Study on Numerical Simulation of Airflow Distribution in Hot Pump Drying Room of Peppercorns

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Abstract. With the transformation of China's agricultural development direction and the vigorous promotion of healthy green condiments, the demand for drying materials such as pepper powder, grain and fruit is increasing, while the traditional drying method is low in efficiency, long drying time, and materials are easy to be contaminated by sediment and various microorganisms. So this article use numerical method to simulate the heat pump drying room air distribution, by changing the internal disturbance conditions, different drying stage and the different initial conditions, characteristics of flow field inside the drying room changes, buoyant jet is analyzed in different initial velocity, initial temperature and the effect of flow field characteristics of Chinese prickly ash drying room; The purpose is to provide theoretical support and design guidance for the design of the hot pump-type pepper drying room.

1. Introduction
In this paper, a reasonable THREE-DIMENSIONAL turbulent flow equation is constructed, the flow control equation is discretized by the finite volume method, and the boundary condition is set in combination with the actual measurement. The air distribution in different drying stages of drying room is mainly analyzed under the premise of meeting the drying temperature and drying efficiency. By changing the supply parameter values, different to drying room drying stage drying velocity field and temperature field distribution inside the room of the simulation results were analyzed, and choose some representative monitoring points, with the root mean square deviation for the average temperature of the measured points to reflect the sample dispersion degree, practical and effective optimization method is proposed to improve the drying efficiency.

2. Numerical Simulation Method
Prickly ash in this paper, we study the heat pump drying room there is a mixed convection indoor environment, and Chinese prickly ash drying room as the typical heat source, therefore in the process of numerical simulation to consider the effect of buoyancy lift, aiming at the complex flow and physical phenomenon, using numerical method, and the different discrete format in a particular field computation speed stability and accuracy to achieve the best combination, can efficiently solve various fields after considering the complex flow calculation problem, use combined with a wall function of renormalization group The flow distribution in the drying room of Prickly ash was numerically simulated by the K - range model [1], so as to make the numerical simulation of turbulence mechanism more consistent with the actual situation.

2.1. Governing Equation
The governing equation of the numerical simulation is expressed as follows:
continuity equation:
\[
\frac{\partial \rho}{\partial t} + \frac{\partial (\rho u_x)}{\partial x} + \frac{\partial (\rho u_y)}{\partial y} + \frac{\partial (\rho u_z)}{\partial z} = 0
\]  (1)

momentum equation:
\[
\frac{\partial (\rho u_x)}{\partial t} + \text{div}(\rho u_x \vec{u}) = -\frac{\partial p}{\partial x} + \frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} + \frac{\partial \tau_{zx}}{\partial z} + \rho f_x
\]
\[
\frac{\partial (\rho u_y)}{\partial t} + \text{div}(\rho u_y \vec{u}) = -\frac{\partial p}{\partial y} + \frac{\partial \tau_{yx}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{zy}}{\partial z} + \rho f_y
\]
\[
\frac{\partial (\rho u_z)}{\partial t} + \text{div}(\rho u_z \vec{u}) = -\frac{\partial p}{\partial z} + \frac{\partial \tau_{zx}}{\partial x} + \frac{\partial \tau_{zy}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z} + \rho f_z
\]  (2)

energy equation:
\[
\frac{\partial (\rho T)}{\partial t} + \text{div}(\rho \vec{u} T) = \text{div}\left(\frac{k}{c_p} \text{grad}T\right) + S_T
\]  (3)

where, \(c_p\) is the specific heat, \(T\) is the temperature, \(k\) is the heat transfer coefficient of the fluid, \(S_T\) is the internal heat source of the fluid and the part where the fluid's mechanical energy is converted into heat energy due to the action of viscosity, sometimes referred to as the viscous dissipation term.

2.2. Geometrical Model
Geometric model According to the measured model, the necessary simplified treatment of prickly ash drying room length, width and height are 6.79, 4.80 and 3.2 m (X, Y and Z) respectively. The simple model is shown in figure 1. In order to ensure the prickly ash drying effect, considering the convenience shop staff layer materials, combined with drying room of the actual situation of the construction site of dry indoor each place four material car, the horizontal spacing of 0.47 m, the longitudinal spacing of 0.6 m, each material cart single-layer placed four material tray, pack material each of 4 layers, each should install 12 kg raw material (The stacking thickness of each layer of Prickly ash was H =0.05 m)

![Figure 1. Schematic diagram of calculation model.](image)

2.3. Numerical Simulation Setting
The boundary conditions are set in table 1:

In the measured data, the influence of cold air penetration and cold air intrusion is not considered [2]. The air outlet is in the form of a square air outlet with a wind speed of 2 m/s. The air supply temperature at different stages is 313, 323, and 333 K; the air outlet is also in the form of Square; adjust the boundary conditions of the heat source and observe its changing law.
Table 1. Boundary condition setting table.

| Boundary Name | Boundary type | Details           |
|---------------|---------------|-------------------|
| Siding        | Pressure outlet | P=0 T=314 K      |
| Windows, doors| Pressure outlet | P=0 T=310 K      |
| Heat source   | Velocity-inlet | Vz=2.5 m/s Tz=323 K |
| Interior wall | Velocity-inlet | Vf=0-3.5 m/s Tf=350-600 K T=26 K |
| Tuyere        | Velocity-inlet | V=-2.5 m/s T=333 K |

3. Results and Discussion

In order to study the influence of different parameters on the airflow characteristics of the drying room at different drying stages, the air outlets are arranged on parallel and opposite walls in the space. The length, width and height of the room are 6.79 m x 4.80 m x 3.26 m. The lower part of the square tuyere is 2.2 m above the ground. The vertical section of the Z-axis section of the drying room is selected for analysis; the front and back two surfaces are set as the pressure boundary, thereby offsetting the influence of the ventilation form on the internal flow of the pepper drying room. The impact of the place, other surfaces are set as walls.

3.1. Speed Distribution in the Initial Drying Stage

It can be seen from the above figure that in the initial drying stage, when Z=1.2 m, the maximum axial velocity can reach 1.89 m/s. From profile Z of 1.2 m to profile Z of 1.9 m in good air flow condition, the maximum velocity of the axis can reach 1.89 m/s [3]. The flow velocity of the gas inside the whole pepper drying room is relatively low, and the overall flow rate will not exceed 2 m/s. According to the conservation of energy, when the height increases, as the surrounding air is continuously entrained, the speed will continue to decrease; at the Z=2.8 section, the wind speed in the front area of the left tuyere is 0.6 m/s, and the wind speed in the rear area is about 0.3 m/s. The airflow organization is poor; the airflow velocity in most areas is close to 0 except that the airflow velocity in local areas reaches 0.3 m/s. The air velocity is so small that the hot air can hardly reach the upper space and the fluid is basically in a stagnant state that shown in figure 2.

![Diagram of velocity distribution at Z=1.2 m](image1)

(a) Diagram of velocity distribution at Z=1.2 m

![Diagram of velocity distribution at Z=1.9 m](image2)

(b) Diagram of velocity distribution at Z=1.9 m

![Diagram of velocity distribution at Z=2.5 m](image3)

(c) Diagram of velocity distribution at Z=2.5 m

![Diagram of velocity distribution at Z=2.8 m](image4)

(d) Diagram of velocity distribution at Z=2.8 m

Figure 2. Speed distribution in the initial drying stage.
3.2. Speed Distribution at Constant Speed Setting Drying Stage

The cross-sections at Z=1.2 m, 1.9m, 2.5m and 2.8m were selected to analyze the wind speed distribution of the pepper drying room during the constant-speed drying stage. When the height of the profile Z is 1.2 m to the profile Z is 1.9 m, the uniformity of the velocity distribution becomes worse that shown in figure 3, and the flow pattern still shows better and better conditions. The mainstream core wind speed with cross-section Z=1.9 m can reach up to 2.342 m/s [4-6]. At a profile height of 0.4m and a height of 0.6m, the uniformity of the wind speed distribution is the worst and the wind speed is low, and the airflow near the ground level is almost stagnant; the section height near the roof is 2.6 m and the wind speed of 2.8 m, The uniformity of distribution is also poor, which is similar to the flow state near the ground, but the relative deviation between the two shows a larger trend.

(a) Diagram of velocity distribution at Z=1.2m  (b) Diagram of velocity distribution at Z=1.9m

(c) Diagram of velocity distribution at Z=2.5m  (d) Diagram of velocity distribution at Z=2.8m

Figure 3. Speed distribution diagram of constant-speed setting drying stage.

3.3. Speed Distribution during Complete Drying

It can be seen from the figure 4 that when the height of the profile Z is 1.2 m to the profile Z is 1.9 m, the uniformity of the velocity distribution still shows better and better flow conditions [7]. The mainstream core wind speed with cross-section Z=1.9 m can reach up to 2.8 m/s. The wind speed distribution uniformity at the profile height of 0.8m and height of 1m is the worst and the wind speed is low; when the airflow outlet speed and the air outlet temperature in the complete drying stage will continue to increase, with the continuous increase of the Z axis; The distribution trend of the shaft speed remains the same [8-10]; within a certain height range, the overall shaft speed first increases and then decreases.
Figure 4. Speed distribution diagram in the complete drying stage.

4. Conclusion
Through simulation analysis, this paper compares and analyzes the air distribution in different section directions of the drying room. The simulation results show that as the height of the drying rack changes during the pepper drying process, the air distribution on each section becomes more and more uneven and the phenomenon of thermal stratification is obvious near the air outlet; at the same time, by changing the value of the air supply parameter, in the Z axis direction, there is a deviation from the left and right sides of the geometric center of the hot air outlet to the center. In the complete drying stage, when the height reaches 1.6 to 2.0 m, the maximum offset distance of the axis distance is 0.5 m along with the height change. The simulation shows that controlling the stacking height of the pepper drying rack within a certain range can make the drying effect more secure. Within a certain height, the temperature field and velocity field are more uniformly distributed, avoiding local airflow short-circuits, and reducing energy. Therefore, a radiant plate can be added to the top plate to effectively improve the drying effect.

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