

Influence of External and Intrinsic Parameters on Convective Drying of Cassava Cubic Samples

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Abstract This work aims to study the behavior of cassava subjected to convective drying, taking into account the external temperature and varying the dimensions of the cubic-shaped samples. The temperatures used are 40°C, 50°C, 60°C and 70°C. The results show that drying is faster at higher temperatures. For example, for cubes with a side of 1 cm, drying takes 240, 320, 600 and 520 minutes at 40°C, 50°C, 60°C and 70°C respectively. For cubes of 1.5 cm, the drying times are longer: 380, 510, 520 and 630 minutes. The drying rate curves show that the rate increases with temperature, reaching higher peaks at 70°C. In comparison, smaller samples dry faster than larger ones, especially at higher temperatures. At 40°C, the influence of size is less noticeable, but at higher temperatures (50°C, 60°C, 70°C), sample size becomes more significant. For example, at 70°C, 1 cm, 1.5 cm and 2 cm cubes dry in 240, 380 and 480 minutes, respectively. In summary, higher temperatures speed up drying, but lower temperatures slow down drying, but it can preserve the nutritional quality of cassava. Small cassava cubes dry faster than large ones, especially at higher temperatures.

Keywords: convective drying, cassava, temperature, size, cubic

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1. Introduction

For an agricultural transformation as desired by the states of developing countries, in order to achieve food self-sufficiency, drying constitutes a possibility that should not be neglected [1]. To achieve this, a perfect mastery of the transfer processes that govern drying is required [2,3,4].

In the context of drying 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 by [6] for thin layers of figs, [7] for grapes 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. Pretreatment is also taken into account [1,3,14]. 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 the 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 present work, we set the objective of understanding the behavior of cassava samples, subjected to convective drying. The external parameter which is the temperature is taken into account. As for the intrinsic parameters, we keep a fixed form which is cubic, while varying the dimensions.

2. Material and Method

2.1. Sample Processing

Cassava is obtained from a local market in Bobo-Dioulasso, Burkina Faso. They are transported to the LaMHE laboratory. They are peeled and then cut into cubes using a stainless-steel knife. The edges are measured using a digital micrometer (MITUTOYO, Japan, with a precision of 2.10-5m) Figure 1

Convective drying of cassava was carried out in an oven. The temperature is set to that set for drying. As soon

as thermal equilibrium is reached, the samples are introduced into the oven enclosure. We minimize the measurement time so as not to disturb the thermal equilibrium already established in the product. For some samples, we measure the length of the sections that have been marked during drying.



Figure 1. Cassava: a) freshly harvested tubers, b) the cut-out cubic shapes

2.2. Data Processing

2.2.1. Water Content

Since drying of agri-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 m_e , divided by the mass of solid matter m_s according to Eq.1.

$$X_0 = \frac{m_e}{m_s} = \frac{m_0 - m_s}{m_s} \quad (1)$$

where m_0 is the initial mass of the sample and m_s is the mass of the sample after all water has been removed (drymass).

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 water contents as a function of drying time were

plotted from the experimental data. From the mass of the sample at time t , we deduce the water content according to Eq.2:

$$X(t) = \frac{m(t) - m_s}{m_s} \quad (2)$$

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 Eq 3:

$$q_{m,0} = - \left(\frac{m_s}{S_0} \right) \frac{dX}{dt} \quad (3)$$

where q_m is the drying rate, m_s the mass of the solid skeleton, S_0 the initial exchange surface, and X the water content on a dry basis.

m^* the mass of water evaporated per unit of time given by :

$$m^* = m_s \left(- \frac{dX}{dt} \right) \quad (4)$$

Or :

m_s the dry mass of the product.

$\left(- \frac{dX}{dt} \right)$ the drying rate ($\text{Kg}_e \cdot \text{Kg}_{ms}^{-1} \cdot \text{s}^{-1}$) given by:

$$\left(- \frac{dX}{dt} \right) = \frac{X(t - \Delta t) - X(t)}{\Delta t} \quad (5)$$

And:

$X(t)$ the water content of the product ($\text{Kg}_e \cdot \text{Kg}_{ms}$);

Δt the drying time step (s).

3. Results and Discussions

3.1. Influence of Temperature on Cassava Cubic Samples Convective Drying

For a cubic shape, we varied the temperatures of the drying air in order to investigate the contribution of the temperature on the drying of the cassava.

The temperatures of 40°C, 50°C, 60°C and 70°C are used. We can easily notice for the samples of cubic shape for $a = 1.5$ cm (figure 1.a), that the higher the temperature, the faster the drying. The same trend is observed for the samples of dimensions $a=1$ cm. It is noteworthy that the drying efficiency at 50°C appears to be higher than 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 on the same cassava root, can influence the result. These remarks must be taken into account when evaluating the drying of agri-food products.

For cubic samples with edge $a=1\text{cm}$, these samples take 240 minutes at 70°C , 320 minutes at 60°C , 520 minutes at 60°C and 600 minutes at 40°C respectively to reach their end of drying, at the zero level in the humid base, as indicated in figure 1, a).

In Figure 1 b), For cubic samples with edge $a=1.5\text{cm}$, these samples take 380 minutes at 70°C , 520 minutes at 60°C , 510 minutes at 50°C and 630 minutes at 40°C , respectively to reach their end of drying, at the zero level in the humid base.

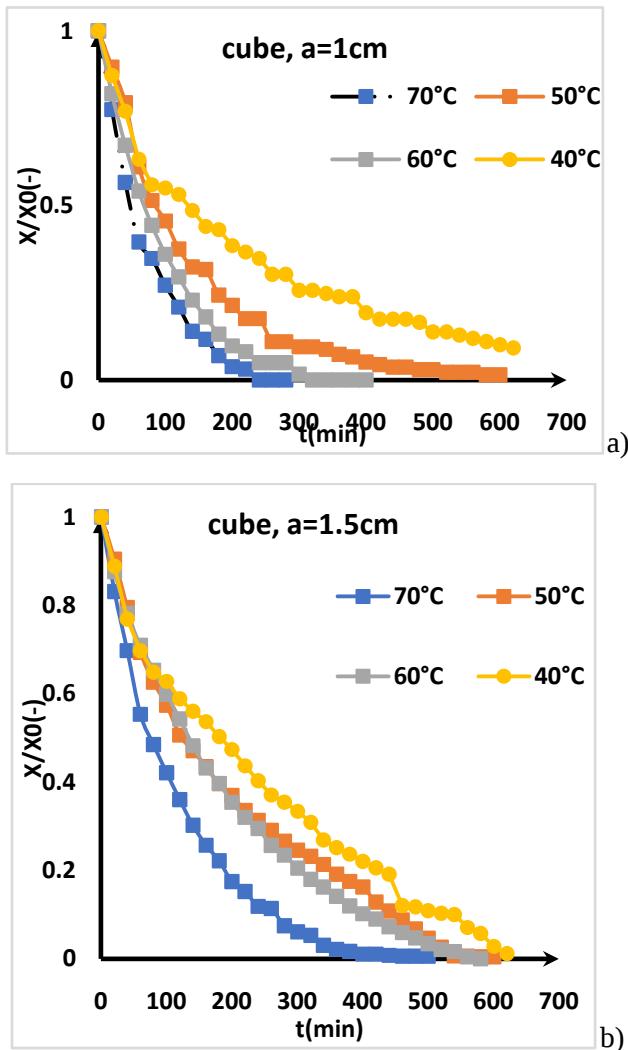


Figure 2. Influence of temperature on the drying of cubic cassava samples: a) 1cm edge cubes, b) 1.5cm edge cubes

3.2. Influence of Temperature on Drying Rates

Figure 2 groups together the curves of the evolution of drying rate versus drying time, for cassava cubic samples, subjected to temperatures of 40°C , 50°C , 60°C and 70°C .

All these curves have a shape, which starts 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 flat section of the curves near the maximum. This observation could be linked to the small size of the samples, suggesting, 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 cubic samples with edge $a=1.5\text{cm}$, the standardized drying rate reaches a peak of $0.0072 \text{ Kg}_e.\text{Kg}_{ms}^{-1}.\text{s}^{-1}$; $0.0097 \text{ Kg}_e.\text{Kg}_{ms}^{-1}.\text{s}^{-1}$; $0.0127 \text{ Kg}_e.\text{Kg}_{ms}^{-1}.\text{s}^{-1}$ and $0.0137 \text{ Kg}_e.\text{Kg}_{ms}^{-1}.\text{s}^{-1}$ respectively for temperatures of 40°C , 50°C , 60°C and 70°C . It can be deduced that the highest temperatures accelerate drying more. This confirms the results on drying kinetics in the previous paragraph.

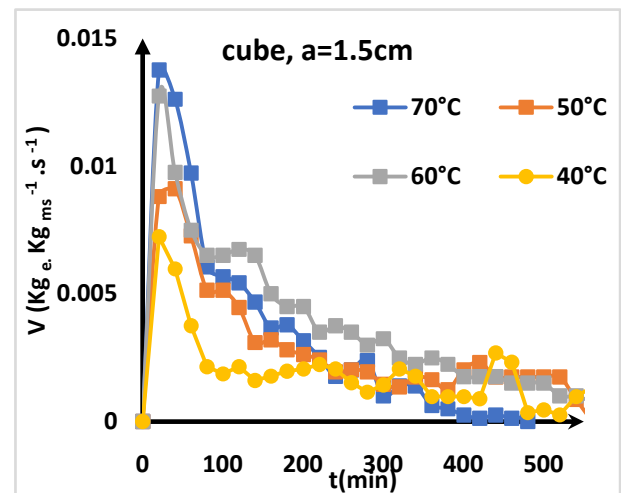


Figure 3. Influence of temperature on drying speeds

3.4. Influence of Size on Cassava Cubic Convective Drying

For the four different temperatures, namely 40°C , 50°C , 60°C and 70°C , we used a cubic shape of different sizes, namely 1cm, 1.5cm and 2cm edge. The results are reported in Figure 3. All comparisons of the curves at the same temperature indicate that the small samples dry faster than the large samples. It is noted that for the low temperature of 40°C , the influence of the size is not very perceptible. Indeed, figure 3.a, indicates that the cubic samples of edges 1cm, 1.5cm and 2cm, at the temperature of 40°C have drying curves almost merged.

As the temperature increases, as shown in Figure 3.b (50°C), Figure 3.c (60°C) and Figure 3.d (70°C), the size comes into play in assessing the drying of cassava cubes. As an example, in Figure 3.d, the cubic samples take 240

minutes, 380 minutes, 480 minutes, respectively for the 1cm, 1.5cm and 2cm edges, to dry.

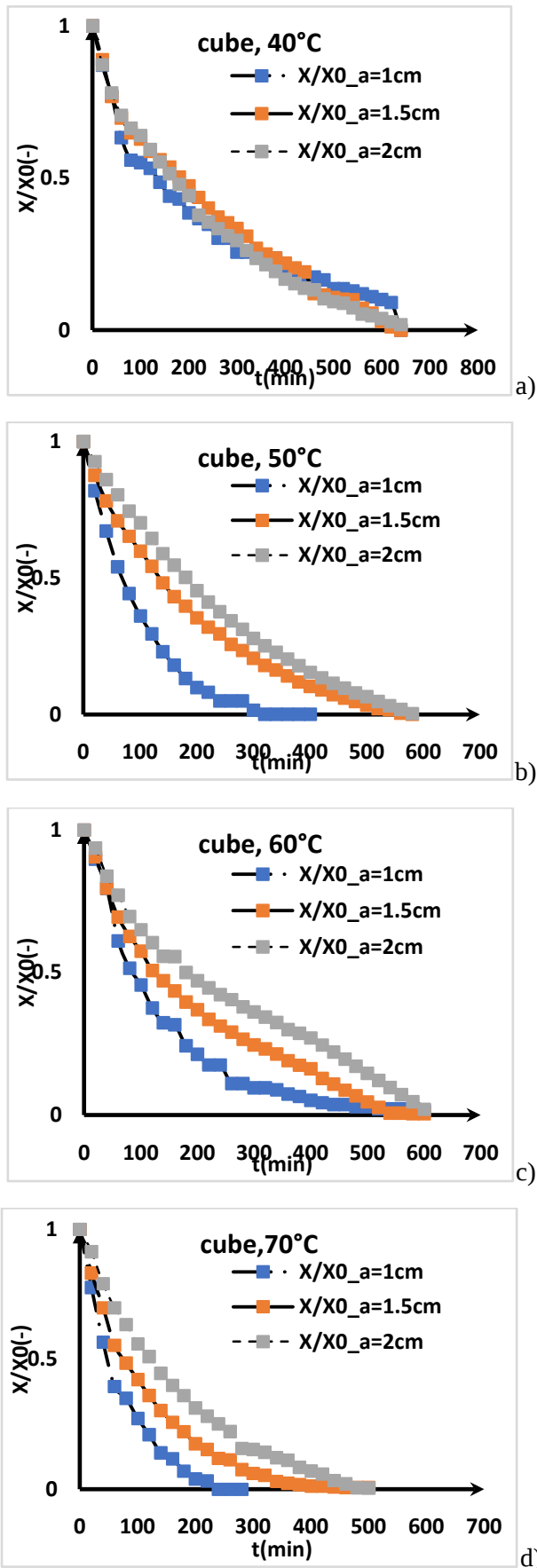


Figure 4. Influence of size on convective drying of cubic cassava samples: a) at 40°C, b) at 50°C, c) at 60°C, d) at 70°C

4. Conclusion

This work investigated the influence of temperature and size of cassava cubic samples on their convective drying. The results show that drying is faster at higher temperatures, with a notable acceleration of the drying rate at 70°C. However, at 50°C, the temperature seems more efficient than 60°C, which can be attributed to the complexity of the biological properties of cassava, such as variation according to the cutting area and the provenance 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. In comparison, smaller samples drying faster than larger ones, especially at higher temperatures. However, at 40°C, the influence of size is less pronounced.

In summary, temperature is a crucial factor to accelerate drying, and small sample sizes promote faster drying. These results can be taken into account to optimize drying conditions for cassava products, balancing temperature and sample size to ensure maximum efficiency while preserving product quality.

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