THE SIMULATION OF MALT DRYING OPERATION IN A MULTIFUNCTIONAL CASSETTE

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Abstract: Obținerea unui gradient de temperatură şi umiditate cât mai uniform în timpul uscării este importantă în obținerea unui malț de calitate superioară. În acest sens a fost proiectată o casetă multifuncțională de obținere a malțului în condiţii de laborator. Simularea procesului de uscare în caseta multifuncțională face posibilă obținerea unei distribuții uniforme a temperaturii și umidității în stratul de malț. Validarea modelului matematic utilizat în simularea uscării s-a realizat prin măsurarea umidității malţului în mai multe puncte din strat. Standul proiectat pentru uscare permite variaţii largi ale temperaturii şi umidităţii de intrare a aerului cald, fiind prevăzut cu senzori de temperatură şi umiditate precum şi cu posibilitatea variaţiei parametrilor aerului cald. Optimizarea casetei multifuncționale realizată prin simularea procesului de uscare permite creșterea calităţii produsului uscat.

Key words: numerical simulation, drying process, malt.

Introduction

Malt drying operation is important in the process of brewing. This process involves high energy consumption and management according to the drying process resulting in the final of malt and beer quality. The malt is produced from barley and drying operations are carried out by following malt bed of hot air flow. Hot air flow through the malt porous layer bottom-up heating products and takes a certain amount of moisture in it and drains with air. The loss of moisture is lost and a significant amount of heat particularly where air is not recovered. Many mathematical models have been developed to simulate the heat and the moisture transfer in aerated bulk stored grains. The models were obtained at relatively low temperatures and low humidity to grain. The models simulated forced convective heat and moisture transfer in vertical direction, but the model was not validated. (Chang *et al.*, 1994) and (Sinicio *et al.*, 1997) developed a rigorous model to predict the temperature and moisture content of wheat during storage with aeration, and found that prediction result is in reasonable agreement with observed data. (Thorpe, 2008) calculated on CFD models to a software that simulates heat and moisture transfer in the bad grain. Based model and simulation of (Thorpe, 2008), (Wilson *et al.*, 2010) developed and validated by experimental measurements of temperature transducers introduction the theoretical model at different points in a grain silo. This paper purposes the simulation of flowing of hot air into multifunctional cassette to obtain a more homogeneous distribution of velocities and temperatures under the sieve with green malt which is subjected to drying.

Knowing the temperature distribution in the malt bed indicate overheating or unheating areas and can get a uniform temperature in the layer. By knowing the moisture profile in the layer of malt can optimize the air flow under the sieve of multifunctional cassette by introducing some baffles for air distribution.

Materials and methods

The multifunctional cassette is designed to obtain malt in laboratory conditions, in batch up to 2 kg and with the possibility to perform four operations of barley seeds (washing, softening, germination and drying of germinated seeds). The CFD simulation (Computational Fluid Dynamics) was done for two variants of multifunctional cassette for drying operation. The geometry of the cassette was conditioned by the shape of the drying chamber, being accomplished with the purpose to be easily attached to the dryer.

In the first constructive version of the cassette, under support sieve for barley, the air entrance was freely done without any accessory inside (fig. 1). The second constructive version of the multifunctional cassette has at the bottom side, under the sieve with seeds, a dispenser with six baffles for homogeneous distribution of hot air in the seed layer (fig. 2) with dimensions showed in Table 1.

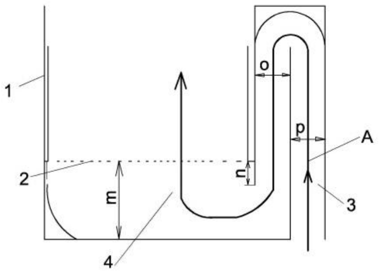

Fig. 1 Multifunctional cassette without baffles: 1 wall; 2 sieve for barley seeds; 3 air input; 4 air channel under sieve; A air flow inside the cassette.

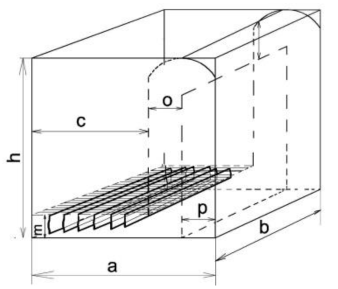

Fig. 2 Multifunctional cassette with baffles

Table 1 Dimensions for multifunctional cassette

Nr.	Types	Dimension [mm]					
		a	b	c	o	p	h
1	Multifunctional cassette without baffles	360	360	220	70	70	300
2	Multifunctional cassette with six baffles						

The geometry discretisation of the multifunctional cassette with six baffles is unstructured and is done with Ansys-Gambit software (*fig. 3*). In the region of the six baffles and the seed layer subjected to drying, the discretisation was done with a greater number of nodes. The two cassette versions were discretised with sufficiently large volumes, without affecting the precision, and computing time to be reasonable, taking into account the simulation is unsteady. The average number of nodes obtained after discretisation was of 594,075, and the quality of discretisation 0.7.

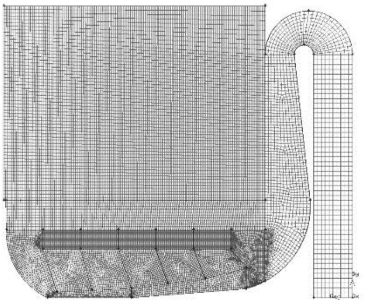

Fig. 3 Grid for multifunctional cassette with baffles

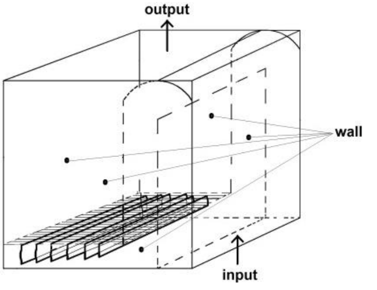

Fig. 4 Boundary sections for multifunctional cassette with baffles

The contour conditions were imposed by the dimensions of free volume inside the dryer, where a multifunctional cassette for malt obtaining is attached. The input and output surfaces of the air in the free volume and the four vertical surfaces were defined in Gambit/Fluent according to their role and position into discretisated cassette version (*fig. 4*), *Table 2*.

Table 2 Boundary conditions for multifunctional cassete

Boundary sections	Boundary conditions
Inlet	velocity v=ct.; temperature T_a=f(τ); moisture X_a= f(τ)
Outlet	p=0
Wall	$\partial v/\partial n = 0$ (n – normal to the surface)
Volums	fluid (air)/solid bed (malt)

Through the multifunctional cassette flows hot air, directed by the baffles, for flowing uniformity under the malt sieve. In the processing CFD simulation stage, the necessary conditions for computing to determine the velocities, temperature and moisture field from multifunctional cassette were introduced, *Table 3*.

Table 3 Processing conditions

v (m/s)	T_a(K)		X_a (Kg water/Kg dry air)	ρ_a (kg/m^3)	η (kg/ms)	C_{pa} (J/kgK)
	input	wall				
1	T=f(τ)	295.1	X_a= (τ)	1.225	$1.9\cdot10^{-5}$	1006

where: ρ_a density of air, η dynamic viscosity of air; C_{pa} specific heat of air.

The temperature and absolute moisture of the air at the input into multifunctional cassette varies in time, according to the functions presented in Table 4.

Table 4 Input functions

T_a(K)	$T = -3\cdot10^{-8}\cdot\tau^2 + 0{,}0026\cdot\tau + 301{,}36$
X_a (Kg water/Kg dry air)	$X_a = -2\cdot10^{-12}\cdot\tau^2 + 6\cdot10^{-7}\cdot\tau + 0{,}0094$

The flowing regime at the input of the hot air in the multifunctional cassette is laminar, and is determined by Reynolds criterion. The product layer from the sieve is of 80 mm, while the initial moisture of the green malt is 46.6%. The thermo physics characteristics of the green malt are introduced into simulation as average values (ρ_p= 725 kg/m^3, C_{pp}= 1985 J/kgK, product conductivity K = 0.117 W/mK). The porosity index of the green malt layer is introduced into simulation with 0.3 value and is determined by the experiment. The CFD simulations were done in unstationary regime for a period of 8 hours of drying time. The drying simulation was done with the working station TYAN (2XCPU-Intel Xeon 3.33GHz; RAM 16 GB DDR3 2600).

Results and discussion

The simulation results are presented as velocity, temperature and moisture fields, and as pathlines trajectory in the simulation field of multifunctional cassette. The simulation was done both for the cassette without baffles, where only the hot air path lines were presented, and for the multifunctional cassette with baffles as well, where the analysis of green malt drying was done. The 3D simulation of the hot air flowing in the cassette without baffles presents an irregular field of pathlines, which concentrates on the left side of the sieve from the cassette (*fig. 5*).

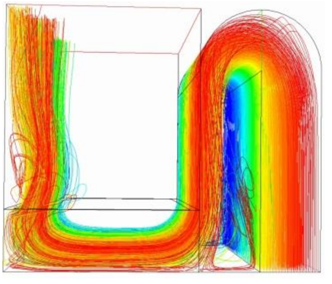

Fig. 5 The pathlines of the hot air inside the multifunctional cassette without baffles

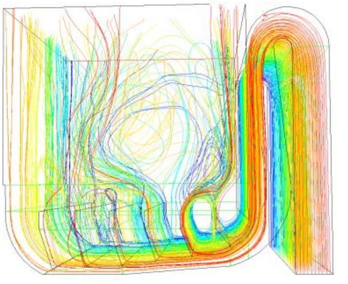

Fig. 6 The pathlines of the hot air inside the multifunctional cassette with baffles

This distribution presents the disadvantage of irregular drying of the malt layer, which leads to an irregular distribution of the temperature and moisture in the layer. To correct this distribution of the hot air stream under the drying sieve of the cassette, six baffles were done. The pathlines field at the multifunctional cassette with six baffles is presented in *fig. 6* where a uniformity of pathlines distribution is observed.

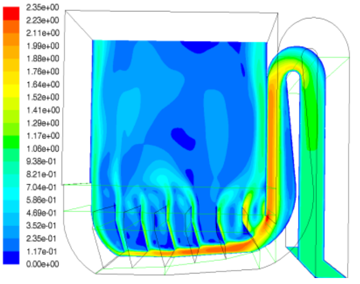

Fig. 7 The air velocity field across to the cassette plane (m/s)

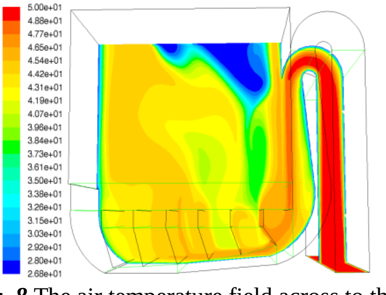

Fig. 8 The air temperature field across to the cassette plane (°C)

The same uniformity appears in the velocity field distribution as well on the whole length of the sieve, with values between 1 m/s and 1.3 m/s, according to *fig. 7*A uniform velocity field in the cross section of the cassette in the sieve attract and improved uniformity of temperature field with values between 42^{0}C and 46.5^{0}C, *fig. 8*.To verify the malt moisture gradient from the cassette sieve with six baffles, a new

simulation was done, where the malt layer was introduced, according to technological parameters previously used for hot air flowing simulation. The CFD simulation results about the moisture field are showed in two horizontal sections plane, parallel, one at the sieve level and the other at the superior level of the malt layer.
After the analysis of simulation at the end of drying, the moisture malt distribution at the sieve plane (*fig.9*) shows a distribution of moisture values between 8.84% and 8.86%, while for the plane from the superior layer of the green malt layer subjected to drying, *fig. 10*, the moisture values are between 9.02% and 9.07%. In the two plane of the malt layer, a slightly overheating could be observed in the left side of the sieve, where the air circulation is slightly more intense, and the temperature of the air is slightly higher, according to *fig.7* and *fig.8* respectively. Also, at the end of drying, reduced moistures with a difference of 0.2% at the inferior level were observed, compared to the superior one.

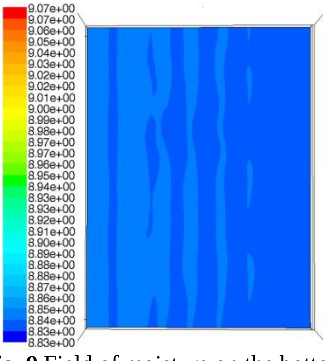

Fig. 9 Field of moisture on the bottom surface of the layer of green malt (%)

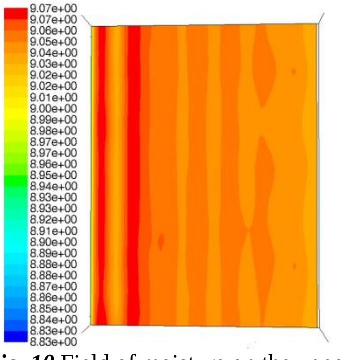

Fig. 10 Field of moisture on the upper surface of the layer of green malt (%)

The CFD simulation of multifunctional cassette with six baffles was calibrated by using the experimental data from the drying unit for velocity, temperature and moisture parameters of hot air input the cassette, and by repeated determinations of temperature at the sieve level on the whole length with and without malt layer.

Also, to determine the accurate grade of the simulated model, some samples were collected after 8 hours of drying of malt and by three rehearsals, the moisture at the sieve level and at the superior level of the layer was determined. The average values of malt moisture obtained by experiment were of 7.54% at the sieve level and 8.68% at the superior level of the layer.

Conclusion

The CFD simulation of the hot air flowing through a multifunctional cassette led to the optimisation of its constructive shape.

By constructive optimisation, a cassette with six baffles was obtained, with the role of uniformity of the hot air at the malt layer level subjected to drying.

The velocity and temperature gradient obtained by simulation along the cassette multifunctional sieve is within the range $\Delta_V \leq 0.3$ m/s for velocity and $\Delta_T \leq 4.5^0$C for temperature.

The moisture gradient in the malt layer obtained by CFD simulation and experiment is uniform, with small differences of 1%.

The CFD simulation calibrated with the experiment offers a powerful instrument that leads to the obtaining of quality malt in the drying process.

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