

CUMCM-2026 Problem A

The Problem of Drying Medicinal Materials

Drying is one of the crucial processes that determine the quality of finished Chinese medicinal materials, and hot-air drying is a common drying method. This method mainly includes two stages: preheating equilibrium stage and drying stage with constant temperature, which completes the drying of medicinal materials by regulating the temperature and humidity environment of the drying chamber. In the drying process of Chinese medicinal materials, improper selection of process parameters may lead to problems such as low drying efficiency, high energy consumption, and unstable quality of finished products. However, there is high cost and long cycle time in the traditional experimental optimization approach, so it is urgent to obtain the law of drying mechanisms by using mathematical analysis and numerical simulations.

Please establish mathematical models to solve the following problems.

Problem 1 A certain Chinese medicinal material is approximately cylindrical in shape, with a length of 25 cm and a radius of 2 cm. At the beginning of drying, the temperature of the material is 28 °C, the moisture concentration (i.e., dry basis moisture content) of the material is 2.55 kg/kg, and the changes in temperature (unit: °C) and moisture concentration (unit: kg/kg) in the drying chamber are shown in Attachment 1. Please establish a mathematical model for the variation of temperature and moisture concentration of the medicinal material during the preheating equilibrium stage (the relevant parameters are given in Appendix 2). In the paper, present the results for distances of 0, 0.5, 1, 1.5, and 2 cm from the center of the medicinal material at 100, 300, 600, 900, 1200, 1500, and 1800 s in the format of Table 1 and Table 2, and save the complete results for every 1 s within 1800 s and every 0.1 cm distance from the center of the medicinal material to the file result1.xlsx (the template file is given in Attachment 3). All results should be rounded to four decimal places (the same below).

Table 1 Temperature of the medicinal material within 30 minutes

Time/s	Distance from the center of the medicinal material/cm				
	0	0.5	1	1.5	2
100					
300					
600					
900					
1200					
1500					
1800					

Table 2 Moisture concentration of the medicinal material within 30 minutes

Time/s	Distance from the center of the medicinal material/cm				
	0	0.5	1	1.5	2
100					
300					
600					
900					
1200					
1500					
1800					

Problem 2 The drying process generally lasts for 2-3 days, and the parameters are different between the preheating equilibrium stage and the drying stage with constant temperature. Please establish a mathematical model for the variation laws of temperature and moisture concentration of the medicinal material during the entire drying process (for simplicity, the relative empirical formulas adopted uniformly are given in Appendix 3). In the paper, present the results for every 0.5 h within 3 h and distances of 0, 0.5, 1, 1.5, and 2 cm from the center of the medicinal material in the format of Table 3 and Table 4, and save the complete results for every 1 s and every 0.1 cm distance from the center of the medicinal material to the file result2.xlsx (the template file is given in Attachment 3).

Table 3 Temperature of the medicinal material within 3 hours

Time/h	Distance from the center of the medicinal material/cm				
	0	0.5	1	1.5	2
0.5					
1.0					
1.5					
2.0					
2.5					
3.0					

Table 4 Moisture concentration of the medicinal material within 3 hours

Time/h	Distance from the center of the medicinal material/cm				
	0	0.5	1	1.5	2
0.5					
1.0					
1.5					
2.0					
2.5					
3.0					

Problem 3 According to the drying requirements, the moisture concentration of medicinal material in all parts should be lower than 0.15 kg/kg. Please determine the time required for drying

the medicinal material (unit: h). In the paper, present the results for every 6 h and every 0.5 cm distance from the center of the medicinal material in the format of Table 5, and save the complete results for every 60 s and every 0.1 cm distance from the center of the medicinal material to the file result3.xlsx (the template file is given in Attachment 3).

Table 5 Moisture concentration of the medicinal material during the drying process

Time/h	Distance from the center of the medicinal material/cm				
	0	0.5	1	1.5	2
6					
12					
18					
...					
End time of drying					

Problem 4 During the actual drying process, the medicinal material will undergo dimensional changes due to moisture loss. Please determine the drying time of the medicinal material based on Attachment 2 (the relevant empirical formulas are given in Appendix 4). In the paper, present the results for every 6 h and every 0.5 cm distance from the center of the medicinal material in the format of Table 6, and save the complete results for every 60 s and every 0.1 cm distance from the center of the medicinal material to the file result4.xlsx (the template file is given in Attachment 3).

Table 6 Moisture concentration of the medicinal material during the drying process

Time/h	Distance from the center of the medicinal material/cm			
	0	0.5	...	Medicinal material surface
6				
12				
18				
...				
End time of drying				

Appendix 1 Description of attachments

Attachment 1 provides the temperature (unit: °C) and moisture concentration (unit: kg/kg) of the drying chamber at each time point (unit: s) during the initial drying phase.

Attachment 2 provides the radius (unit: cm) of the medicinal materials at each time point (unit: s) during the drying process.

Attachment 3 is a folder containing four template files for the results.

result1.xlsx The template file for the results of Problem 1

In the “Temperature” and “Moisture concentration” sheets, save the temperature (unit: °C) and moisture concentration (unit: kg/kg) required in Problem 1, where column A represents time

(unit: s), and row 1 represents the distance from the center of the medicinal material (unit: cm).

result2.xlsx The template file for the results of Problem 2

In the “Temperature” and “Moisture concentration” sheets, save the temperature (unit: °C) and moisture concentration (unit: kg/kg) required in Problem 2, where column A represents time (unit: s), and row 1 represents the distance from the center of the medicinal material (unit: cm).

result3.xlsx The template file for the results of Problem 3

Save the moisture concentration (unit: kg/kg) required in Problem 3, where column A represents time (unit: s), and row 1 represents the distance from the center of the medicinal material (unit: cm).

result4.xlsx The template file for the results of Problem 4

Save the moisture concentration (unit: kg/kg) required in Problem 4 where column A represents time (unit: s), and row 1 represents the distance from the center of the medicinal material (unit: cm).

Appendix 2 Relevant parameters for Problem 1

The density is 820 kg/m^3 , the specific heat capacity is 2600 J/(kg K) , the thermal conductivity is 0.36 W/(m K) , the convective heat transfer coefficient is $25 \text{ W/(m}^2 \text{ K)}$, convective mass transfer coefficient is $8 \times 10^{-7} \text{ m/s}$, the empirical formula for the moisture concentration diffusion coefficient is

$$D = 7 \times 10^{-9} e^{-\frac{0.89}{C}}$$

where D is the moisture concentration diffusion coefficient (unit: m^2/s), and C is the moisture concentration of the medicinal material (unit: kg/kg).

Appendix 3 Relevant empirical formulas for Problem 2 and Problem 3

Some empirical formulas adopted in Problems 2 and 3

$$\begin{aligned}\rho &= 650 + 128C \\ c_p &= 1450 + 2736 \cdot \frac{C}{C + 1} \\ k &= 0.21 + 0.38 \cdot \frac{C}{C + 1} \\ D &= 2.4 \times 10^{-3} e^{-\frac{0.45}{C}} e^{-\frac{3850}{T}}\end{aligned}$$

where ρ is the density (unit: kg/m^3), c_p is the specific heat capacity (unit: J/(kg K)), k is the thermal conductivity (unit: W/(m K)), D is the moisture concentration diffusion coefficient (unit: m^2/s), C is the moisture concentration of the medicinal material (unit: kg/kg), and T is the temperature of the medicinal material (unit: K).

Appendix 4 Relevant empirical formulas for Problem 4

Some empirical formulas adopted in Problem 4

$$\begin{aligned}\rho &= 760 + 90C \\ c_p &= 1850 + 2150 \cdot \frac{C}{C + 1} \\ k &= 0.12 + 0.20 \cdot \frac{C}{C + 1} \\ D &= 4.2 \times 10^{-4} e^{\frac{0.30}{C}} e^{-\frac{3850}{T}}\end{aligned}$$

where ρ is the density (unit: kg/m³), c_p is the specific heat capacity (unit: J/(kg K)), k is the thermal conductivity (unit: W/(m K)), D is the moisture concentration diffusion coefficient (unit: m²/s), C is the moisture concentration of the medicinal material (unit: kg/kg), and T is the temperature of the medicinal material (unit: K).