Effect of Temperature and Initial Sample Dimensions on the Convective Drying Behavior of Parallelepiped Cassava Samples

.

ABSTRACT

|  |
| --- |
| The objective of this study is to examine the behavior of cassava during convective drying, taking into account the external temperature and changing the dimensions of the parallelepiped-shaped samples. The following temperatures were used: 40 °C, 50 °C, 60 °C and 70 °C. The conclusions indicate that the drying process is faster at higher temperatures. To illustrate, the drying time of a parallelepiped with dimensions 2 cmx1.5 cmx1 cm is 620 minutes at 40 °C, 540 minutes at 50 °C, 520 minutes at 60 °C and 460 minutes at 70 °C. For parallelepipeds measuring 2 cmx1.5 cmx1.5 cm, the drying times are increased: 640min, 600min, 540min and 480min. This mainly concerns the larger ones, especially at higher temperatures. At a temperature of 40 °C, the impact of size is less obvious, however at higher temperatures (50 °C, 60 °C, 70 °C), the importance of sample size is more felt. For example, at a temperature of 70 °C, parallelepipeds with dimensions 2 cmx1.5 cmx1 cm, 2 cmx1.5 cmx1.5 cm and 2 cmx1.5 cmx2 cm dry out in 440 minutes, 460 minutes and 500 minutes respectively.  In conclusion, higher temperatures promote drying, up to a drying time difference of 100 min for the same sample shape between 50 °C and 60 °C. Small pieces of cassava tend to dry faster than large ones, especially at higher temperatures. |

*Keywords: convective drying, cassava, temperature, size, parallelepiped*

1. INTRODUCTION

Drying represents an option to consider for agricultural processing, as desired by developing countries to achieve food self-sufficiency [1]. To be successful, it is essential to perfectly master the transfer processes that control drying [2-4]. In the drying of agri-food products, several parameters must be taken into account. We can cite external parameters such as the temperature of the drying air as shown [6] for thin layers of figs, [7] for bunches or [8] for eggplants. There are also parameters related to the sample to be dried. [9] for the variety of onion, [10] for the maturity of okra, [11] and [12] for the initial size. Pretreatments are also taken into account [13,14] These last parameters are multiple, due to the complexity of the material that constitutes the agri-food product [15] and [16]. It goes without saying that its state of maturity [11], its size [17], its shape [18], etc. constitute important parameters in the evaluation of convective drying of agri-food products.

Many studies have shown that drying curves evolve according to the above-mentioned parameters. We can list, on potatoes [1], on bananas [19], on figs [6] on different products (celery, onion, garlic, tomato, corn, etc.) [3].

On tomatoes [5] and on garlic (2 to 4 mm thick) [4], the drying time decreases when the thickness decreases while the drying rate increases, allowing thus to preserve the quality of food product.

In this work, we aim to understand the behavior of cassava samples when subjected to convective drying. The external influence of temperature is taken into account. Regarding the intrinsic parameters, we maintain a fixed parallel shape, while modifying the dimensions. Mastering these parameters will help ensure finished products of appreciable organoleptic quality. It will also allow the automation of cassava drying based on the parameters studied.

2. material and methods

**2.1 Sample processing**

Cassava is purchased from a local market in Bobo-Dioulasso, Burkina Faso. It is transferred to the LaMHE laboratory. It is peeled and then cut into a parallelepiped shape with a stainless steel knife. We measure the edges with a digital micrometer (MITUTOYO, Japan, accuracy 2.10 -5 m), as shown in Figure 1.

Convective drying of cassava was carried out in an oven. The temperature was set to the drying temperature. For each type of sample, three identical samples are used. A first exploitation was to validate the results by having identical curves for the three samples of the same type. In this article, after the validity of the experiment, an average of the three curves is retained. Once thermal equilibrium was reached, the samples were introduced into the oven chamber. At a time interval of approximately 10 minutes, the samples are removed from the oven and their mass is weighed using a SARTORIUS balance, 0.001 g precision, France. Following these measurements, the samples are reintroduced into the AIR concept oven, temperature varying from 40 to 250°C, digital display.

We minimized the measurement time so as not to disturb the thermal equilibrium already established in the product. Note that the samples are arranged so that the direction of the convective air current is the characteristic dimension, that is, for example, the thickness for parallelepipeds

|  |  |
| --- | --- |
| a) | b) |

Fig.1 : Cassava:

a) freshly harvested tubers,

b) cut-out parallelepiped shapes

**2.2 Data processing**

**2.2.1 water content**

Since drying of food products involves the loss of its water, it is essential to be able to monitor the evolution of its water content during the drying process. A given product contains water whose initial content or the initial water content of the product is the quotient of the total mass of water contained in the freshly cut product , divided by the mass of solid matter according to Eq.1.

where is the initial mass of the sample and ms is the dry mass of the sample.

However, monitoring the temporal evolution of the water loss of the product during its drying acquires knowledge, at each instant of its water content. The curves of the water contents as a function of the drying time were plotted from the experimental data. From the mass of the sample at instant , we deduce the water content according to Eq.2:

where m(t) is the mass of the sample at time t of drying.

**2.2.2 drying rate**

Drying, estimated in terms of drying rate, gives a good perception of drying.

The drying rate is expressed as the mass of water extracted from the solid per unit of time and per unit of surface exposed to the drying air according to the following relationship (Perré et al., 2007, Dissa et al., 2008) (Eq3):

where is the drying rate, the mass of the solid skeleton, the initial exchange surface, and the water content on a dry basis.

: the mass of water evaporated per unit of time given by Eq4 :

Or :

the dry mass of the product.

 : the drying rate (Kg e. Kg ms -1 .s -1 ) given by Eq5:

And :

: water content of the product (Kg e. Kg ms -1 ) ;

: drying time step (s).

3. results and discussion

3.1 Influence of temperature on cassava parallelepiped samples convective drying

In a study on cassava parallelepiped shape convective drying, we modified the drying air temperatures in order to observe the influence of temperature on cassava behavior during its convective drying process.

The temperatures of 40 °C, 50 °C, 60 °C and 70 °C were used. It is obvious that with the parallelepiped-shaped samples of 2 cmx1.5 cmx1 cm (figure 2.a), an increase in temperature leads to an acceleration of drying. A similar trend is also noted for the samples of dimensions 2 cmx1.5 cmx1.5 cm (figure 2 b)). Note, however, that the drying temperature of 50 °C seems to be more effective than that at 60 °C. This can be explained by the complexity of organic products. Indeed, ouoba et al [20] showed that the organic product, in the context of okra, behaves differently, depending on the cutting area. Also, the origin of the sample, which is not necessarily cut from the same cassava root, can influence the result. These remarks should be taken into account when evaluating the drying of agri-food products.

For the 2 cmx1.5 cmx1 cm parallelepiped samples, these samples take 620min, 540min, 520min and 460min, respectively at temperatures of 40 °C, 50 °C, 60 °C and 70 °C to reach their end of drying, at the zero level in the humic base, as indicated in Figure 2, a).

In Figure 2 b), for the 2 cmx1.5 cmx1.5 cm parallelepiped samples, these samples take 640min, 600min, 540min and 480min, respectively at temperatures of 40 °C, 50 °C, 60 °C and 70 °C to reach their end of drying, at the zero level in the humic base, as indicated in Figure 2.

|  |  |
| --- | --- |
| a) | b) |

Fig. 2 : Influence of temperature on the drying of parallelepiped cassava samples:

a) parallelepiped 2 cmx1.5 cmx1 cm ,

b) parallelepiped 2 cmx1.5 cmx1.5 cm

3.2 Influence of temperature on drying rates

Figure 3 shows the graphs of drying speed variation over time, for parallelepiped-shaped samples of cassava, exposed to temperatures of 40 °C, 50 °C, 60 °C and 70 °C. All these curves have a shape, which begins without initial speed, undergoing a jump in value to reach a maximum before starting to decrease. Note that contrary to the general shape presented by some authors [20], we did not observe a plateau near the maximum. This observation could be linked to the small size of the samples. Indeed, from the first moments, all the water contained in the material is active and ready to be evaporated for small samples, unlike samples of large dimensions.

After this peak, the curves decrease globally towards a zero asymptote which marks the end of drying. An important observation is the irregularity of the curves. Drying can accelerate at times, or slow down. We attribute this irregularity to the fact of the removal of the samples for mass gain, which slows down the transfers, and its reintroduction into the oven which accelerates the transfers. This phenomenon can also be due to the structure of the material as observed by ouoba [20] and [21] for cassava, which bursts, i.e. small cracks, ensuring the accelerated evacuation of the water trapped in the internal solid matrix.

For the 2 cmx1.5 cmx1.5 cm parallelepiped samples, the standardized drying rate reaches a peak of 0.0024; 0.0057; 0.0064 and 0.0097 respectively for the temperatures of 40 °C, 50 °C, 60 °C and 70 °C. It can be deduced that the higher temperatures accelerate the drying more. This confirms the results on the drying kinetics of the previous paragraph.

Fig. 3 : Influence of temperature on drying rate

3.4 Influence of size

For the four different temperatures, namely 40 °C, 50 °C, 60 °C and 70 °C, we used a form parallelepiped of different sizes, namely 2 cmx1.5 cmx1 cm, 2 cmx1.5 cmx1.5 cm and 2 cmx1.5 cmx2 cm. The results are recorded in Figure 4. All comparisons of the curves at the same temperature indicate that the small samples dry faster than the large samples. It should be noted that for the low temperature of 40 °C, the influence of the size is not very perceptible. Indeed, Figure 4.a, indicates that the parallelepiped samples of dimensions 2 cmx1.5 cmx1 cm, 2 cmx1.5 cmx1.5 cm and 2 cmx1.5 cmx2 cm, at the temperature of 40 °C have drying curves almost merged. Their drying time is around 640min.

As the temperature increases, as shown in Figure 4.b (50 °C), Figure 4.c (60 °C) and Figure 4.d (70 °C), size is taken into account in assessing the drying of parallelepiped cassava samples.

For example, in Figure 4.c, the parallelepiped samples take 520 min, 560 min and 600 min, respectively for the parallelepiped samples of dimensions 2 cmx1.5 cmx1 cm, 2 cmx1.5 cmx1.5 cm and 2 cmx1.5 cmx2 cm, to dry.

|  |  |
| --- | --- |
| a) | b) |
| c ) | d) |

**Fig. 4 : Influence of size on convective drying of parallelepiped cassava samples:**

**a) at 40 °C,**

**b) at 50 °C,**

**c) at 60 °C,**

**d) at 70 °C**

As for the temperature of 70 °C, in Figure 4.d, these drying times are ranked as 440 min, 460 min and 500 min.

4. Conclusion

This research examined the impact of temperature and size of parallelepiped-shaped cassava samples on their convective drying process. Observations indicate that the drying process occurs more quickly at higher temperatures, with a significant increase in drying speed at 70 °C. However, at 50 °C, the heat appears to be more efficient than at 60 °C, which could be due to the complexity of cassava's biological characteristics, such as disparities depending on the cutting location and the origin of the samples.

Analysis of drying rates reveals that they peak before decreasing to an asymptote, with irregularities due to sample handling. Sample size also has a significant impact on drying, with smaller samples drying faster than larger ones, especially at higher temperatures. However, at 40 °C, the influence of size is less pronounced.

In essence, temperature plays a key role in accelerating drying, and smaller sample size contributes to faster drying. These findings can be used to improve dehydration conditions for cassava-derived products by adjusting temperature and sample size to ensure optimal performance while maintaining product quality.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

References

1. Bonazzi, C., Dumoulin, E. and Bimbenet, J.J. (2008). Le séchage des produits alimentaires. Industries Alimentaires et Agricoles, 125, 12-22.
2. Madamba, P.S., Driscoll, R.H. and Buckle, K.A. (1996). The Thin-Layer Drying Characteristics of Garlic Slices. Journal of Food Engineering, 29, 75-97  
   [https://doi.org/10.1016/0260-8774(95.00062-3](https://doi.org/10.1016/0260-8774(95)00062-3)
3. Clemente, G., Frías, A., Sanjuan, N., Benedito, J. and Mulet, A. (2011). Influence of Air Velocity in Dehydration of Potato Cubes. III European Drying Conference, Palma de Mallorca, 26-28 October, 26-28.
4. Krokida, M.K., Karathanos, V.T., Maroulis, Z.B. and Marinos-Kouris, D. (2003). Drying Kinetics of Some Vegetables. Journal of Food Engineering, 59, 391-403.  
   [https://doi.org/10.1016/S0260-8774(02.00498-3](https://doi.org/10.1016/S0260-8774(02)00498-3)
5. Brooks, M.S., El-Hana, N.A. and Ghaly, A.E. (2008). Effects of Tomato Geometries and Air Temperature on the Drying Behavior of Plum Tomato. American Journal of Applied Sciences, 5, 1369-1375.  
   <https://doi.org/10.3844/ajassp.2008.1369.1375>
6. Babalis, S.J. and Belessiotis, V.G. (2004). Influence of the Drying Conditions on the Drying Constants and Moisture Diffusivity during the Thin-Layer Drying of Figs. Journal of Food Engineering, 65, 449-458.  
   <https://doi.org/10.1016/j.jfoodeng.2004.02.005>
7. Bingol, G., Roberts, J.S., Balaban, M.O. and Devres, Y.O. (2012). Effect of Dipping Temperature and Dipping Time on Drying Rate and Color Change of Grapes. Drying Technology, 30, 597-606. <http://dx.doi.org/10.1080/07373937.2011.654020>
8. Russo, P., Adiletta, G. and Di Matteo, M. (2013). The Influence of Drying Air Temperature on the Physical Properties of Dried and Rehydrated Eggplant. Food and Bioproducts Processing, 91, 249-256.   
   <http://dx.doi.org/10.1016/j.fbp.2012.10.005>
9. Beye, N. , Kane, C. , Ayessou, N. , Talla, C. , Sene, A. and Diop, C. (2018). Influence of Variety and Maturity Level on Natural Convective Heat Drying of Four Onion Varieties Grown in Senegal. *Food and Nutrition Sciences*, **9**, 997-1013.

doi: [10.4236/fns.2018.98073](https://doi.org/10.4236/fns.2018.98073).

1. Honoré, O. , François, Z. , Raguilignaba, S. , Aboubacar, T. and Hélène, D. (2014). Characterization of Okra Convective Drying, Influence of Maturity. *Food and Nutrition Sciences*, **5**, 590-597.

doi: [10.4236/fns.2014.56069](http://dx.doi.org/10.4236/fns.2014.56069).

1. Ouoba, K. , Zougmore, F. and Desmorieux, H. (2018). Effect of Initial Size and Shape Importance on Masse Transfer during Convective Drying. *Food and Nutrition Sciences*, **9**, 1514-1524.

doi: [10.4236/fns.2018.912109](https://doi.org/10.4236/fns.2018.912109).

1. Ganame, A. , Ouoba, K. and Zougmore, F. (2020). Consideration of Size and Dimension in the Evaluation of Transfers during Convective Drying of Sweet Potato. *Journal of Analytical Sciences, Methods and Instrumentation*,  **10**, 104-112.

doi: [10.4236/jasmi.2020.104008](https://doi.org/10.4236/jasmi.2020.104008).

1. Adiletta, G. , Senadeera, W. , Liguori, L. , Crescitelli, A. , Albanese, D. and Russo, P. (2015). The Influence of Abrasive Pretreatment on Hot Air Drying of Grape. *Food and Nutrition Sciences*,  **6**, 355-364.

doi: [10.4236/fns.2015.63036](http://dx.doi.org/10.4236/fns.2015.63036)

1. Cinquanta, L., Di Matteo, M. and Esti, M. (2002). Physical Pre-Treatment of Plums (Prunus domestica.. Part 2. Effect on the Quality Characteristics of Different Prune Cultivars. Food Chemistry, 79, 233-238.  
   [http://dx.doi.org/10.1016/S0308-8146(02.00138-3](http://dx.doi.org/10.1016/S0308-8146(02)00138-3)
2. Abdou-Salam, G. , Honore, O. and François, Z. (2020). Taking into Account the Complex Nature and the Intrinsic Parameters of Agro-Food. *Journal of Biophysical Chemistry*, **11**, 1-13.

doi: [10.4236/jbpc.2020.111001](https://doi.org/10.4236/jbpc.2020.111001).

1. Honoré, O. , Hélène, D. and François, Z. (2019). What Process Optimizes Convective Drying of Farm Products with Complex Constitution: Case of Okra (*Abelmoschus esculentus*.. *Journal of Agricultural Chemistry and Environment*,  **8**, 14-22.

doi: [10.4236/jacen.2019.81002](https://doi.org/10.4236/jacen.2019.81002).

1. Erenturk, S., Gulaboglu, M.S. and Gultekin, S. (2005). The Effects of Cutting and Drying Medium on the Vitamin C Content of Rose Hip during Drying. Journal of Food Engineering, 68, 513-518.  
   <http://dx.doi.org/10.1016/j.jfoodeng.2004.07.012>
2. Honore, O., Abdou-Salam, G., Salam, I., Désiré, B. and François, Z. (2023). Validation of a Characteristics Dimensions for Transfers during Convective Drying of Sweet Potato Cubic, Cylindrical and Spherical Shapes. *Open Journal of Applied Sciences*, **13**, 1714-1722.

doi: [10.4236/ojapps.2023.1310135](https://doi.org/10.4236/ojapps.2023.1310135).

1. Doymaz, I. (2010). Evaluation of Mathematical Models for Prediction of Thin-Layer Drying of Banana Slices. International Journal of Food Properties, 13, 486-497.
2. Honoré, O. , Francois, Z. and Hélène, D. (2019). Effect of Farm Product Intrinsic Properties on Convective Drying: Case of Okra. *American Journal of Plant Sciences*,  **10**, 101-110. doi: [10.4236/ajps.2019.101009](https://doi.org/10.4236/ajps.2019.101009).
3. Honore, O. , Abdou-Salam, G. , Salam, I. , Désiré, B. and François, Z. (2023). Validation of a Characteristics Dimensions for Transfers during Convective Drying of Sweet Potato Cubic, Cylindrical and Spherical Shapes. *Open Journal of Applied Sciences*,  **13**, 1714-1722. doi: [10.4236/ojapps.2023.1310135](https://doi.org/10.4236/ojapps.2023.1310135).