Operational Improvement of a Convective Coffee Dryer by Numerical Methods and Computational Fluid Dynamics

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Introduction

- The Colombian coffee growers face many complications when attempting to sun dry their goods.
  - High cloudiness and low direct sun radiation.
  - Harvest peaks coincide with the wet season.

- To solve the derived issues (post-harvest processes delays and incomplete grain dryness) low-capacity three chamber rectangular convective dryers are built.

- The most commercialized dryer (Figure 1) was re-designed:
  - Improved dryer geometry, air inlet and coffee bed thickness.
  - Enhance air distribution, increase moisture removal and reduce the product's drying time.

Methodology

- Based on literature suggestions the actual dryer was re-designed into a cylindrical shape with a conical configured vertical drying air inlet (Perazzini et al., 2018).
  - Keeping the same operating conditions and processed coffee amount.
  - A comparative Computational Fluid Dynamics study was carried out between both dryers to observe the air distribution and velocity.

- A predictive drying simulation code was done based on the Thompson (Thompson et al., 1968) and MSU (Bakker-Arkema et al., 1974) grain drying models.
  - The coffee was treated as a static bed.
  - The thermal and physical properties of the coffee were described following published data.
  - The cylindrical unit held a 66mm thinner coffee bed and a cross sectional area larger in 0.43m^2.

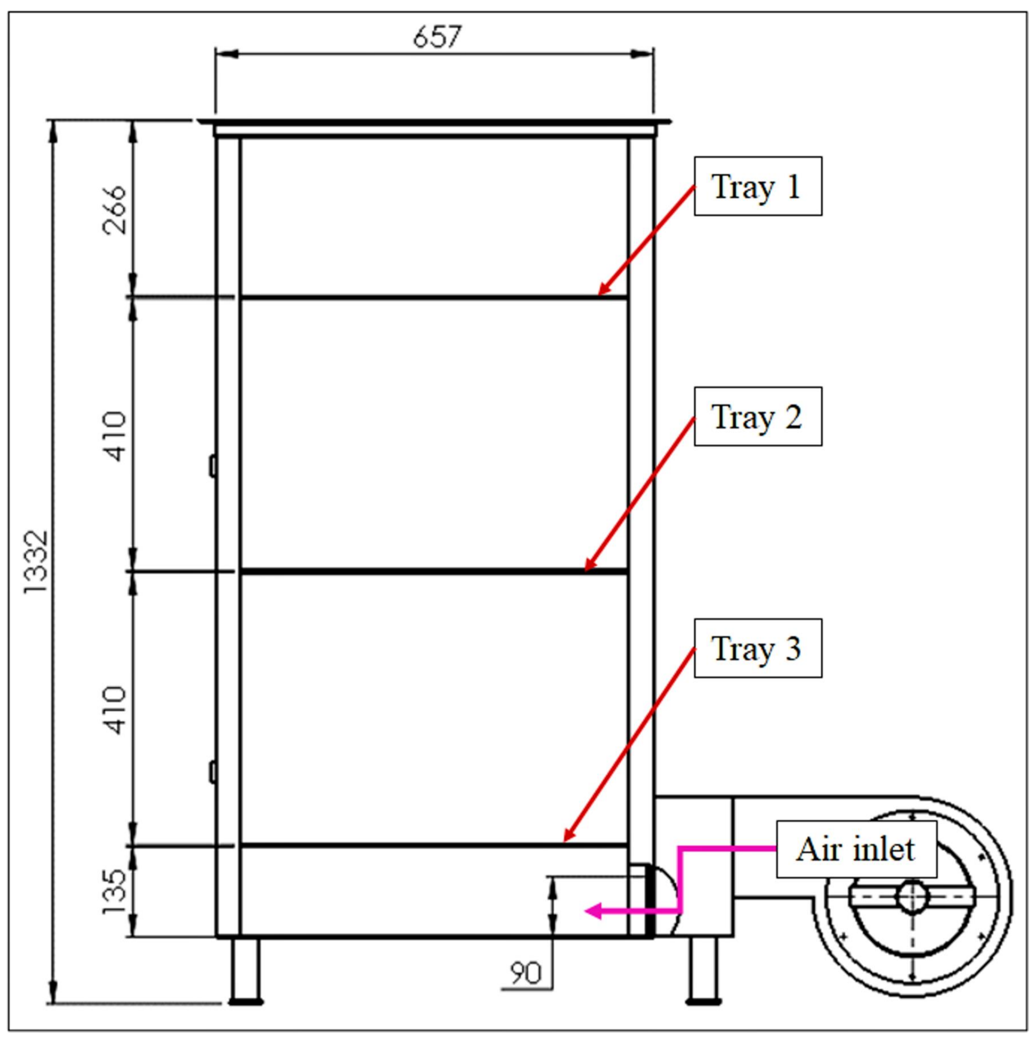

Figure 1. General dimensions of the rectangular-shaped coffee dryer.

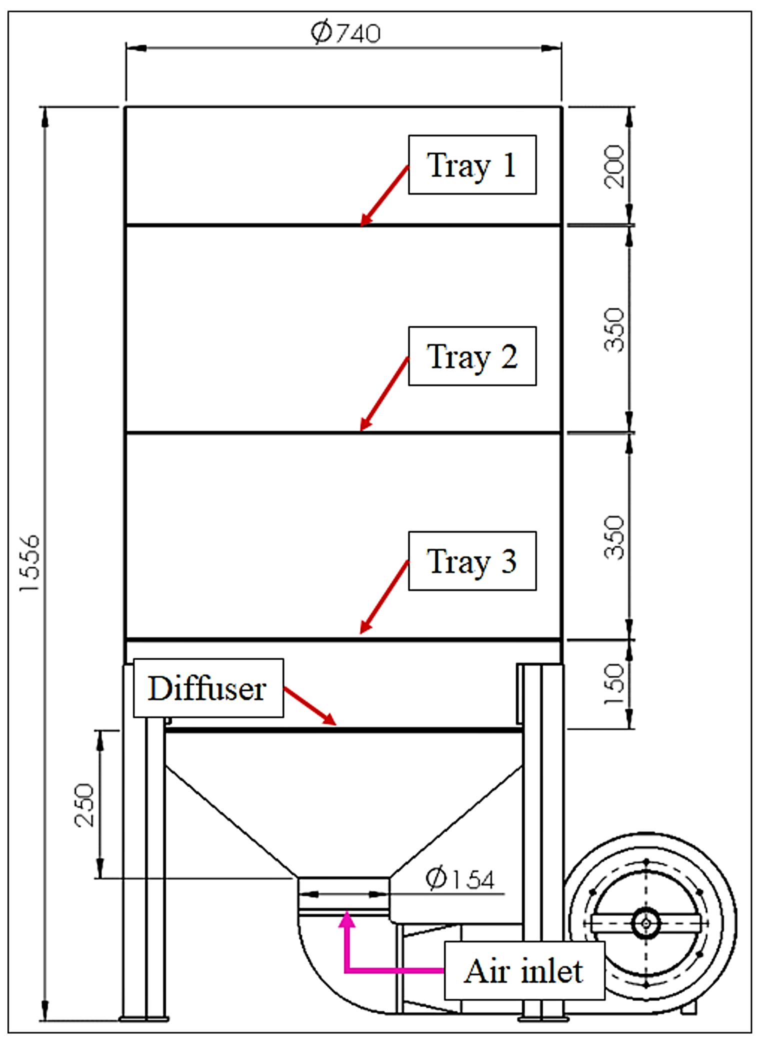

Figure 2. General dimensions of the cylindrical-shaped coffee dryer

Results

- Both dryers were simulated under the same conditions (initial grain moisture, amount and temperature; air's relative humidity air/humidity ratio and velocity) at three different drying air temperatures.
  - The cylindrical dryer displayed a lower drying time for all the 3 studied temperatures (Figure 3, 4).

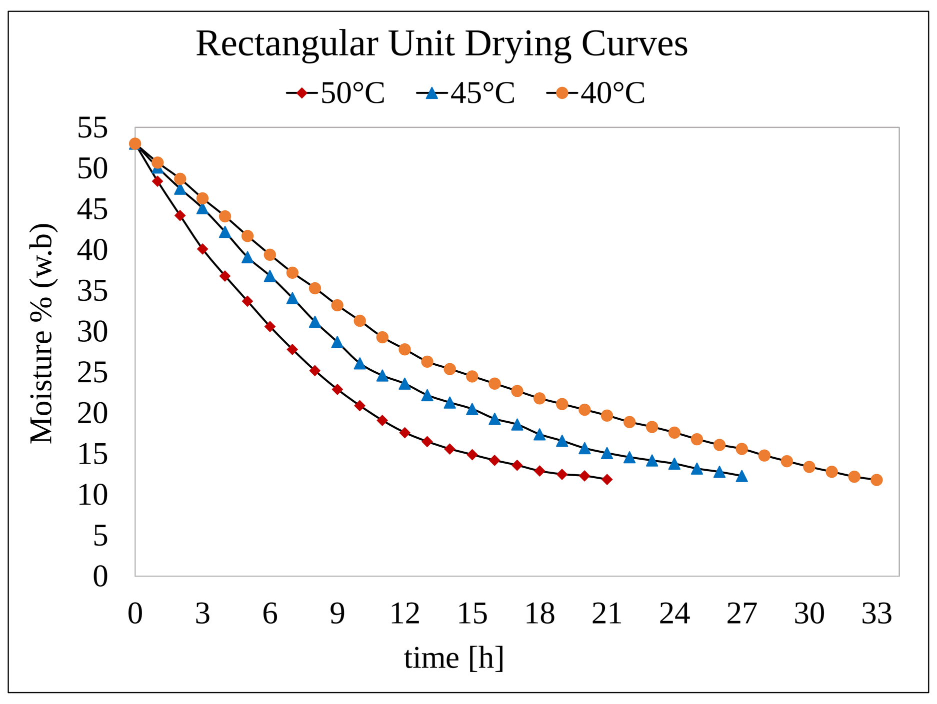

Figure 3. Rectangular unit comparative drying time plot.

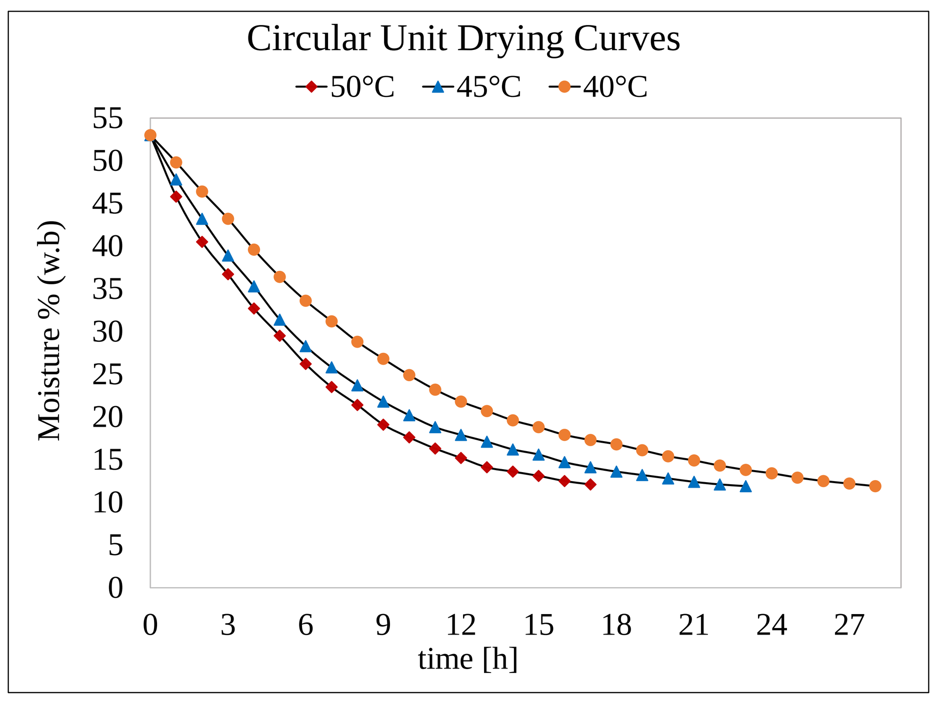

Figure 4. Cylindrical unit comparative drying time plot.

- The drying air behaviour CFD simulation within the rectangular dryer (Figure 5) suggests that:
  - The rectangular dryer holds a difficult air-transiting geometry deriving in velocity losses (Figure 5A) hence a heat loss is also expected.
  - Uneven air distribution in the dryer's chamber; therefore, the moisture removal will not be equal (Figure 5B) .

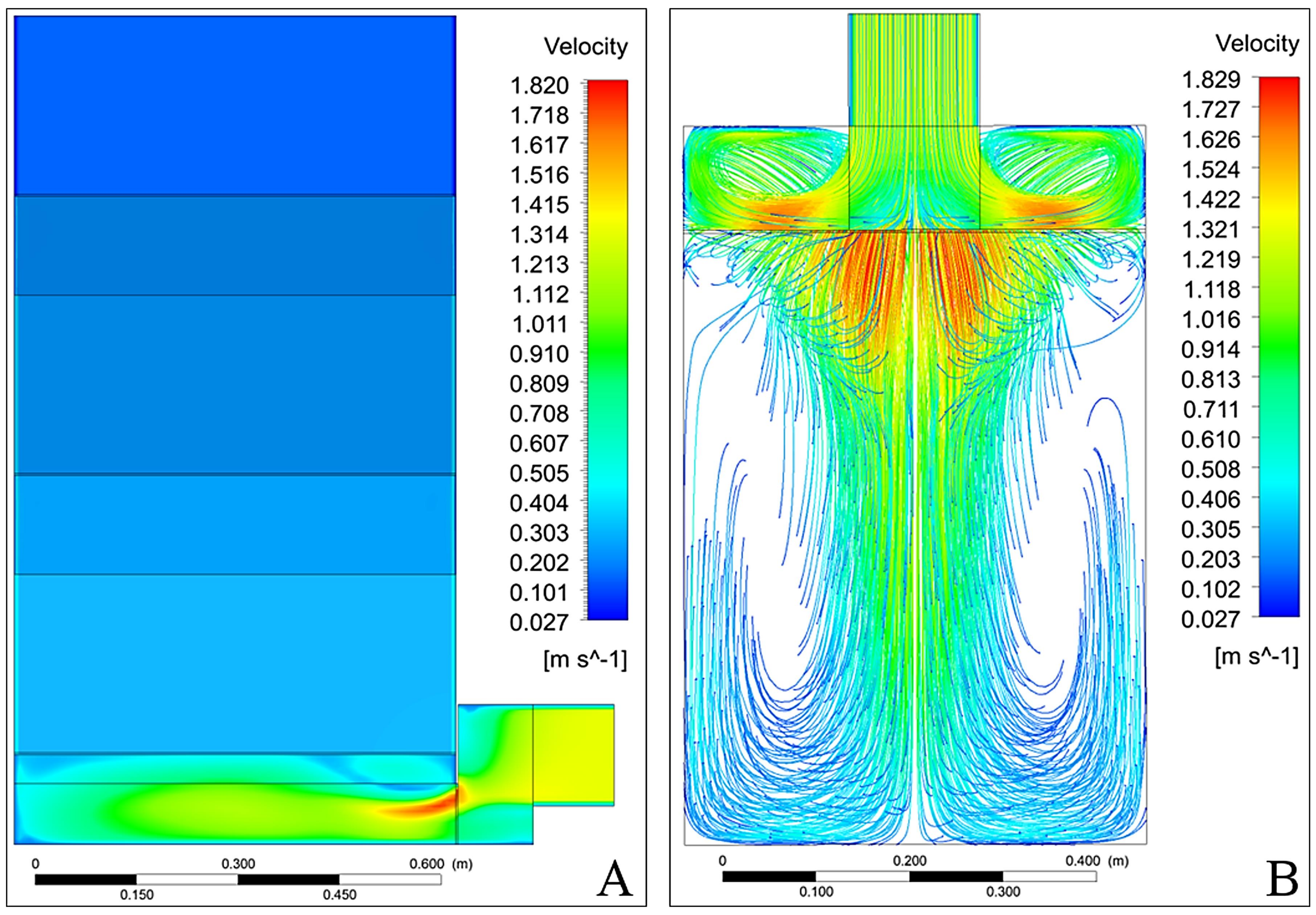

Figure 5. A. Rectangular-shaped unit velocity contours, B. Rectangular-shaped unit velocity streamlines top view.

- The drying air behaviour within the cylindrical dryer (Figure 6) displays:
  - An easier transit-through geometry, keeping a higher velocity (Figure 6A) , therefore air temperature (Zhang & Long, 2017).
  - The air distribution is homogeneous, ensuring an even moisture removal (Figure 6B).

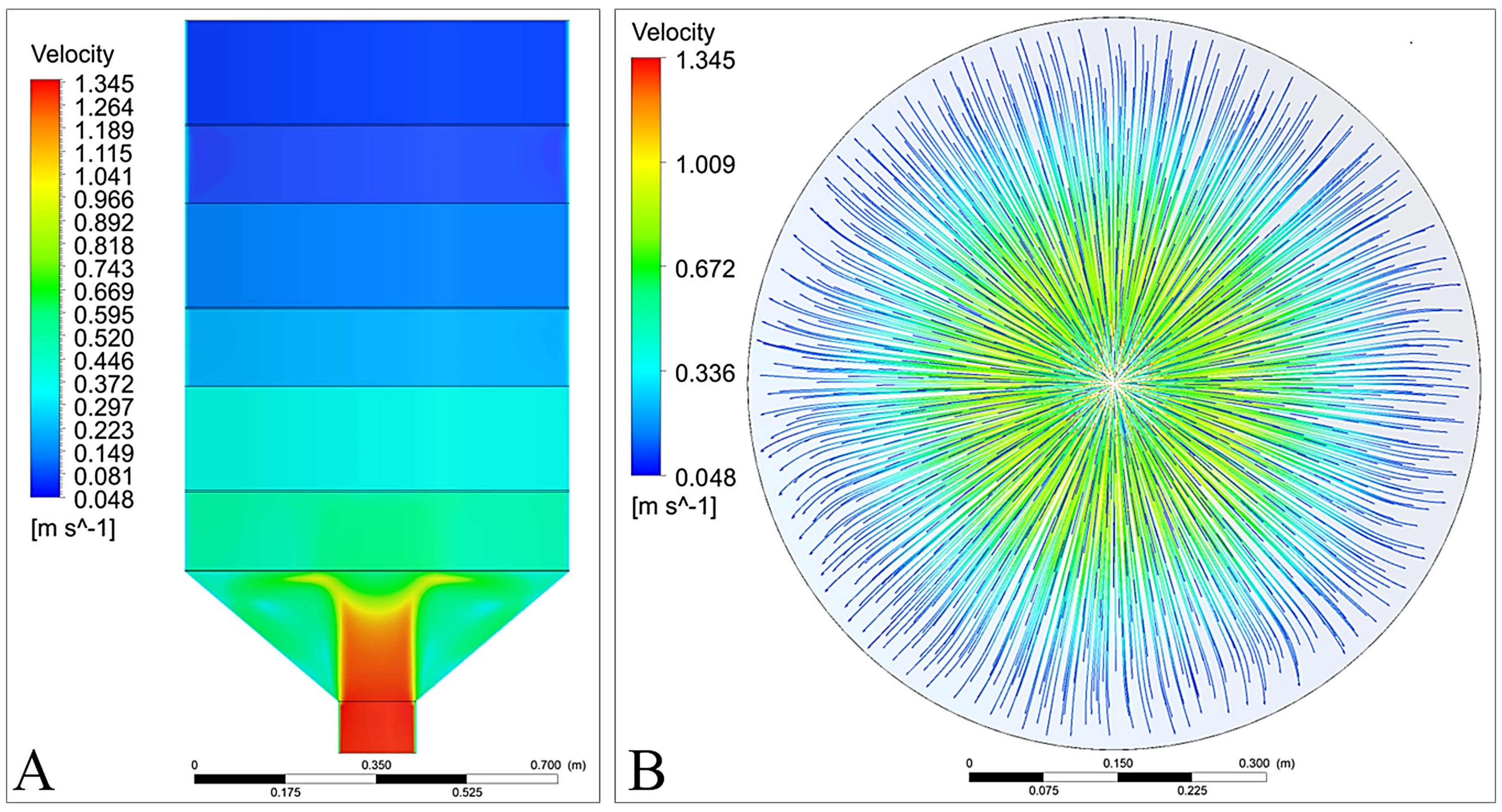

Figure 6. A. Rectangular-shaped unit velocity contours, B. Rectangular-shaped unit velocity streamlines top view.

Conclusions

- The computational fluid dynamics analysis confirmed that the drying air usage would be improved by changing the unit's geometry.
- The cylindrical dryer exhibited a significant theoretical reduction in the drying time, foreseeing a better seed preservation quality.
- The cylindrical unit drying capacity is higher, resulting in an increased capability to process wet coffee, accompanied by a lower energy and gas consumption.
- An increased drying capacity will positively impact the final income for the small-scale coffee producers in Colombia.
- A cylindrical dryer with a vertical air inlet enhances air distribution and velocity.
- Low bed heights with large cross sections improve the drying time and air temperature.

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