Vol. 16(3) pp. 58-62, March 2022
DOI: 10.5897/AJFS2021.2163
Article Number: AA9C2E468741
ISSN: 1996-0794

http://www.academicjournals.org/AJFS

ACADEMIC JOURNALS
expand your knowledge

African Journal of Food Science

Full Length Research Paper

Effects of charcoal kiln and microwave oven drying techniques on the chemical and thermal characteristics of tomato and yam slices

Chibuzo S. Nwankwo[1]*, James T. Mbachiantim[2], Victor O. Olanegan[1], Okpomor O. Endurance[3], Carew E. Irene[1], Chigozie F. Okoyeuzu[4], Belay Dereje[5] and Abebe Teshome[6]

[1]Department of Food Science and Technology Federal University of Agriculture Makurdi, Benue State, Nigeria.
[2]Department of Nutrition and Dietetics, College of Food Technology and Human Ecology, Federal University of Agriculture, Makurdi, Benue State, Nigeria.
[3]International Centre for Biotechnology (ICB) Under the Auspices of UNESCO, at the University of Nigeria, Nsukka, Enugu State, Nigeria.
[4]Department of Food Science and Technology, Faculty of Agriculture, University of Nigeria, Nsukka, Enugu State, Nigeria.
[5]Department Food Process Engineering, College of Engineering and Technology, Wolkite University, Ethiopia.
[6]Department of Chemical Engineering, Kombolcha Institute of Technology, Wollo University, Wollo, Ethiopia.

Received 1 December, 2021; Accepted 1 February, 2022

Most drying equipment required constant electricity, which is rarely available in Sub-Saharan African countries for local farmers. In order to reduce postharvest loss, it is important to develop and use alternative equipment that is cheap and does not require electricity. The aim of this study was to compare the charcoal kiln oven and microwave oven on the drying characteristics of tomato and yam slices, as well as the effects of these different drying techniques on the chemical parameters of tomato and yam slices. The experiment was laid out based on a completely randomized design. In the charcoal kiln, the final moisture content of dried tomato and yam slices was 16.20 and 5.70%, while in the microwave it was 12.25 and 6.60%. These differences were significant ($p<0.05$). The ash content was higher in microwave-dried tomatoes (1.35%) and kiln-dried yams (3.15%) slices. The protein and carbohydrate contents of kiln-dried tomato slices were significantly ($p<0.05$) higher than microwave-dried ones, but microwave-dried yam slices were significantly ($p<0.05$) higher than kiln-dried yam slices. The potassium and iron contents of kiln-dried yam slices were significantly ($p<0.05$) higher than microwave-dried samples. The heat transfer in microwave-dried tomato and yam slices was significantly ($p<0.05$) higher than in kiln-dried ones. The charcoal kiln oven was better at drying yam than tomato. Local farmers could benefit from charcoal kiln dryers for the drying process since they do not require power supply.

Key words: Drying, microwave, kiln, tomato, yam.

INTRODUCTION

White yam (*Dioscorea rotundata*) is an important food security crop in West Africa because it is nutritious, cost-effective, and healthy. Yam is one of the most significant sources of energy in the diet, consisting primarily of starch but also containing some proteins, lipids, vitamin C, vital minerals, anti-aging, and fertility-promoting characteristics (Nugraheni et al., 2021). Tomato is also one of the world's most significant fruits. It is easily and widely cultivated, and can grow in a variety of soils and temperatures. Tomatoes are also high in vitamins and minerals (Arslan and Özcan, 2011; Jorge et al., 2018). Yam and tomato are perishable fruits due to their high moisture content, high respiration rates, and lack of a protective cuticle (Hattim et al., 2019; Okeke et al., 2020). Postharvest losses of yam are estimated to be more than 20%, owing primarily to fungus-caused rot during storage.

Postharvest losses have a severe impact on farmers' and dealers' income, putting food security efforts in jeopardy. As a result, yams must be consumed within a few weeks of harvesting or processed into flour by peeling, slicing, blanching, and drying (Okeke et al., 2020). Because tomatoes have such a limited shelf life, it is no surprise that a large amount of the harvest gets consumed, cooked, or processed (Jorge et al., 2018). Tomatoes, on the other hand, are highly perishable in their raw state, resulting in waste and losses during peak harvesting season (Bashir et al., 2014). It is critical to avoid these losses and wastage, especially when there is a supply and demand imbalance during the harvesting off-season (Bashir et al., 2014; Hattim et al., 2019). Tomatoes and yams can be dehydrated and sold as a substitute for fresh produce. Tomatoes and yams have been dehydrated for many years as a way of preserving them (Arslan and Özcan, 2011; Jorge et al., 2018). Drying is one of the technologies that can be utilized to generate high-quality goods while also reducing postharvest losses in tomatoes and yams. Drying, a typical food preservation technique, is an important part of food processing and can be used to create a new type of product (Mechlouch et al., 2012).

Microwaves have been widely used in food processing technologies and offered significant energy savings, with a potential reduction in drying times in addition to the inhibition of the surface temperature of the treated material (Celen and Kahveci, 2013; Figiel, 2009; Abano and Amoah, 2015), but the microwave oven is costly and required constant electricity. Electricity is rarely constant in sub-Saharan African countries, especially Nigeria. There is a need to develop and use alternative equipment, such as charcoal kiln ovens, that is cheap and cost-effective and could be accessible by farmers in rural areas in order to reduce postharvest loss (Idi et al., 2018). Charcoal kiln ovens have been used for drying all kinds of fish (Idi et al., 2018; Issa et al., 2020). However, the aim of this study was to compare the charcoal kiln oven and microwave oven on the drying characteristics of tomato and yam slices, as well as the effects of these different drying procedures on the chemical parameters of tomato and yam.

MATERIALS AND METHODS

Procurement of the sample

Fresh plum tomatoes (*Lycopersicon esculentum*) at ripe stage, uniform size, red colour and examined to exclude all virtual defects were purchased from the modern market located in Makurdi metropolis, Benue State, Nigeria. The mature white yam (*D. rotundata*) used for the study was also purchased from the modern market located in Makurdi metropolis, Benue State, Nigeria. Fresh plum tomatoes (4 kg) and white yam (10 kg) were processed for drying in the microwave and charcoal kiln oven, respectively, immediately after purchase.

Drying methods

Kiln oven drying

The charcoal kiln oven used for drying was locally fabricated with wrought iron (2 mm thickness) in the Department of Food and Technology at the Federal University of Agriculture Makurdi, Benue State, Nigeria. The charcoal kiln oven has three chambers: drying, charcoal, and fan chambers. The operation was based on heat supply by burning charcoal and air supply by a solar-powered fan. The dimensions of the charcoal kiln oven cavity were 400, 400 and 400 mm, respectively.

Microwave drying

A programmable domestic microwave oven (Arcelik ARMD 580, Turkey) with a maximum output of 700 W and 2450 MHz was used for drying experiments. The dimensions of the microwave cavity were 345, 6 340, and 6 225 mm, respectively.

Analytical methods

Sample preparation and analysis

Ripened and healthy tomatoes were sorted, washed and then sliced with a stainless steel knife to thickness of 0.005 m and area of 0.0013 m^2. The yams was peeled with a knife to separate the edible portion from the peel and then sliced uniformly to have thickness of 0.005 m and surface area of 0.0013 m^2. The tomato and yam slices were dried in charcoal kiln and microwave oven, respectively, thereafter the chemical characteristics of dried tomato and yam in both charcoal kiln and microwave oven were determined by AOAC (2010). Thermal conductivity and heat transfer of the sample was determined according to Berk (2018).

$$\text{Thermal conductivity (K)} = 0.25X_C + 0.155X_P + 0.16X_F + 0.135X_a + 0.58X_W \quad (1)$$

E-mail: toteupstar@yahoo.com. Tel: 08165444222.

Table 1. Chemical composition (dry basis) and thermal characteristics of dried tomato and yam slices.

Chemical composition (%)	Tomato			Yam		
	Fresh	Charcoal kiln dried	Microwave dried	Fresh	Charcoal kiln dried	Microwave dried
Moisture (%)	90.34[a]±0.04	16.20[b]±0.06	12.25[c] ±0.03	66.30[a]±0.06	5.70[c]±0.01	6.60[b] ±0.03
Ash (%)	0.54[c]±0.06	1.30[b]±0.08	1.35[a]±0.03	1.58[c]±0.05	3.15[a]±0.03	2.60[b]±0.03
Fat (%)	0.01[c]±0.00	0.50[a]±0.11	0.04[b]±0.03	1.00[b]±0.00	2.10[a] ±0.03	2.10[a] ±0.06
Fiber (%)	0.01[c]±0.00	7.15[b]±0.04	9.75[a]±0.03	0.65[c]±0.03	2.35[a]±0.01	1.65[b]±0.01
Protein (%)	1.65[c]±0.01	6.64[a]±0.03	5.69[b]±0.01	2.63[c]±0.04	4.38[b]±0.03	5.26[a]±0.01
Carbohydrate (%)	7.45[c]±0.12	49.21[b]±0.32	61.56[a]±0.13	28.84[c]±0.18	84.32[a]± 0.08	83.79[b]±0.14
Pro-vitamin A (mg/g)	623.8[a]±0.14	456.5[c]±0.14	608.6[b]±0.28	623.7[b]±0.28	440.7[c]±0.28	717.6[a]±0.14
Vitamin C (mg/g)	17.20[a]±0.03	15.62[b]±0.3	15.41[c] ±0.01	5.13[b]±0.4	8.63[a]±0.04	8.63[a]±0.01
Potassium (mg/g)	4.80[c]±0.14	6.00[b]±0.02	15.20[a]±0.28	4.40[c]±0.28	7.60[a]±0.14	5.00[b]±0.28
Magnesium (mg/g)	0.02[c]±0.01	0.15[a]±0.03	0.17[b] ±0.03	0.03[a]±0.03	0.02[b]±0.01	0.03[a]±0.01
Iron (mg/g)	1.26[c]±0.03	3.06[a]±0.03	2.57[b]±0.03	1.38[c]±0.01	1.96[a]±0.01	1.59[b]±0.01
Thermal Conductivity (W/(m.°C)	0.54[c]	0.24[a]	0.25[b]	0.46[a]	0. 25[c]	0.26[b]
Heat transfer (J)	ND	66.95[b]	92.06[a]	ND	68.86[b]	207.66[a]
Drying Efficiency (%)	ND	82.1[b]	86.4[a]	ND	91.4[a]	90[a]
Drying time (g/min)	ND	70[a]	40[b]	ND	50[a]	24[b]

Values are means ± standard deviation of three determinations. Values on the same row with different superscripts are significantly different (p<0.05). ND = not determined.

Where X represents mass fraction, c = carbohydrate, p = protein, f = fat, a = ash, w = water.

$$Heat\ transfer\ (q) = KA\frac{T1-T2}{z} \quad (2)$$

Where A = Area (m^2); K = Thermal conductivity (W/(m.°C); z = Thickness of the samples (m); T_1 = Initial temperature (°C); T_2 = Final temperature(°C).

Then drying time, (g/min) was determined according to Adeboye (2012);

$$\text{Drying time (g/min)} = \frac{Initialmass(g)-finalmass\ (g)}{Time\ (m)} \quad (3)$$

Drying efficiency was calculated according to Mercer and Eng (2007) and Matuam et al. (2015) as the ratio of energy E_1 required to evaporate all the water in the sample to the energy E_2 used to evaporate water from the sample during drying.

$$E_1 = M_a \times L \quad (4)$$

$$E_2 = M_b \times L \quad (5)$$

$$DryingEfficiency\ (\%) = \frac{E_2}{E_1} \times 100 \quad (6)$$

Where $M_a(L/kg) = Massofwater\ contained\ in\ freshfood\ sample$; $M_b(L/kg) = Mass\ ofwaterevaporated\ from\ fresh\ food\ sample$ $L\left(\frac{J}{kg}\right) = Latent\ heat\ of\ vaporization\ of\ water.$

RESULTS AND DISCUSSION

Chemical composition and thermal characteristics of dried tomato and yam slices

Table 1 showed that the moisture content of tomato and yam decreased significantly (p<0.05) after drying in a charcoal kiln (16.20 and 5.70%) and a microwave (12.25 and 6.60%) ovens. The present observation agreed with that of Nugraheni et al. (2021), who worked on the effect of various drying methods on the physical characteristics of purple yam powder. Lower moisture content is suitable for extended shelf life (Nugraheni et al., 2021). Surendar et al. (2018) reported that moisture content was not significantly affected by the drying method, which was contrary to the results obtained from this study. The ash content of the dried samples was found to be high in microwave dried tomato (1.35%) and charcoal dried yam (3.125%). The low ash (0.54%) value for the fresh tomato strongly suggested that the tomato is not a good source of ash (Haile, 2013; Ramya et al., 2017).

The fat content of charcoal kiln and microwave dried tomato and yam slices ranged from 0.04 to 2.10%. The results obtained for both charcoal kiln and microwave dried yam were similar to the reports of Falade et al. (2007) and Nugraheni et al. (2021). The fibre content of tomato slices was found to be 7.15% for charcoal kiln ovens and 9.75% for microwave ovens. The same result was reported by Surendar et al. (2018). The fibre content of yam slices was found to be 2.35% for charcoal kiln oven and 1.65% for microwave oven, respectively. The higher fat and fiber content in dried tomato and yam slices compared to fresh tomato and yam slices could be attributed to the lower moisture content (Yusufe et al., 2017; Surendar et al., 2018). The protein content of tomato slices was 6.64% for the charcoal kiln oven and 5.69% for the microwave oven, while the yam slice was 4.38% for the charcoal kiln oven and 5.26% for the microwave oven, respectively. The significant (p<0.05) increase in protein content of tomato and yam slices may be due to the concentration of nutrients because of a significant ($p<0.05$) decrease in moisture content after drying (Surendar et al., 2018).

The carbohydrate content of dried tomato increased after drying with a microwave (61.56%) and a charcoal kiln oven (84.32%). The pro-vitamin A content of microwave dried tomatoes and yams was significantly ($p<0.05$) higher than charcoal-dried tomatoes and yam slices. The vitamin C content of microwave and kiln-dried tomato and yam slices was not significant ($p>0.05$), but it is important to note that drying with microwave and kiln oven affected the vitamin C content of the tomato and yam slices when compared to fresh tomato and yam slices. This could be due to the destruction of ascorbic acid content by heat (Dauda et al., 2019). Charcoal kiln dried tomato slices had significantly ($p<0.05$) higher magnesium and iron content than microwave dried tomatoes, but were low in potassium content. Arslan and Özcan (2011) and Agoreyo et al. (2011) reported similar findings. Charcoal kiln dried yam slices had significantly ($p<0.05$) higher potassium and iron content than microwave dried yam slices but were low in magnesium content. The oven drying method's wave strength may cause damage to these minerals (Arslan and Özcan, 2011). The thermal conductivity of fresh tomatoes and yams was significantly ($p<0.05$) higher than microwave and charcoal kiln dried tomato and yam slices. It was observed that the higher the moisture content, the higher the thermal conductivity and vice versa. A reduction in moisture content caused a substantial reduction in thermal conductivity. This has important implications for unit operations that involved the conduction of heat through food to remove water (Fellows, 2009). The heat transfer in microwave dried tomato and yam was significantly ($p<0.05$) higher compared to kiln dried tomato and yam slices. The microwave oven has significantly ($p<0.05$) higher drying efficiency (86.4 and 90.00%) and less drying time (40 and 24 min) than the charcoal kiln oven for both the tomato and yam slices, respectively.

Conclusion

The two drying techniques showed a significant ($p<0.05$) effect on the chemical composition and thermal characteristics of tomato and yam slices. Charcoal kiln driers were better at drying yams than tomato in terms of chemical composition. The heat transfer in microwave dried tomato and yam slices was significantly ($p<0.05$) higher compared to kiln dried tomato and yam slices. Although, the microwave oven has significantly ($p<0.05$) higher drying efficiency and less drying time than the charcoal kiln oven for both the tomato and yam slices, the charcoal oven kiln dryer could be useful to local farmers in terms of cost and accessibility to dry their produce and reduce postharvest loss, especially in Sub-Saharan African countries where there is no constant electricity to use the microwave oven.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Abano EE, Amoah RS (2015). Microwave and blanch-assisted drying of white yam (*Dioscorea rotundata*). Food Science and Nutrition 3(6):586-596.

Adeboye OA (2012). Effect of some drying parameters on the drying rate and proximate composition of green plantain (*Musa paradisiaca*). Master's Degree Thesis (Unpublished) Submitted to Department of Agricultural and Biosystems Engineering, University of Ilorin, Nigeria.

Agoreyo BO, Akpiroroh O, Orukpe OA, Osaweren OR, Owabor CN (2011). The effects of various drying methods on the nutritional composition of *Musa paradisiaca*, *Dioscorea rotundata* and *Colocasia esculenta*. Asian Journal of Biochemistry 6(6):458-464.

AOAC (2010). Official Methods of Analysis. Association of Official Analytical Chemists. 18th ed. AOAC International, Gaithersburg, MD.

Arslan D, Özcan MM (2011) Drying of tomato slices: Changes in drying kinetics, mineral contents, antioxidant activity and color parameters. CyTA - Journal of Food 9(3):229-236.

Bashir N, Bhat MA, Dar BN, Shah MA (2014). Effect of different drying methods on the quality of tomatoes. Advances in Food Sciences 36(2):65-69.

Berk Z (2018). Food Process Engineering and Technology (3rd Edition), Academic Press, London.

Celen S, Kahveci K (2013). Microwave drying behaviour of tomato slices. Czech Journal of Food Sciences 31(2):132-138.

Dauda A, Abiodun O, Salami T, Akintayo O (2019). Chemical and microbiological evaluation of dried tomato slices for Nigerian system. Global Journal of Nutrition and Food Science 1(5):1-4.

Falade KO, Olurin TO, Ike, EA, Aworh OC (2007). Effect of pretreatment and temperature on air-drying of *Dioscorea alata* and *Dioscorea rotundata* slices. Journal of Food Engineering 80(4):1002-1010.

Fellows PJ (2009). Food processing technology: principles and practice. Elsevier.

Figiel A (2009). Drying kinetics and quality of vacuum-microwave dehydrated garlic cloves and slices. Journal of Food Engineering 94(1):98-104.

Haile MA (2013). Microwave-vacuum drying effect on drying kinetics, lycopene and ascorbic acid content of tomato slices. Journal of Stored Products and Postharvest Research 4(1):11-22.

Hattim MMM, Maissa MAA, Dina OMA (2019). Effects of natural and artificial drying methods on the nutritional value and functional properties of vegetables grown in Sudan. Pakistan Journal of Nutrition 18:800-804.

Idi OAM, Ogori AF, Omoniyi SA (2018). Design and fabrication of pneumatic charcoal kiln drying characteristics and residence temperature for cat fish smoking. Journal of Nutritional Health and Food Engineering 8(1):9-12.

Issa WA, Fatile OE, Abdulmumuni B, Ologunye OB, Okpara IN (2020). Design and Fabrication of a Charcoal Fish Smoking KILN. International Journal of Recent Technology and Engineering 9(1):1487-1495.

Jorge A, Sauer Leal E, Sequinel R, Sequinel T, Kubaski ET, Tebcherani SM. (2018). Changes in the composition of tomato powder (*Lycopersicon esculentum* Mill) resulting from different drying methods. Journal of Food Processing and Preservation 42(5):e13595.

Matuam B, Edoun M, Kuitche A, Zeghmati B (2015). Experimental evaluation of the thermal performance of dryer airflow configuration. International Journal of Energy Engineering 5(4):80-86.

Mechlouch RF, Elfalleh W, Ziadi M, Hannachi H, Chwikhi M, Aoun AB, Elakesh E, Cheour F (2012). Effect of different drying methods on the physico-chemical properties of tomato variety 'Rio Grande'. International Journal of Food Engineering 8(2).

Mercer DG, Eng P (2007). An intermediate course in food dehydration and drying. Department of Food Science, University of Guelph,

Ontario, Canada.
Nugraheni NF, Karyadi JNW, Tarwaca SN, Indrasari YP, Albyan R, Setiyadi I, Ayuni D (2021). Effect of various drying methods on the physical characteristics of purple yam powder. IOP Conference Series: Earth and Environmental Science 644(1):012079.
Okeke C, Eje BE, Eze PC (2020). Drying characteristics of yam varieties: A comparative analysis.Poljoprivredna Tehnika 45(1):20-37.
Ramya HN, Ashwini A, Veena B, Fazal.AA, Hanumanthraju KN (2017). Influence of different drying techniques on dehydrated tomato powder. International Journal of Creative Research Thoughts 5(3):474-482.
Surendar J, Shere DM, Shere PD (2018). Effect of drying on quality characteristics of dried tomato powder. Journal of Pharmacognosy and Phytochemistry 7(2):2690-2694.
Yusufe M, Mohammed A, Satheesh N (2017). Effect of drying temperature and duration on nutritional quality of cochoro variety tomato (*Lycopersicon esculentum* L.). Annals of Food Science and Technology 18(2):145-152.