Convective drying of cherry tomato: Study of skin effect

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1. Introduction

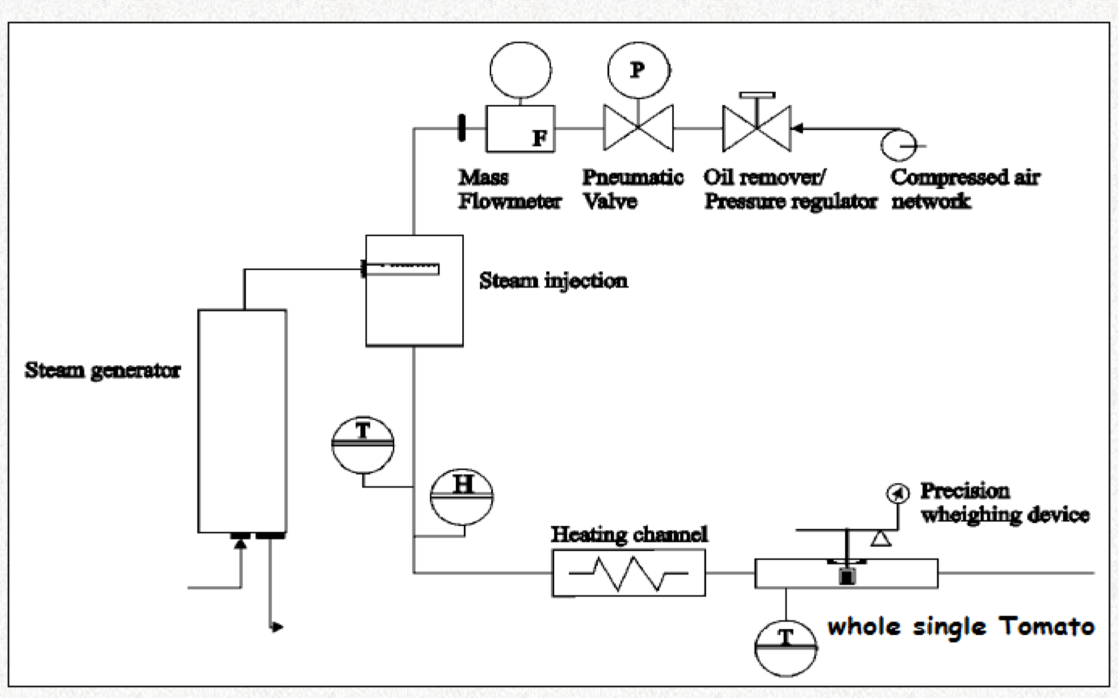
The cherry tomato (L. Esculentum var. Cerasiforme) is considered to be an ancestral variety of tomato, based on the fact that both its size and its shape (2 to 2.5 cm in diameter) are intermediary between wild and domesticated tomatoes. (Heredia & Andrés, 2008). The nutritional and healthy properties of certain tomato components, such as lycopene, make it interesting to use osmotic dehydration to obtain stable products that maintain their quality attributes and improve sensorial acceptability (Heredia & Andrés, 2008).

This study is focused on the drying of cherry tomato, in order to put in evidence the influence of the skin on water removal. X-ray microtomography is proposed as an advanced characterization tool to investigate the evolution of size, shape and texture of soft materials during drying operation. To our knowledge, it seems that no study relating to the skin effect during drying of fruits was done until now.

2. Materials

The micro-dryer

Drying experiments are carried out in a micro-dryer specially designed for handling small individual samples. The micro drier unit is described in Figure 1. It is composed of two parts: the air conditioning and feeding system and the drying chamber. The tomato is put in the drying chamber on a supporting grid linked underneath to a precision weighing device (BP 150 from Sartorius, Germany; accuracy: 0.001 g). The sample surroundings are such that drying can occur on the whole external surface. The weighing device is connected to a PC that records the mass every one second. The results reported in this paper have been obtained at a constant speed of 0.42 m/s, with air at ambient humidity without any vapour addition and three drying temperature (50, 60, 70°C).



The X-ray tomographic device

The X-ray tomographic device is a ‘‘Skyscan-1172 X-ray scanner’’ (Skyscan, Belgium). The X-ray source operates at 100 kV and 250 mA. The detector is a 3D, 4000×2300 pixels, 12-bit CCD camera with a spatial resolution of from 34 to 2-3 µm. The sample can be either rotated in a horizontal plane or moved vertically in order to get scans at different vertical positions. The acquisition protocol was defined in order to scan the whole tomato sample and to characterize its 3D structure.

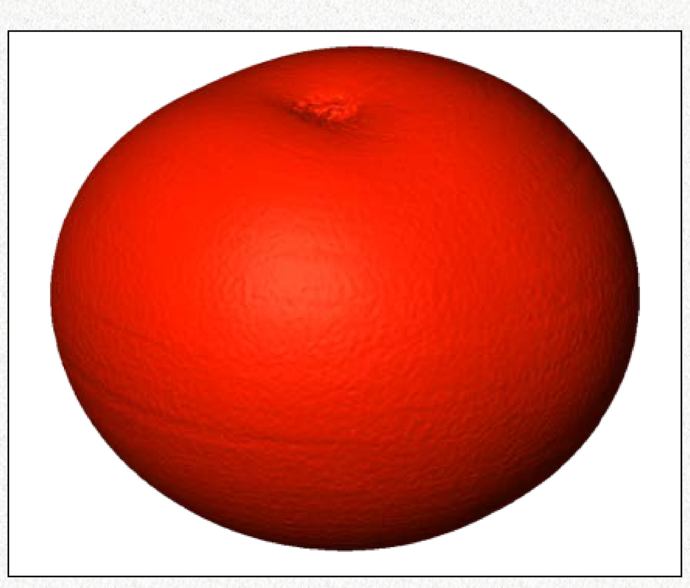


Fig. 2a - Tomato before drying

Fig. 2b – Tomato after drying

Figures 2a and 2b show the significant variation of volume between the beginning and the end of drying, obtained after 3D reconstruction of images obtained by microtomography. Shrinkage curves are determined from these 3D images by calculated the volume at increasing drying times.

3. Results and discussion

Figure 3 shows the drying curves $X/X_0 = f(t)$.The effect of the temperature on the kinetics is very clear: drying time is shorter by increasing this parameter but it is much shorter if the skin of the fruit is removed.
In the case with skin, the drying time of cherry tomato, at 50°C, is 305 h whereas it is 157 hours with 70°C (the half); On the other hand, in the case without skin, for the same temperatures, drying times are of 27 h and 18 h respectively.

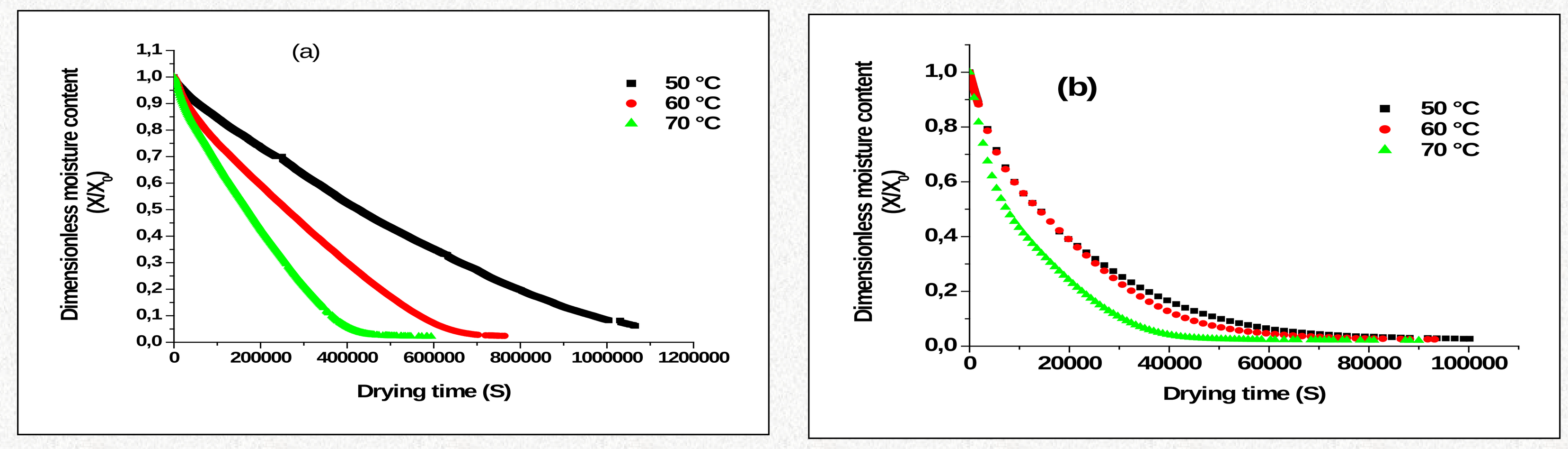
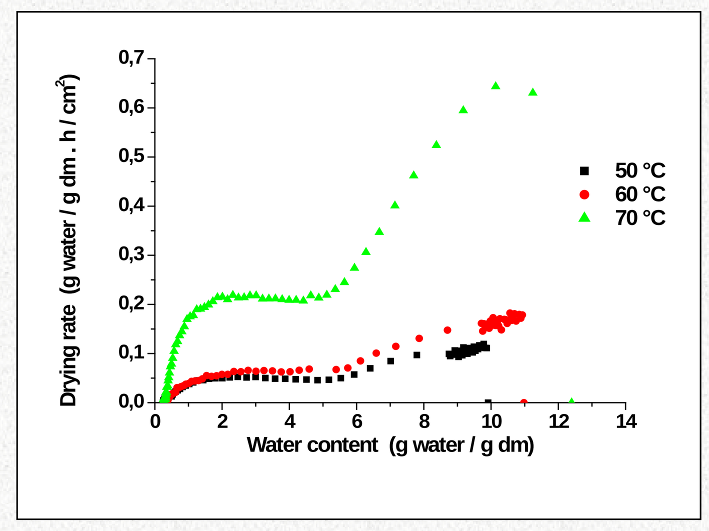
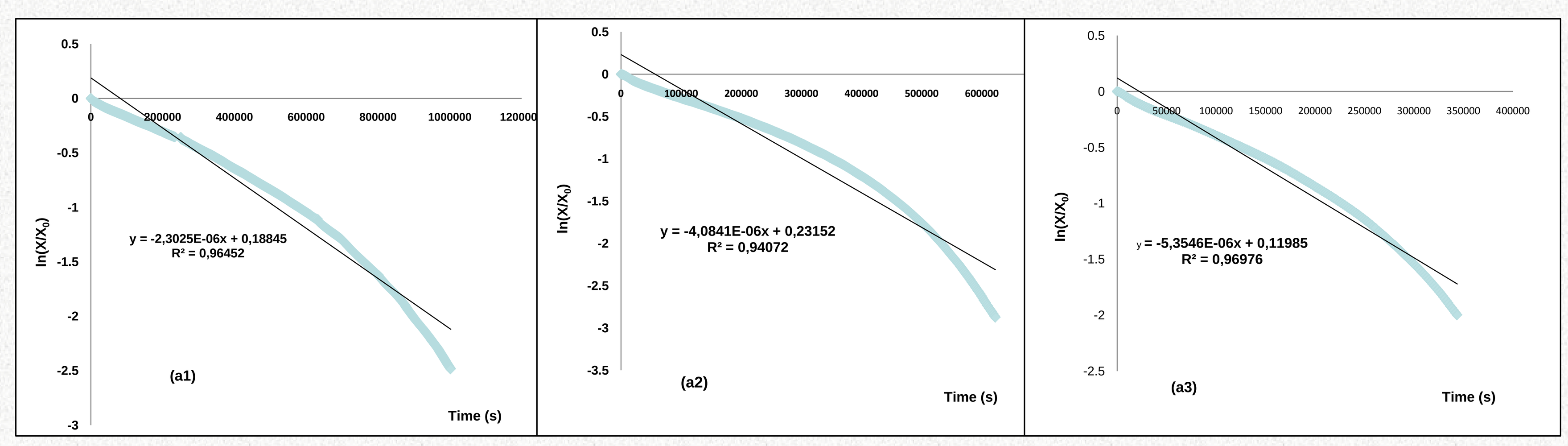


Fig. 3. Drying curves during drying (a): With skin, (b): Without skin



On Figure 4, the temperature effect can also be clearly observed, especially between 60 and 70°C, with higher drying rates throughout the drying process. This figure also show a very short adaptation phase followed by a dominant falling drying rate phase which seems to be divided into 3 sub-periods.

Fig. 4. Drying kinetics during cherry tomato convective drying Without skin



The plots of the experimental results as $\ln(X/X_0)$ vs. time are shown in Figure 5 Crank (1975) analytical solution, with introduction of sample shrinkage, is used to determine the mass transfer diffusion coefficient. The values obtained at the different temperatures are summarized in table 1.

The diffusion coefficient is determined under Arrhenius form permitting the calculus of the activation energy, E (Eq.). D_0 is a constant, T the temperature and R the perfect gas constant = 8.314 J/ K.mol:

$$D_{eff} = D_0 \exp\left(-E / RT\right)$$

The constant D_0 and Activation energy (E), for the two cases with and without skin, are deduced and the results are shown in Table 2.

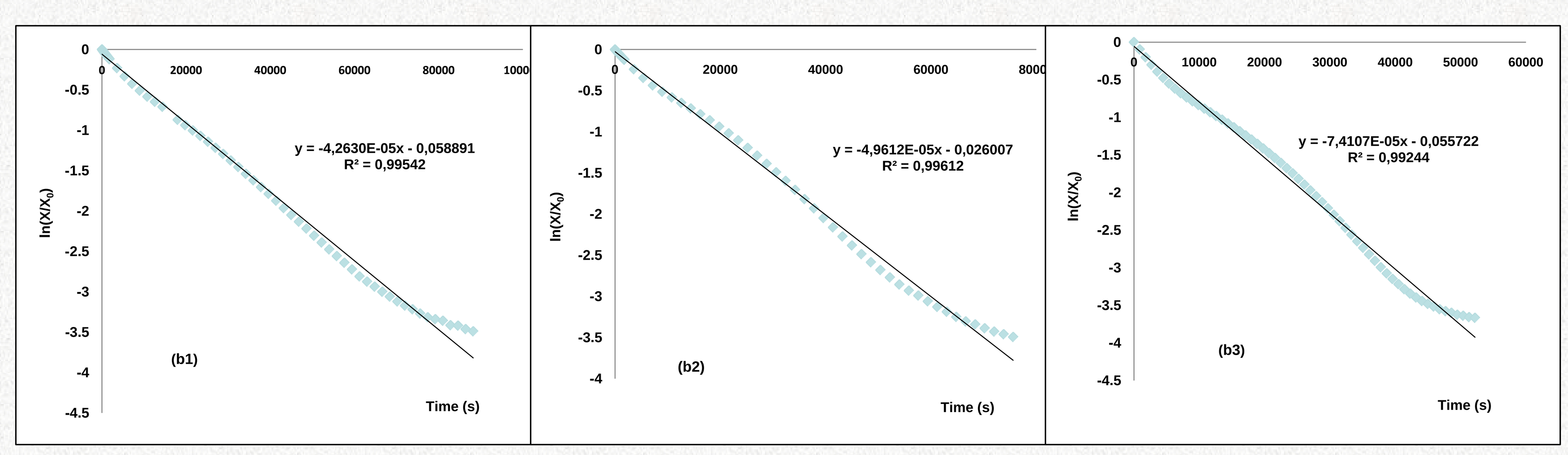


Fig. 5. Variation of the moisture with time for different temperatures. (a1):With skin at 50°C, (b1): Without skin at 50 °C, (a2):With skin at 60 °C, (b2): Without skin at 50 °C, (a3):With skin at 70 °C, (b3): Without skin at 70 °C

	D_{eff} ×10^{-11} ($m^2.s^{-1}$) With skin	D_{eff} ×10^{-10} ($m^2.s^{-1}$) Without skin
50 °C	2.56	4.59
60 °C	4.12	6.05
70 °C	7.67	6.73

Table 1. Variation of diffusion coefficient

Cherry tomato	Ln (D_0) ($m^2.s^{-1}$)	E (KJ/mol)
With skin	- 5.64	50.43
Without skin	- 14.91	17.64

Table 2. Determination of the parameters

4. Conclusions

The main conclusions of this study can be summarized as follows:

1- The convective drying kinetics show the existence of two main phases : adaptation phase and falling drying rate phase with an increase of the drying rate with the temperature increase.
2- The follow-up of the shrinkage effect represented by variation of the product volume with its moisture content using X-ray microtomography allowed the observation of the product behavior and it showed that this effect is largely happening during the process.
3- The skin effect is clearly determined as the diffusion coefficient obtained from the drying experiments of a cherry tomato is largely higher when the skin is removed.

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