Multiphysics modeling of warm-air drying of potatoes slices

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Introduction: In this work, experimental data and theoretical model are compared to study simultaneous transport mechanism during drying of potatoes slices. The model captures both the transport of liquid water in the capillary domain, and the transport of water vapor. At the hygroscopic. The critical moisture point (CMP) was considered, since it is a transition zone and represents the point where water saturation is near from cero and hygroscopic domain begins. A phenomenological model was solved by coupled equations in Comsol Multiphysics EDP mode.

Computational Methods: Partial differential equations (EDP) were written for moisture content, temperature, and dry-air conservation. The moisture transport equation is:

$$\frac{\partial W}{\partial t} + \nabla \cdot \left\{ \frac{1}{\rho_s} \left(\rho_l \vec{V_l} + \rho_v^g \vec{V_v} \right) \right\} = 0$$

The energy general balance takes into account the mass flux for each phase:

$$\rho Cp \frac{\partial T}{\partial t} + \left[\left(\rho_l \vec{V_l} Cp_l + \rho_a^g \vec{V_a} Cp_a + \rho_v^g \vec{V_v} Cp_v \right) \right] \nabla T - \nabla \cdot (\lambda \cdot \nabla T) = 0$$

Free water evacuation is written by using the concept of *Capillary Diffusivity*,

$$\rho_l \vec{V_l} = -D_c \cdot [\nabla W]$$

Mobility of water vapor, is considered by both a pressure and concentration gradient:

$$\rho_v^g \vec{V_v} = \rho_v^g \frac{k.k_{rg}}{\mu_g} \cdot \nabla P_g^g - \rho_g^g D_{eff} \cdot \nabla C_v^g$$

The model is based on the following assumptions:

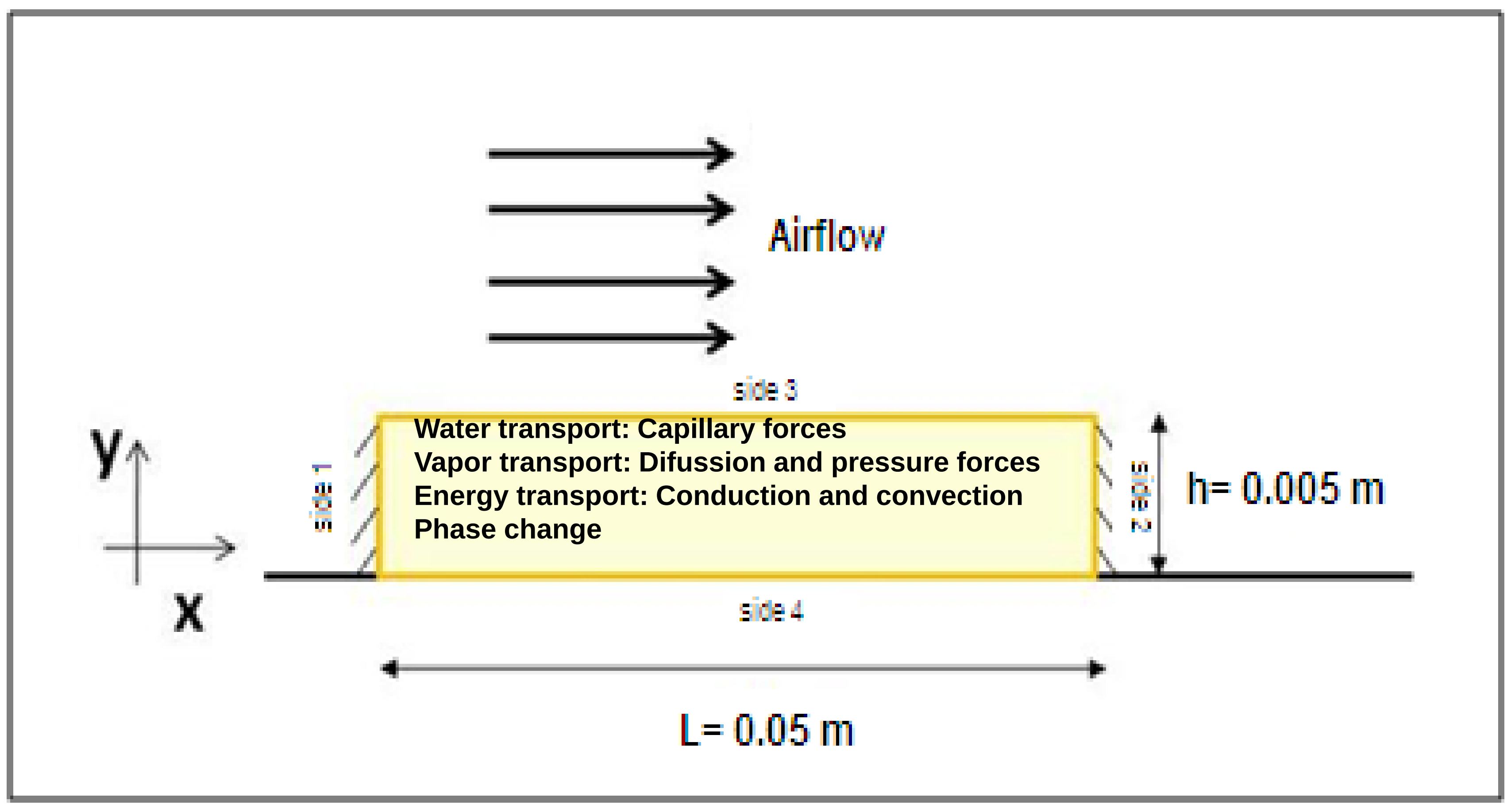

Figure 1. Physical Model

Results: The capillary domain governed the system until 0.385 kg water/kg dry mass (CMP), where moisture internal gradients were observed and the hygroscopic domain start.

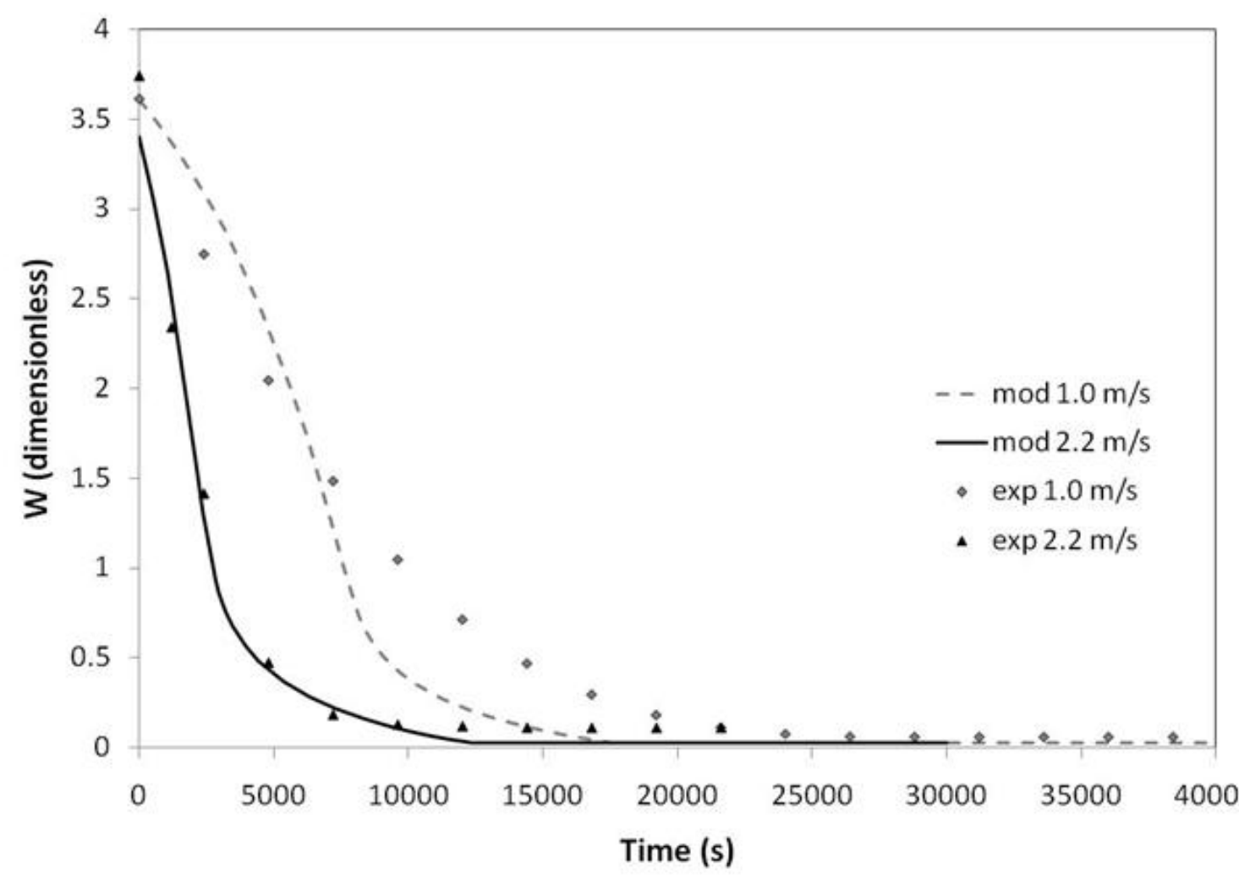

Figure 2. Experimental and simulated drying kinetics at 1.0 and 2.2 m/s.

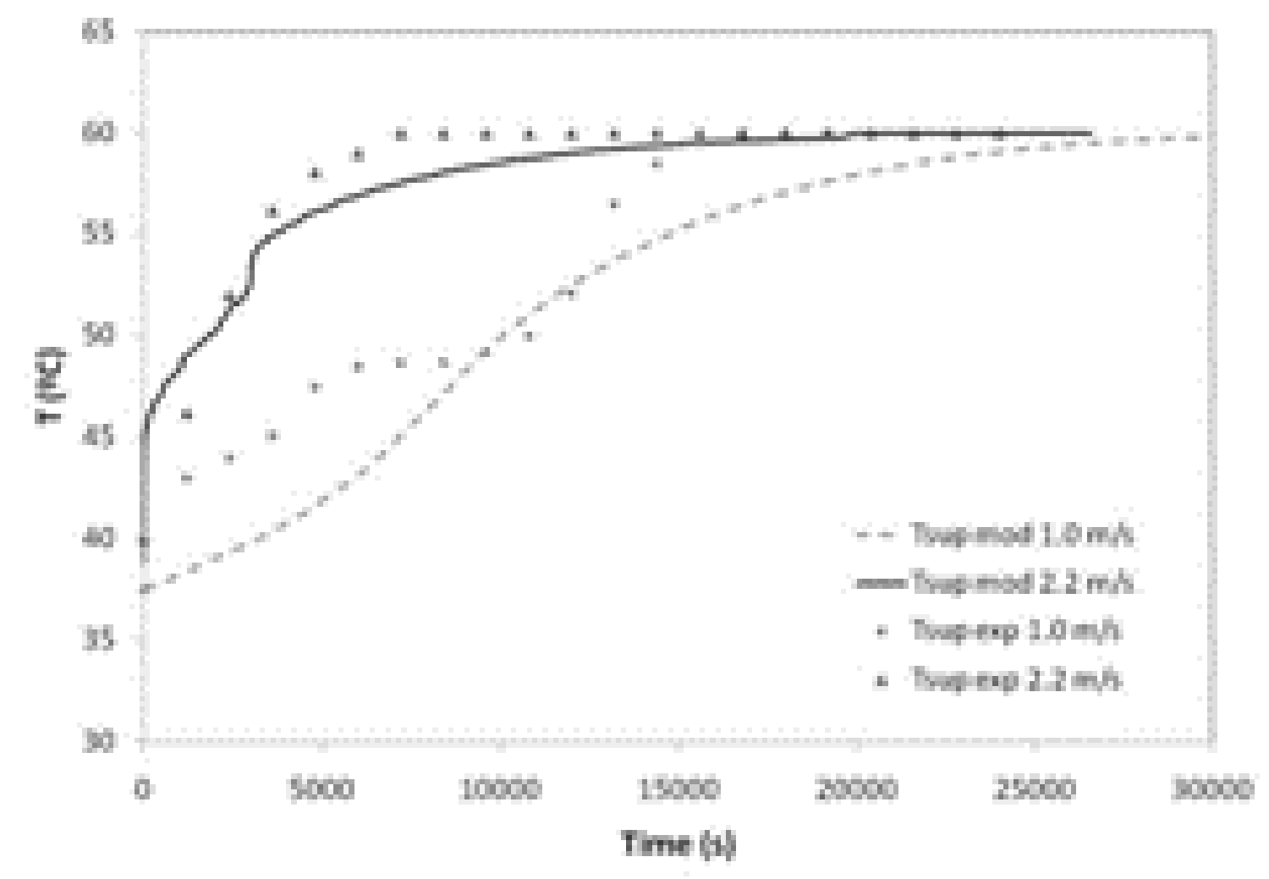

Figure 3. Thermal surface evolution at 1.0 and 2.2 m/s.

In fact at 1 m/s the evaporation is slower than at 2 m/s. At 1 m/s we identify several periods, between them the constant drying period.

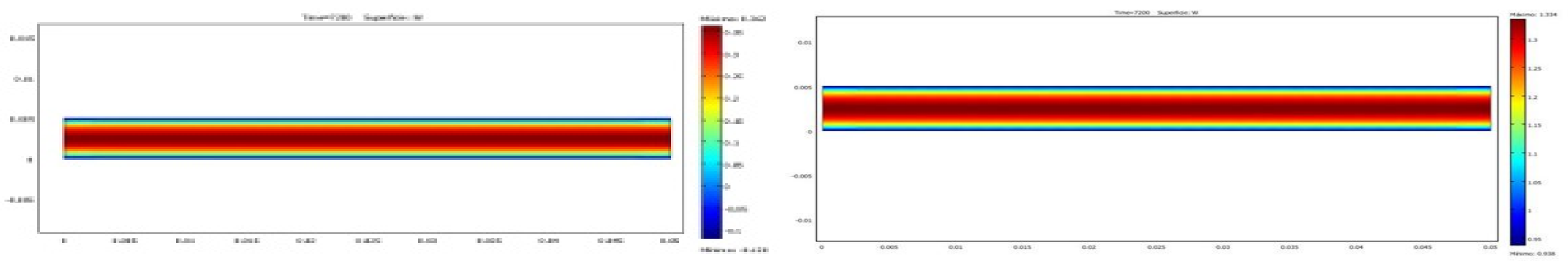

Figure 4. Moisture distribution after 2 hours of drying.

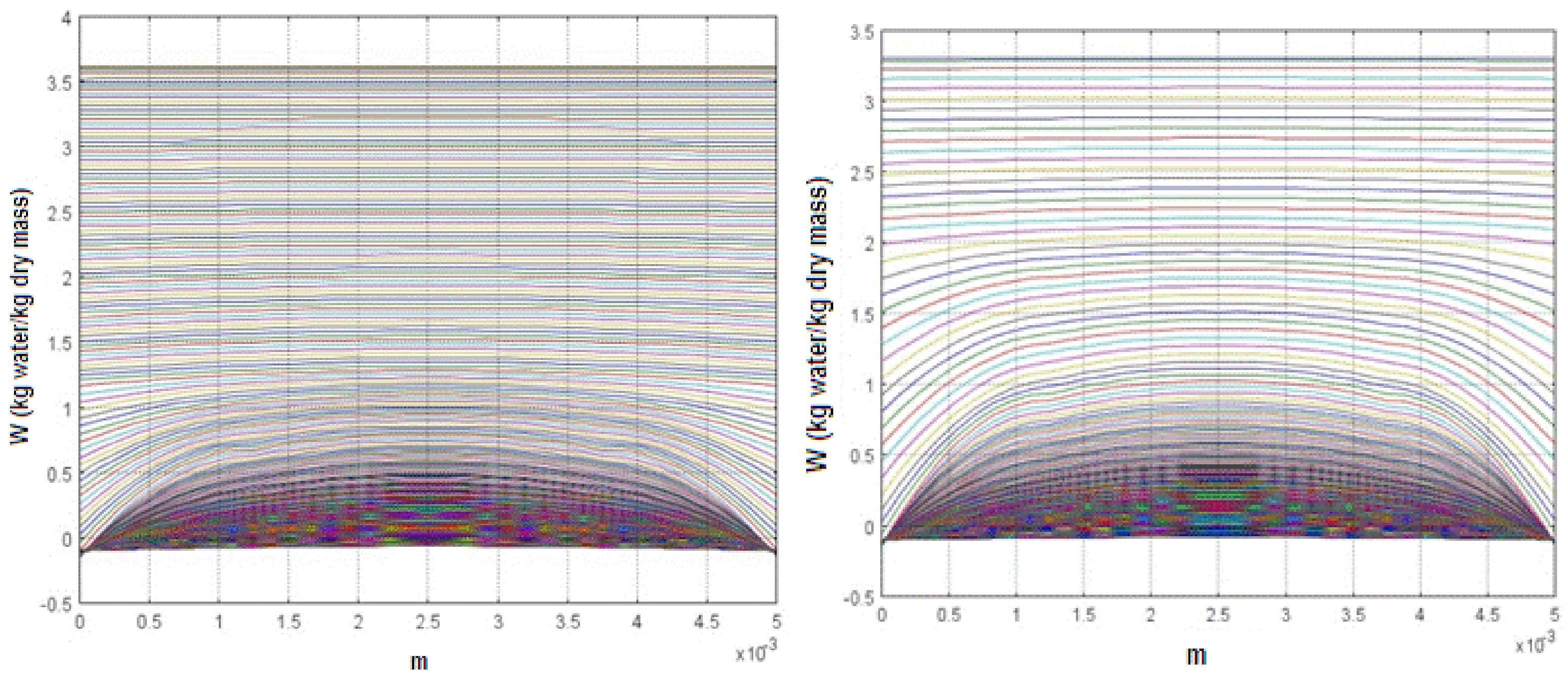

Figure 5. Moisture profile at 1.0 and 2.2 m/s

Conclusions: The moisture content evolution is well simulated, the moisture pattern and temperature show two behaviors depending on air-flow velocity. Deviations are attributed to thermo-physical variation of the material.

References:

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