UNIVERSITY OF HOHENHEIM

TROPENTAG 2021

INSTITUTE OF AGRICULTURAL ENGINEERING
Tropics and Subtropics Group

Experimental analysis and CFD-based Modeling of Grain Bulk Drying Dynamics

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Introduction

- Drying is of great importance in the postharvest processing of agricultural commodities. It hinders the occurrence of diverse moisture-related deteriorative reactions and contributes to quality preservation.
- This study aimed to develop a CFD-based model to simulate the temporal and spatial dynamics of drying of agricultural commodities under controlled conditions.

Material and Methods

- Wheat variety (Pionier A, DSV AG) was used as a reference product.
- A robust and automated measurement system using a high precision balance was utilized as a basis for the real-time and continuous acquisition of drying data (Fig. 1).

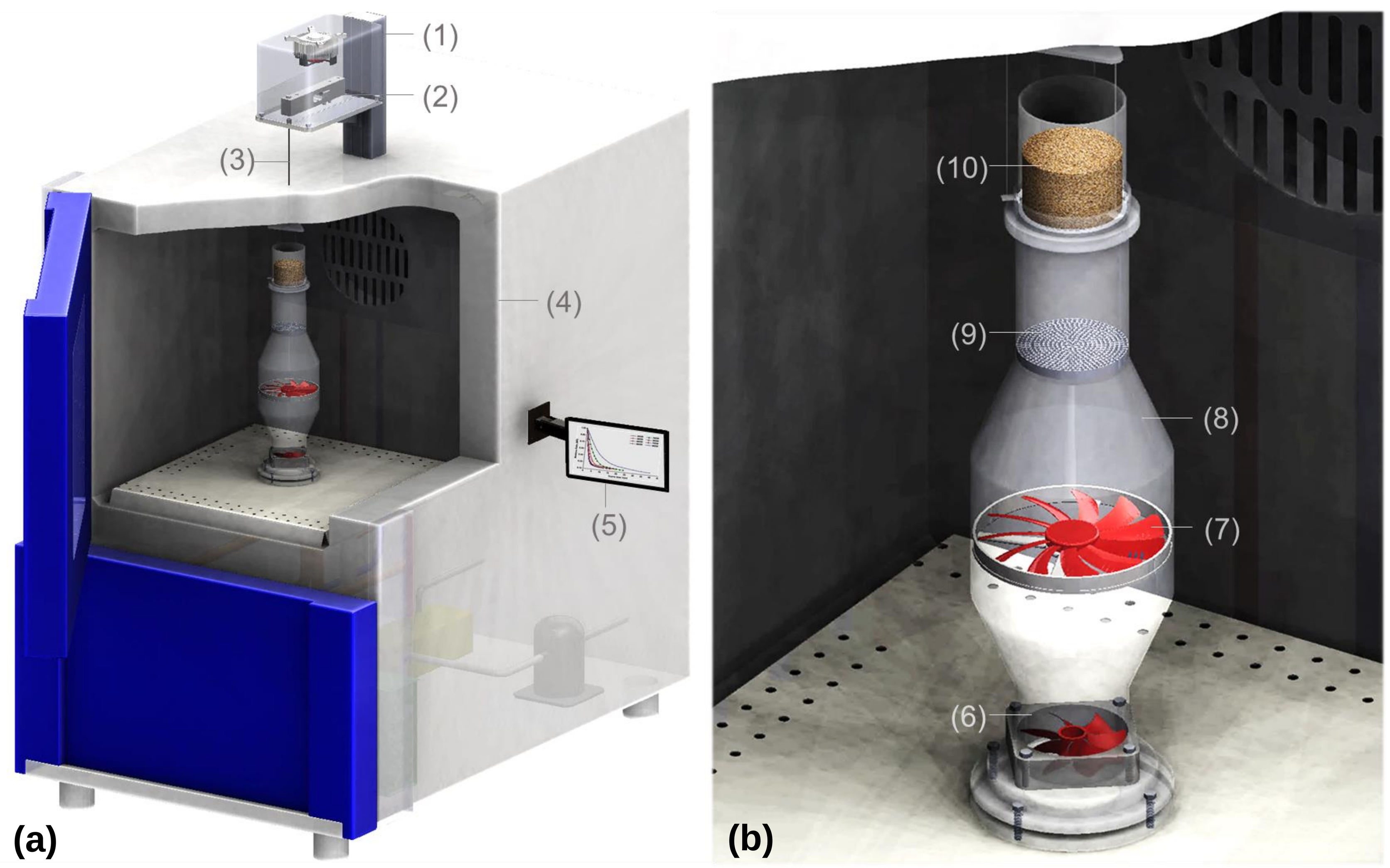

Fig. 1. (a) The schematic CAD design of the automated drying system; (b) Magnified view of system interior. The system is composed of (1) spindle drive, (2) load cell, (3) nylon string, (4) climatic test chamber, (5) laboratory computer, (6) axial fan, (7) anemometer, (8) drying column unit, (9) airflow straightener, and (10) grain bulk.

- CFD with integrated porous media approach was used to simulate the flow resistance within grain bulk (Tab. 1).
- A coherent set of drying conditions (temperature T = 10 – 50ºC, relative humidity RH = 20 – 60%, airflow velocity v = 0.15 – 1.00 ms^{-1}) was used to validate the model.

Tab. 1. Properties of wheat bulk (Pionier A, DSV AG)

Parameter	*Value*
Surface area, (m^2)	3.63×10^{-3}
Bulk volume, (m^3)	1.45×10^{-4}
Void fraction, (–)	0.5
Inertial resistance, (m^{-2})	2.21×10^{7}
Viscous resistance, (m^{-1})	1.15×10^{3}

Results

- Compared to the tedious physical experiments, simulation provided fast and in-depth information about the drying process.
- A good agreement ($R^2 \geq 0.99$ and MAPE ≤ 14.94%) was observed between the simulated and experimental results in terms of temperature and moisture content when drying at T = 40°C, RH = 40% and v = 0.15 ms^{-1} (Fig. 2).

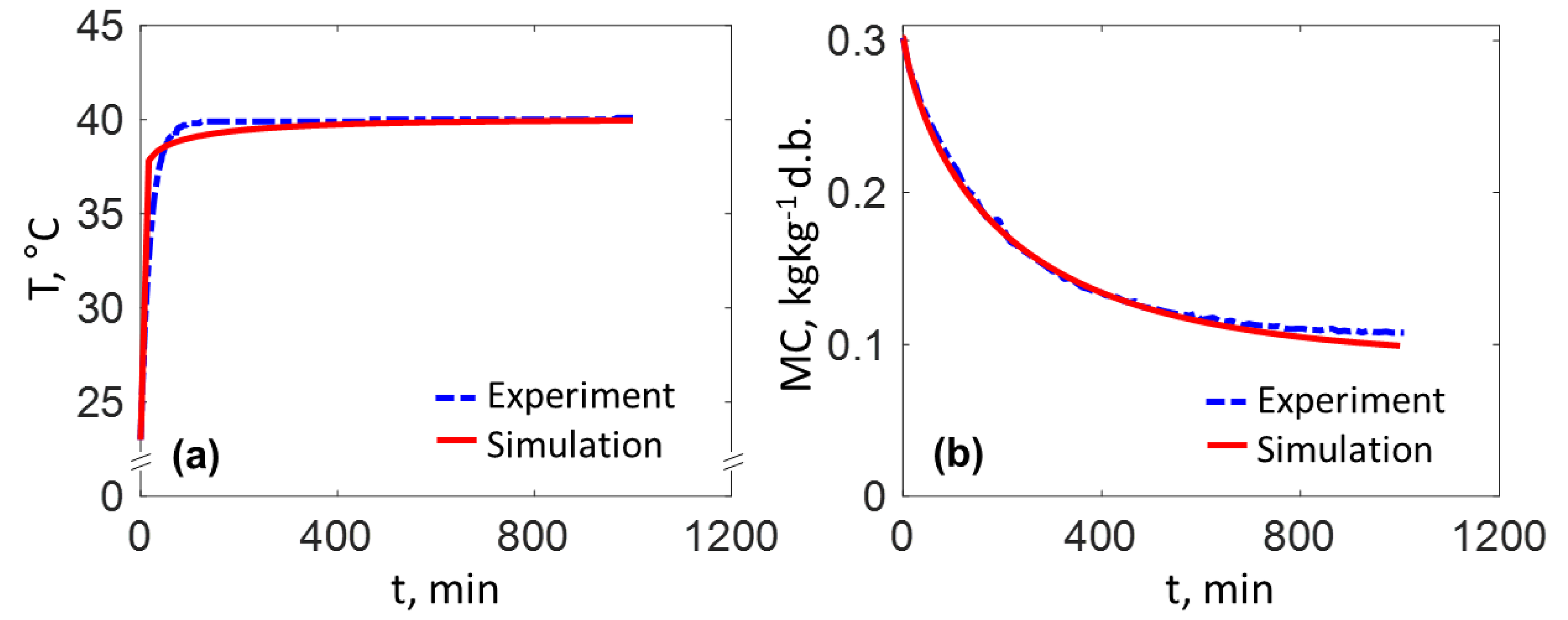

Fig. 2. Experimental and simulated results for (a) temperature T and (b) moisture content MC of grain at drying conditions of T = 40°C, RH = 40% and v = 0.15 ms^{-1}.

- The CFD model is capable of simulating and portraying graphically the dynamics of temperature and moisture content to permit insights into drying processes (Fig. 3 and Fig. 4).

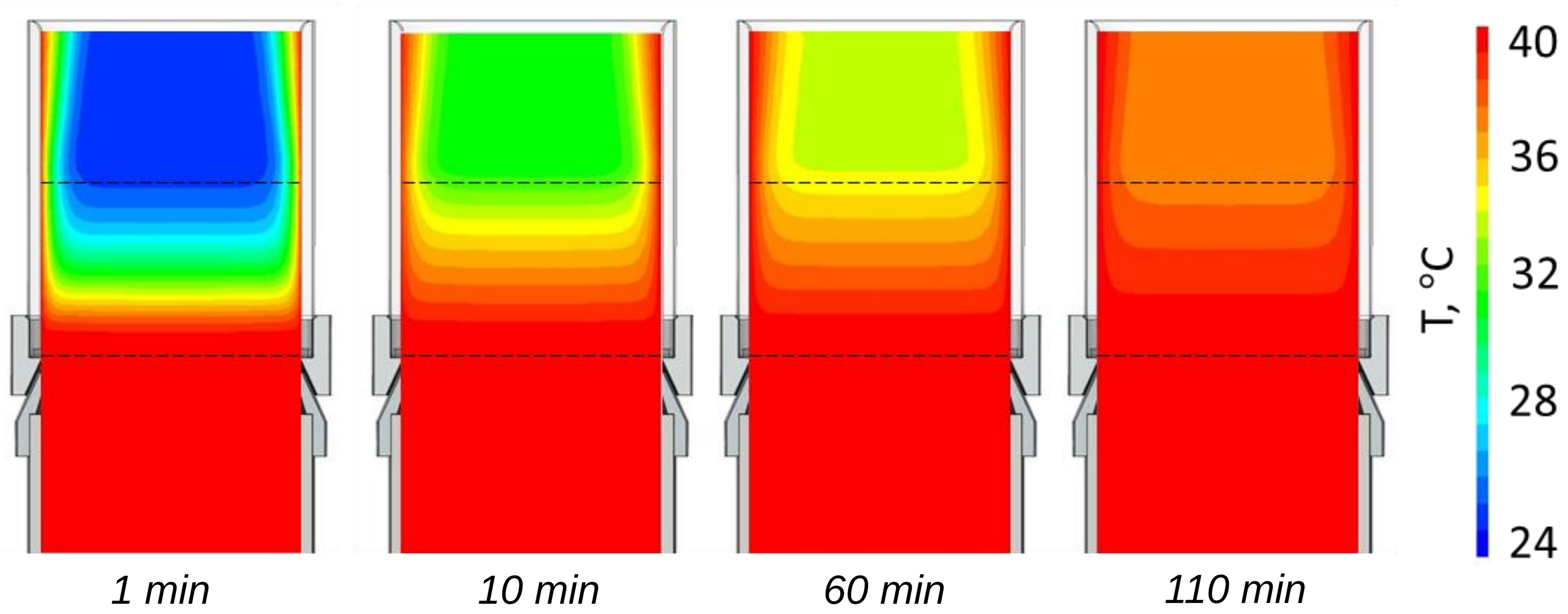

Fig. 3. The spatial and temporal distribution of predicted temperature within grain bulk. Dotted lines indicate the position of grain bulk.

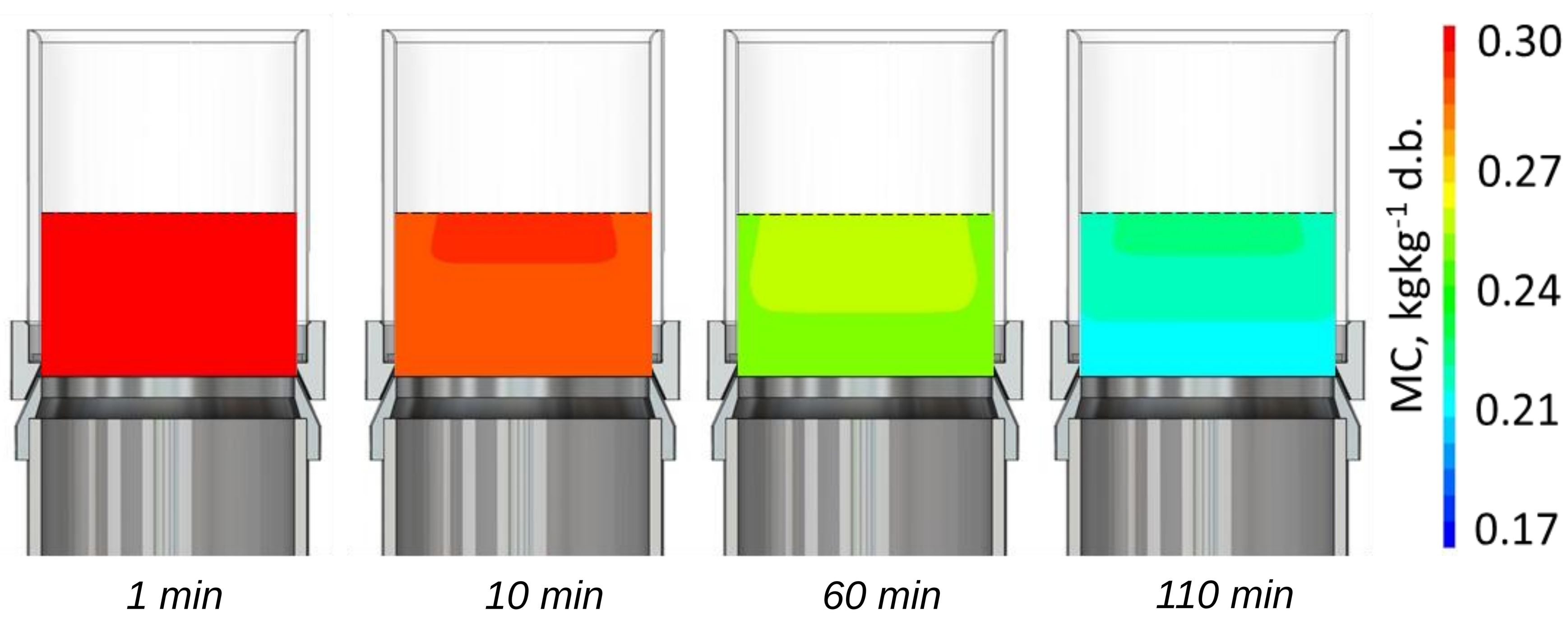

Fig. 4. The spatial and temporal distribution of predicted moisture content within grain bulk.

Conclusions

- CFD-based model proved to be an efficient tool in predicting with high temporal and spatial resolution the mechanisms underlying the drying processes.
- The capability of proposed model should be further assessed for other drying technologies, operating conditions and/or agricultural commodities.

Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages
ZIM Zentrales Innovationsprogramm Mittelstand

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