YUMSUK
JOURNAL OF PURE AND APPLIED SCIENCES

IMPACT OF SALT PRETREATMENT METHOD AND TEMPERATURE ON THE DRYING CHARACTERISTICS AND NUTRITIONAL PROPERTIES OF DRIED MANGO (*MANGIFERA INDICA* L.) SLICE

[1] Ahmad R K., [1] Abdullateef J., [1] Muhammad A I., [1] Sarki H A.,
[1]Department of Agricultural and Environmental Engineering, Bayero University Kano, 3011 Kano, Nigeria
*Corresponding Author's email: rkahmad.age@buk.edu.ng

Abstract

Mango is one of the most widely grown fruit in Nigeria, which is cultivated across the six geo-political zones. Mango production significantly contributes to Nigeria's agricultural industry and makes the country one of the world's and Africa's top producers of mango. Dried mangoes are further processed to create fruit powder and dried chips/flakes, which are then added to a variety of foods as supplement. In addition to their nutritive benefits, finding techniques to conserve mangoes after harvest is essential. This study was to ascertain the impact of salt pretreatment method and drying temperatures on the drying characteristics and nutritional properties of dried mango slices. Julie mango variety of an average slice thickness of 3 mm was dried in an oven at varied temperatures (55°C, 65°C, 75°C, 85°C, and 95°C) using salt solution dips and control. The results of the analysis of variance showed that the temperatures and pretreatment methods vary greatly. The quickest drying time and lowest moisture content were achieved at 95°C. Furthermore, the nutrient analysis revealed that the pretreatment method and the temperature had a substantial impact on the dried mango slices.

Keywords: *Mangifera indica, Temperature, Salt Pretreatment, Drying characteristics, Nutritional value*

INTRODUCTION

Mango is a valuable and popular fruit possessing rich dietary source (carbohydrates, fiber minerals), antioxidants such as vitamin C, carotenoids, and phenolic compounds which have shown various health benefits (Gámez *et al*. 2017, Uranga-Soto *et al*. 2022). The mango plant is native to South and Southeast Asia and are now enjoyed all over the world. Much of the world's mangoes come from the Asia Pacific region, specifically India, China, Indonesia, and Thailand and Mexico. Besides the top producers, mangoes are also grown in countries such as Pakistan, the Philippines, Brazil, Egypt, and Nigeria, among others. The global production volume of mangos, mangosteens, and guavas was a little over 57 million metric tons in 2021, a small increase from around 56.69 million metric tons in 2020. Mangoes are a significant commodity in international trade, with countries exporting fresh mangoes, mango pulp, and processed mango products to various markets worldwide. Mango production can face challenges such as pests, diseases (e.g., anthracnose), and climate-related issues like cyclones or droughts. Sustainable and environmentally friendly mango production practices are becoming increasingly important due to concerns about environmental impact and climate change. In addition to fresh mangoes, many countries produce value-added products such as mango juice, dried mango slices, mango puree, and mango-based snacks. Nigeria is one of the world's top mango-producing countries, ranking fourth after India, China, and Thailand etc. (Edom 2023). The mango fruit is not only popular in Nigeria but also in many other parts of the world due to its delicious taste and numerous health benefits. It is a rich source of vitamins, minerals, antioxidants, and dietary fiber. Additionally, the mango is often used to make different food products like juice, jams, and pickles. States producing mango in Nigeria include Benue, Jigawa, Plateau, Kebbi, Niger, Kaduna, Kano, Bauchi, Sokoto, Adamawa, Taraba and the Federal Capital Territory (FCT) with Benue considered the highest producer (Ogah *et al*. 2019). There are hundreds of mango varieties, each with its unique flavor, aroma, and appearance. Some varieties are more suitable for export, while others are primarily grown for local consumption. Mangoes can be processed into various products such as mango pulp, juices, jams, dried fruits, and even frozen slices. These value-added products have a longer shelf life and can be sold even during the off-season, reducing wastage (Ademola *et al*. 2013).

Different parts of the mango offer different benefits, such as anti-inflammatory, antioxidant, anticancer, anti-diabetic, antimicrobial, anti-hyperlipemic, and immunomodulatory activities (Ajila & Prasada 2013, Ediriweeraet *et al*. 2017, Lauricella *et al*. 2017). However, mangoes are also a great source of potassium, beta-carotene, folate, choline, magnesium, vitamin A, and vitamin C. The fruit's three components are the peel, pulp, and seed. The portion of the mango that is most frequently eaten is the pulp. Depending on the ripening stage, it can either be consumed raw or processed into a variety of products (Singh *et al*. 2022). The nutritional composition of mango pulp mainly depends on the type/variety of the mango, the locality and climatic conditions of its production region, and the maturity of the fruit (Abbasi *et al*. 2015, Maldonado-Celis *et al*. 2019). The mango pulp contains carbohydrates (16-18%), proteins, amino acids, lipids, organic acids, as well as dietary fiber (Lemmens *et al*. 2013). Mango pulp contains 75-85% water (Lebaka *et al*. 2021). In spite of its excellence, its short harvest season and perishable characteristics severely restrict its usage. Mango fruit is seasonal, which causes shortages during the offseason and surpluses during periods of abundance (Nyangena*et al*. 2019). This is related to the limited industrial capacity for transforming the fruit into goods with a lengthy shelf life (Andrés *et al*. 2007).

There are different methods by which agricultural products are preserved, and one of the most popular primary ways of food preservation is dehydration. It is defined as a process of moisture removal due to simultaneous heat and mass transfer, with the goal of removing water to the point where microbial spoilage and deterioration reactions are greatly reduced. It also provides longer shelf-life, takes up less storage space, and is lighter to transport. The quality of dried foods can be enhanced by performing chemical, thermal, or osmotic pretreatments before drying (Nyangena *et al*. 2019). Choosing salt pre-treatment before drying mango can significantly enhance the quality, safety, and shelf-life of the dried product. Salt acts as a preservative by reducing water activity, inhibiting the growth of spoilage microorganisms and pathogens, thus extending shelf-life. It also enhances the natural flavor, balances sweetness, and helps retain the vibrant color of the mango slices by reducing enzymatic browning. Additionally, salt pre-treatment can improve texture, preserve nutrients, and reduce overall drying time, making the process more energy-efficient and the dried mango more appealing and nutritious (Kumar *et al*. 2014). However, it is important to carefully control the amount of salt to avoid an overly salty taste and consider the health implications of salt consumption. Optimizing the pre-treatment process and selecting the proper drying temperature and method are crucial to ensure the benefits are maximized without negatively affecting the final product characteristics such as color, texture, nutrient retention, and antioxidant activity. Mango slices lose moisture more quickly at higher temperatures, which might result in faster drying rates. This benefits commercial drying processes by lowering energy consumption and processing time (Akoy 2014b). However, high drying temperature can cause product shrinkage, browning, loss of nutritional content, and reduced sensory quality. Thus, manufacturers can fine-tune their processing techniques, including pretreatment methods, slice thickness and optimum temperature, to improve the nutritional value of dried mango slices. This may involve conducting experiments to identify the optimal combination of factors. Therefore, it is important to study the drying method to maintain the quality attributes of the dried mango slice. Fruits and vegetables are dried using a variety of techniques such as microwave, convective, and microwave-convective (Izli & Isik 2015), microwave and hot air dryer (Rasooli *et al*. 2021). Several studies have been carried out on different fruits and vegetables such as thin-layer drying characteristics of mango slices (Goyal *et al*.2006), effect of drying temperature on moisture content and drying kinetics of Pleurotus florida (P. florida) and Pleurotus sajor-caju (P. sajor-caju) (Tran *et al*. 2020). However, in comparison to earlier studies, this study is distinctive since it includes more information on pretreatment method and nutritional properties. To obtain a high-quality product, however, an appropriate drying technique under ideal conditions is required. Optimal conditions should be selected to produce high-quality dried mango slices with desirable attributes. This paper investigates the effect of salt pretreatment and temperature on the drying characteristics of mango using a hot air oven method. Five different temperatures in conjunction with salt solution dip pretreatment were employed for this purpose.

MATERIALS AND METHODS

Sample preparation

The 'Julie' mango variety was obtained from 'Yankaba market in Kano, Nigeria. Generally, mango samples of uniform sizes were selected. The mangoes were cleaned, and the premature and spoiled mangoes were separated manually. The fruits were then manually peeled and sliced using a stainless-steel knife to the nearest 30 g (3 mm thickness).

Salt solution dip is one of the most common pretreatment methods, it involves dipping the fruit sample into a solution of salt and distilled water. The mango slice samples of equal weight and thickness were weighed and then dipped in a 10% salt solution and allowed in the solution for 10 minutes ensuring full coverage of the slices. The pretreated slices were removed from the solution and distributed evenly across a perforated tray, where the excess solution was allowed to drain off for 20 minutes (Nyangena *et al*. 2019).

The initial moisture content of the mango slices was determined according to the standard method for drying fruits and vegetables (Mohsenin 1980). The mango fruit with an average initial moisture content of 89.23% (w.b) was selected for the drying experiment.

Experimental procedure

Oven drying (Dehydration method)

Fruits can be dried using a variety of techniques, including sun, dehydration, freezing, and microwave drying. Dehydration has been used for decades as one of the ways of the preservation of mango fruits to increase their shelf-life, which aims to reduce post-harvest losses and improve food security during the off-season (Bouba *et al*. 2014). In this study, the dehydration experiments of the mango slices were performed in a hot-air oven having an accuracy of ±2 °C. The experiment was conducted in 3 replications at 55 °C, 65 °C, 75 °C, 85 °C and 95 °C of drying air temperatures, a thickness of 3 mm and salt solution dip pretreatment method. These values were selected because they fell within the acceptable range for drying agricultural products. During the process, the samples were placed in a laboratory drying oven set at a low temperature to gradually remove moisture. This method requires careful monitoring to prevent over-drying or burning. The average air temperature and humidity during the drying were 55±2 °C and 20±1%, respectively. For the pretreatment procedure, each sample was treated with salt solution as described in sample preparation, and a sample for each temperature was left untreated as a control. Throughout the experiment, the samples were weighed every hour. By using a digital balance with an accuracy of 0.05g, the weight loss was recorded at a specific interval. Drying was carried out until a steady weight was attained. The samples were stored in a desiccator during a power outage to keep them from absorbing moisture or losing it. To ensure the experiment's accuracy, it was conducted three times.

Nutritional properties

In order to assess the nutritional value, proximate analysis was used. To determine the impact of the pretreatment procedure on the mango slice, it was carried out both before and after the drying trials. This analysis employed a 3 mm thick sample. The choice of temperature affects the quality of dried mango. High temperatures can lead to color changes, texture alterations, and flavor degradation. Therefore, lower temperatures are often preferred for preserving the visual and sensory qualities of dried mango. Mangoes are a good source of vitamins and antioxidants, but these compounds can be sensitive to heat. Drying at high temperatures can result in nutrient loss, particularly for heat-sensitive vitamins like vitamin

C. Lower drying temperatures are better for preserving the nutritional content of dried mango. Drying at lower temperatures may result in a product with a longer shelf life due to reduced oxidative degradation of lipids and other compounds (Barta *et al.* 2012). The nutritional properties were evaluated using the least temperature (55°C) due to the reasons highlighted above. Crude protein, crude fat, ash, crude fiber, and moisture content were among the factors identified using sample powder of the dried mango.

Moisture ratio

The difference between the initial moisture content and the moisture content at any given time is measured by the moisture ratio:

$$\text{Moisture ratio } = \frac{\text{Mt}}{\text{Mo}} \times 100\% \qquad 2.1$$

where,

M*t* = Moisture content (%) at that particular time,

M*o* = Moisture content (%) at time, t = 0

Drying rate

The drying rate (DR) was estimated using the weight of water removed per unit time per kilogram of dry matter, given in kg H2O/kg dm/h. The drying rate is determined using the following equation (Doymaz 2004, Pala *et al.* 1996):

$$\text{DR} = \frac{\textit{amount of water removed}}{\textit{time taken}} \qquad 2.2$$

Statistical analysis

Microsoft Excel with the Analysis Toolpak add-in was used to perform a two-factor analysis of variance (ANOVA). This approach was employed to conduct inferential statistics on the data and determine the significance of mean differences. The least significant difference (LSD) method was used to group the means at the 0.05 probability level, with differences considered statistically significant at $P<0.05$.

RESULTS AND DISCUSSION

The initial moisture content of the controlled tests was 87.23% on a wet basis and 86.70% wet basis after treatment with salt solution. Despite having a high natural sugar content, mangoes can be semi-moist up to a moisture level of 25% when measured on a wet basis (Sunil 2020). As expected, the drying temperature had a significant effect on the drying characteristics of the mango slices as shown in Figures 1 to 3.

Effect of temperature against moisture content of untreated and treated mango slice

Mango fruit is highly perishable; therefore water must be removed to improve preservation by lowering water activity (Nyangena *et al.* 2019). Figure 1 shows the changes in moisture content of (a) untreated and (b) treated mango slices with drying time at various air temperatures of 55°C, 65°C, 75°C, 85°C and 95°C at a fixed thickness (3 mm). The shape of the drying curves (Figure 1) indicates a rapid moisture content removal from the product at the initial stage, which later decreased with the increase in drying time. Thus, the moisture content decreased continually with the drying time and temperature. The highest temperature had the lowest moisture content of 9.14% w.b and 8.41% w.b for the untreated and treated samples at a short drying time of 5 h and 4 h, respectively. However, the drying time was longer before the moisture was removed at the lowest (55°C) temperature. It took up to 10 hours and 7 hours for the moisture to be 11% w.b. and 9.73% w.b. for the untreated and treated samples, respectively. This implies that pretreatment and temperature are among the factors affecting the drying of mango slices. Moreover, it was discovered that the final moisture contents of the treated samples were lower than those of the untreated samples. This is clear since the results could alter as a result of the pretreatment with salt. Temperatures exceeding 70°C are normally required for high-temperature drying, though they can reach 85°C or higher. This approach is quicker but may result in increased nutritional loss and flavor and texture alterations. It is frequently used for fruits like raisins where maintaining the appearance and texture is not as important (Barta *et al.* 2012). Food products are recognized to have extra value added when they are dried, which also extends their shelf life. When water is removed from a product under controlled circumstances, the moisture content of the food is reduced to some amount, which slows down microbial growth, enzyme activity, and unfavorable chemical changes (Rasooli *et al.* 2021). Hence it is important to carefully select the temperature of drying the mango slice to avoid over drying which will affect its quality.

Effect of temperature against moisture ratio of untreated and treated mango slice

As shown in Figure 2, the moisture ratio for the untreated and treated mango samples is plotted as a function of drying time. The shape of the drying curves in Figure 2(a) and 2 (b) indicates a rapid moisture content removal from the untreated and treated samples at the initial stage, which later decreased with the increase in drying time. Thus, the moisture ratio decreased continually with the drying time and temperature. The time required to reduce the moisture ratio to any given level was dependent on the drying temperature, being highest at 55°C and lowest at 95°C. It was observed that the main factor influencing drying kinetics was the drying temperature (Ahmed *et al*. 2018). Thus, a higher drying temperature produced a higher drying rate and consequently the moisture content decreased faster. This is due to increase of air enthalpy to the mango slices and subsequent acceleration of water migration within the mango slices. Therefore, a greater drying air temperature led to a quicker drying rate, which in turn caused the moisture content to drop off more quickly. This is brought on by the product's increased rate of air heating and rapid transfer of water within the mango slices (Akoy 2014a).

Effect of temperature against drying rate of untreated and treated mango slice

Early drying proved to have a high moisture removal rate, leading to a higher slope because of the loss of free surface moisture as shown in Figure 3. This was also reported in previous work (Aditya *et al*. 2014). It can be observed that there is no constant rate of drying period in the drying process of mango slices, and all the drying process occurs in the falling rate period (Figures 3(a) and (b)), thus, an increase in temperature resulted in reduced drying time. This indicates that diffusion is the dominant physical mechanisms governing moisture movement within the mango slices. Nevertheless, the drying temperature had an impact on the period it was required to decrease the moisture content to a specific level; it was greatest at 55°C and lowest at 95°C. At 85°C, 75°C, and 65°C, respectively, it took 6, 8 and 10 h for the untreated and 4, 5 and 6 hours for treated samples to reduce the moisture content of mango slices from 89.23% (w.b.) to the final moisture content <10% (w.b.). Thus, a higher drying temperature produced a higher drying rate and consequently the moisture content decreased faster. Heat must be applied with enough force to evaporate any moisture from the product during drying, and airflow is necessary to remove the evaporated moisture. The drying process is governed by two main mechanisms. Moisture is first transferred from a product's inside to its surface, and then it is evaporated into the surrounding air from that surface. The amount of moisture in the product and its temperature have a significant impact on how quickly it dries.

Effect of salt pretreatment on nutritional properties of the mango slice

As variables such as temperature, affects the quality of a product, so does pretreatment method. Figure 4 shows the approximate values for the treated and untreated samples of dried mango for ash, moisture content, dry matter, crude fiber, fat, and crude protein. The treated samples have higher ash content, moisture content, crude fiber and fat values than the untreated sample does. However, the untreated samples' values for dry matter and crude protein are higher than those of the treated sample. This illustrates that pretreatment may have an effect on some of the proximate properties of dried mango. The ANOVA results indicated that there is a 5% difference in the nutritional value of the dried mango samples. The choice of pretreatment and drying temperature can affect the texture of dried mango. Proper pretreatment can help maintain a desirable texture (Nyangena *et al*. 2019). Mangoes are a good source of vitamin C, but it is sensitive to heat. Drying at high temperatures can lead to significant vitamin C loss (Shyam & Devina 2012). Low temperature drying or freeze-drying is more effective at preserving this vitamin. Mangoes are rich in carotenoids, such as beta-carotene, which is a precursor of vitamin A (Nyangena *et al*. 2019). Pretreatment methods and low-temperature drying can help preserve these vitamins content. The results highlight how important pretreatment and temperature are in maintaining the nutritional value of dried mango slices. This demonstrates how the final product's nutrient content can be directly impacted by processing variables.

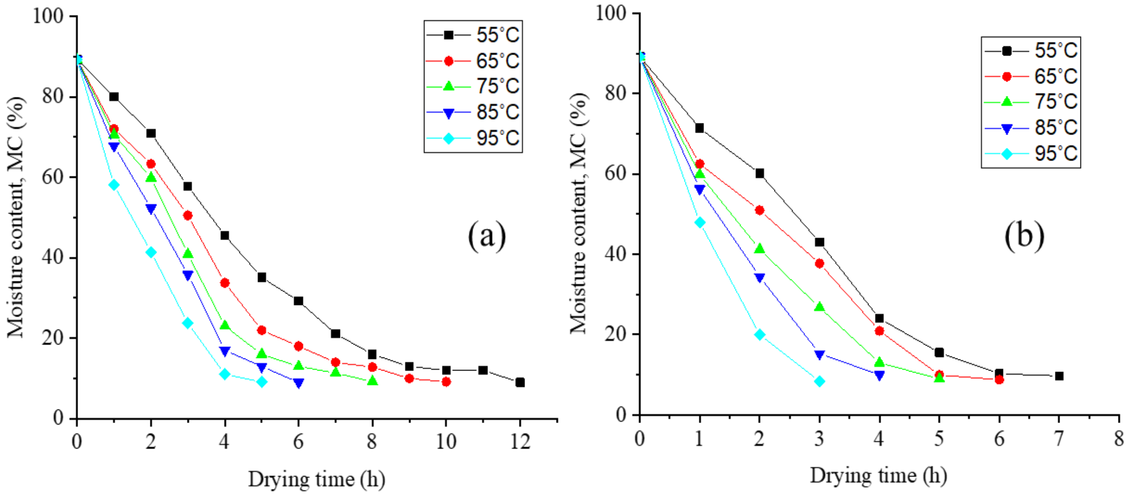

Figure 1: Effect of temperature on moisture content for (a) untreated and (b) treated mango slice samples.

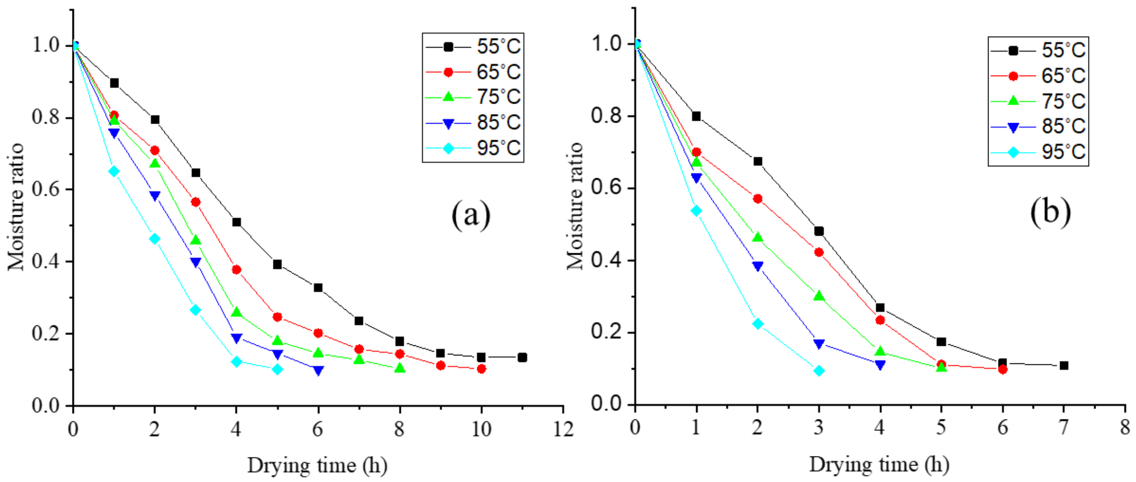

Figure 2: Effect of temperature on moisture ratio for (a) untreated and (b) treated mango slice samples.

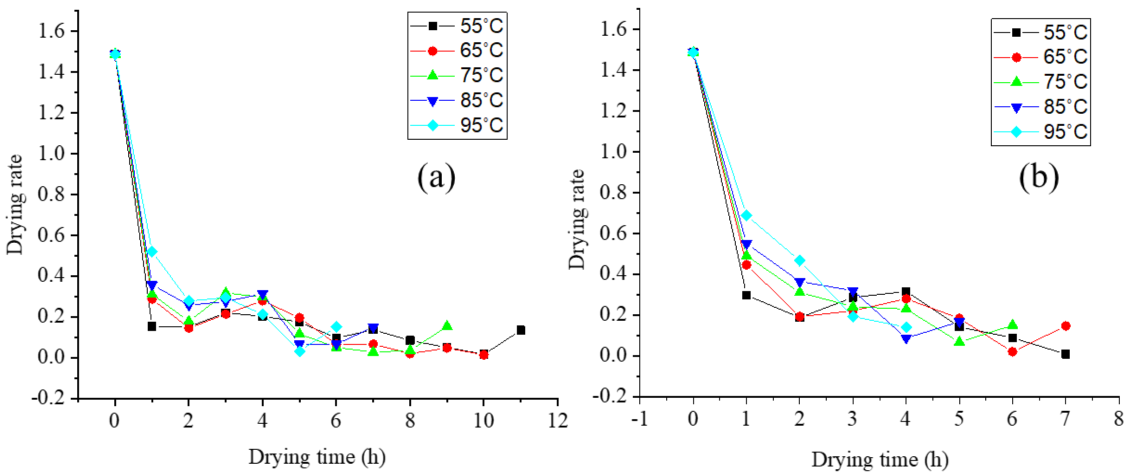

Figure 3: Effect of temperature on drying rate for (a) untreated and (b) treated mango slice samples.

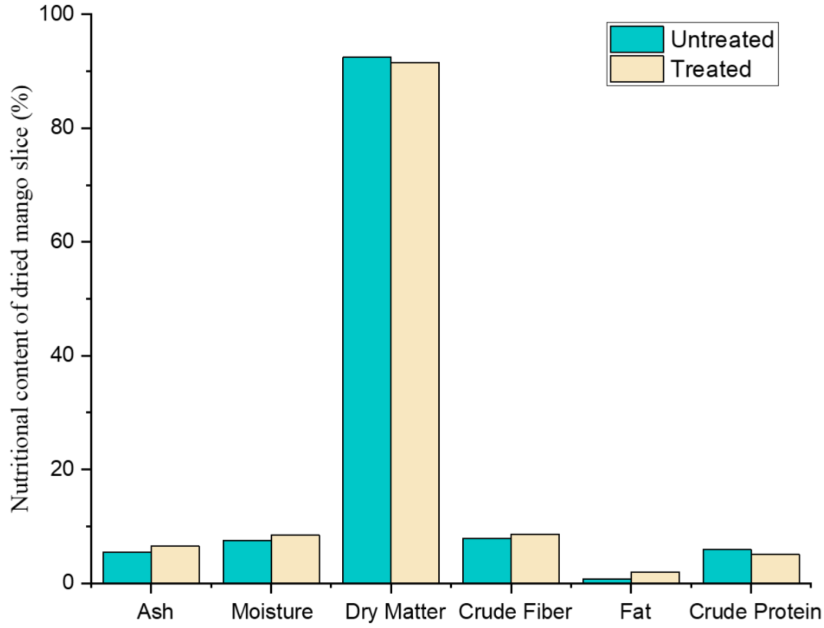

Figure 4: Nutritional content of untreated and treated mango slice samples

CONCLUSION

In conclusion, both the pre-treatment method and drying temperature play crucial roles in determining the quality and nutritional properties of dried mango slices. The drying curves and the quality of the dried product are influenced by characteristics such as drying time, moisture content, and temperature. While the highest temperature (95°C) results in the shortest drying time, increased heat exposure may negatively impact the product's quality. Nevertheless, prioritizing the nutritional quality of the food product is paramount. To minimize nutrient loss and preserve overall product quality, meticulous monitoring of temperature control, pretreatment, and drying duration is essential.

REFERENCES

Abbasi, A. M., Guo, X., Fu, X., Zhou, L., Chen, Y., Zhu, Y., & Liu, R. H. (2015). Comparative assessment of phenolic content and in vitro antioxidant capacity in the pulp and peel of mango cultivars.*International Journal of Molecular Sciences*, 16(6), 13507-13527.

Ademola, K. A., Adedokun, A., Joshua, A., & Olayinka, R. (2013). Effect of slice thickness and temperature on the drying kinetics of mango (*Mangifera indica). International Journal of Recent Research and Applied Studies*. 15.

Aditya, M., Akash, P., & Nanje Gowda, N. A. (2014). Mathematical modelling of thin-layer drying process of bamboo (*bambusa bambos*) shoots at varying temperature.*Research & Reviews: Journal of Botany*, 3(1).

Ahmed, M. W., Aziz, M. G., & Islam, M. N. (2018). Modeling of moisture adsorption isotherm of selected commercial flours of Bangladesh', *The Agriculturists*. 16, 35-42.

Ajila, C. M., & Prasada R. (2013). Mango peel dietary fibre: composition and associated bound phenolics. *Journal of Functional Foods*, 5(1), 444-450.

Akoy, E. O. (2014a). Effect of drying temperature on some quality attributes of mango slices. *International Journal of Innovation and Scientific Research*, 4(2), 91-99.

Akoy, E. O. (2014b). Experimental characterization and modeling of thin-layer drying of mango slices. *International Food Research Journal*, 21(5), 1197–1911.

Andrés, A., Fito, P., Heredia, A., & Rosa, E. M. (2007). Combined drying technologies for development of high-quality shelf-stable mango products. *Drying Technology*, 25(11), 1857-1866.

Barta, J. O., Balla, C. & Vatai, G. (2012).

Dehydration Preservation of Fruits. In N. K. Sinha, J. S. Sidhu, J. O. Barta, J. S. B. Wu, & M. P. Cano (Eds.), Handbook of Fruits and Fruit Processing A John Wiley & Sons, Ltd.

Bouba, A. A., Njintang, N. Y., Nkouam, G. B., Mang, Y. D., El-Sayed Mehanni, A. H., Scher, J., & Mbofung, C. M. (2014). Desorption isotherms, net isosteric heat and the effect of temperature and water activity on the antioxidant activity of two varieties of onion (*A llium cepa* L). *International Journal of Food Science & Technology*, 49(2), 444-452.

Doymaz, I. (2004). Drying kinetics of white mulberry. *Journal of Food Engineering*, 61(3), 341-346.

Ediriweera, M. K., Tennekoon, K. H., & Samarakoon, S. R. (2017). A review on ethno pharmacological applications, pharmacological activities, and bioactive compounds of *Mangifera indica* (Mango). *Evid Based Complement Alternat Med*.

Edom, S. (2023). How To Start A Lucrative Mango Farming Business In Nigeria and Africa: *The Complete Guide*.

Gámez, B. I., Caballero, M. K., Ledesma, N., Sáyago, A. S., García, M. M., Bishop, W. E. V., & Montalvo-González, E. (2017). Changes in the nutritional quality of five Mangifera species harvested in two-maturity stages.*Journal of the Science of Food and Agriculture*, 97(14).

Goyal, R. K., Kingsly, A. R. P., Manikantan, M. R., & Ilyas, S. M. (2006). Thin-layer drying kinetics of raw mango slices. *Biosystems Engineering*, 95(1), 43-49.

Izli, N., & Isik, E. (2015). Color and microstructure properties of tomatoes dried by microwave, convective, and microwave-convective methods. *International Journal of Food Properties*, 18(2), 241-249.

Kumar, P., Sagar, V. R., & Singh, R. R. (2014). Effect of different pre-treatments and drying methods on quality of dehydrated mango slices.*Journal of Food Science and Technology*, 51(9), 2517-2524.

Lauricella, M., Emanuele, S., Calvaruso, G., Giuliano, M., & D'Anneo, A. (2017). Multifaceted health benefits of mangifera indica l. (mango): the inestimable value of orchards recently planted in sicilian rural areas. *Nutrients*, 9(5).

Lebaka, V. R., Wee, Y.-J., Ye, W., & Korivi, M. (2021). Nutritional composition and bioactive compounds in three different parts of mango fruit.*International Journal of Environmental Research and Public Health*, 18(2), 741.

Lemmens, L., Tchuenche, E. S., Van Loey, A. M., & Hendrickx, M. E. (2013). Beta-carotene isomerisation in mango puree as influenced by thermal processing and high-pressure homogenization. *European Food Research and Technology*, 236(1), 155–163.

Maldonado-Celis, M. E., Yahia, E. M., Bedoya, R., Landázuri, P., Loango, N., Aguillón, J., & Guerrero Ospina, J. C. (2019). Chemical composition of mango (*Mangifera indicaL.*) fruit: nutritional and phytochemical compounds. *Frontiers in Plant Science*, 10:1073

Mohsenin, N. N. (1980). Physical properties of plant and animal materials. Gordon and Breach Science Publisher: New York-London-Paris.

Nyangena, I. O., Owino, W. O., Imathiu, S., & Ambuko, J. (2019). Effect of pretreatments prior to drying on antioxidant properties of dried mango slices. *Scientific African*, 6, e00148.

Onwuchekwa, O., Afiukwa, C. A., Onwe, O., Nwoba, E. G., Igwe, D. I., & Ogbu, K. I. (2019). Comparative evaluation of the proximate and amino acid composition of dried fruit pulps of mango *(Mangifera indica L.)* Accessions in Ebonyi State, Southeast Nigeria. *Journal of Biochemistry, Biotechnology and Allied Fields*, 4(2), 10-20.

Pala, M., Mahmutoglu, T., & Saygi, B. (1996). Effects of pre-treatments on the quality of open-air and solar dried products.*Nahrung/Food*, 40, 137-141.

Rasooli, S. V., Kaveh, M., Abdi, R., Szymanek, M., & Tanaś, W. (2021). Estimation of moisture ratio for apple drying by convective and microwave methods using artificial neural network modeling. *Scientific Reports*, 11(1), 9155.

Shyam, G., & Devina, A. (2012). Effect of solar drying on physico-chemical and antioxidant properties of mango, banan. papaya,*National Academy Science Letters*. 37(1), 51-57.

Singh, S., Kawade, S., Dhar, A., & Powar, S. (2022). Analysis of mango drying methods and effect of blanching process based on energy consumption, drying time using multi-criteria decision-making. *Cleaner Engineering and Technology*, 8, 100500.

Sunil, C. (2020). Drying and dehydration of fruits and vegetables. In T. Nadu (Ed.). Indian Institute of Food Processing Technology, Ministry of Food Processing Industries, Govt. of India Thanjavur: India.

Tran, T. N., Khoo, K. S., Chew, K. W., Phan, T. Q., Nguyen, H. S., Nguyen-Sy, T., & Show, P. L. (2020). Modelling drying kinetic of oyster mushroom dehydration-The optimization of drying conditions for dehydration of *Pleurotus* species. *Materials Science for Energy Technologies*, 3, 840-845.

Uranga-Soto, M. A., Vargas-Ortiz, M. A., León-Félix, J., Heredia, J. B., Muy-Rangel, M. D., Chevalier-Lucia, D., & Picart-Palmade, L. (2022). Comparison of the effect of hydrostatic and dynamic high-pressure processing on the enzymatic activity and physicochemical quality attributes ofmango nectar. *Molecules*, 27(4), 1190.