Effect of thickness and pre-treatment on drying kinetics of cocoyam

Babatunde Olayinka Oyefeso[1*], Abdulganiy Olayinka Raji[2]

(1. Lecturer, Department of Agricultural and Environmental Engineering, University of Ibadan, Ibadan - 200284, Nigeria;
2. Professor, Department of Agricultural and Environmental Engineering, University of Ibadan, Ibadan - 200284, Nigeria)

Abstract: Cocoyam (*Xanthosoma sagittifolium*) corms and cormels are among the staple foods in Nigeria. The cormels are processed into cocoyam flour and utilized for various purposes. Drying is an essential unit operation in the conversion of the cormels into cocoyam flour and the knowledge of the effect of drying variables on the drying characteristics of the cormels is necessary for analysis, optimization and control of the drying process. This study therefore, investigated the drying kinetics of cocoyam cormels as influenced by slice thickness and pre-drying treatment. White-fleshed (NXs. 001) and pink-fleshed (NXs. 002) cocoyam cormels were used for this study. Drying kinetics of the pre-treated cormels (blanched by soaking in hot water at 100°C for 5 minutes) and fresh cormel slices of 2, 3 and 4 mm thicknesses were examined at 60°C. Drying of the cocoyam slices was predominantly in the falling rate period which indicated that moisture removal occurred mainly by diffusion. Drying of thin pre-treated slices of cocoyam cormels is recommended to obtain the faster moisture removal and subsequently, a reduction in the drying period.

Keywords: cocoyam cormels, drying process, pre-drying treatment, falling rate period, thin layer drying.

Citation: Oyefeso, B.O., and A.O. Raji. 2020. Effect of thickness and pre-treatment on drying kinetics of cocoyam. Agricultural Engineering International: CIGR Journal, 22 (2):160-166.

1 Introduction

Cocoyam (*Xanthosoma sagittifolium* (L.) Schott) is cultivated for its corms and cormels which form major food items for the populace in the tropics including Nigeria. Cocoyam has tremendous potentials that are yet to be fully tapped into and the Federal of Government of Nigeria created several initiatives towards improving the utilization of the crop by adding value to the corms and cormels. National Root Crop Research Institute (NRCRI), Umudike, was therefore, established in 1976 and Root and Tuber Expansion Programme (RTEP) was launched in 1995 to promote the production and use of root and tuber crops including cocoyam. NRCRI had, among other objectives, the mandate to diversify value-added products obtained from cocoyam corms and cormels to increase the shelf life of cocoyam products and meet consumers' acceptability such as the production of cocoyam crisps or flakes, soup thickener powder, flour (for confectionary) and starch (National Root Crop Research Institute [NRCRI], 2011).

Cocoyam is used in essentially the same way as yam. It can be eaten boiled, baked, fried in oil or pounded into *fufu*. It can also be made into porridge, chips and flour. Cocoyam flour has the added advantage of being highly digestible and this makes it useful for invalids and as an ingredient in baby foods (Food-info, 2011). Various cultivars of cocoyam have a lot of potentials such as production of lager beer (Onwuka and Eneh, 1998; Owusu-Darko et al., 2014), binding agents in paracetamol tablet formulation in combination with potato starch

Received date: 2017-01-03 **Accepted date:** 2020-03-02

***Corresponding author: Babatunde Olayinka Oyefeso,** Ph.D., Lecturer of Department of Agricultural and Environmental Engineering, University of Ibadan, Nigeria. Email: oyefesobabatunde@gmail.com. Tel: +2348025950339.

(Odeku et al., 2005; Adeyanju et al., 2019), source of carbohydrate in the diet of juvenile African catfish (Aderolu, 2009) and as soup thickener (Enwere, 1998; Falade and Okafor, 2014; Boakye et al., 2018).

Cocoyam in its fresh state is highly susceptible to both pre-harvest and post-harvest diseases which reduce the storage stability and overall quality of the cormels (Onwueme, 1978; Hahn, 1984; Owusu-Darko et al., 2014; and Adeyanju et al., 2019). One of the most important unit operations involved in the conversion of fresh cocoyam cormels into flour is drying. Drying is the process of removing moisture from agricultural products to a pre-determined level and it is the most widely used method of preservation due to its various applications in different fields (Mujumdar, 1997; Adejumo and Oje, 2017). It makes the food products suitable for storage, prolongs the shelf life and protects them against attack of insects, molds and other micro-organisms during storage (Sahay and Singy, 1994; Kılıç and Çınar, 2019).

There are two different modes of drying namely thin-layer drying and deep-bed drying. Thin layer drying involves the process of moisture removal from a porous media by evaporation in which excess drying air is passed through a thin layer (often a single kernel thickness) of the material until the equilibrium moisture content (EMC) is reached under the specified conditions. Deep-bed drying can simply be described as the drying of several thin layers and the understanding of thin layer drying characteristics would be helpful in simulating moisture removal in deep bed. Numerous mathematical models have been developed by various researchers to describe the rate of moisture loss during the thin layer drying of agricultural products (Ronoh et al., 2010; Oyefeso, 2016). The interactions of various operating conditions such as the conditions of the drying air, the characteristics of the crop, pre-drying treatments and methods of drying as well as their effects on the thin layer drying of agricultural materials are promising areas of study for researchers. These interactions of drying conditions have been investigated with the purpose of determining their effects on the drying kinetics and optimizing the process (Jaiyeoba and Raji, 2012). The effects of various drying variables such as slice thickness, pre-treatment, temperature etc on the thin layer drying kinetics have been studied for various food and agricultural materials such as tomato slices (Hawlader et al., 1991), finely chopped coconut pieces (Niamnuy and Devahastin, 2005), potato chips (Leeratanarak et al., 2006), Uryani plum (Sacilik et al., 2006), banana slices (Pan et al., 2008), leek slices (Doymaz, 2008), fermented ground cassava (Nwabanne, 2009), lemon grass (Ibrahim et al., 2009), pre-treated cassava chips (Tunde-Akintunde and Afon, 2010), Amaranth grains (Ronoh et al., 2010), apple slices (Meisami-asl, 2010), pumpkin slices (Limpaiboon, 2011), cocoa beans (Musa, 2012), mango (Aremu et al., 2013), fresh tannia slices (Nwajinka et al., 2014), yam slices (Owa et al., 2015), moringa leaves (Sinthiya et al., 2017), black mulberry (Doymaz and Kipcak, 2019) and red pepper (Horuz et al., 2020). This study therefore, investigated the effect of slice thickness and pre-drying treatment on the drying kinetics of the cocoyam slices with the aim of understanding the drying process and making recommendations on suitable drying conditions for control and optimization of the process.

2 Materials and methods

White-fleshed and pink-fleshed cocoyam (*X. sagittifolium*) cormels were obtained from Ogunmakin market, Ogunmakin town in Ogun State, South-Western part of Nigeria. The cormels were cleaned, peeled manually using a sharp stainless steel knife and prepared for use in carrying out the drying experiments.

Thin layer drying of the cocoyam cormels was carried out in a laboratory oven (Uniscope Laboratory Oven, SM 9053, England) at the Department of Agricultural Engineering laboratory, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria. The experimental site is located on latitude 8° 07' 60.00" N and longitude 4° 14' 60.00" E. The drying characteristics such as variations in moisture content, drying rate and moisture ratio during drying were investigated at 60^{o}C temperature level. The cocoyam cormels were blanched by soaking in hot water at 100^{o}C for 5 minutes as a form of pre-treatment before drying commenced. Blanching of cocoyam cormel is one of the processes involved in the production of cocoyam flour among the women in the

South Eastern part of Nigeria to enhance the drying process (Ukonze and Olaitan, 2010). Drying of fresh and blanched cocoyam cormel slices of 2, 3 and 4 mm thicknesses was carried out to investigate the effect of pre-treatment and slice thickness on the drying characteristics of the cormels.

The masses of the cocoyam slices before, during and after drying were measured using an electronic weighing balance (Ohaus Scout Pro Portable Electronic Balance, 600 g max, 0.1 g, England). Moisture losses were recorded at 30 minutes for the first three hours and at 60 minutes intervals subsequently (Fawohunre et al., 2019; Horuz et al., 2020). The drying processes continued until there was no significant reduction in the moisture content of the cocoyam slices being dried as the drying period increased. The dimensionless moisture ratio (MR), which is defined as the ratio of the moisture still present in a material at any particular time to the total free water which was initially available in the material before the commencement of the drying process, was calculated using Equation 1 (Aremu et al., 2013; Fawohunre et al., 2019).

$$MR = \frac{M_t - M_e}{M_i - M_e} \quad (1)$$

where: M_t = moisture content of the cormel at any given time, t (%, dry basis),

M_i = initial moisture content of the cormel (%, dry basis), and

M_e = EMC of the cormel (%, dry basis).

The drying rate was calculated using Equation 2 (Kadam et al., 2011; Raviteja et al., 2019).

$$DR = \frac{M_w}{M_d\, t} \quad (2)$$

where:

$DR = \text{drying rate (kg water/kg Dry Matter} - \text{h)}$

$M_w = \text{mass of moisture removed (kg)}$,

$M_d = \text{mass of the dry matter (kg)}$, and

t = drying time (h).

3 Results and discussion

Effect of slice thickness on fresh and blanched cocoyam slices was investigated in this study. The drying curves for the fresh and blanched (white-fleshed and pink-fleshed) cocoyam cormels of various slice thicknesses (2, 3 and 4 mm) are presented in Figures 1 and 2. Effect of pre-drying treatment on the drying kinetics of the white-fleshed and pink-fleshed varieties of cocoyam slices was also investigated by comparing the drying curves of fresh and blanched cormels of different slice thicknesses. The drying curves for the fresh and blanched cocoyam cormels are presented in Figures 3 and 4 while the variation in the maximum drying rates of white-fleshed and pink-fleshed cocoyam slices is as shown in Figure 5.

Moisture content of the cocoyam cormels reduced continuously as the drying progressed for all slice thicknesses of white-fleshed and pink-fleshed cocoyam cormels (Figures 1 to 4). The rate of moisture removal decreased as the drying period continued with no marked constant rate drying period. The thinner slices dried faster than the thicker ones for both white-fleshed and pink-fleshed cocoyam slices. This is obvious from the steeper slopes obtained for the thinner slices of the cocoyam cormels (Figures 1 and 2). This could be attributed to the variation in the surface area exposed to the heated air for a given volume of the product and the distance that the moisture in the cocoyam slices had to travel from the core of the slices before reaching the surface from where it could be easily evaporated. Therefore, the thicker the cocoyam slices, the longer the distance to be covered by moisture from the core of the cocoyam slices and consequently, the longer the drying process took to reach the equilibrium moisture content at a given temperature. The thinner cocoyam slices have increased surface area exposed to the heated air with respect to the total volume of the slices. This subsequently, resulted in reduced drying period for the thinner cocoyam slices. Similar results have been reported for leek slices (Doymaz, 2008), kiwi fruit (Mohammadi et al., 2008), Quercus fruits (Tahmasebi et al., 2011), mango (Aremu et al., 2013), ginger slices (Afolabi et al., 2014), and yam slices (Ojediran et al., 2020)

The drying rates for the blanched white-fleshed and pink-fleshed cocoyam cormels were higher than the drying rates of the fresh cocoyam cormels for all thicknesses investigated (Figures 3 and 4). Blanching resulted in increased moisture content of the cocoyam slices and subsequently, increased the quantity of free or loosely-bound moisture that was easily evaporated from the cormels. The blanched white-fleshed and pink-fleshed cocoyam slices of 2 mm thickness had the highest rates of 1.46 and 0.90 kg water/kg Dry Matter-h respectively while the fresh white-fleshed and pink-fleshed cocoyam of 4 mm thickness had the lowest drying rates of 0.47 and 0.36 kg water/kg Dry Matter-h respectively (Figure 5). The increased drying rates associated with the pre-treated cocoyam slices could be as a result of the softening effect of blanching as a pre-treatment on the tissues of the cocoyam cormels which helped to reduce the resistance to moisture diffusion from the core of the cocoyam cormels to the surface of the slices from where the moisture was easily evaporated by the heated air. Similar observations have been reported for *Ziziphus mauritian* fruit (Tembo et al., 2008), leek slices (Doymaz, 2008), pre-treated cassava chips (Tunde-Akintunde and Afon, 2010), pumpkin slices (Limpaiboon, 2011) and wild edible oyster mushroom (Ibrahim et al., 2017).

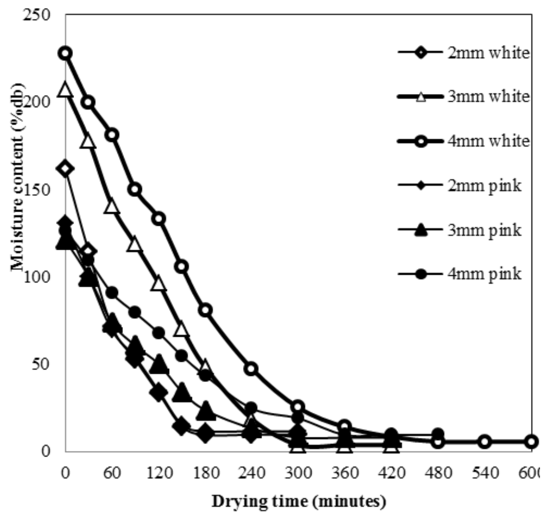

Figure 1 Drying curve for fresh cocoyam slices

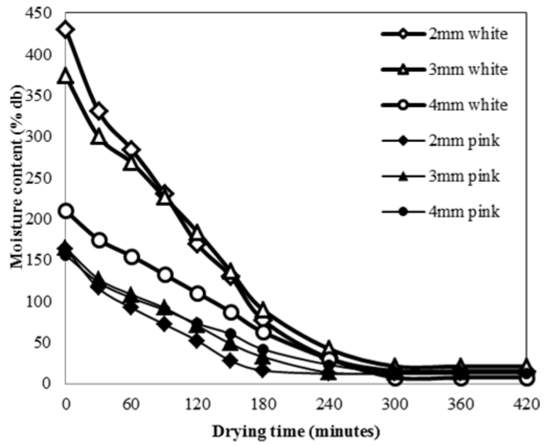

Figure 2 Drying curve for blanched cocoyam slices

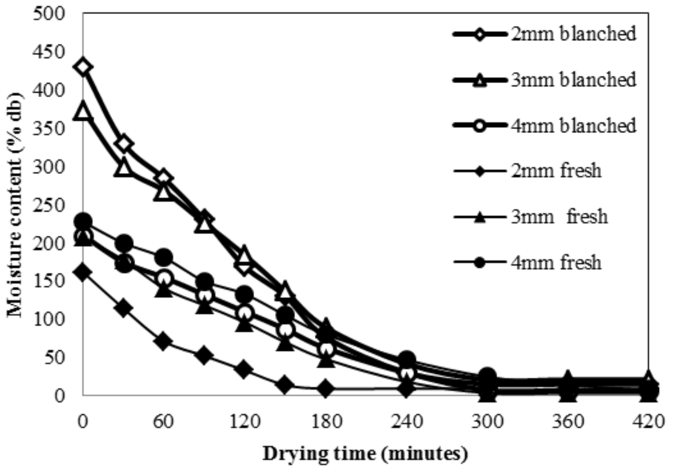

Figure 3 Drying curve for white-fleshed cocoyam slices

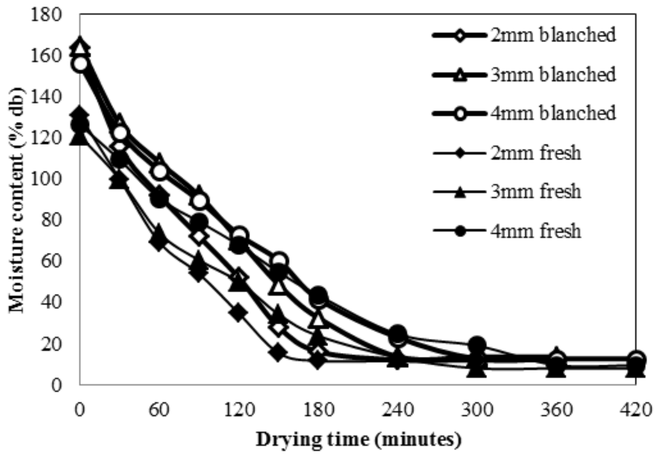

Figure 4 Drying curve for pink-fleshed cocoyam slices

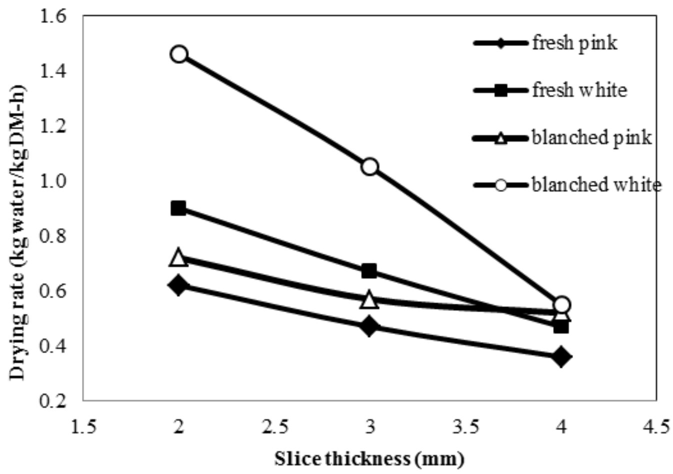

Figure 5 Drying rate of cocoyam slices

Drying rates were higher at the commencement of the drying process and the drying rates decreased with time as the moisture content of the cocoyam cormels decreased until EMC was reached under the specified conditions. Combination of reduced cocoyam slice thickness and blanching have the advantage of faster moisture removal and the attendant merit of energy saving. The drying process was observed to occur predominantly in the falling rate drying period which indicates that the moisture removal was mainly driven by diffusion mechanisms and can be represented by the Fick's law of diffusion. This agreed with the earlier results as reported for leek slices (Doymaz, 2008), lemon grass (Ibrahim et al., 2009), pre-treated cassava chips (Tunde-Akintunde and Afon, 2010), castor seeds (Ojediran and Raji, 2011), Quercus fruit (Tahmasebi et al., 2011), mango (Aremu et al., 2013), plantain (Ashaolu and Akinbiyi, 2015; Fawohunre et al., 2019), cassava flour (Adejumo and Oje, 2017), black mulberry (Doymaz and Kipcak, 2019) and red pepper (Horuz et al., 2020).

4 Conclusions

Drying kinetics of cocoyam cormels have been examined in this study. Cocoyam slice thickness and pre-treatment levels significantly influenced the drying characteristics of white-fleshed and pink-fleshed cocoyam cormels. Blanched cocoyam slices had higher drying rates than the fresh cocoyam cormels and reduced slice thickness helped to reduce the drying period. The drying process was found to be predominantly in the falling rate period. This showed that the drying process can be described principally by the diffusion mechanism. Combination of thin slices of cocoyam with some level of pre-treatment such as blanching is recommended for faster moisture removal from the cocoyam cormels.

References

Adejumo, O. A., and K. Oje. 2017. Simulating the drying kinetics of cassava flour in a laboratory model dryer using finite difference method. *Arid Zone Journal of Engineering, Technology and Environment*, 13(5): 577-592.

Aderolu, A. Z. 2009. Processed cocoyam tuber as carbohydrate source in the diet of juvenile African catfish (*Clarias gariepinus*). *European Journal of Science Research*, 35(3): 453-460.

Adeyanju, J. A., G. O. Babarinde, A. O. Abioye, A. S. Olajire, and I. D. Bolarinwa. 2019. Cocoyam processing: food uses and industrial benefits. *International Journal of Science and Engineering Research*, 10(9): 1658-1663.

Afolabi, T. J., T. Y. Tunde-Akintunde, and O. J. Oyelade. 2014. Influence of drying conditions on the effective moisture diffusivity and energy requirements of ginger slices. *Journal of Food Research*, 3(5): 103-112.

Aremu, A. K., A. J. Adedokun, and A. O. Raji. 2013. Effect of slice thickness and temperature on the drying kinetics of mango (*Mangifera indica*). *International Journal of Research and Reviews in Applied Sciences*, 15(1): 441-450.

Ashaolu, M. O., and J. O. Akinbiyi. 2015. Effects of chips sizes on thin layer drying characteristics of some plantain varieties (Dwarf cavendish and Musa sapientum). African Journal of Food Science and Technology, 6(1): 18-27.

Boakye, A. A., F. D. Wireko-Manu, I. Oduro, W. O. Ellis, M. Gudjónsdóttir, and I. S. Chronakis. 2018. Utilizing cocoyam (*Xanthosoma sagittifolium*) for food and nutrition security: A review. *Food Science and Nutrition*, 6(4): 703-713.

Doymaz, I., and A. S. Kipcak. 2019. Drying characteristics investigation of black mulberry dried via infrared method. *Journal of Thermal Engineering*, 5(2, Special Issue 9): 13-21.

Doymaz, I. 2008. Influence of blanching and slice thickness on drying characteristics of leek slices. *Chemical Engineering and Processing Process Intensification*, 47(1):41-47.

Enwere, J. N. 1998. *Foods of Plant Origin*. Nsukka, Nigeria: Afro-Orbis Publications.

Falade, K. O., and C. A. Okafor. 2014. Physical, functional, and pasting properties of flours from corms of two cocoyam (*Colocasia esculenta* and *Xanthosoma sagittifolium*) cultivars. *Journal of Food Science and Technology*, 52(6): 3440-3448.

Fawohunre, A. J., B. A. Adewumi, O. U. Dairo, and O. P. Sobukola. 2019. Fitting model for the thin layer drying of plantain (*Musa acuminata*). *American Journal of Engineering Research*, 8(8): 160-166.

Food-info. 2011. Cocoyam. Available at: http://www.food-info.net. Accessed 22 December 2011.

Hahn, S. K. 1984. Tropical root crops, their improvement and utilization. In *IITA Paper Presented at the Conf. on "Advancing Agric. Production in Africa*", 13-17. Arusha, Tanzania, Accessed 18 January 2012.

Hawlader, M. N. A., M. S. Uddin, J. C. Ho, and A. B. W. Teng. 1991. Drying characteristics of tomatoes. Journal of Food Engineering, 14(4): 259-268.

Horuz, E., H. Bozkurt, H. Karatas, and M. Maskan. 2020. Microwave-conventional drying characteristics of red pepper: modeling, temperature profile, diffusivity and activation energy. *Journal of Agricultural Science and Technology*, 22(2): 425-437.

Ibrahim, T. A., K. M. Adaramola-Ajibola, A. T. Adesuyi, S. O. Olanrewaju, and E. B. Akinro. 2017. Effect of pretreatments and drying methods on the chemical quality and microbial density of wild edible oyster mushroom. *Archive Food and Nutritional Science*, 1(1): 39-44.

Ibrahim, M., K. Sopian, and W. R. W. Daud. 2009. Study of the drying kinetics of lemon grass. *American Journal of Applied Science*, 6(6): 1070-1075.

Jaiyeoba, K. F., and A. O. Raji. 2012. Effects of drying temperature on the effective coefficient of moisture diffusivity and activation energy in Ibadan-local tomato variety (L*ycopersicum esculentum*). *Journal of Information Engineering and Applications*, 2(4): 24-38.

Kadam, D. M., R. K. Goyal, K. K. Singh, and M. K. Gupta. 2011. Thin layer convective drying of mint leaves. *Journal of Medicinal Plants Research*, 5(2):164-170.

Raviteja, G., P. S. Champawat, S. K. Jain, and S. Chavan. 2019. Drying characteristics of mint leaves in tray dryer. *International Journal of Current Microbiology and Applied Science*, 8(3): 543-551.

Kılıç, E. E., and İ. Çınar. 2019. Convective hot air drying characteristics of selected vegetables. *International Advanced Researches and Engineering Journal,* 3(1): 7-13.

Leeratanarak, N., S. Devahastin, and N. Chiewchan. 2006. Drying kinetics and quality of potato chips undergoing different drying techniques. *Journal of Food Engineering*, 77(3): 635-643.

Limpaiboon, K. 2011. Effects of temperature and slice thickness on drying kinetics of pumpkin slices. *Walailak Journal of Science and Technology*, 8(2): 159-166.

Meisami-asl, E. 2010. Determination of suitable thin layer drying curve model for apple slices (variety- Golab). *Plant Omics*, 3(3): 103-108.

Mohammadi, A., S. Rafiee, A. Keyhani, and Z. Emam-Djomeh. 2008. Estimation of thin-layer drying characteristics of kiwifruit (cv. hayward) with use of Page's model. *American-Eurasian Journal of Agriculture and Environmental Science*, 3(5): 802-805.

Mujumdar, A. S. 1997. Drying fundamentals. In I*ndustrial Drying of Foods*, ed. C. G. J. Baker, 7-30. London: Chapman & Hall.

National Root Crop Research Institute. 2011. Cocoyam programme. Available at: http://www.nrcri.ng.com. Accessed 22 December 2011.

Niamnuy, C., and S. Devahastin. 2005. Drying kinetics and quality of cocoyam dried in a fluidized bed dryer. *Journal of Food Engineering*, 66(2): 267-271.

Nwabanne, J. T. 2009. Drying characteristics and engineering properties of fermented ground cassava. *African Journal of Biotechnology*, 8(5): 873-876.

Nwajinka, C. O., C. D. Okpala, and B. Udoye. 2014. Thin layer drying characteristics of cocoyam corm slices. *International Journal of Agriculture and Biosciences*, 3(5): 241-244.

Odeku, O. A., O. O. Awe, B. Popoola, M. A. Odeniyi, and O. A. Itiola. 2005. Compression and mechanical properties of tablet formulations containing corn, sweet potato, and cocoyam starches as binders. *Pharmaceutical Technology*, 29(4): 82-90.

Ojediran, J. O., and A.O. Raji. 2011. Thin-layer drying characteristics of castor (R*icinus communis*) seeds. *Journal of Food Processing and Preservation*, 35(5): 647-655.

Ojediran, J. O., C. E. Okonkwo, A. J. Adeyi, O. Adeyi, A. F. Olaniran, N. E. George, and A. T. Olayanju. 2020. Drying characteristics of yam slices (*Dioscorea rotundata*) in a convective hot air dryer: application of ANFIS in the prediction of drying kinetics. *Heliyon*, 6(e03555): 1-12.

Onwueme, I. C. 1978. *The Tropical Tuber Crops, Yam, Cassava, Sweet Potato and Cocoyam*. New York and Brisbane Toronto: John Wiley and Sons.

Onwuka, N. O., and O. C. Eneh. 1998. The potentials of cocoyam (*Colocasia*) in stout beer brewing. *Journal of Science and Technology*, 4(1): 78-80.

Owa, T. W., L. A. S. Agbetoye, and R. O. Akinbamowo. 2015. Effects of pre-treatment on drying rate and protein content of yam slices. *Scholars Journal Engineering and Technology*, 3(1A): 1-4.

Musa, N. A. 2012. Drying characteristics of cocoa beans using an artificial dryer. *Journal Engineering Applied Science*, 7(2): 194-197.

Owusu-Darko, P. G., A. Paterson, and E. L. Omenyo. 2014. Cocoyam (corms and cormels)—An underexploited food and feed resource. *Journal of Agricultural Chemistry and Environment*, 3(1): 22-29.

Oyefeso, B. O. 2016. Selected engineering properties and drying kinetics of cocoyam (*Xanthosoma sagittifolium* (L.) Schott) cormels. Ph.D. diss., Department of Agricultural and Environmental Engineering, University of Ibadan, Ibadan, Nigeria.

Pan, Z., C. Shih, T. H. McHugh, and E. Hirschberg. 2008. Study of banana dehydration using sequential infrared radiation heating and freeze-drying. *Food Science and Technology*, 41(10): 1944-1951.

Ronoh, E. K., C. L. Kanali, J. T. Mailutha, and D. Shitanda. 2010. Thin layer drying kinetics of amaranth (*Amaranthus crueentus*) grains in a natural convention solar tent dryer. *African Journal of Food Agriculture*, *Nutrition and Development*, 10(3): 2218-2233.

Sacilik, K., A. K. Elicin, and G. Unal. 2006. Drying kinetics of Üryani plum in a convective hot-air dryer. *Journal of Food Engineering*, 76(3): 362-368.

Sahay, K. M., and K. K. Singy. 1994. *Unit Operations of Agricultural Processing*. 1st ed. India: Vikas Pub. House Pvt. Ltd.

Sinthiya, R., S. Sindhu, R. Polson, and P. Vivegashree. 2017. Drying characteristics of moringa leaves. *International Journal of Current Research*, 9(8): 55448-55450.

Tahmasebi, M., T. T. Hashjin, M. H. Khoshtaghaza, and A. M. Nikbakht. 2011. Evaluation of thin-layer drying models for simulation of drying kinetics of quercus (*Quercus persica* and *Quercus libani*). *Journal of Agriculture Science and Technology*, 13(2): 155-163.

Tembo, L., Z. A. Chiteka, I. Kadzere, F. K. Akinnifesi, and F. Tagwira. 2008. Blanching and drying period affect moisture loss and vitamin C content in *Ziziphus mauritiana* (Lamk.) *African Journal of Biotechnology*, 7(8): 3100-3106.

Tunde-Akintunde, T. Y., and A. A. Afon. 2010. Modelling of hot-air drying of pre-treated cassava chips. *CIGR E-Journal*, 12(2): 34-41.

Ukonze, J. A., and S. O. Olaitan. 2010. Competency improvement needs of women in agriculture in processing cocoyam into flour and chips for food security in South Eastern Nigeria. *African Journal of Teacher Education*, 1(1): 149-157.