Coffee Bean Drying Shrinkage Comparison by Finite Element Simulations and Real Image Processing.

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Introduction

- Coffee bean's seeds shrink upon drying, affecting:
  - × Seed's heat transfer when drying.
  - × Air chamber in the bean is generated.
  - × Porosity of the drying bed.
  - × Bulk thermal conductivity (Burmester & Eggers, 2010).
- These issues influence the final product's quality.
- To obtain accurate data on the phenomena:
  - → Transient mass diffusion Finite Element Model (FEM) was done.
  - → Image analysis of coffee parchment and seed's cross sections.
  - → Comparison between both processes.

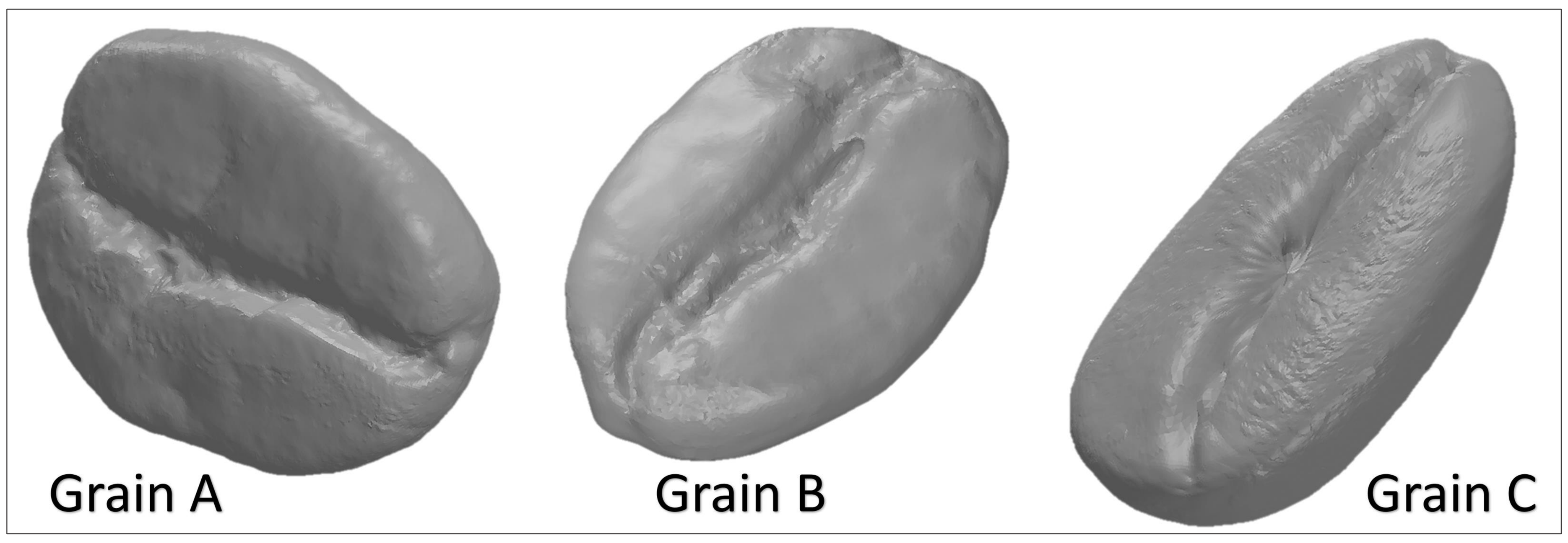

Figure 1. 3D Scanned coffee beans.

Methodology

- 3 coffee beans were 3D scanned and used as geometry files for the FEM simulation.
  - → The mass diffusion of water was a function of the drying air relative humidity and its temperature.

$$M = \frac{c}{s}$$

  - → The normalized mass concentration of water *M* is a function of the concentration *c* and the solubility *s*.
  - → Using Fick's first law of diffusion the grain's water removal is simulated (Cavalcanti-Mata et al., 2020; Tian, Lin, & Guo, 2021).

$$\vec{J} = -\vec{D} \cdot \frac{dc}{d\vec{x}}$$

- 100 grains were dried in laboratory conditions, at 5 different moisture *M* contents (53, 42, 32, 22 and 10% (wb)).
  - → 20 grains were removed from the batch at each *M*.
  - → Their parchment was removed, flattened and its area was calculated using Image processing as well as their cross-sectional areas.
- A comparison between the processes was done.
  - → In order to find a precise shrinking ratio and validate the accuracy of the FEM model.

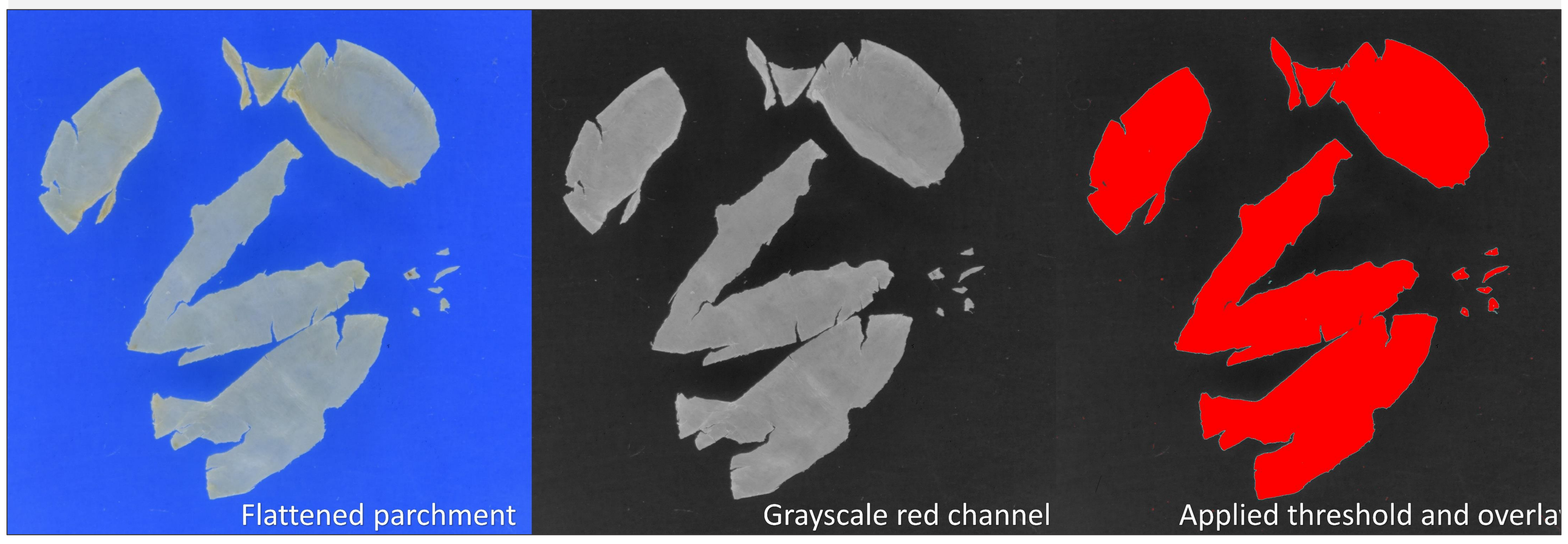

Figure 2. Image analysis process.

Results

- Both processes recorded a shrink reduction in the seed's surface area.
  - → The parchment's surface area remains the same along the drying process.
  - → The shrinking effect occurs on the seed.
  - → A level of similarity of **96.5%** between the FEM model and the image processing was attained.
  - → An average shrinking of **7.3%** in the seed's surface area was recorded (Nilnont et al., 2012).
  - → The drying time was the same for both processes.

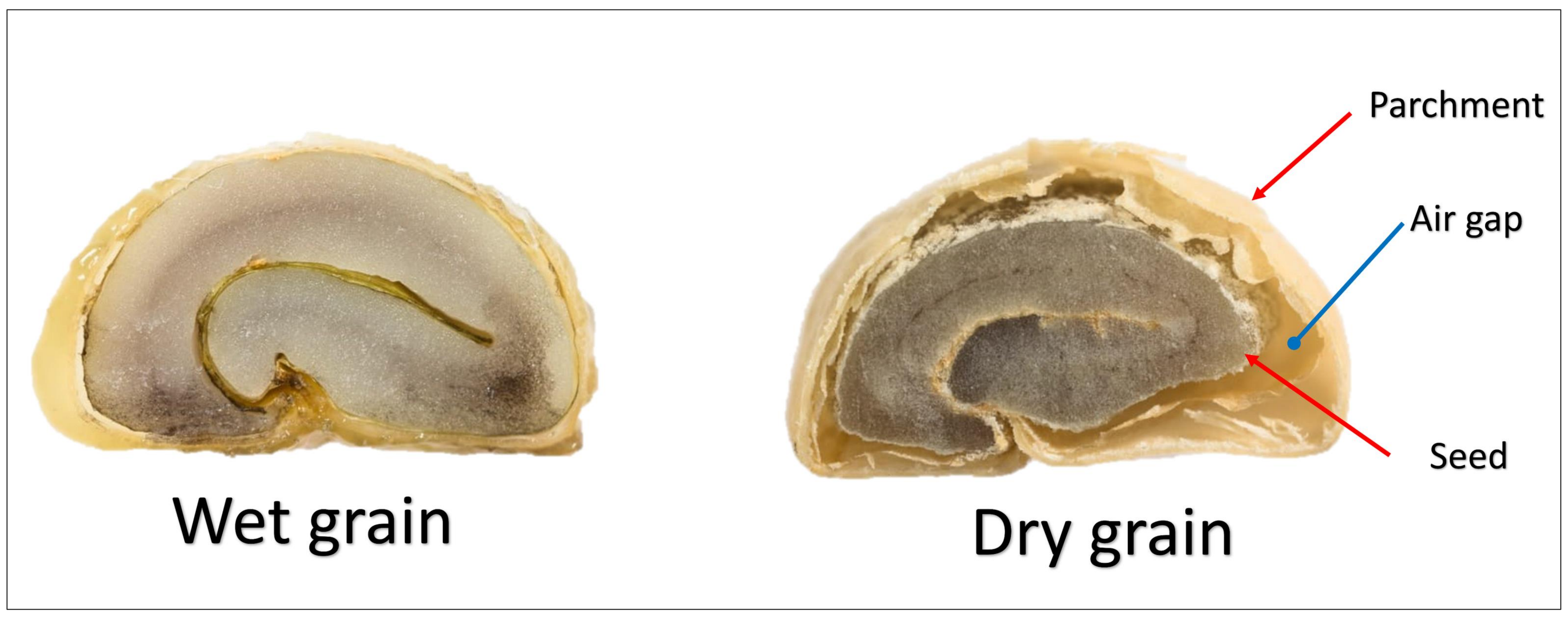

Figure 3. Transversal cut of the coffee bean.

- An air gap is created between the parchment and the seed:
  - × Limiting the heat transfer and bulk thermal conductivity when drying.

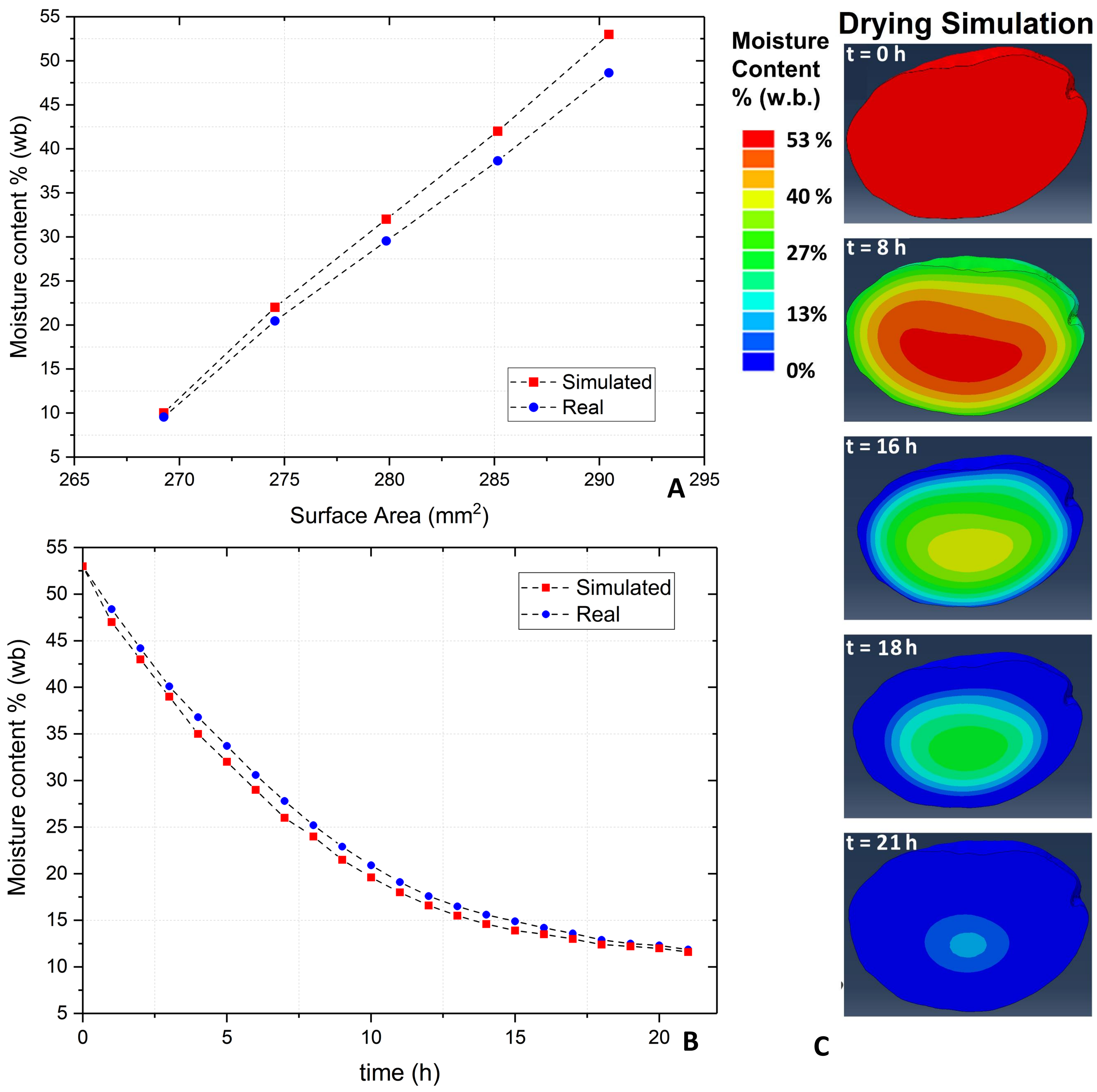

Figure 4. A. Surface area. B. Drying curves. C. FEM Drying simulation – moisture distribution.

Conclusions

- Coffee seed shrinking happens at an average ratio of **7.3%.**
- The FEM model's accuracy is verified through the image analysis process.
- The techniques used in this research can be applied to different materials for similar applications.
- Understanding the shrinking phenomena allows to control and better predict the drying process.
- When controlling the drying process, threats as microorganisms, mycotoxins and moulds can be avoided.

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