THE EFFECT OF INTERMITTENT DRYING ON DRYING KINETICS AND QUALITY CHANGE DYNAMICS OF ORGANIC CARROT (*DAUCUS CAROTA* V. *LAGUNA*)

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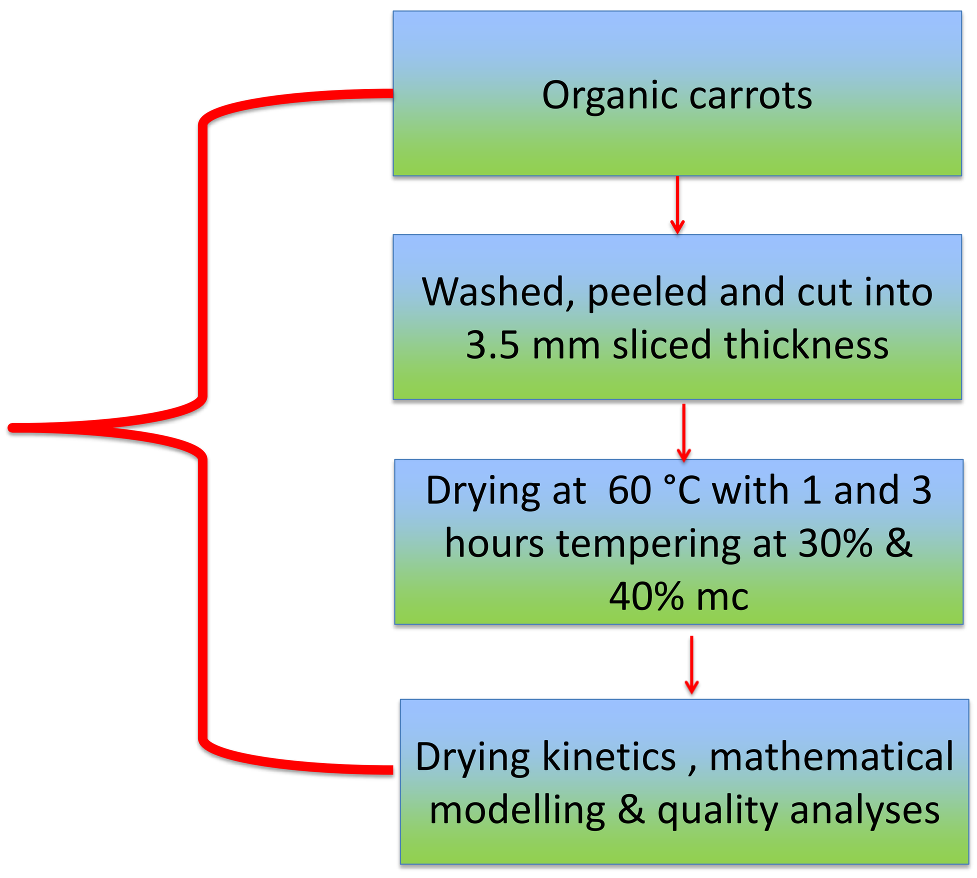
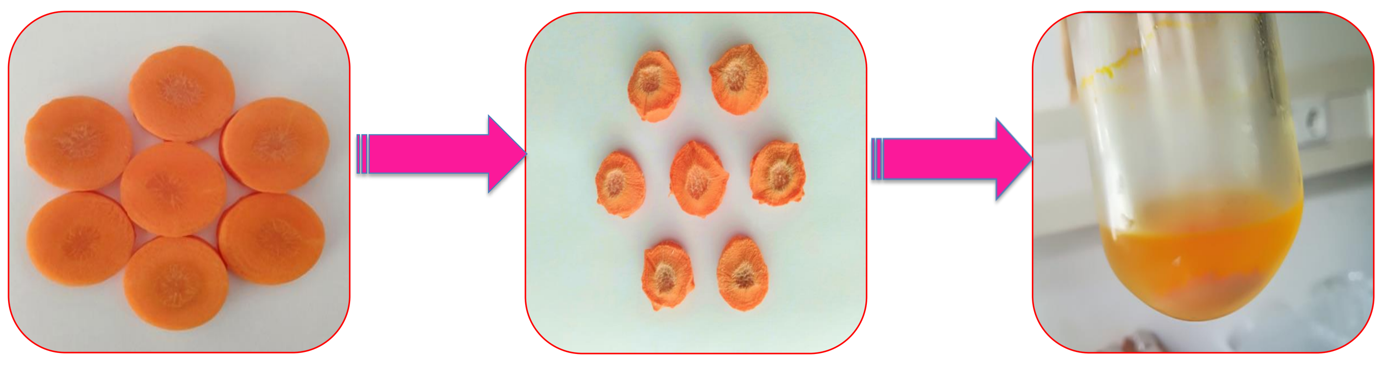
INTRODUCTION

Convective drying with continuous heat supply is the most common drying technique due to its easy application and available technology globally. However, there is a growing trend to combine different drying technique according to product characteristics in order to minimize energy consumption and to preserve product quality [1] [2]. One strategy is the application of intermittent drying which involves a resting period or tempering during the drying process which includes pulsating of the three main process parameters: heat input, chamber pressure and air velocity as heat is applied discontinuously [3]. The technique has shown a positive response towards preserving the active ingredients in agricultural crops [4] [5]. So, based on this, the intermittent drying technique was tested as measures to determine its effect on drying kinetic, dynamic quality changes and moisture diffusivity of organic carrot in a convective cabinet dryer at 60°C with 1 and 3 hours tempering period. Tempering was performed at 30% and 40% moisture level. The temperature and moisture levels were chosen due to the fact that the highest retention of total carotenoids was observed at 60 °C which is based on our previous study [6] . We also found that, rapid deterioration of total carotenoids was observed between 40% to 30% moisture levels which indicates that the critical degradation lies in this area at which point appropriate process and parameters setting need to be controlled.

MATERIALS & METHOD





RESULTS & DISCUSSION

The results show that tempering for 1 and 3 hours at 40% and 30% moisture content shortened the effective drying time by 18.2 % to 24.5% in comparison to the control (Figure 1 and Table 1). A decrease in effective drying time is the result of rapid moisture removal from the surface of the material to the environment due to the tempering period. Tempering period during the drying process allows sufficient time for the moisture to diffuse from the interior to the surface of the material when no heat is supplied and consequently resulting in better moisture distribution within the sample and finally leading to a shorter drying time as compared with continuous drying [7]. It was also observed that, the slopes of the drying curves reduce with time which indicated that the drying process was fully within the falling rate period. The displayed graph in Figure 1 also showed that, the moisture ratio starts to level off after 180 minutes of drying and onwards for all treatments. Tempering at 40% moisture level had shown longer drying time as compared with 30% moisture level (Table 1). This is because the samples contain slightly higher moisture content initially at the beginning of the tempering period so more time is needed to remove the extra moisture to the desired moisture content. The effective moisture diffusivity as in Table 1 was increased for all tempering treatment as compared with continuous drying.

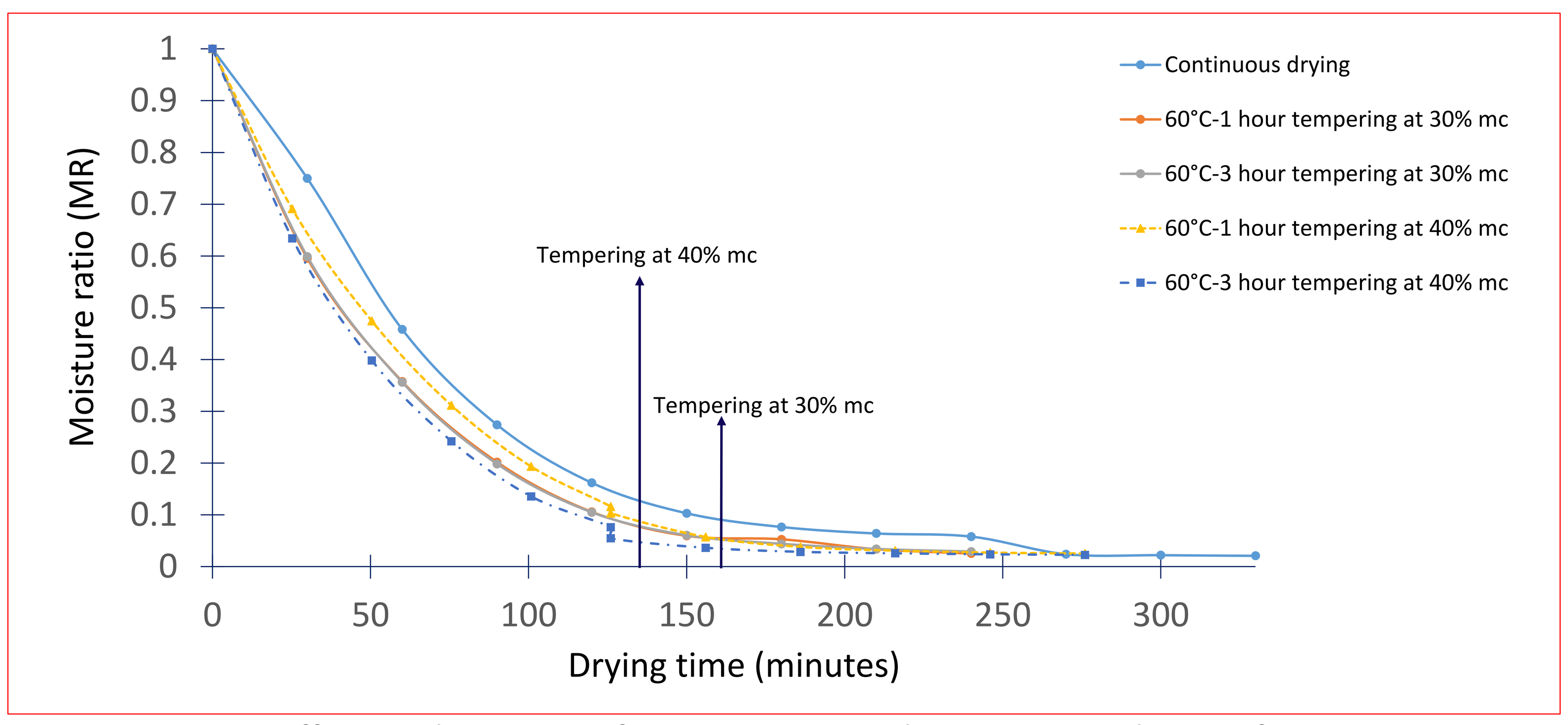


Fig.1. Effective drying time for continuous and intermittent drying of carrots.

Table 1 : Moisture diffusivity and effective drying time during intermittent drying of organic carrot.

Drying treatment	Moisture diffusivity (m^2/s)	Effective drying time (min)
60°C-continuous drying	3.247×10^{-10}	330
60°C-1 hour tempering at 30% mc	3.909×10^{-10}	246
60°C-3 hour tempering at 30% mc	3.909×10^{-10}	246
60°C-1 hour tempering at 40% mc	3.516×10^{-10}	270
60°C-3 hour tempering at 40% mc	4.219×10^{-10}	270

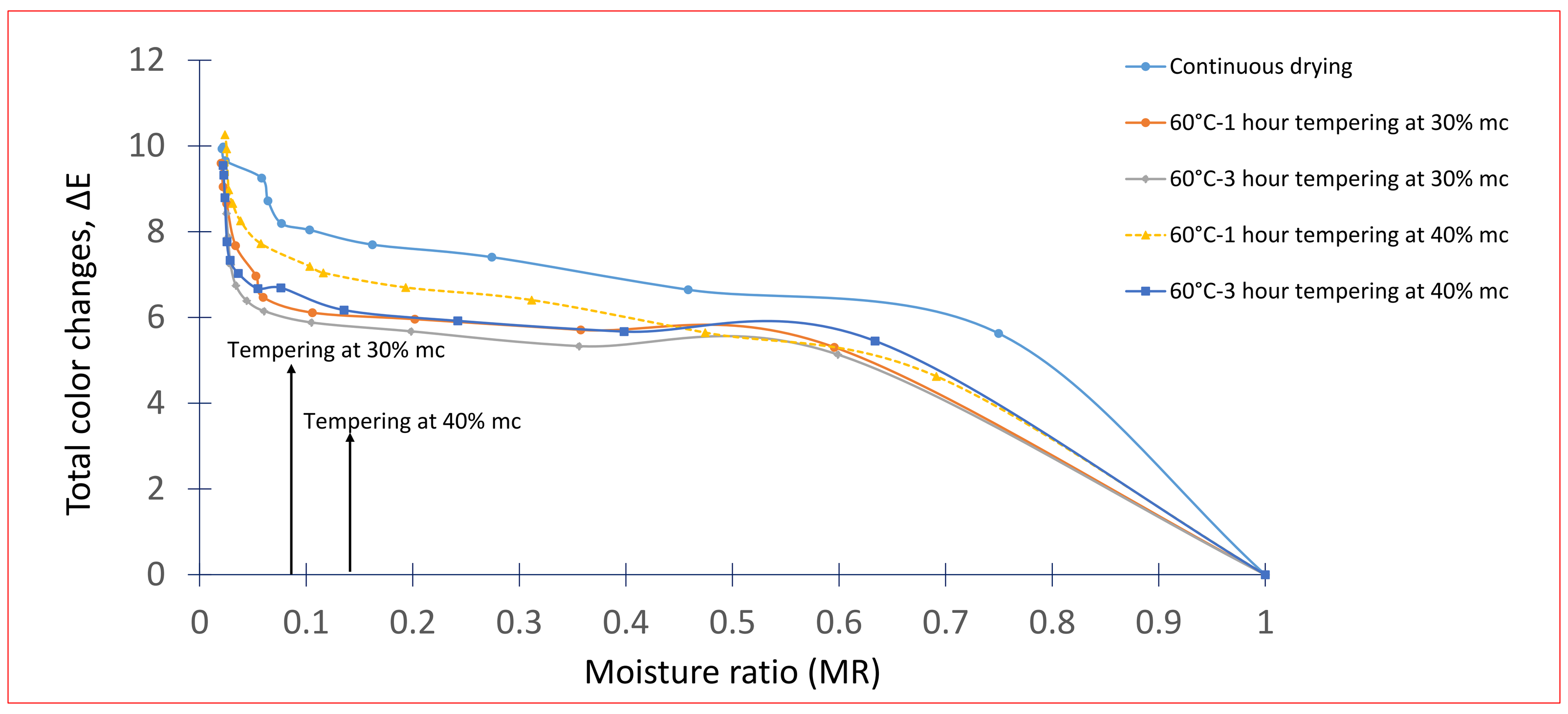


Fig. 2. Total color changes (ΔE) of carrot during continuous and intermittent drying.

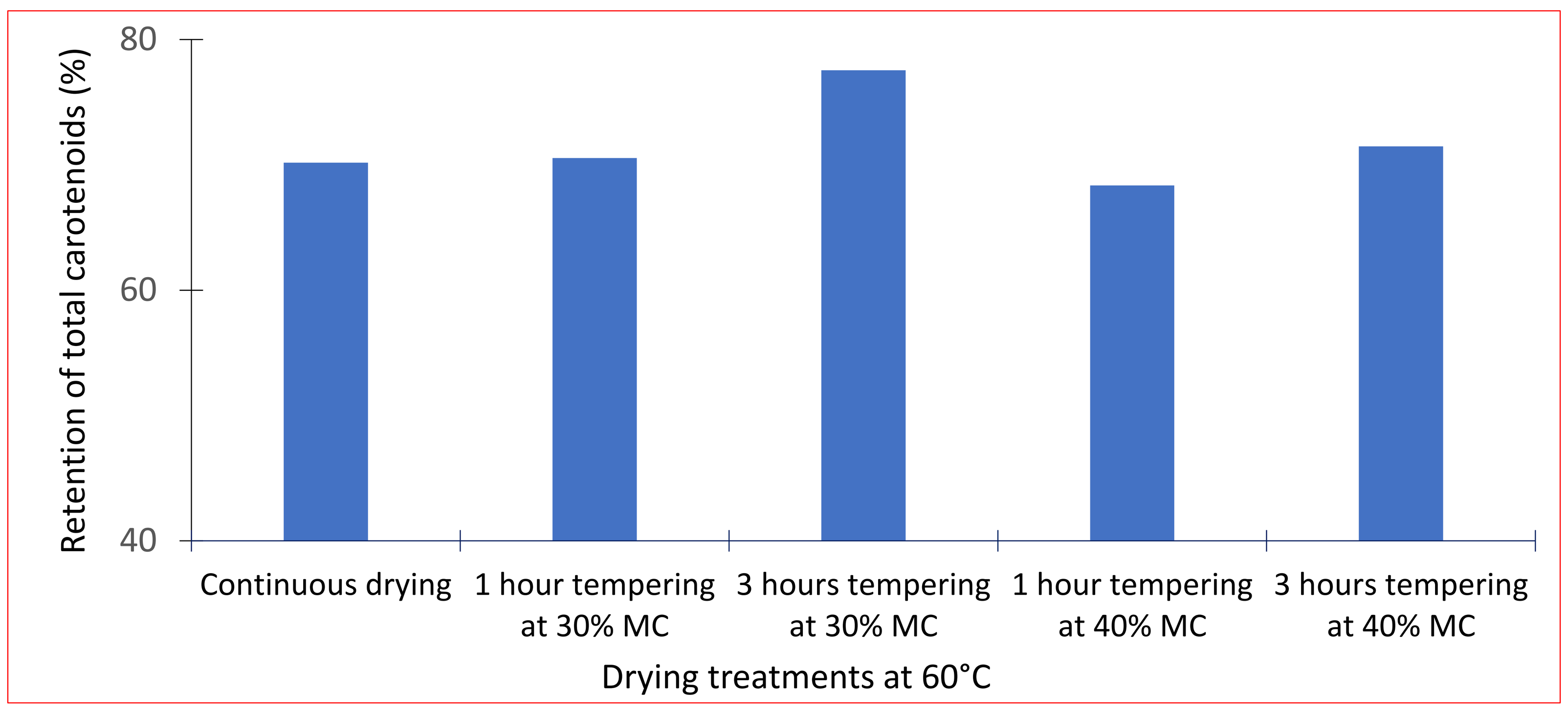


Fig.3. Retention of total carotenoids of carrot during continuous and intermittent drying

High retention of total carotenoids at 78% with minimal color changes at 8.4 (Figure 2 and 3) can be obtained when tempering for 3 hours at 30% moisture content (wb) due to shorter effective drying time that could reduce the exposure time to hot air and consequently minimise the degradation of total carotenoid with better color retention. Tempering for 1 hours had shown almost no significant effect on total carotenoids retention for both moisture levels because shorter tempering time is not sufficient to allow moisture migration towards the surface and finally leading to deterioration of total carotenoids. It was documented that, sufficient layer of water on the surface will preserve total carotenoids from heat damage and consequently minimize the degradation [8].

CONCLUSION

The study indicates that, intermittent drying with tempering is promising due to reduced drying times and increased quality retention for convective drying of organic carrots. Further research needs to be focused on dynamic changes of product quality throughout the process since changes in process settings at significant points will help to increase the retention of valuable components leading to high quality product for consumers. Moreover better process control can be developed and improved for industrial application in the future.

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REFERENCES

[1] Ramallo, L. A., Lovera, N. N., & Schmalko, M. E., 2010, Effect of the application of intermittent drying on Ilex paraguariensis quality and drying kinetics. *Journal of Food Engineering*, *97*(2), 188-193.
[2] Menshutina, N.V., Gordienko, A.A., Voynovsky, M.G. and Kudra, T., 2004, Dynamic analysis of drying energy consumption. *Drying Technology*, 22, 2281-2290.
[3] Chua, K.J., Mujumdar, A.S. and Chou, S.K., 2003, Intermittent drying of bioproducts-an overview. *Bioresource Technology,* 90, 285-295.
[4] Lekcharoenkul, P., Tanongkankit, Y., Chiewchan, N., and Devahastin, S., 2014, Enhancement of sulphoraphane content in cabbage outer leaves using hybrid drying technique and stepwise change of drying temperature.*Journal of Food Engineering*, 122, 56-61.
[5] Hii, C.L., Law, C.L. and Law, M.C., 2013, Simulation of heat and mass transfer of cocoa beans under stepwise drying conditions in a heat pump dryer. *Applied Thermal Engineering*, 54, 264-271.
[6] Md Saleh, R., Kulig, B., Hensel, O. And Sturm, B., 2019, Investigation of dynamic quality changes and optimization of drying parameters of carrot. Journal of Food Process Engineering (under review).
[7] Jumah, R., Al-Kteimat, E., Al-Hamad, A., & Telfah, E., 2007, Constant and intermittent drying characteristics of olive cake. *Drying Technology*, *25*(9), 1421-1426.
[8] Ramakrishnan, T. V., & Francis, F. J.,1979, Stability of carotenoids in model aqueous systems 1. *Journal of Food Quality*, *2*(3), 177-189.