported that at fixed temperature, the drying time of a product increases as the product becomes thicker mainly because the moisture dissipation inside the product and finally its departure from the product would face more resistance, hence prolonging the drying time. Aremu et al, [16] when investigating the effect of slice thickness on drying kinetics of mango reported that the drying time increased as the slice thickness increase. This is in agreement with the findings of Etoamaihe and Ibeawuchi [14] in drying different slices of cassava.

It was found out that the effect of the blanching was profound as seen in Fig. 7. The blanched sample (Fig. 7) took a shorter time to dry than the unbleached sample (Fig. 6). This could be as a result of some structural changes resulting from blanching. Blanching tends to alter the structural arrangement of the materials by weakening some bonds which bind free water so that the rate of moisture loss in blanched samples becomes higher than that of un-blanched samples at the same conditions. Though blanching caused the initial moisture content of the yam sample to increase, yet it took 270 minutes to reach equilibrium while it took 300 minutes for the un-blanched sample to reach equilibrium at the same condition (2.0 mm, 50^{o}C and 2.5 m/s). The moisture content was seen to decrease with time as expected because drying removes the water molecules in the food samples [17]. With the 2mm thick slices of blanched sample, drying of yam samples attained equilibrium moisture content at 270 minutes while for the 4mm thick slice, a time of 390 minutes was needed to attain equilibrium moisture content. When a bigger slice thickness of 6mm was used, it took a time of about 510 minutes to achieve equilibrium moisture content.

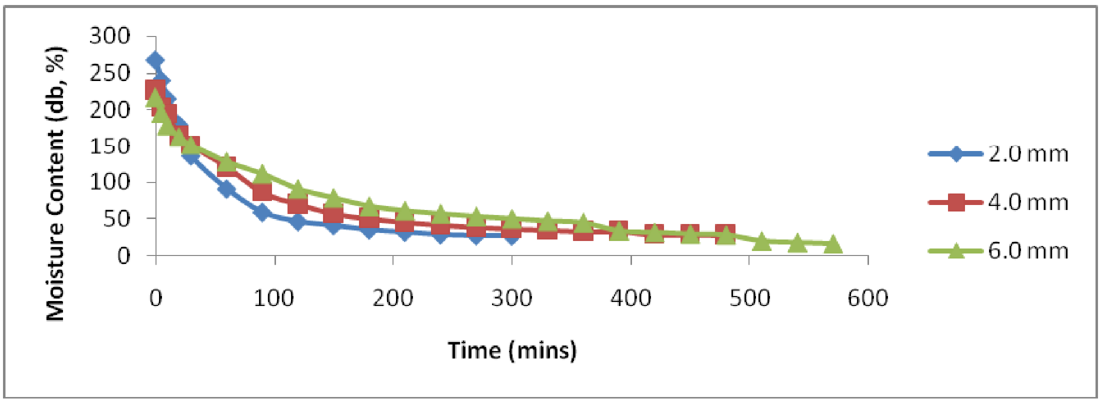


Figure 6: Effect of slice thickness on moisture content for drying of unblanchedaerial yam.

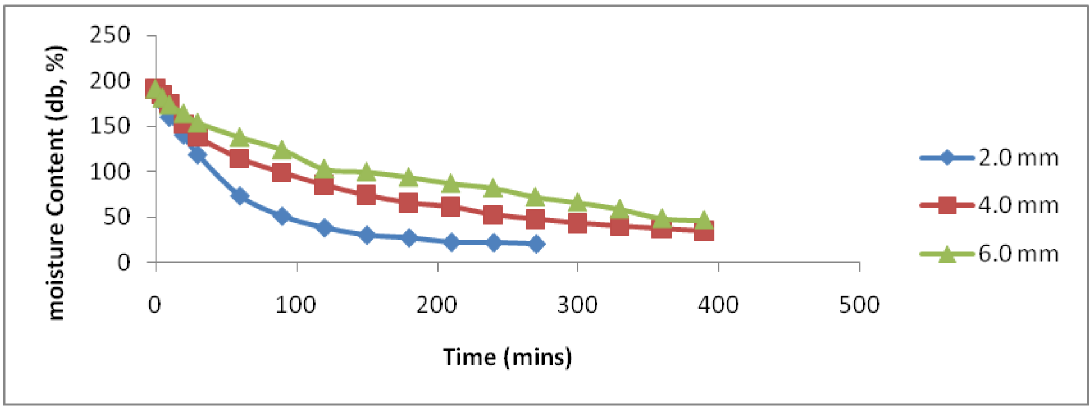


Figure 7: Effect of slice thickness on moisture content for drying of blanchedaerial yam.

3.4. Effect of Drying Air Speed on Moisture Content

Different air speeds were used to study the effect of air speed on the drying characteristics of the yam sample as given in Figs. 8 and 9 for un-blanched and blanched aerial yam respectively, at constant slice thickness (2.0mm). The air speeds used were 2.0, 2.5, 3.0, 3.5 and 4.0 m/s. A decrease in the drying time and increase in the drying rate of the yam samples was observed as the air speed was increased. This is because one of the requirements for drying is that the air must be moving. When the hot dry air absorbs water from the surface of the drying product, it needs to be quickly moved on so that another set of air can repeat the process. The faster this process, the higher the drying rate will be. Hence, it is seen that the drying time is decreased as the air speed increased.

With an air speed of 2m/ in convectional dryers, a drying time of 300 minutes was required in other to attain equilibrium moisture content while for drying with an air speed of 3m/s, a drying time of 270 minutes was required. When the air speed was increased to 4 m/s, a lower drying time of 240 minutes was required to achieve equilibrium moisture content.
There was a significant difference in the time to attain equilibrium moisture content for both the blanched and unbalanced yam samples. The blanched yam samples (Fig. 8) have higher initial moisture content hence, it dried much faster than the unbalanced yam samples (Fig. 9). In thin layer drying model, the rate of change in the moisture content of materials in the falling rate drying period is proportional to the instantaneous difference between material moisture content and the expected moisture content when it comes into equilibrium with the drying air [15]. The combination of higher temperature, movement of the air and lower humidity in a solar dryer increases the rate of drying. The moisture content decreases continuously with drying time [18].

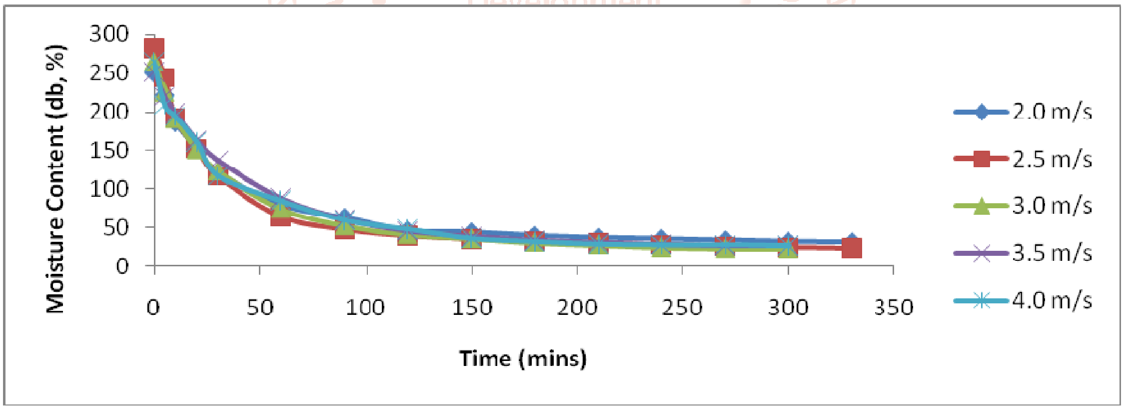


Fig. 8: Effect of drying air speed on moisture content of unblanched aerial yam.

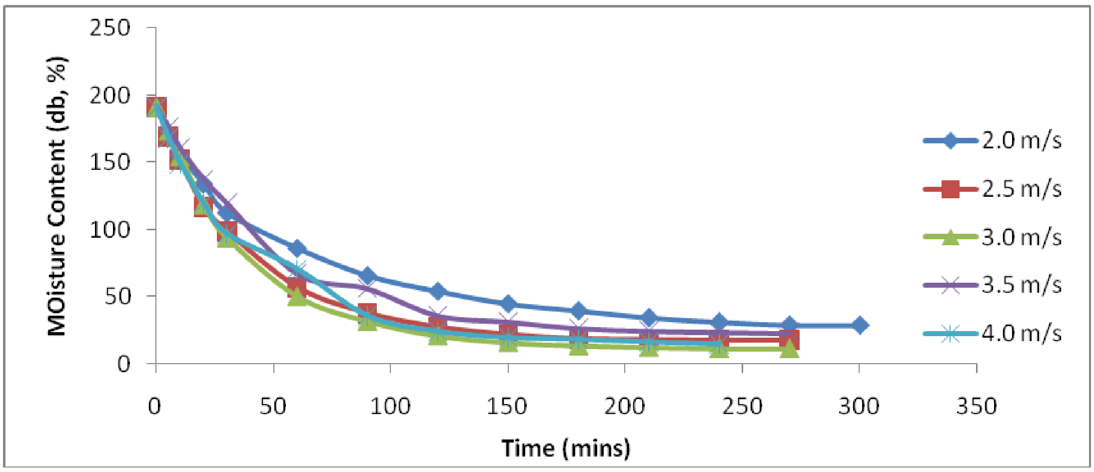


Fig. 9: Effect of drying air speed on moisture content of blanched aerial yam.

3.5. Effect of Temperature on Moisture Content

The effect of changes in the drying temperature of the convective dryer on the moisture content was investigated using different temperature at constant slice thickness of 2mm and constant air speed of 2.5 m/s and the results are presented in Figs. 10 and 11. The temperatures used were 40, 50, 60 and 70 °C. These ranges of temperatures were used because using a very high temperature may cause the food item to be hardened on the surface [19].

The effect of the blanching was significant in the effect of temperature because the plots indicated that the blanched yam samples dried faster than the unbalanced yam samples.

The results showed that as the temperature increased, the drying time to attain equilibrium moisture content was decreased. Using drying temperature of 40 °C (Fig. 10), a drying time of 420 minutes was required to reach equilibrium moisture content while a temperature of 50 °C gave a drying time of 300 minutes. When a temperature of 70°C is used a drying time of just 210 minutes was needed to achieve equilibrium moisture content.

This is due to the fact that as the temperature increased, the average kinetic energy of the moisture increases making it easier for the moisture to diffuse out of the products. It was seen that drying at higher temperature affected the drying time as would have been expected.

Wankhade et al [18] and Saeed et al [20] reported that air temperature had a significant effect on the moisture content of samples. Increasing the temperature brings about a decrease in drying time because both the thermal gradient inside the object and the evaporation rate of the product increase [15].

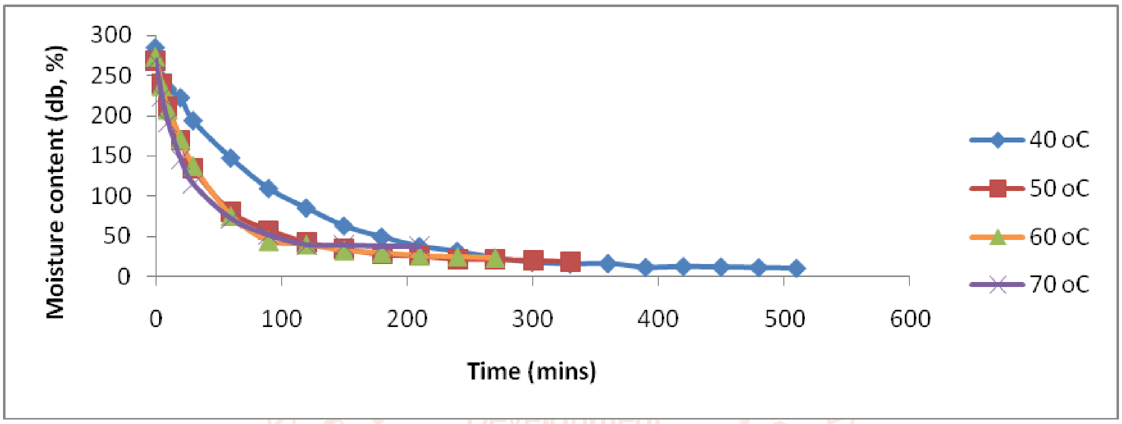


Fig. 8: Effect of Temperature on moisture content unblanchedaerial yam.

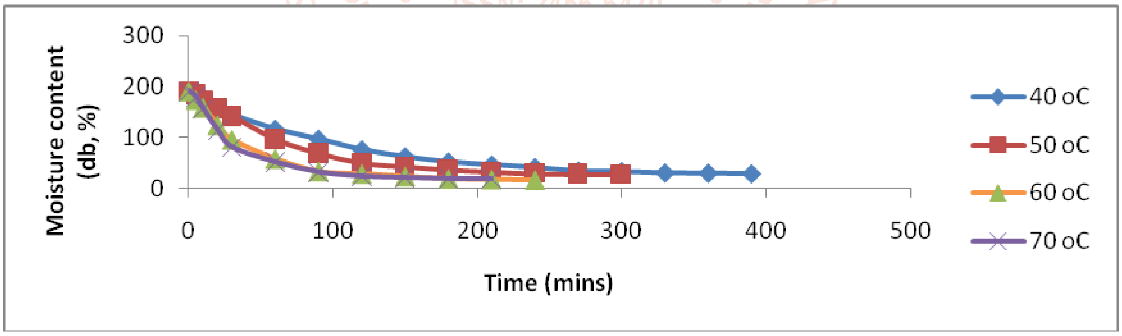


Fig. 8: Effect of Temperature on moisture content blanched aerial yam.

3.6. Drying rate

3.6.1. Effect of drying rate on slice thickness

The main factor that controls the drying rate is the rate at which moisture can move from the interior of a piece of food to the surface. Therefore the shorter the distance that moisture has to travel, the faster the drying rate will be. Different slice thickness of 2mm, 4mm and 6mm were used to investigate the effect of slice thickness on the drying rate of the aerial as shown in Figs. 12 and 13 for un-blanched and blanched sample at constant airs speed and temperature of 2.5 m/s and 50 °C, respectively.

The drying rate gradually decreased as the slice thickness increased. After 90 minutes of drying, the drying rate of the 2 mm slice thickness was 0.353 g/g.min for drying of aerial yam while for 4 mm and 6 mm slice thickness, the drying rate were 0.261 and 0.169 g/g.min.

The drying rate was less for the un-blanched yam samples (Fig. 13). Reducing the slice thickness increases the surface area of the food in relation to the volume of the pieces which increases the rate at which water can be evaporated from the food. During the initial period, drying rate is high. This is due to the fact that the energy required to evaporate the surface moisture is low [21]. With moisture content, the drying rate decreases as the moisture content decrease. This is probably because the amount of moisture removed depends on the quantity of moisture in the product.

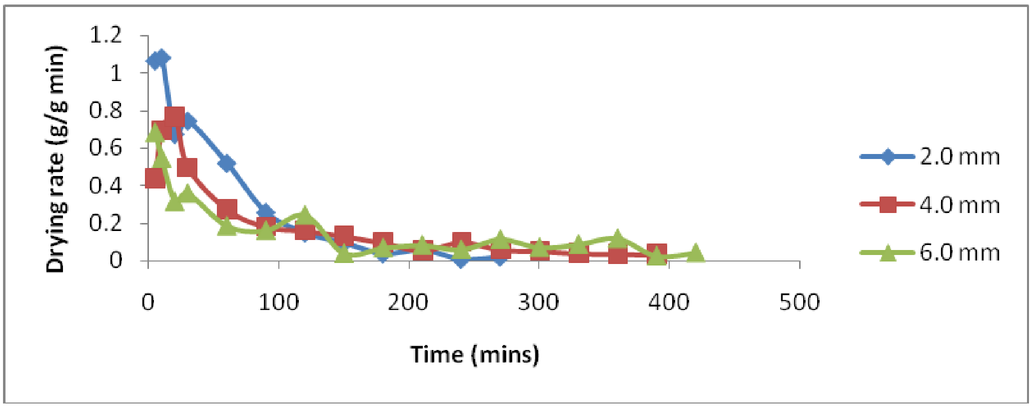


Fig. 12: Plot of drying rate against time at different slice thicknesses of unblanchedaerial yam.

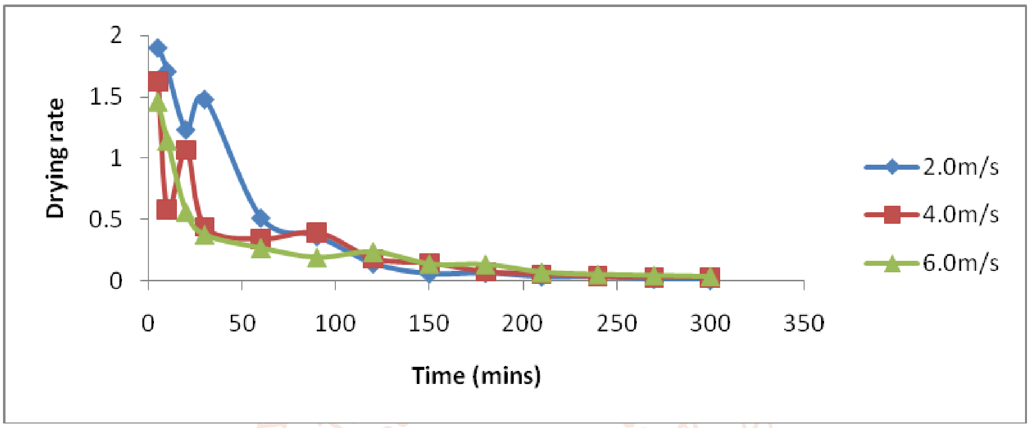


Fig. 13: Plot of drying rate against time at different slice thicknesses of blanched aerial yam.

3.6.2. Effect of Drying Air Speed on the Drying Rate

Various air speeds of 2.5m/s, 3.0m/s, 3.5m/s and 4.0m/s at constant thickness were used to study the effects of drying sir speed on the drying rate as given in Figs 14 and 15 for un-blanched and blanched aerial yam. It was seen that increase in air speed leads to a relative increase in the drying rate at the initial time of drying before decreasing for both balanced and unbalanced yam samples. Mirzaee et al [22] reported a similar trend. It is apparent that the drying rate is higher at the beginning of the drying process and decreases continuously with the drying time. Mirazaee et al, [22] reported the same trend. According to Wankhade et al [18], the drying rate goes on decreasing with decrease in moisture content. The rate of drying also has an important effect on the quality of dried food products.

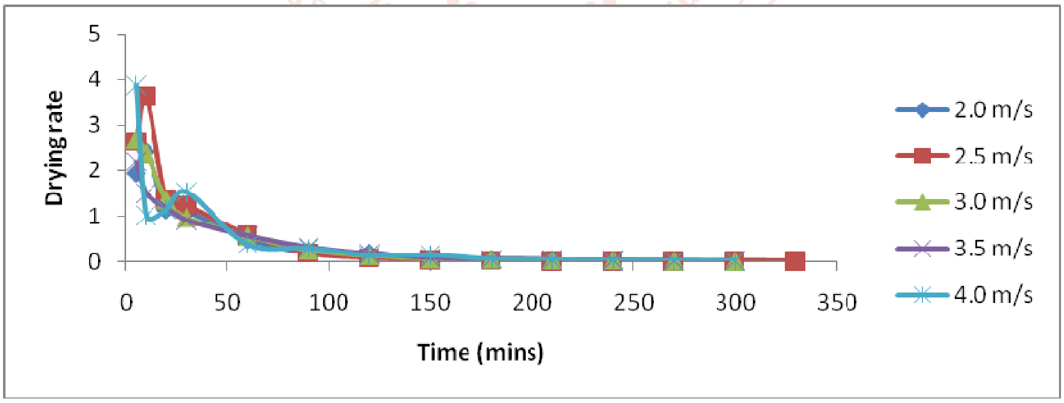


Fig. 14: Plot of drying rate of unblanched aerial yam against time at different air speeds

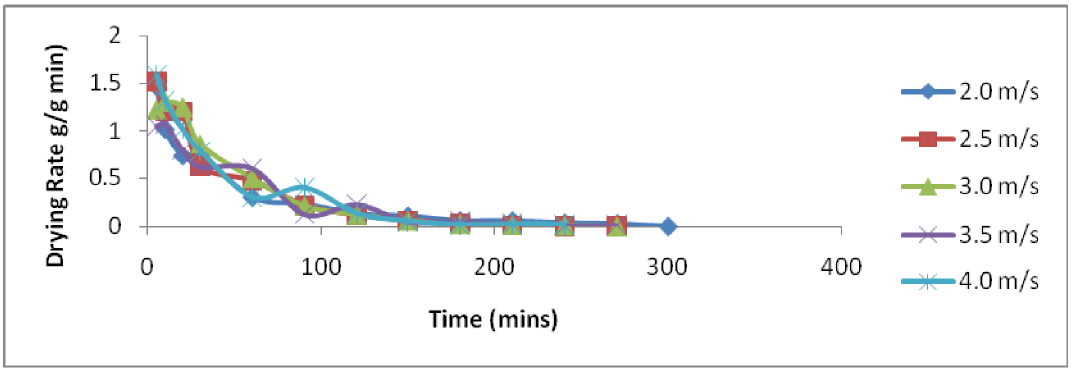


Fig. 15: Plot of drying rate of blanched aerial yam against time at different air speeds

3.6.3. Effect of Temperature on Drying Rate

Temperature is one of the factors that affect the drying rate. Various temperatures of 40, 50, 60 and 70 °C were used to investigate the effect of temperature on the drying rate for convectional dryer at constant airspeed and slice thickness of 2.5 m/s and 2.0 mm, respectively. The effects of temperature on the drying rate were given in Figs. 16 and 17 for un-blanched and blanched aerial yam samples. It is seen that increase in temperature increases the rate of drying. This is attributed to increased evaporation of water both on the surface and in the products due to the increased temperature [23]. As the drying process continues, less free water on the surface of the product is available and hence, the drying rate starts to decrease for both the blanched and un-blanched yam samples. The high drying rate at high drying temperature could be due to more heat energy which speeds up the movement of water molecules and results in higher moisture diffusivity within the yam samples [23]. The curve of the drying rate did not give a perfect curve probably because of the nature of the drying products and the diffusion mechanism inside the products as the drying progresses. Divine et al [24] obtained similar drying rate curve against temperature.

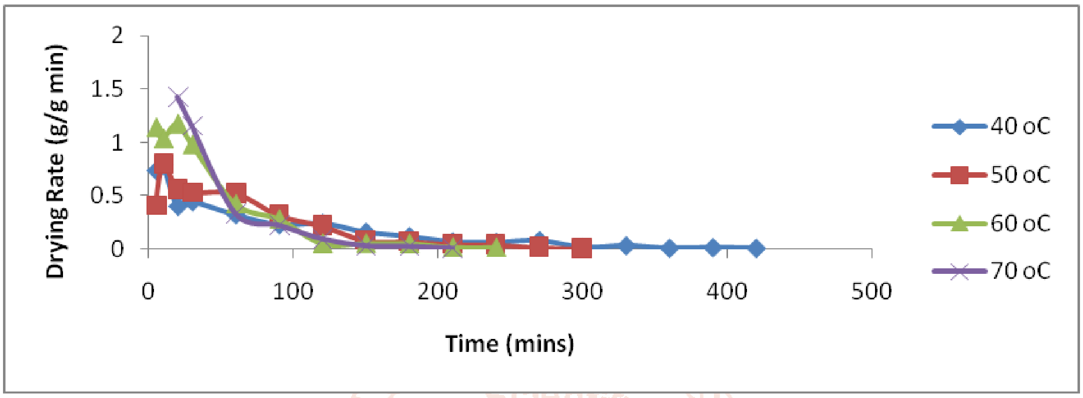


Fig. 16: Effect of temperature on drying rate of unblanchedaerial yam

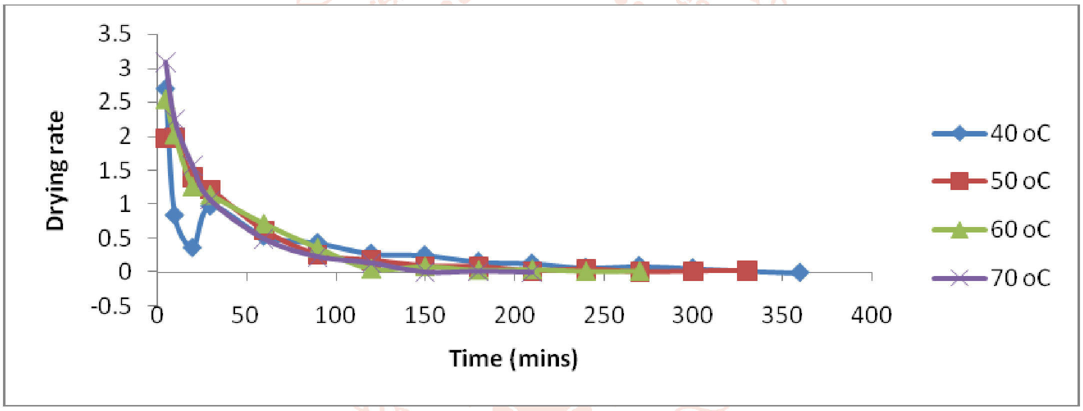


Fig. 17: Effect of temperature on drying rate of blanched aerial yam

4. Conclusion

The FTIR and SEM results showed that that drying at the various temperature did not alter the important functional groups or nutrient components of this variety of yams which is one of the goals of food preservations and processing. It also showed that increase in temperature and air speed increase the drying rate but increase in slice thickness of the sample decrease the drying rate. The result also revealed that blanching increase the rate of moisture content removal from aerial yam.

Reference

[1] Aidoo, K. (1993). Post-harvest storage and preservation of tropical crops. *International Biodeterioration& Biodegradation* 32(1-3): 161-173. DOI: 10.1016/0964-8305(93)90048-7.

[2] Okigbo, R. N., (2004). A review of biological control methods for postharvest yams (Dioscorea spp.) in storage in South Eastern Nigeria. *KMITL SciTechnol Journal*, 4(1): 207-215.

[3] Dramani, Y. (2013). Effect of postharvest waxing treatments, yam variety and tuber size on shelf life of white yam (DioscorearotundataPoir). Thesis (MPHIL)-University of Ghana. 1-93.

[4] Dincer, I., &Sahin, A. Z. (2004). A new model for thermodynamic analysis of a drying process, International journal of Heat Mass Transfer., 47: 645-52, 2004.

[5] Soyal, Y. (2004). Microwave Drying Characteristics of Parsley. *Bio systems Engineering*, 89(2): 167-173.

[6] Adewale, O., Omolola, A. I., Jideani, O., &Kapila, K. F. (2015).Drying kinetics of banana (Musaspp.). *AsociaciónInterciencia Caracas, Venezuela* VOL. 40 (6). 374-380.

[7] Kayode, R. M. O., Buhari, O. J., Otutu, L. O., Ajibola, T. B., Oyeyinka, S. A., Opaleke, D. O. & Akeem, S. A. (2017). Physicochemical Properties of Processed Aerial Yam (Dioscoreabulbifera) and Sensory Properties of Paste (Amala) Prepared with Cassava Flour. *The Journal of Agricultural Sciences*, Vol. 12(2), Pp 84-94.

[8] Nwadike, E. C., Enibe, S. O., &Nwabanne, J. T. (2018). Determination of the Engineering Properties of Aerial

Yam and Water Yam, *International Journal of Advances in Scientific Research and Engineering (ijasre)*. 4(11), 297-306.

[9] Sanful, R. E., Addo A, Oduro, I., & Ellis, W.O. (2015). Air Drying Characteristics of Aerial Yam (*Dioscoreabulbifera*). *Scholars Journal of Engineering and Technology (SJET)*, 3(8): 693-700.

[10] Sanfu, R. E. (2016). Effect of Blanching on the Proximate and Sensory Qualities of the Aerial Yam Composite Cookies. *Caribbean Journal of Science and Technology*. Vol.4, 963-968

[11] Kouassi, N. K., Nindjin, C; Tetchi, A. F & Amani, G. N. (2010). Evaluation of type of process and on nutritional and anti-nutritional composition of yams (Dioscoreacayanensisrotundata). *Journal of Food Tech*., 8: 191-199.

[12] Akissoe, N., Mestres,C., Hounhouigan, J., &Nago, M. (2005). "Biochemical Origin of Browning during the Processing of Fresh Yam (Dioscorea spp.) into Dried Product." *Journal of Agricultural and Food Chemistry,* 53(7): 2552-2557.

[13] Daniel, M., Prasad, R., Anirban, D., Sawinder, K., & Chayanika, S. (2017). Recent advances in convectional drying of foods. *Journal of Food Technology and Preservation* (2017) Volume 1, Issue 1.

[14] Etoamaihe, U. J. and Ibeawuchi, K. O. (2010) Prediction of the drying rates of cassava slices during oven drying. Journal of Eng and Applies sciences 5(4) 308-311.

[15] Mohammad, Z., Seyed, H. S. and Barat, G. (2013) Kinetic drying and mathematical modeling of Apple slices in dehydration process. Journal of food process and technology. 4, (7): 1-4.

[16] Aremu, A. K., Adedokun, A. J. and Abdulganiy, O. R. (2013) Effects of slice thickness and temperature on the drying kinetics of mango. International journal of research and reviews in applied sciences. 15, (1) : 41-50.

[17] John, S. Roberts, David R. Kidd, Olga. Padilla. Zakour. (2008) Drying kinetics of grape seeds. Journal of food Engineering .89 (2008) 460- 465.

[18] Wankhade, P. K., Sapkal, R. S. and Sapkal, V. S. (2012) Drying Characteristics of Okra Slices using Different Drying Methods by Comparative Evaluation. Proceedings of the World Congress on Engineering and Computer Science San Francisco, US October 24-26, 2012.

[19] Adu, E. A., Bodunde, A. A., Awagu, E. F. and Olayemi F. F. (2012) Design, Construction and Performance Evaluation of a solar Agricultural Drying Tent. International journal of engineering research and technology. 1, (10): 1 – 12.

[20] Saeed, I. E., Sopian, K., &Zainol, A. Z. (2008) Thin-layer drying of RoselleMathematical modeling and drying experiments. Agricultural engineering International: CIGR Journal S 1-22.

[21] Sajith, K. G. &Muraleedharan, C. (2004) Economic Analysis of a Hybrid Photovoltaic/Thermal Solar Dryer for drying Amla. International Journal of Engineering Research and Technology. 3,(8) : 907 – 911.

[22] Mirzaee, E., Rafiee, S., Keyhani, A. and Emam-Djomeh, Z. (2009) Determination of moisture diffusivity and activation and activation energy in drying of apricots. Res. Agr. Eng. 55(3): 114 – 120.

[23] Junling, S., Zhongli, P., Tara, H. M., Delilah, W., Edward, H. and Don, O. (2008). Elsevier – Food Science and Technology. 41, 1962 – 1972

[24] Divine, N. B., Charles, F. A., Dzudie, T., Cesar, I., Clerge, T. and Zephirin, M. (2013). Indirect solar drying kinetics of sheanut (vitellariaparadoxaGaetn) Kernels. Journal of Engineering and Applied science. 8(6) 183-191.