7th International Conference on Thermal Equipment, Renewable Energy and Rural Development

TE-RE-RD 2018

Drobeta Turnu Severin
31 May - 2 June 2018

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TE-RE-RD 2018

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Thursday, May 31	**Friday, June 01**	**Saturday, June 02**
	Breakfast	Breakfast
15.00-16.00 Registration of participants	08.30-09.30 Registration of participants	09.00-12.00 Networking
16.00-16.30 Opening ceremony	09.30-11.00 Oral presentations "Sections 1, 2"	12.00 Participants departure
16.30-18.30 Plenary session	11.00-11.30 Coffee break	
19.00-21.00 Welcome Cocktail	11.30-13.00 Oral presentations "Section 1, 2"	
	13.00-14.30 Lunch	
	14.30-16.30 Oral presentations "Section 1, 2"	
	16.30-17.00 Coffee break	
	17.00-18.30 "Workshop”	
	19.30-22.00 Conference dinner	

CONTENTS

SECTION 1: THERMAL EQUIPMENT AND RENEWABLE ENERGY

SECTION 2: RURAL DEVELOPMENT AND RENEWABLE ENERGY

INNOVATIVE MODEL OF VERTICAL DRYER FOR CEREAL SEEDS

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ABSTRACT

Generally, after harvesting, healthy cereal seeds are subjected to conservation technologies, the most common being drying. This is a complex energy-intensive process of heat and mass transfer, the installations used having high energy consumption per kilogram of product, as well as a long drying time. In order to properly optimize the drying process, it is necessary to deeply know the phenomena related to the behavior of wet materials (seeds) in the drying installations. To this is added the highlighting of the decisive influence of their specific parameters on the decrease of moisture.

The paper presents a synthesis of mathematical modelling and simulations conducted in order to identify and determine a series of parameters based on which was dimensioned and designed the innovative Model of vertical dryer with heat recovery (MIUV-0).

1. INTRODUCTION

Reducing post-harvesting loses contributes to the increase of food safety and depends on threshing, cleaning, drying and depositing seeds. Drying represents removing moisture so that it allows seeds depositing for long periods, as well as satisfying the quality conditions the quality conditions imposed for seeds destined for consumptions or sowing, thus adequately responding to handling and processing [4].

Drying is the most intense energy process in the food industry. That is why, in the case of seed dryers, it is necessary to manage the thermal regime thoroughly by knowing their technical and functional parameters. Reducing energy consumption and ensuring high quality, with minimal increase in economic inputs, have become the targets for the continuous modernization of these machines [2,12]. Heating intensity and the energy consumption depend on the dimensions and on the initial temperature, the moisture of the bodies, the microstructural characteristics of porous materials, their anisotropy, the content and the aggregate state of the water inside them, the temperature and moisture values of the heating medium, etc. [11]

In general, the model is considered as a simplified (material or symbolic) representation of the objective reality (sometimes of an abstract theory) that is subordinated to the purpose of the research. The purpose of mathematical modeling is to build a tool (mathematical) that provides a comprehension of the action that raises interest and to make accurate predictions on its evolution. Always, the complexity of a model implies a balance between its simplicity and its accuracy of representation [1, 5, 6].

The innovative vertical dryer model with heat recovery (MIUV-0) was dimensioned and designed based on mathematical modeling and simulations conducted to identify and determine a series of specific parameters.

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2. METHODOLOGY

In order to estimate and track the evolution of temperature and moisture fields over time at any point of the product layer (cereal seeds) subjected to the drying process, a mathematical model was developed using CFD (Computational Fluid Dynamics) simulation and a laboratory dryer, which can be equipped with two drying boxes: rectangular (fig.1) or cylindrical (fig.2). The equipment allows the control and monitoring of the drying process parameters, which can be selected by the operator before or during the drying process [2, 3].

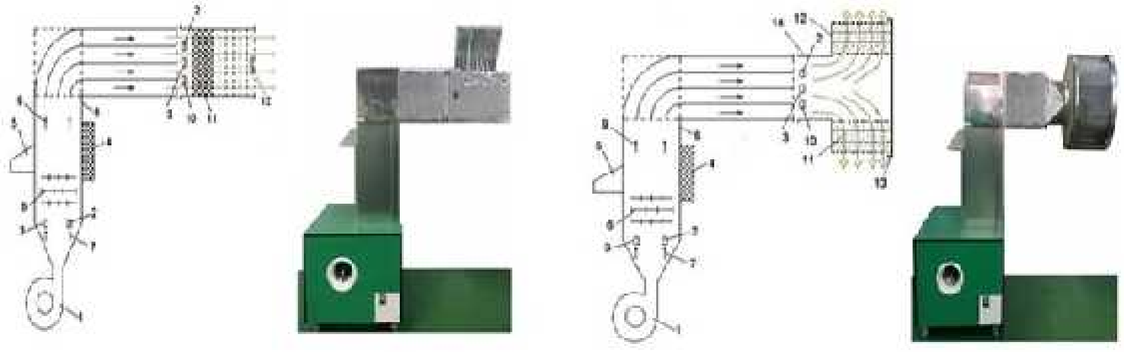

Figure 1: Diagram and general view of the laboratory drier [2]

With rectangular box	With cylindrical box
1 - ventilator; 2 – temperature sensor; 3 – moisture sensor; 4 – insulation layer; 5 – control panel; 6 – electrical resistance; 7 – cold air; 8 - body; 9 – hot air; 10 – speed sensor; 11 – drying cells.	
12 – moisture sensor for the drying agent used.	12 – fixed cover; 13 – mobile cover; 14 – section changing.

The process of drying cereal seeds is carried out by convection, the heat being brought into the layers of material (considered porous), through the means of hot air (the drying agent). Once it enters the cereal mass, mass transfer (water) begins from the inside of the product towards its surface. The water moves both under the influence of capillary forces as well as due to the contraction of the product during dehydration, easily reaching the surface where the evaporation phenomenon occurs. Air is the transfer medium that takes up the vapors produced. Towards the end of the drying process, water transfer is slower due to the dry layer formed on the surface of the product [2, 3, 7, 8].

The mathematical model of the convective drying process is based on the theory of fluids dynamics, mass balance and energy. During the drying process, moisture decreases continuously, following complex variation laws [2].

Heat agent flow was simulated numerically for both types of dryers. For the cylindrical case, the current lines of thermal agent obtained had a laminar flow at the entrance to the box, and the thermal agent had a uniform distribution in the layers of seeds subjected to drying along the cylindrical sieve (fig. 3). This had favorable consequences in terms of the drying time, which was of a lower duration as well as on the uniformity of drying (fig.4). For cereal seeds is not recommended to use aggressive drying conditions, characterized by high temperatures and low moisture content of the drying agent, because they negatively influence the initial quality of the material, expressed mainly by the gluten content [2, 3]. The values of the temperature, the relative moisture of the drying agent and its speed (parameters of the drying regime) influence both the drying process and the quality of the material to be dried [2, 3, 7, 8].

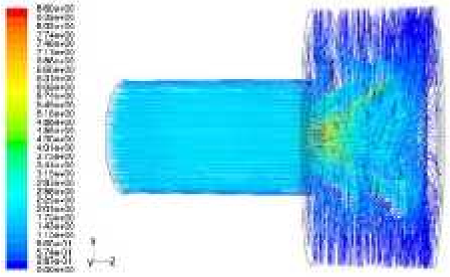

Figure 3: (Path lines) Flow of air field lines [2]

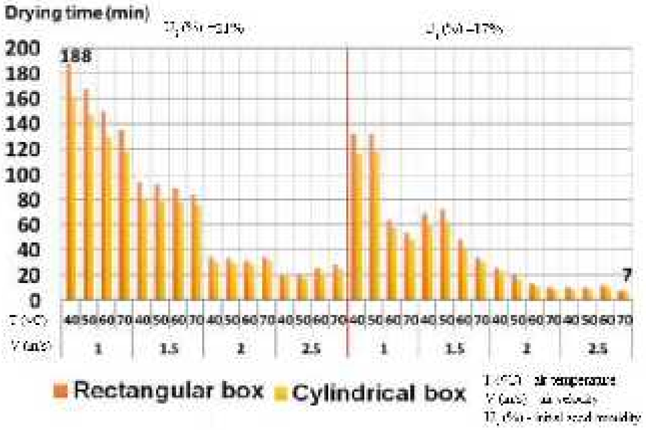

Figure 4: Variation of drying time for cereal seeds (wheat) [3]

By knowing the temperature profile in the grain seed layer is possible to optimize the air flow and temperature in the layers. For this purpose, the mathematical modeling of mass and heat transfer was achieved in a three-layered cereal seed dryer. Experimentally, a three-concentric layer cylindrical drier was designed and developed to study temperature and moisture distribution for improving qualitative indices of corn seed for preservation (Fig.5). The interior deflectors of the drier have the role of uniformizing the hot air, on the height of the layer [7].

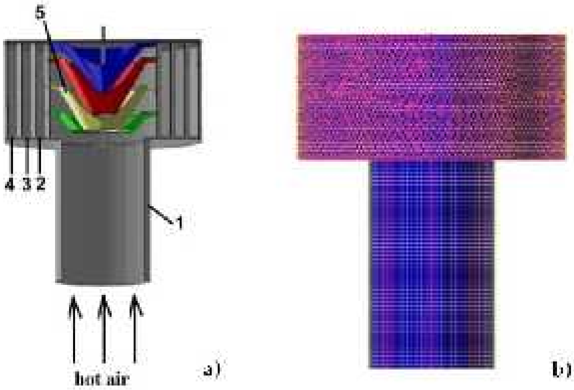

Figure 5: Geometry of driers and deflectors: a) section; b) hybrid mesh
(1 thermal agent pipe (hot air), 2 layer I of seeds, 3 layer II, 4 layer III, 5 deflectors) [7]

The research method was developed by mathematical modeling of mass and heat transfer phenomena in corn seed layers based on a series of data obtained and verified by experimenting on the laboratory model. The equations governing mass and heat transfer are expressed in general terms, see Eq. (1). In order to model the phenomena that occur during the drying of corn, it is necessary to adapt them [7]. The partial differential equation of general form mathematically describing the drying phenomenon:

$$\frac{\partial(\rho_a \Phi)}{\partial t} + \nabla(\rho_a v \Phi) = \nabla(\Gamma \nabla \Phi) + S\Phi \qquad (1)$$

Φ is the amount of interest that in this case is the energy or moisture content of the intergranular air, ρ_a is the air density, v is the superficial velocity or air load, as opposed to the average velocity of air flowing between corn seeds, Γ is the actual diffusion coefficient of Φ through the layer of corn seeds, t is time, Δ is del operator, SΦ is a source term. Eq. (1) refers to a small differential corn region and this implies that the properties were averaged over a given final volume [7].

Thus, the standard CFD package has been modified to be used to simulate the transfer of moisture (mass) and heat occurring during the corn drying process. Characteristics that specifically apply to bulk dried corn have been adapted to operator defined functions (UDFs). These have been translated into "C" language and then inserted into the FLUENT software [7].

For CFD simulation, the geometry of the drying zone and its discretization in the form of a hybrid meshing having 938,000 elements (Fig.5b), using the GAMBIT software. Both for the experimental version and the CFD simulation were imposed the same initial conditions for seeds, and for seed initial moisture, the drying agent temperature, drying speed and drying time were considered the same values. After post-processing of CFD simulations, the main parameters of interest in the color scheme of the corn seed drying process for each calculation node were presented as temperature fields or by showing the flow of air through the lines of current depending on its speed and temperature. Subsequent processing was performed for the three layers of corn seeds following temperature and moisture distribution, see Fig. 6 [7].

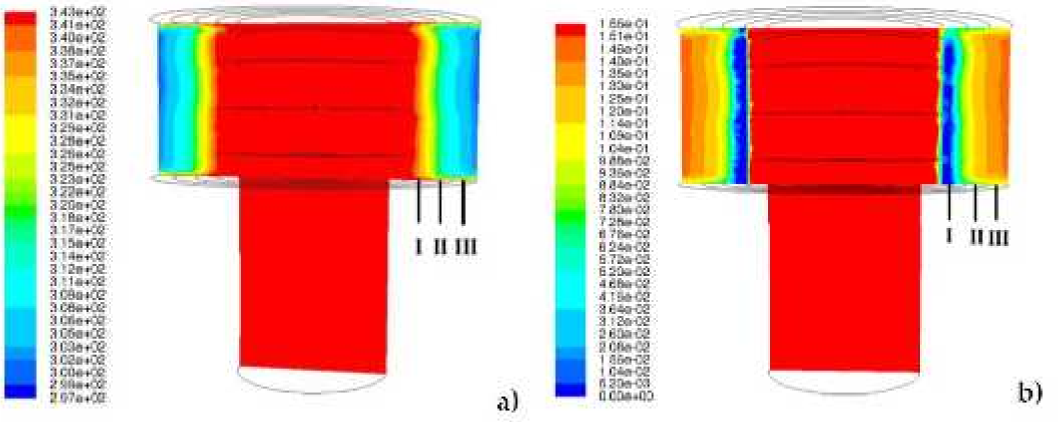

Figure 6: Vertical drier: a) temperature field K; b) absolute moisture field kg water vapors / kg dry product; I first layer; II second layer, III-third layer. (v = 2 m s^{-1}; T = 343 K=70 ° C) [7]

Following the mathematical modeling of mass and heat transfer and of the use of experimental data, CFD simulation resulted in an optimum thickness of 0.1 m corn layer in the dryer.

Based on mathematical modeling, the use of experimental data and CFD simulations, calculations were performed (energy balance, pneumatic transport, sizing, resistance, etc.) for a cereal seed dryer with heat recovery, modulated, of cylindrical shape, for which were considered: the maximum temperature of the drying agent 70^{o}C; atmospheric air temperature of 20^{o}C; relative air moisture 50%, etc. The hourly heat quantity required for the operation of the installation was evaluated, dimensioning the air current generating ventilator, the system for heating the medium, the pneumatic system for feeding the seed dryer and the supporting frame elements were evaluated. [9,10].

After evaluating the execution documentation, MIUV-0 was constructed. In order to solve the heat flow and heat transfer problems inside the vertical drier, the CFD simulation method was used. The complex construction geometry of the innovative vertical drying model with heat recovery for drying cereal seeds (Figure 7) was simplified for CFD simulation, so that the inner flow areas of the thermal agent and the transfer of heat that occurs during drying (Figure 8) cab be visualized. The dimensions of the dryer used in the CFD simulation were identical with those of the built-in model, and the simplifications of the vertical drier geometry did not influence the physical phenomena occurring during the drying process (height - 3 m, diameter - 1 m, layer thickness - 0.1 m, module height - 0.4 m; Φ hot-air inlet - 0.2 m) [8].

Figure 7: Innovation vertical drier with heat recovery

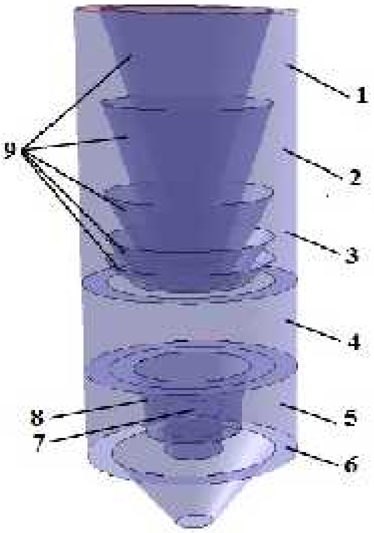

Figure 8: Vertical drier geometry for CFD simulation 1, 2, 3 drying sections; 4, 5 cooling sections; 6 grain seed layer; 7 warm air inlet for drying; 8 nozzle; 9 deflector cones [8]

CFD simulation allowed the temperature fields to be drawn in point of the vertical dryer (fig. 9), which would not be allowed by placing a large number of temperature transducers [8].

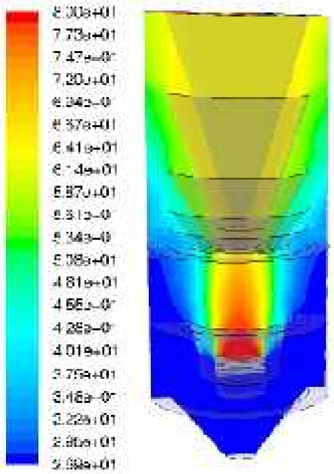

Figure 9: Temperature field on the vertical section (°C)

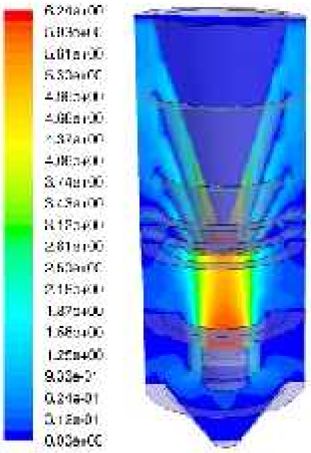

Figure 10: Velocity field on the vertical section (ms^{-1}) [8]

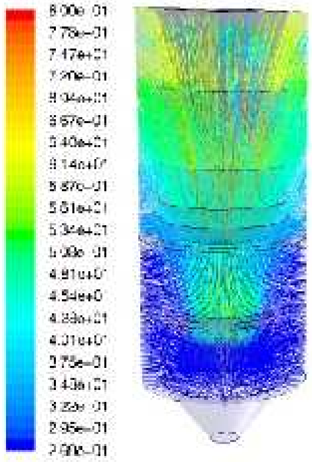

Figure 11: Path lines field on the vertical section [8]

By introducing the five cones inside the drier, air velocity distribution in the three drying zones became uniform, and the velocity vector was directed from inside the drier to the outside (fig. 10). In the two cooling regions at the bottom of the drier, the insertion of the injector made it possible to orient the velocity vector from the outside to the inside by absorbing the cold air from the atmosphere to cool the cereal layer. The air velocity at the entrance of the dryer was 6 m s-1, and in the cereal layer was 1...2 m s-1 [8].

The distribution of current lines from the exterior and the thermal agent inside the vertical dryer (fig. 11) shows the role of deflector cones and of injector nozzle formed inside the drier. By the construction formation of the injector and by placing it in the lower part of the dryer, a local pressure drop occurs, leading to the absorption of air from the atmosphere through the two lower cooling regions of the dryer, causing cooling of the dried cereals. Thus, part of the heat they accumulated through the drying process was recovered and reintroduced into the dryer's general circuit. The temperature obtained by CFD simulation had an error of ± 5% compared to the experimental determinations, representing an acceptable level in the heat transfer domain.

CONCLUSIONS

Following the CFD simulations on the pilot installation, the calculations and the design, a modular Innovative Vertical Dryer Model with heat recovery was developed, equipped with heating / cooling agent equalizing devices. Modulated construction offers the possibility of assembly and adequate adjustments inside the dryer, at the level of devices for temperature and velocity parameters uniformity. The development of the machine contributes to the development of research in the field of additional devices for guiding airflow towards the cereals layers, because vertical driers that are currently available on the market, are not provided with such endowments.

ACKNOWLEDGEMENTS

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