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Optimization Analysis on Distribution of Temperature of a Corn Based on Fluent

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Abstract

Traditional method of drying corn is using higher temperature to dry quickly. But high drying temperature can make the corn lost nutrients. Provide the foundation of designing a new corn drier which can dry corn efficient as well as sustain nutrition.Optimization analysis on distribution of temperature of a corn by Fluent. It shows that:1).Hot winds is 0.8m/s, temperature is 343K. Temperature distributions of corn is evenlier. The highest temperature is below 333K.2).More fluid inlet make corn evenlier. Change the angle between corn and velocity vector will not impact the temperature distributions of corn.

Keywords: *Corn Kernels;Fluent; Drying .*

1. Introduction

China is an agricultural country, as the second largest planting area in the domestic corn crops, mainly distributed in northeast area in China [1].Jilin province is China's largest corn belt, due to the climate, the autumn harvest the corn moisture content is generally higher than 25%, jilin province did not prevent mildew of corn storage and needs process to dry precipitation timely[2].To store corn, from the beginning of the 2000 national invested in the construction of northeast area more than 150 sets of large and medium-sized corn dryers [3]. Due to the cost of pressure, most companies will artificially increase grain drying temperature, speed the production up. The temperature of the corn grain caused more than 333 k of corn protein denaturation and starch gelatinization [4].So guarantee the temperature of drying maize grain below 333 k and the ability to quickly drying corn dryer is the future development direction of grain dryers. In recent years, due to the calculation result is accurate, intuitive and 3 d finite element method is more and more application in the study of corn drying [5]. Now for the calculation method of corn drying analysis, more is useing matlab software, such as construction of corn drying numerical partial differential model, get the grain moisture content variation law with time, and no visual expression of the distribution of temperature field on the surface of corn [6-7]. Application of computational fluid dynamics software Fluent fluid-structure coupled thermal field analysis can be intuitive single corn surface temperature distribution. In this paper, by using Fluent computational software, application of fluid-solid coupling simulation technology, visual expression of a single process for heating and massing transfer the hot between air and corn, the design that quickly drying corn and stay corn grain nutritional provides guidance basis.

2. Simulation Method

The temperature distribution of corn grain surface is closely related to the way of the surrounding fluid flow, the fluent software can be an effective numerical simulation method for the flow field around the space temperature distribution of corn. The main steps of a single corn drying analysis by Fluent software are:(1) establish a simplified

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model of single corn dry and air flow filed based on 3d CAD software SolidWorks; (2) local structured grid and grid refining technique based on Hypermesh; (3) fluid-structure area definition and boundary conditions setting based on the Gambit; (4) realizing the corn drying fluid visualization results display and obtain relevant data based on Fluent calculation module and post-processing model [8].

3. The Establishment of a Single Corn Drying Fluid Model

The shape of the corn grain and corn cob mostly present an irregular cone type, in order to accurately simulate the corn grain and corn cob geometry, digital industrial camera were used for entities of the multiple corn profile, and the 0.02 mm vernier caliper was used for the corn profile measurement , thus the average 3D sizes were calculated indirectly[9]. The 2d model of corn grain can be simplified in the case of guarantee calculation accuracy by auto CAD picture imaging software; and the 3d model of corn and corn flow field around can be established by Solidworks software.

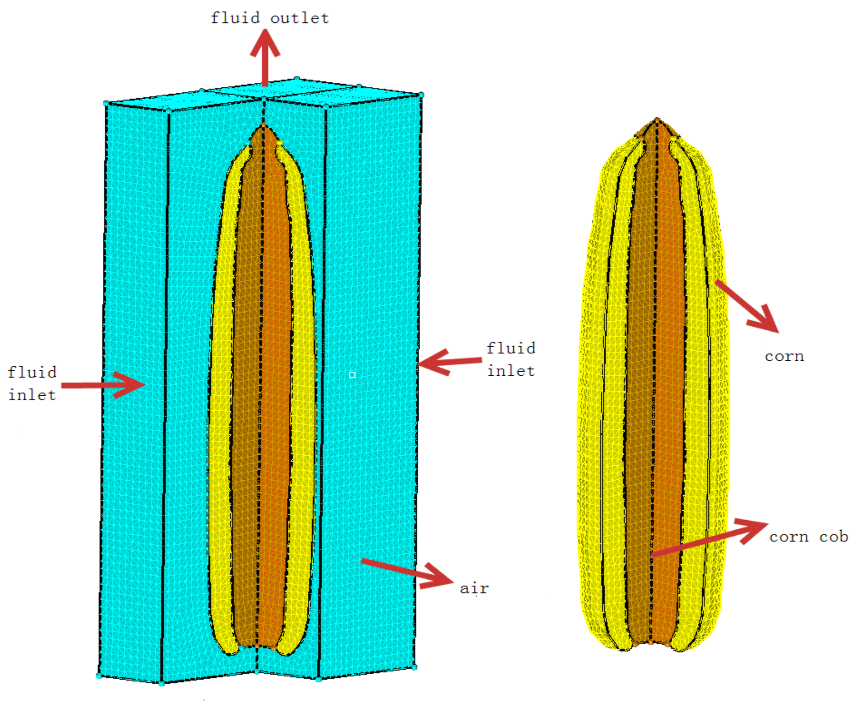

Figure 1. A Single Corn Drying 3d Grid Model and Boundary Conditions

All the 16 kinds of parameter combination of geometric model was set up based on the incident angles of corn and the wind speed was 0 ℃, 10 ℃, 20 ℃ and 30 ℃, and the number of hot air entry was 1, 2, 3, 4. The 3d geometric model was mapped meshed by Hypermesh software, irregular part adopts adaptive tetrahedron grid, and grid encrypting processing of corn kernels, as shown in Figure 1.

4. Setting of the Material and Boundary Conditions

The corn grain drying model put forward by Peishi Chen was used for corn grain material definition [10]; this model was based on the drying model defined by Suzuki[11], adding the moisture migration mechanism under the condition of wet and dry. The material parameters of corn cob and air were determined through experiments [12]. The material parameters of corn grain and corn cob as shown in table 1.

Table 1. Material Parameter of Corn Grain and Corn Cob

	Density $\rho_0(kg/m^3)$	Thermal conductivity K(w/m·k)	Water content U(kg/solid)
corn grain	123.6	0.07+0.65U	0.31
corn cob	212.11	0.139	0.327

The hot air flow rate was set according to the technological parameter of general 8t corn drying tower provided by Changchun Jida Scientific Instruments Equipment Co., LTD. The process parameters such as table 2 . The boundary conditions were set as follows: the hot air inlet velocity was set of 0.2m/s,0.4 m/s, 0.6 m/s, and 0.8 m/s, the time of a single corn from the top of tower down to the end is about 2 s according to the equation of free fall. Then set the positive direction of flow and turbulivity, *etc*. Set the air outlet to pressure-outlet, and the outlet pressure is set to 0.1MPa; Build a wall between corn cobs and corn grain set as solid - solid thermal coupling surface, the walls between corn grain and air, corn cob and air are set as solid-liquid coupling surface, and the rest of the wall as the default boundary conditions. The K-epsilon turbulence model is used for equation solving and opening the energy equation; and the fluid-solid coupling heat transfer equation and melting equation of governing equations are discrete with two order upstream schemes; the diffusion term is discrete with central scheme; and the convective term is discrete with second order form.

Table 2. Technological Parameter of General 8t Corn Drying Tower

	parameters	unit	numerical value
drying tower	cavity dimension	cm	2000×1600×700
drying machine	boundary dimension	mm	3900×1910×7130
	cubage	m3	≤5800
	total power	kw	14.5
exhaust blower	revolving speed	r/min	1700
	total pressure	pa	999
	power	kw	4
hot-blast stove	thermal power	MJ/h	294.656
	maximum temperature	℃	75

5. The Numerical Simulation Results

5.1 The Influence of Changing the Number of Hot Air Inlet on Altering the Distribution of Temperature on Corn Surface

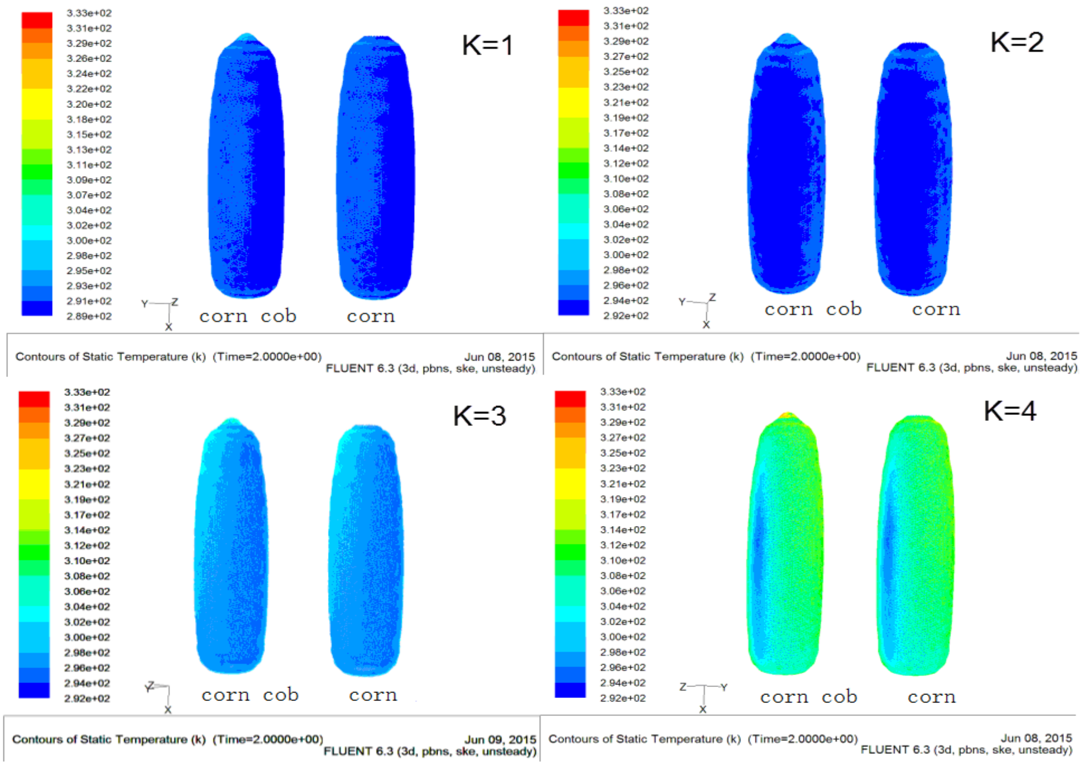

Figure 2. The Temperature Contours of Corn and Corn Kernels Surface when the Number of Hot Air Inlet is K

Hot air flows in along the radial direction of corn, flows out along the axial direction. The direction of fluid flows in and flows out could be seen in Figure 1. Set the number of hot air inlet K = 1,2,3,4. To ensure the hot air mass flow inlet must be different numbers, according to calculations, setting the direction of the hot air flow inlet, respectively 0.2m/s、0.1m/s、0.67m/s、0.5m/s. Air temperature is 333K.The temperature contours of corn and corn kernels surface when the number of hot air inlet is K is shown in Figure 2. According to Figure 2,we can draw the following conclusions:

1. Under the same condition of ensuring the mass flow, the more the number of entries, the closer the surface temperature of the corn approaches the heating temperature. When K = 1, the corn grain surface is heated almost nothing, most of the surface are dark blue corn kernels, only corn cob top portion is heated to about 300K. When K = 3, the surface temperature of the whole corn increased to about 300K. When K = 4, the surface of the maize grain temperature may reach 314K.

2. Under the same condition of ensuring the mass flow, the more the number of entries, the more uniform temperature distribution. When K = 1, K = 2, corn grains surface temperature distribution is extremely uneven, we can clearly see the large area of light blue and dark blue temperature area intersection. When K = 3, the maize grain surface temperature distribution tends to be uniform, most are light blue. When K = 4, most of the maize grain surface temperature is about 314K, a small number of pale blue.

As can be seen from Figure 2, under the same condition of ensuring the mass flow, when the number of hot air inlet number K=4, the corn kernel temperature is the highest, and the surface temperature distribution of maize kernel is uniform.

5.2. The Influence of Changing the Velocity of Hot Air Inlet on Altering the Distribution of Temperature on Corn Surface

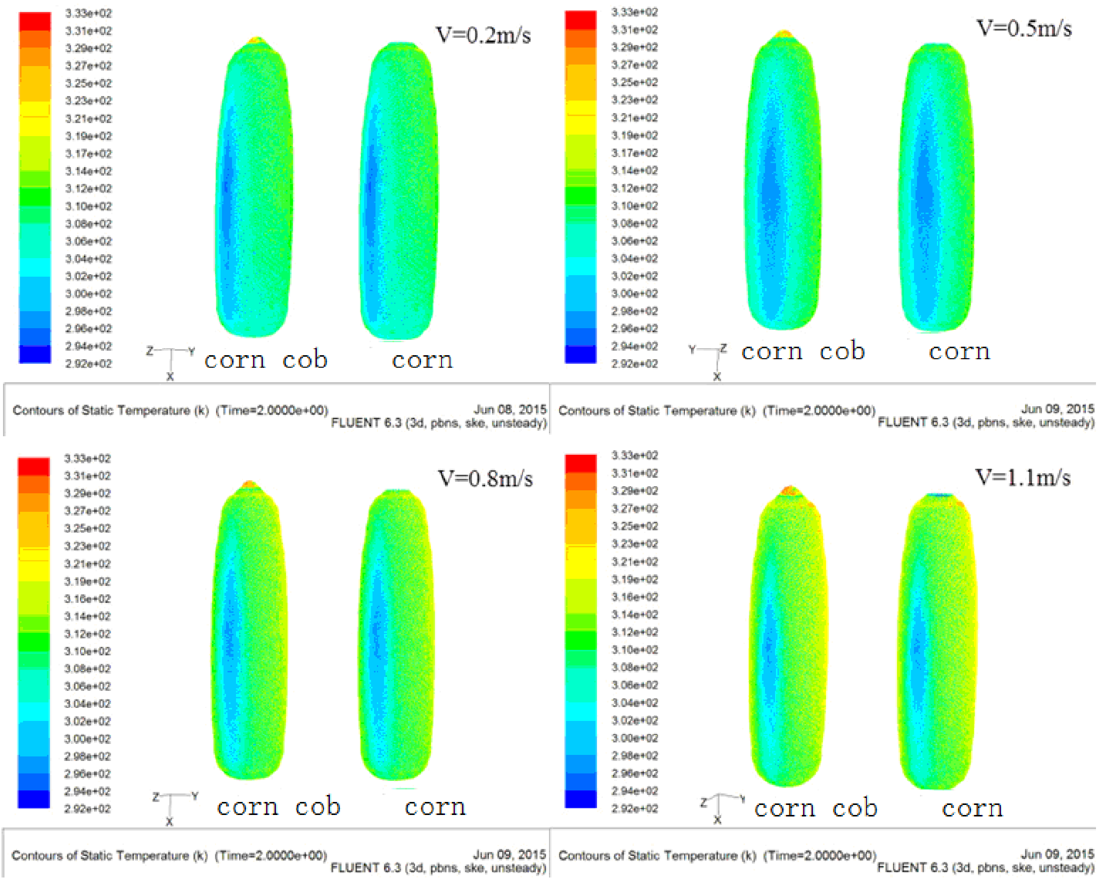

Figure 3. The Temperature Contours of Corn and Corn Kernels Surface when the Velocity of Hot Air Inlet is K

Take different number of entries and analysis optimal results. Set the number of hot air inlet K = 4, the wind speed 0.2m / s, 0.5m / s, 0.8m / s, 1.1m / s. Air temperature is 333K. Figure 3 is the maize and maize grain surface temperature contours when the wind speed is V. According to Figure 3, the following conclusions are obtained: 1.When V = 0.2m / s and V = 0.5m / s , the surface temperature of the corn kernels are distributed around 314K, there is no clear high temperature zone. When V=0.8m/s, the temperature of the surface of the corn kernel has obvious orange red area, which indicates that the temperature has a great improvement. When the wind speed reaches 1.1m/s, the surface temperature of the corn kernel will be further enhanced, but the surface temperature of the 0.8m/s corn is not much different from that of the wind speed. 2. The uniformity of maize grain surface temperature are not very different wen V = 0.2m / s and V = 0.5m / s ,and dark blue area is very similar. When V = 0.8m / s, corn grain surface temperature distribution gradually becomes uniform, and dark blue area hypothermia significantly reduced. When V=1.1m/s, the deep blue and low temperature region of maize kernel is further decreased, but the high temperature region of the orange red region increased. Therefore, when the wind speed is 0.8m/s, the surface temperature distribution of maize kernel is the most uniform.

Figure 3 illustrates, when the wind speed reaches 0.6m / s, the temperature will have significant changes. Wind speed increase, the blower energy consumption will be further increased. Therefore, in order to ensure the uniformity of corn drying, the selection of the wind speed of 0.8m/s is relatively good.

5.3. The Influence of Changing the Temperature of Hot Air Inlet on Altering the Distribution of Temperature on Corn Surface

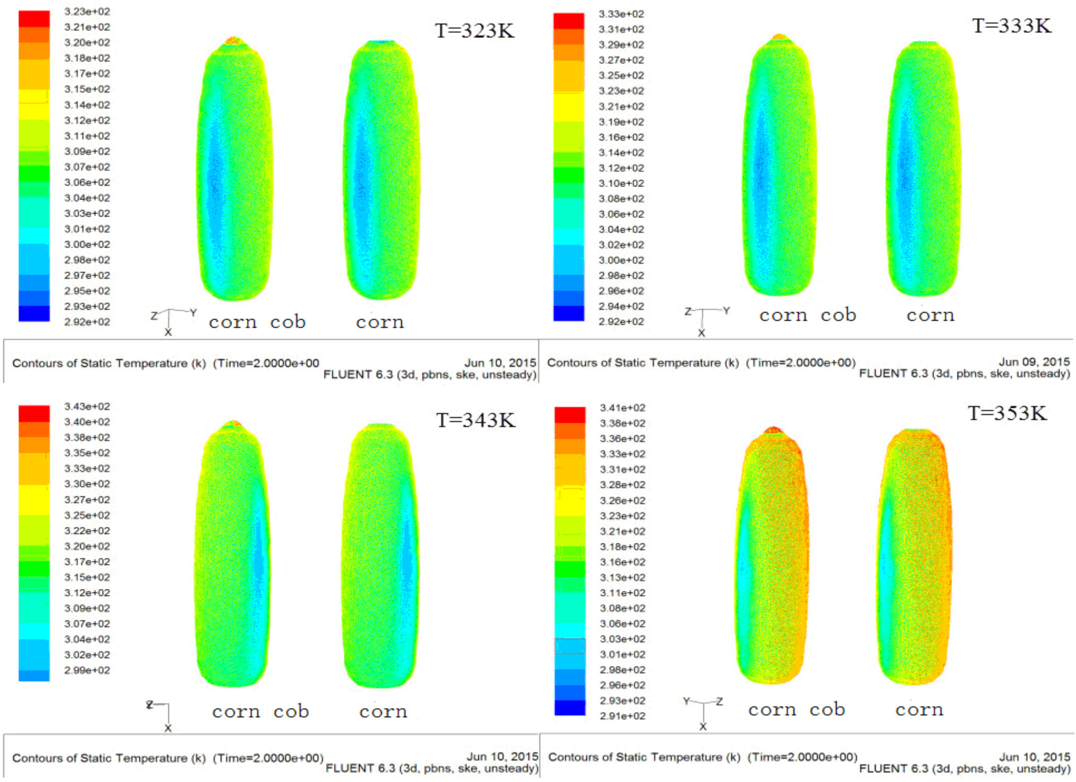

Figure 4. The Temperature Contours of Corn and Corn Kernels Surface when the Temperature of Hot Air Inlet is T

Take different wind velocity and analysis the optimal results. Set the hot air entrance number K = 4, wind speed 0.8 m/s. Set the hot blast temperature, respectively, for T = 323 k, 333 k, 343 k, 353 k. Figure 4 is the corn grain surface temperature contours when the inlet temperature is T. According to Figure 3, the following conclusions are obtained:

1. It can be seen from the contours that, when T=343K, the surface temperature distribution of maize kernel was the most uniform, blue low temperature area is relatively small. When T= 323 k and T = 333 k blue low temperature area is relatively large. When T=353K, it can be seen that the distribution of the high temperature area of the orange red, and the temperature distribution is very uneven.

2. When T = 323 k, the highest surface temperature of corn kernels is 317 k. When T = 333 k, the highest surface temperature of corn kernels is 327 k. When T = 343 k, the highest surface temperature of corn kernels is 333 k. When T = 353 k , the highest surface temperature of corn kernels is 338 k. When the air temperature is 323 k, 333 k, 343 k, the highest surface temperature of corn kernels are lower than 333 k.

Figure 4 shows that when the air temperature is 343 k, corn grain surface drying is uniform, and corn grain temperature does not exceed 333 k, which will not change the corn grain nutrients.

5.4 The Influence of Changing the Angle between Corn and Velocity Vector of Hot air Inlet on Altering the Distribution of Temperature on Corn Surface

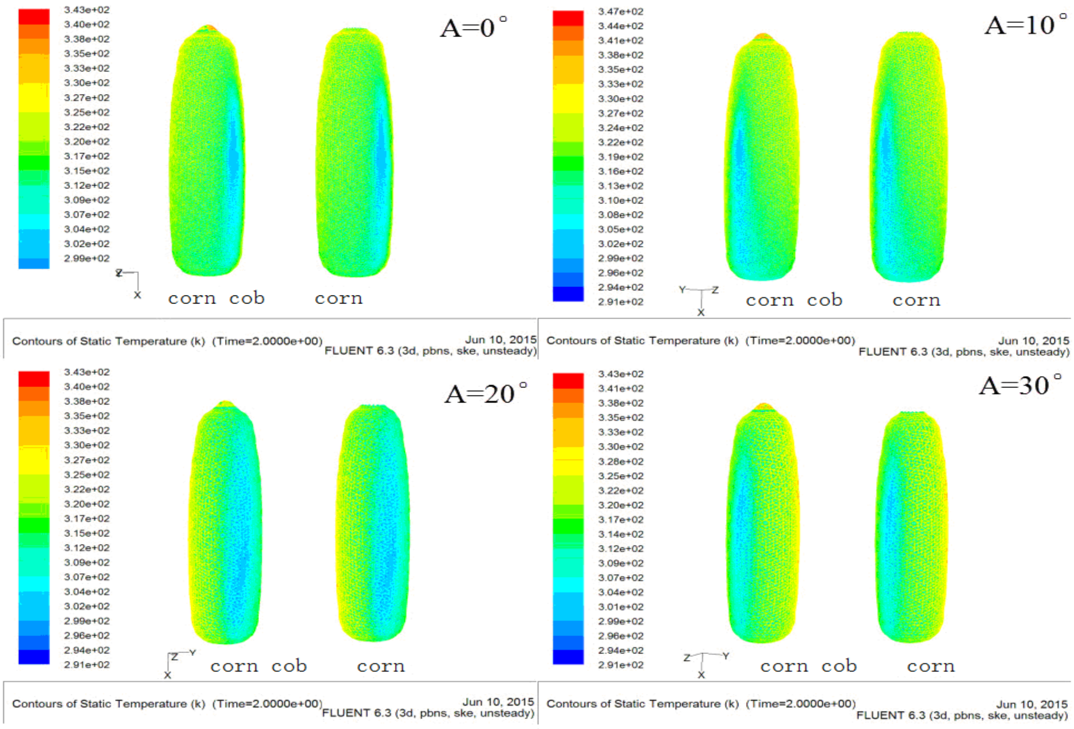

Figure 5. The Temperature Contours of Corn and Corn Grain Surface when the Angle between Corn and Velocity Vector is A

Set the number of hot air inlet K=4, the wind speed is 0.8m/s, the hot air temperature is 343K. The hot air velocity vector and corn angles were A=0, 10, 20 and 30 respectively. Figure 5 is the temperature contours of the corn and corn kernels surface when the inlet air velocity vector and the corn angle were A. Conclusions can be get according to the Figure 5:

It can be seen from the contours that blue zone with low temperature will increase gradually with the increase of the angle at low temperature, and it will become smaller gradually when the angle is greater than 20°.So the angle of corn in hot air doesn't have much influence on the temperature uniformity and the highest temperature of the corn surface.

6. Conclusions and Discussion

This paper, using CFD (computational fluid dynamics software) to simulate the heating situation of a single corn in drying tower. The fluid flow entrance number surrounding a single corn, flow velocity, fluid temperature, fluid velocity and the Angle of the corn may serve as variables. Simulation analysis shows that under the condition of ensuring the same quality of the hot air flow , the more fluid inlet around the corn , the more uniform of the temperature distribution. When the hot air flow velocity is of 0.8 m/s and the temperature is of 343 k, corn temperature distribution turns out to be the most uniform, the highest temperature of corn grain does not exceed 333 k. The angle between the fluid flow and the corn grain surface will not affect temperature distribution.

Acknowledgments

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