RUFORUM Working Document Series (ISSN 1607-9345), 2021, No. 19 (1):1063-1069.
Available from http://repository.ruforum.org

Research Application Summary

Role of cold plasma pre-treatment in enhancing the drying of 'Keitt' mango

Yanclo, L.A., [1,2,] Sigge, G.,[2] Belay, Z.A.,[1] October, F.,[3] Oluwafemi , J. C. [1,3*]

[1]Agri-Food Systems and Omics Laboratory, Post-Harvest and Agro-Processing Technologies (PHATs), Agricultural Research Council (ARC) Infruitec-Nietvoorbij, Private Bag X5026, Stellenbosch, 7599, South Africa
[2]Department of Food Science, Stellenbosch University, Private Bag X1, Stellenbosch 7600, South Africa
[3]Post-Harvest and Agro-Processing Technologies (PHATs), Agricultural Research Council (ARC) Infruitec-Nietvoorbij, Private Bag X5026, Stellenbosch, 7599, South Africa
[4]Faculty of Agronomic Science, University of Abomey-Calavi, Private Bag 01BP526, Abomey-Calavi, Benin Republic
***Correspondence Author:** calebo@arc.agric.za

Abstract

Mango (*Mangifera indica* L.) is a popular tropical fruit consumed throughout the world. However, when untreated before storage, the fruit undergoes progressive undesired changes, which result in postharvest losses. A management technique for reducing the above-mentioned undesired changes is to dehydrate the fruit by hot air drying, which reduces the water activity in the fruit, thereby avoiding the deteriorating process and extending the shelf life. Consequently, this study aimed to evaluate the influence of cold plasma pre-treatment prior hot air (at 60°C) drying on the drying kinetics of dried 'Keitt' mango slices. The drying was performed in a house-designed dehydrator with an airflow rate of 49.50 Hz. Results showed a continuous decrease in the moisture ratio of dried mango slices over drying time in all the samples until equilibrium after 10 hours. Results indicates that cold plasma has a promising potential for use as a pretreatment method in the drying of mango as it enhances the drying.

Keywords: Convective drying, dehydration, hot air, *Mangifera indica* L., moisture content

Résumé

La mangue (*Mangifera indica* L.) est un fruit tropical populaire consommé dans le monde entier. Cependant, lorsqu'il n'est pas traité avant le stockage, le fruit subit des modifications progressives indésirables, qui entraînent des pertes après récolte. Une technique de gestion pour réduire les changements indésirables mentionnés ci-dessus consiste à déshydrater les fruits par séchage à l'air chaud, ce qui réduit l'activité de l'eau dans les fruits, évitant ainsi le processus de détérioration et prolongeant la durée de conservation. Par conséquent, cette étude visait à évaluer l'influence du prétraitement au plasma froid avant le séchage à l'air chaud (à 60˚C) sur la cinétique de séchage des tranches de mangue séchées 'Keitt'. Le séchage a été effectué dans un déshydrateur dans une maison avec un débit d'air de 49,50 Hz. Les résultats ont montré une diminution continue du taux d'humidité des tranches de mangue séchées pendant le temps de séchage dans tous les échantillons

jusqu'à l'équilibre après 10 heures. Les résultats indiquent que le plasma froid a un potentiel prometteur pour une utilisation comme méthode de prétraitement dans le séchage de la mangue car il améliore le séchage.

Mots clés : Séchage convectif, déshydratation, air chaud, Mangifera indica L., teneur en eau

Introduction

Mango (*Mangifera indica* L.) is a tropical and subtropical fruit belonging to the Anarcadiaceae family and is native from southern Asia. Mango fruit has been reported to promote health benefits due to its high content of antioxidant (Sivakumar *et al.,* 2011), phytochemicals (Wall-Medrano *et al.,* 2020) and vitamins (Sogi *et al.,* 2012). The fruit contains 80% water, which makes it very perishable and subjected to dehydration, change in colour and spoilage (Baldwin *et al.,* 1999). Due to its short shelf life, fresh mango fruit consumption is limited as it can spoil within 2-10 days after harvest when stored at ambient temperature (Singh and Zaharah, 2011). Mango fruit loss is approximately 40-50% in developing countries, including South Africa (Kitinoja and Alhassan, 2012). Since mango value increases during off-season, its drying can possibly solve the challenge of post-harvest losses.

Drying is an efficient preservation technique, which can be used to improve mango fruit market value and remove its water content (Aghabashlo *et al.,* 2013). Hot air drying is a process involving heat and mass transfer. During drying, water is transferred by diffusion, from inside the food material to the air-food interface and from the air-food interface to the outside air, simultaneously, by convection (Demiray and Tulek, 2014). Additionally, drying removes moisture from the fruit up to certain threshold value, which prohibits the growth of microorganisms (Ozkan *et al.,* 2007). Drying preserves the flavour and nutritional value of fruit when the moisture content is reduced between 10% and 20% (Dennis, 1999).

Pre-treatment is a widely used method prior drying of agri-products aiming to enhance the drying process and the quality of the dried products (Marfil *et al.,* 2008; Workneh *et al., 2*014). Exposure of cut mango fruit to air leads to darkening hence the use of pretreatments are recommended to prevent the darkening, the non-enzymatic reaction and the oxidation of ascorbic acid, which lead to the browning of fruit (Sivasankar, 2009). Hence, the importance of exploring an effective pre-treatment method for mango slices to improve its drying rate.

Cold plasma is a non-thermal process characterized by energetic reactive gases and is used in the food industry as an alternative method to traditional food preservation (Segura-Ponce *et al.,* 2018). The diffusion of the reactive species generated by cold plasma onto the surface of food product results in physical and chemical modification. Researchers have explored the use of cold plasma as pre-treatment on the drying of chilli pepper and jujube slices and found that the drying rate was improved (Zhang *et al.,* 2019; Bao *et al.,* 2021).

Therefore, the aim of the present study was to evaluate the role of cold plasma pretreatment on the drying of 'Keitt' mango.

Materials and methods

Sample collection. Fresh fully ripe 'Tommy Atkins' mango fruit were obtained at commercial maturity stage from the local shop (-33º92′37.804″S, 18º87′45.250″E) in Western Cape, South Africa, and transported to the Agricultural Research Council (ARC) Infruitec-Nietvoorbij, Agro-Processing Pilot Plant, Stellenbosch, South Africa. Fruit of similar colour and size were sorted for visual defects. Fruit were washed in tap water, peeled with a sharp sterile stainless steel knife, and cut into approximately 8 mm-thick (six) slices.

Methods

Cold plasma treatment and drying procedure. Mango drying experiments were carried out in an in-house designed dehydrator tunnel (assembled in Western Cape, Stellenbosch South Africa) at the ARC Agro-Processing Pilot Plant infruitec laboratory using constant air temperature of 60°C and airflow rate of 49.50 Hz, 35% RH. Fruit weight was hourly monitored during 10 h using a laboratory scale (Labotech Precision Toploader, China). The drying experiments were performed six times for each sample and the average data was calculated. All dried samples were cooled to room temperature for 15 minutes (Zhang *et al.,* 2019) and packed in airtight glass containers.

Moisture ratio and drying rate. In dry base, the moisture content can be calculated by using the different masses obtained after weighing. Therefore, the moisture ratio (MR) was calculated using the following equation (1):

$$Moisture\ Ratio = \frac{M(t)}{M_i} \quad (1)$$

Where M (t) and Mi represent mass of fruit respectively at instant t and initial instant (kg).

Equation (1) was used to determinate the moisture ratio during this experiment. The experiment was stopped after 10 h of drying, and the moisture content used for drawing kinetics were the mean values of moisture content of six replications.

The drying rate was calculated from the experimental moisture loss data using following equation:

$$Drying\ rate = \frac{M}{M_O} \quad (2)$$

Where M is the moisture content at a specific time expressed on dry weight basis (kg water kg db 1), Mo is the initial moisture content (kg water kg db 1).

Statistical analyses. Analysis of variance (ANOVA) was carried out using Statistica software (Statistica13.5.0.17 TIBCO, StatSoft Inc., Tulsa, OK, USA). The mean values were tested using Fisher's LSD test at a level of significance of 95%. The data obtained were presented as means ± standard error.

Results and discussion

Moisture content profiles of 'Keitt' mango fruit. The moisture ratio profiles of the drying of fresh 'Keitt' mango at 60°C versus drying time with different pre-treatment conditions were presented in Figure 1. The moisture of mango fruit was significantly ($p < 0.05$) influenced by the pre-treatments and the drying duration. As shown in Figure 1, moisture ratio of mango samples decreased continuously over drying time from 0 to 9 h in all the samples treated with cold plasma 5 min (from 9.94 to 3.06% d.b.), cold plasma 10 min (from 10.86 to 2.76% d.b.) and from 0 to 10h the untreated (control) sample (from 7.9 to 2.12% d.b.). This implies that cold plasma treatment accelerates the drying rate of mango samples to a certain extent. Similar patterns were observed with jujube slice where cold plasma pretreatment for a short period before drying caused evaporation of water thus accelerating the drying Bao *et al*. (2021). During the drying process, the heat was transferred from the surface of mango slices towards the inner part of the fruit, which increased the vapor pressure. Furthermore, water molecules were migrated towards the surface of the mango slices causing the decline observed in the moisture ratio of treated and untreated samples. In summary, the moisture ratio of dehydrated 'Keitt' mango slices at 60ºC within 10 h decreased continuously due to the evaporation of moisture from the surface of the sample during convective drying.

Drying rate. Figure 2 represents the drying rate versus moisture content of 'Keitt' mango slices untreated and pre-treated with cold plasma pretreatments at the drying temperatures of 60°C. The drying rate showed a rapid increase from 0 to 3 h in all samples treated with cold plasma 5 min (from 1 to 0.56 g/h), cold plasma 10 min (from 1 to 0.50 g/h) and the untreated (control) sample (from 1 to 0.56 g/h). From 2h to 9h, the drying rate showed a continuous decrease as the time period progresses in samples treated with cold plasma 5 min (from 1 to 0.31 g/h), cold plasma 10 min (from 1 to 0.25 g/h) and 2-10h for the untreated (control) sample (from 1 to 0.27 g/h). Cold plasma pre-treatments used prior to drying were found to slowly increase the drying rate

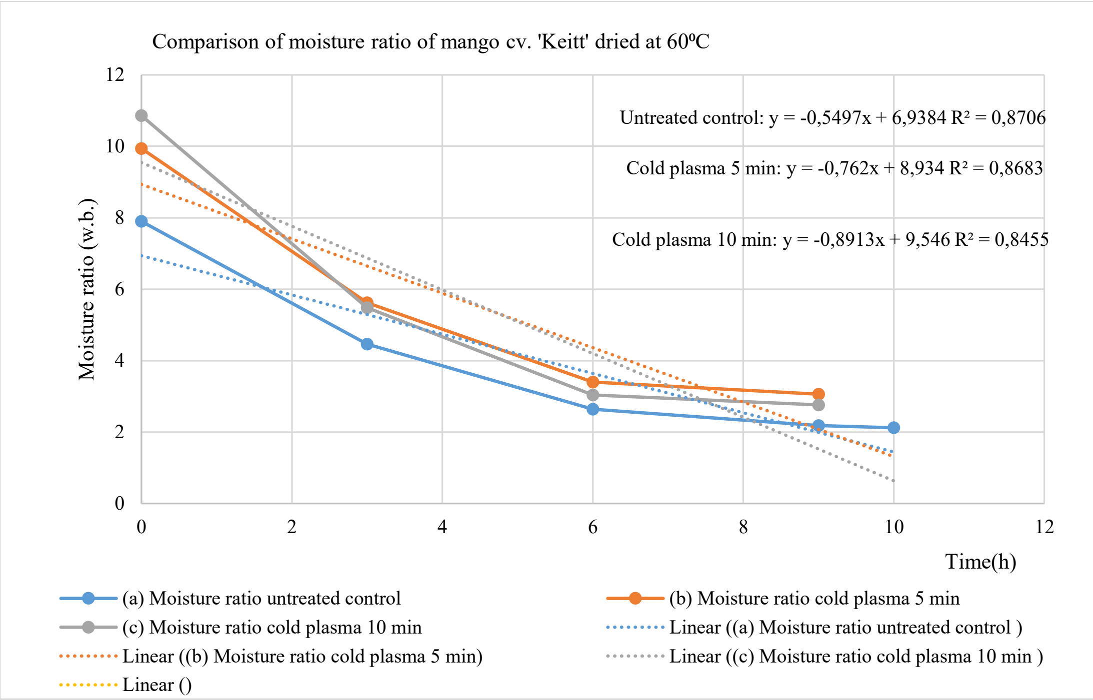

Figure 1. Combined moisture ratio of untreated control mangoes cv. 'Keitt' and pre-treated with cold plasma for 5 minutes, 10 minutes and dehydrated at 60°C

of mango slices when compared to the untreated (control) samples. Similar results have been shown in earlier studies for drying of jujube slices pretreated with cold plasma for 15 s on each side and dried at 60 C (Bao *et al.,* 2021). Previous authors such as Zhao *et al.* (2019) attributed the changes in drying rate to the internal moisture diffusion efficiency. Furthermore, Zhang *et al.* (2019) observed that chili pepper pretreated with cold plasma prior drying, dried faster than the untreated ones. This was explained by the micro-holes generated by the reactive species produced during the application of cold plasma treatment, which facilitate moisture transfer during drying process. Moreover, Bao *et al.* (2021) reported that cold plasma pretreatment of jujube fruit prior drying leads to a change in the surface microstructure. In conclusion, these results point out that pretreatments have a slight effect on the drying rate of 'Keitt' mango slices.

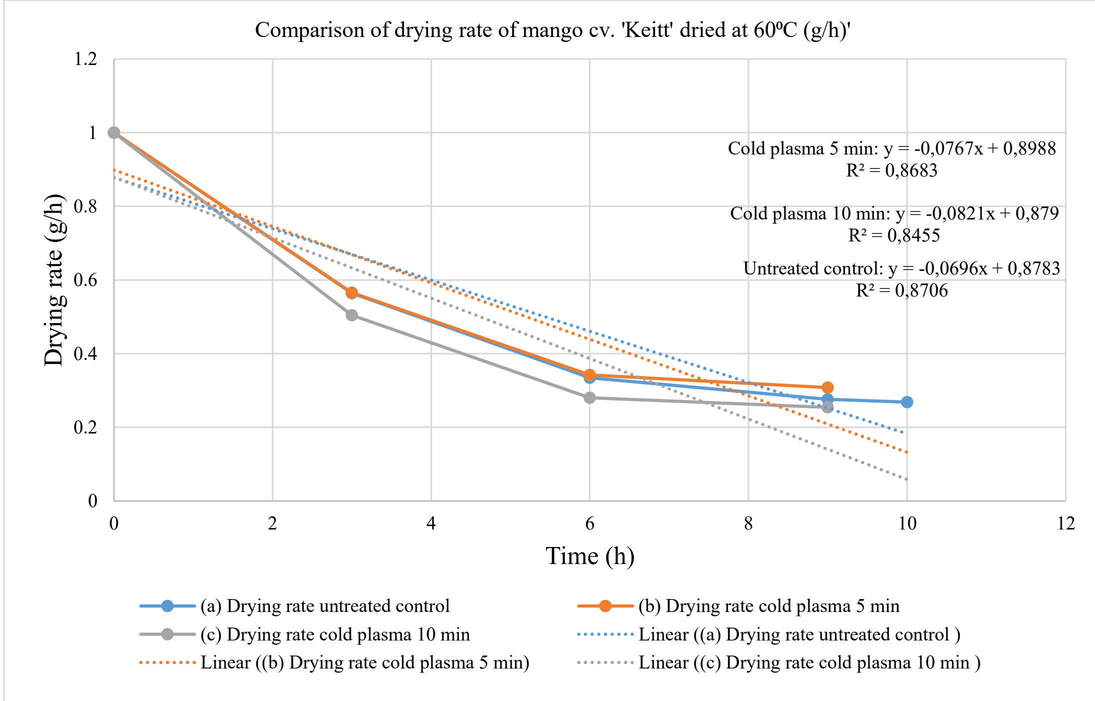

Figure 2. Combined drying rate of untreated control mangoes cv. 'Keitt' and pre-treated with cold plasma for 5 minutes, 10 minutes and dehydrated at 60°C

Conclusion

Mango slices cv. 'Keitt' were pretreated with cold plasma and dehydrated with hot air at 60°C and the moisture content of the slices were evaluated during the drying processes. Cold plasma is efficient in enhancing the drying rate of mango slices cv. 'Keitt' during hot air drying at 60°C. The results of this study showed that cold plasma treatment has potential for use as a pretreatment method in the drying of mango.

Acknowledgements

This work is based upon research supported by the Agriculture Research Council (ARC) and National Research Foundation (NRF), South Africa (Grant Nos.: 116272 and 119192) awarded to

Dr. O.J. Caleb. The award of PhD Fellowship by the Organisation for Women in Science for the Developing World (OWSD) to Ms L.A. Yanclo is gratefully acknowledged. The research support provided by Mr. George Dico, ARC Infruitec-Nietvoorbij is gratefully acknowledged. This paper is a contribution to the Seventh Africa Higher Education Week and RUFORUM Triennial Conference held 6-10 December 2021 in Cotonou, Benin.

References

Aghbashlo, M., Mobli, H., Rafiee, S. and Madadlou, A. 2013. A review on exergy analysis of drying processes and systems. *Renewable and Sustainable Energy Reviews* 22: 1-22.

Baldwin, E. A., Burns, J. K., Kazokas, W., Brecht, J. K., Hagenmaier, R. D., Bender, R. J. and Pesis, E. D. N. A. 1999. Effect of two edible coatings with different permeability characteristics on mango (*Mangifera indica* L.) ripening during storage. Postharvest Biology and Technology, 17(3): 215-226.

Bao, T., Hao, X., Shishir, M. R. I., Karim, N. and Chen, W. 2021. Cold plasma: An emerging pretreatment technology for the drying of jujube slices. *Food Chemistry* 337: 127783.

Demiray, E. and Tulek, Y. 2014. Drying characteristics of garlic (*Allium sativum* L) slices in a convective hot air dryer. *Heat and Mass Transfer* 50 (6): 779-786.

Dennis, S. 1999. Improving solar food dryers; Extracted from Home Power Magazine. 24-34

Kitinoja, L. and AlHassan, H. Y. 2010. Identification of appropriate postharvest technologies for small scale horticultural farmers and marketers in Sub-Saharan Africa and South Asia-Part 1. Postharvest losses and quality assessments. pp. 31-40. In: XXVIII International Horticultural Congress on Science and Horticulture for People (IHC2010): International Symposium on 934.

Marfil, P. H. M., Santos, E. M. and Telis, V. R. N. 2008. Ascorbic acid degradation kinetics in tomatoes at different drying conditions. *LWT-Food Science and Technology* 41 (9): 1642-1647.

Ozkan, I. A., Akbudak, B. and Akbudak, N. 2007. Microwave drying characteristics of spinach. *Journal of Food Engineering* 78 (2): 577-583.

Segura-Ponce, L.A., Reyes, J.E., Troncoso-Contreras, G. and Valenzuela-Tapia, G. 2018. Effect of low-pressure cold plasma (LPCP) on the wettability and the inactivation of *Escherichia coli* and *Listeria innocua* on fresh-cut apple (Granny Smith) skin. *Food and Bioprocess Technology* 11: 1075-1086.

Singh, Z. and Zaharah, S. S. 2011. Controlled atmosphere storage of mango fruit: challenges and thrusts and its implications in international mango trade. pp. 179-191. In: Global Conference on Augmenting Production and Utilization of Mango: Biotic and Abiotic Stresses 1066.

Sivakumar, D., Jiang, Y. and Yahia, E. M. 2011. Maintaining mango (*Mangifera indica* L.) fruit quality during the export chain. *Food Research International* 44 (5): 1254-1263.

Sivasankar, B. 2009. Food processing and preservation. 1st Edition. PHI Learnig Private Limited, New Delhi, India.

Sogi, D. S., Siddiq, M., Roidoung, S. and Dolan, K. D. 2012. Total phenolics, carotenoids, ascorbic acid, and antioxidant properties of fresh-cut mango (*Mangifera indica* L., cv. Tommy Atkin) as affected by infrared heat treatment. *Journal of Food Science* 77 (11): C1197-C1202.

Wall-Medrano, A., Olivas-Aguirre, F. J., Ayala-Zavala, J. F., Domínguez-Avila, J. A., Gonzalez-Aguilar, G. A., Herrera-Cazares, L. A. and Gaytan-Martinez, M. 2020. Health benefits of mango by-products. Food Wastes and By-products: *Nutraceutical and Health Potential* 159-191.

Workneh, T. S., Zinash, A. and Woldetsadik, K. 2014. Blanching, salting and sun drying of different pumpkin fruit slices. *Journal of Food Science and Technology* 51 (11): 3114-3123.

Zhang, X. L., Zhong, C. S., Mujumdar, A. S., Yang, X. H., Deng, L. Z., Wang, J. and Xiao, H. W. 2019. Cold plasma pretreatment enhances drying kinetics and quality attributes of chili pepper (*Capsicum annuum* L.). *Journal of Food Engineering* 241: 51-57.