Journal of Modern Physics, 2024, 15, 1300-1312
https://www.scirp.org/journal/jmp
ISSN Online: 2153-120X
ISSN Print: 2153-1196

# Sterilization Effect of Cooking Process for Guilin Rice Noodles Based on Heat Conduction Model

**Wenyu Wu[1], Fanglei Zou[1,2], Xiaojun Sun[1,2*], Liang Du[1,2]**

[1]College of Physics, Guangxi Normal University, Guilin, China
[2]Guangxi Key Laboratory of Nuclear Physics and Nuclear Technology, Guilin, China
Email: *sxj0212@gxnu.edu.cn

**How to cite this paper:** Wu, W.Y., Zou, F.L., Sun, X.J. and Du, L. (2024) Sterilization Effect of Cooking Process for Guilin Rice Noodles Based on Heat Conduction Model. *Journal of Modern Physics*, **15**, 1300-1312.
https://doi.org/10.4236/jmp.2024.158052

**Received:** May 23, 2024
**Accepted:** July 28, 2024
**Published:** July 31, 2024



## Abstract

Guilin rice noodles, a unique cuisine from Guilin, Guangxi, is renowned both domestically and internationally as one of the top ten "Guilin Classics". Utilizing a heat conduction model, this study explores the effectiveness of the cooking process in sterilizing Guilin rice noodles before consumption. The model assumes that a large pot is filled with boiling water which is maintained at a constant high temperature heat resource through continuous gentle heating. And the room temperature is set as the initial temperature for the preheating process and the final temperature for the cooling process. The objective is to assess whether the cooking process achieves satisfactory sterilization results. The temperature distribution function of rice noodle with time is analytically obtained using the separation of variables method in the three-dimensional cylindrical coordinate system. Meanwhile, the thermal diffusion coefficient of Guilin rice noodles is obtained in terms of Riedel' theory. By analyzing the elimination characteristics of *Pseudomonas cocovenenans* subsp. farinofermentans, this study obtains the optimal time required for effective sterilization at the core of Guilin rice noodles. The results show that the potential *Pseudomonas cocovenenans* subsp. farinofermentans will be completely eliminated through continuously preheating more than 31 seconds during the cooking process before consumption. This study provides a valuable reference of food safety standards in the cooking process of Guilin rice noodles, particularly in ensuring the complete inactivation of potentially harmful strains such as *Pseudomonas cocovenenans* subsp. farinofermentans.

## Keywords

Guilin Rice Noodles, Heat Conduction Model, Temperature Distribution Function, Effective Sterilization

# 1. Introduction

Guilin is a world-famous tourist city, located in the Xiang-Gui corridor where cultures in North and South China meet. Guilin rice noodles, one of the local specialities, is renowned both domestically and internationally. Signboards of Guilin rice noodles can be found in many towns and cities of China, and even in some major cities of the United States [1]. Originated in the Qin Dynasty (2200 years ago), Guilin rice noodle with a deep cultural heritage was selected as one of the top ten "Guilin Classics" in 2023, and its production techniques were voted as the National Intangible Cultural Heritage List in 2021. There are a variety of Guilin rice noodles, among which four types are selected as Guilin's "Four Old Types" including braised vegetable noodles, original soup noodles, beef brisket noodles, and horse meat noodles [2]. Their main ingredient is wet rice noodle, with its production processes of rice-soaking, washing, grinding into thick liquid, size mixing, cropping, cooling forming, noodles cutting, and casing [3] [4]. The cooking procedure before consumption is to place the rice noodles in a mesh spoon, then drop the noodles in a large pot filled with boiling water maintained at a constant high temperature through continuous gentle heating, stir constantly to heat them up evenly, and finally place them into a bowl and add unique secret marinade with different kinds of seasonings after draining insufficient water [4].

The studies had shown that inadequate washing of rice or improper storing of rice noodles during the production process may lead to a certain degree of contamination by *Pseudomonas cocovenenans* subsp. farinofermentans [5]. This case may produce Bongkrekic acid that is the main toxic metabolite causing food poisoning [6] [7]. The optimal growth temperature of *Pseudomonas cocovenenans* subsp. farinofermentans is about 36˚C, and the suitable temperature of producing Bongkrekic acid is about 26˚C [8] [9]. Further studies have shown that the heat-treated food can denature the proteins within this strain, which makes it become inactive and die eventually [8]. In November 2020, Guilin Market Supervision Bureau put forward clear requirements on the processing, packaging and transportation of Guilin rice noodles [10]-[12]. But by now, there are still no studies on the effectiveness of the cooking process to inactivate the strains before consumption of Guilin rice noodles.

This paper will establish the heat conduction model of Guilin rice noodles to describe the temperature distributions in the cooking process before consumption. By using the separation of variables method in the cylindrical coordinate system [13], the temperature distribution function of rice noodle with time is analytically obtained. By analyzing the elimination characteristics of *Pseudomonas cocovenenans* subsp. farinofermentans, this work gives the optimal time required for effective sterilization at the core of Guilin rice noodles.

# 2. Heat Conduction Model

## 2.1. Heat Conduction Model for Guilin Rice Noodles

Guilin rice noodles, with the radius of approximately $R = 1.5$ mm and the length of nearly 50 cm [14], are initially immersed in a vast pot that maintains a gentle heat. Inside the pot, boiling water serves as a constant heat source wth high temperature $T_H$. Meanwhile, the cloddy rice noodles convolved each other for the convenience of transportation are stirred to scatter strip by strip with a pair of long chopsticks. Therefore, it is assumed that the noodles are preheated in an elongated cylinder at a constant heat source, as shown in **Figure 1**. The radial distance, the azimuth and the column length of the arbitrary point $M$ inside the noodles is represented by $r$, $\theta$, $z$ in cylindrical coordinate system, respectively [15]. During the heating process, the internal temperature of rice noodles with the heating time is expressed as the function of temperature, *i.e.*, $U(r,\theta,z,t)$. By combining the boundary conditions and the initial conditions of the preheating process, the three-dimensional heat conduction equation can be expressed as follows

$$\begin{cases} \partial_t U(r,\theta,z,t) = \alpha \cdot \nabla^2 U(r,\theta,z,t), \\ U(0,\theta,z,t) \text{ is bounded}, \\ U(R,\theta,z,t) = T_H, \\ U(r,\theta,z,0) = T_L. \end{cases} \quad (1)$$

where $\alpha$ is the thermal diffusion coefficient of Guilin rice noodles, and $T_L$ is the temperature of Guilin rice noodles before cooking, demonstrating the environmental temperature.

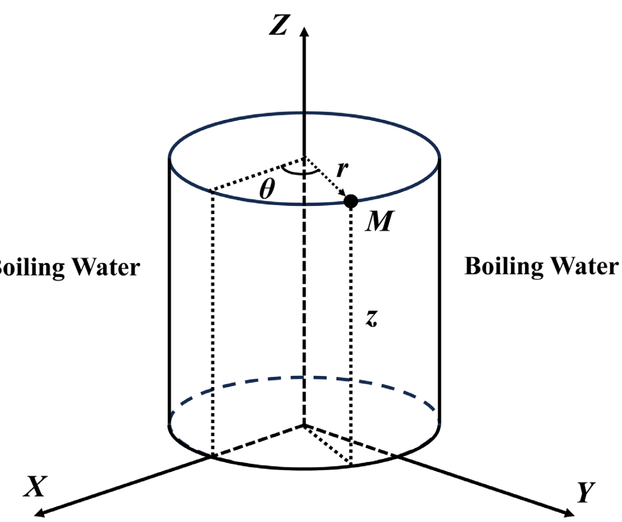


**Figure 1.** Schematic of Guilin rice noodle in a constant heat source in cylindrical coordinate system.

Through the analysis of Guilin rice noodles' properties and cooking process, we deduce the following: 1) Rice noodles are much longer than its radius (*i.e.*, $z \ll R$), so the heat conduction during the heating process mainly comes from the cylindrical side of the rice noodles, and the heat conduction through both cross sections of the ends can be neglected. That is the variable $z$ can be also neglected. 2) The rice noodles are completely immersed in boiling water during the cooking process. From the isotropy as shown in **Figure 1**, it can be seen that the azimuthal angle $\theta$ has no effect on the internal temperature variation of rice noodles, and thus Equation (1) can be simplified as [16] [17]

$$\begin{cases} \partial_t U(r,t) = \alpha \cdot \nabla^2 U(r,t), \\ U(0,t) \text{ is bounded,} \\ U(R,t) = T_H, \\ U(r,0) = T_L. \end{cases} \tag{2}$$

Thus the heat conduction equation is transformed into only two variables of the radial and the time in the cylindrical coordinate system.

## 2.2. Solution of the Heat Conduction Equation

Equation (1) is the inhomogeneous boundary conditions. Therefore, the transformation is performed as follows

$$U(r,t) = u(r,t) + T_H. \tag{3}$$

Thus, the equation of the homogeneous boundary conditions can be expressed as

$$\begin{cases} \partial_t u(r,t) = \alpha \cdot \nabla^2 u(r,t), \\ u(0,t) \text{ is bounded,} \\ u(R,t) = 0, \\ u(r,0) = T_L - T_H = u_0, \end{cases} \tag{4}$$

where $u_0$ is the temperature difference between the environmental temperature and the heat source temperature.

In terms of the separation of variables method, we can define as

$$u(r,t) = f(r) \cdot g(t). \tag{5}$$

By substituting into Equation (4), one can get

$$\begin{cases} g'(t) + \alpha \lambda^2 g(t) = 0, \\ \dfrac{1}{r}\dfrac{\mathrm{d}}{\mathrm{d}r}\left(r\dfrac{\mathrm{d}f}{\mathrm{d}r}\right) + \lambda^2 f = 0 \quad (R > r \geq 0), \\ f(0) \text{ is bounded,} \\ f(R) = 0. \end{cases} \tag{6}$$

The general solution of Equation (6) can be expressed as

$$u(r,t) = \sum_{n=1}^{\infty} C_n \mathrm{e}^{-\alpha \lambda_n^2 t} J_0(\lambda_n r), \tag{7}$$

where $J_0(\lambda r)$ is the zero order Bessel function, and $\lambda_n$ is the eigenvalue derived from $f(R) = J_0(\lambda R) = 0$ as shown in Equation (6). According to the initial condition $u(r,0) = u_0$, the coefficient $C_n$ can be determined as

$$C_n = \frac{2u_0}{R^2 J_1^2(\lambda_n R)} \int_0^R J_0(\lambda_n r) r \mathrm{d}r. \tag{8}$$

According to the recurrence formula $\frac{\mathrm{d}}{\mathrm{d}t}\left[rJ_1(r)\right]=rJ_0(r)$ of Bessel function [13], Equation (8) can be rewritten as following

$$C_n=\frac{2u_0}{\mu_n^{(0)}J_1\left(\mu_n^{(0)}\right)},\tag{9}$$

where $\mu_n^{(0)}$ represents the $n$-th zero value of the zero order Bessel function and $J_1\left(\mu_n^{(0)}\right)$ represents the value of the one order Bessel function at $\mu_n^{(0)}$, as shown in **Table 1**.

**Table 1.** The first 10 zero points of the 0-th order Bessel function and the function values of the 1-st order Bessel function at these zero points..

| $n$ | $\mu_n^{(0)}$ | $J_1\left(\mu_n^{(0)}\right)$ |
|---|---|---|
| 1 | 2.4048 | 0.5191 |
| 2 | 5.5201 | −0.3403 |
| 3 | 8.6537 | 0.2715 |
| 4 | 11.7915 | −0.2325 |
| 5 | 14.9309 | 0.2065 |
| 6 | 18.0711 | −0.1877 |
| 7 | 21.2116 | 0.1733 |
| 8 | 24.3525 | −0.1617 |
| 9 | 27.4935 | 0.1522 |
| 10 | 30.6346 | −0.1442 |

**Table 1** shows the values of the first 10 zero points of the zero order Bessel function and the values of the function of the one order Bessel function at these zero points. When the number of summation terms is taken as $n_{\max}=10$, the accuracy of the zero order and one order Bessel functions is sufficiently high. After substituting $\mu_n^{(0)}$ and $J_1\left(\mu_n^{(0)}\right)$ in **Table 1** into Equation (9), we obtain the value of $C_n$ [18].

The special solution of the internal temperature function of Guilin rice noodles is obtained by combining Equations (3), (7) and (9) as follows

$$U(r,t)=T_H+2u_0\sum_{n=1}^{n_{\max}}\frac{1}{\mu_n^{(0)}J_1\left(\mu_n^{(0)}\right)}J_0\left(\frac{\mu_n^{(0)}}{R}r\right)\mathrm{e}^{-\alpha\left(\frac{\mu_n^{(0)}}{R}\right)^2t}.\tag{10}$$

## 3. Sterilisation Effect

### 3.1. Characteristic of the Temperature-Dependent Inactivation

In order to measure the inactivation of *Pseudomonas cocovenenans* subsp. farinofermentans in rice noodles, the sterilisation efficiency $\eta$ is defined as the effect of sterilisation per unit of time within a certain temperature range, *i.e.*,

$$\eta_0 = \frac{1}{\delta t} \times 100\%. \tag{11}$$

where $\delta t$ represents the time required to reach 100% sterilisation at the given temperature range.

In actual problems, the *Pseudomonas cocovenenans* subsp. farinofermentans in contaminated rice noodles is usually divided into low, medium and high concentrations. It is worth mentioning that the contaminated rice noodles fail to meet the explicit requirements of the Guilin Market Supervision Bureau, so that they cannot be used for consumption [11]-[12]. In an effort to ensure the generalizability of the study results, the medium concentration is selected for investigation. It is evident that the findings in this case are also obviously suitable for the low concentration. Experimental studies have shown that *Pseudomonas cocovenenans* subsp. farinofermentans can be effectively inactivated when the environmental temperature is above 60˚C. When the rice noodles are moderately contaminated, the time required for complete inactivation of the strain is about 90 s after heating at 60˚C. When the heating temperature is 70˚C - 90˚C, the time required for complete inactivation of the strain is reduced to about 60 s. As the heating temperature increases to 100˚C, the time for complete inactivation of the strain is reduced to about 25 s [8]. Based on the above results, the relationship between the sterilisation efficiency $\eta_0$ and the duration time $\delta t$ at different temperature range $T$ during the preheating process of Guilin rice noodles can be summarized as shown in **Table 2**. In this Table, the labels, *i.e.*, I, II, III, and IV, represent different regions where the temperature ranges are corresponding to 60˚C - 70˚C, 70˚C - 90˚C, 90˚C - 100˚C, and constant 100˚C, respectively.

**Table 2.** The relationship between the sterilisation efficiency $\eta_0$ and the duration time $\delta t$ at different temperature range $T$ during the preheating process of Guilin rice noodles.

| Labels of regions | I | II | III | IV |
|---|---|---|---|---|
| $T$ (˚C) | 60 - 70 | 70 - 90 | 90 - 100 | 100 |
| $\delta t$ (s) | 75 | 60 | 43 | 25 |
| $\eta_0$ ($s^{-1}$) | 1.33 | 1.67 | 2.33 | 4.00 |

## 3.2. Temperature of the Heat Source

Before consumption, Guilin rice noodles should be put into a pot with boiling water. The bottom of the pot is heated continuously by a gentle fire to ensure that the water in the pot continues to boil, so the boiling water is regarded as a heat source with temperature $T_H$. The altitude and air pressure of a given area exert an influence on the boiling point of water. Under a standard atmospheric pressure, the relationship between the boiling point of water and the local altitude is as follows [19]

$$y = 1.13 \times 10^5 \left( \frac{100 - T_H}{273 + T_H} \right), \tag{12}$$

where $y$ is the altitude. The average altitude of Guilin is 150 m [20]. According to Equation (12), the average temperature of boiling water in Guilin is 99.5˚C, and this is the high temperature $T_H$ of the heat source for preheating the rice noodles.

### 3.3. Thermal Diffusion Coefficient

The thermal diffusion coefficient is an important physical quantity that describes how quickly the thermal energy propagates in a substance. In 1969, Riedel [21] proposed an empirical formula to describe the thermal diffusion coefficient of foodstuffs with the temperature above the freezing point, *i.e.*,

$$\alpha = 0.088\times10^{-6} + \left(\alpha_w - 0.088\times10^{-6}\right)X_w, \tag{13}$$

where $X_w$ represents the content of water in food. Guilin rice noodles are usually made of wet rice noodles, which have a high content of water about 40% - 50% [14]. And $\alpha_w = 1.4\times10^{-7}\ \text{m}^2/\text{s}$ represents the thermal diffusion coefficient of water. By taking the average content of water in Guilin rice noodles ($X_w = 45\%$) and substituting it into Equation (13), the average thermal diffusion coefficient of Guilin rice noodles can be obtained as

$$\alpha = 1.114\times10^{-7}\ \text{m}^2/\text{s}. \tag{14}$$

### 3.4. Temperature Distribution during Preheating Process

For one of the most common environmental temperatures in the urban area of Guilin, the temperature of the boiling water with a open cover is taken as $T_H = 99.5^\circ\text{C}$, and the initial temperature of rice noodles is taken as room temperature $T_L = 25.0^\circ\text{C}$. By substituting the radius $R$ of rice noodles' cross-section and the heat diffusion coefficient $\alpha$ into Equation (10), we get the relationship between the temperature and the radial distance $r$ of rice noodles and the time $t$. **Figure 2** shows the temperature distribution of rice noodles with radius $r$ for different preheating times, where the horizontal coordinate is the radial distance $r$ of the rice noodles in the cylindrical coordinate system, and the vertical coordinate is the temperature of the rice noodles $U$. The vertical dashed line is corresponding to the location of the radius $R$ of the cross-section of the rice noodles, and the red, green, blue, light blue, purple and dark blue lines indicate the internal temperature distributions of the rice noodles when the time of preheating is $t$ = 1 s, 3 s, 5 s, 10 s, 15 s and 20 s, respectively. As shown in **Figure 2**, the temperature at each point inside the rice noodles increases with the increase of preheating time. Meanwhile, the temperature at the core of the rice noodles is always the lowest, and the radial temperature of the rice noodles gradually converges while the preheating time is enough prolonged.

### 3.5. Temperature Distribution during Cooling Process

When Guilin rice noodles are taken out from the pot, we set the temperature at the core of the noodles to be the same as the temperature of the boiling water, *i.e.*, $T_H$, which is the initial temperature of the rice noodles. And the rice noodles

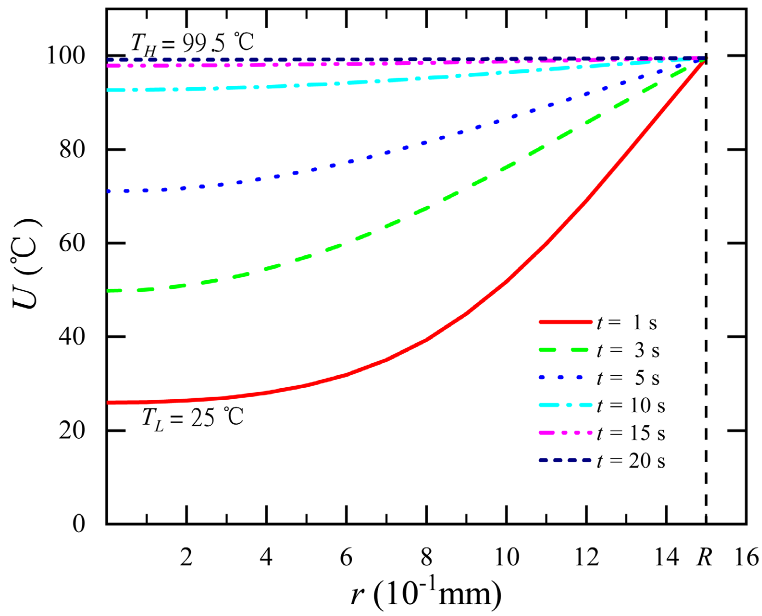


**Figure 2.** Temperature distributions of rice noodle in preheating time versus radius. The vertical dashed line corresponds to the location of the radius $R$ of the rice noodle. The red, green, blue, light blue, purple and dark blue lines indicate the internal temperature distributions of rice noodle after preheating time $t = 1$ s, 3 s, 5 s, 10 s, 15 s and 20 s, respectively.

are subjected to room temperature, meaning that the temperature of outside surface is $T_L$. Therefore, after the rice noodles are taken out from the boiling water, the three-dimensional thermal conduction equation can be reexpressed as follows

$$\begin{cases} \partial_t U(r,t) = \alpha \cdot \nabla^2 U(r,t), \\ U(0,t) \text{ is bounded}, \\ U(R,t) = T_L, \\ U(r,0) = T_H. \end{cases} \tag{15}$$

By the method of Section 2.2, the temperature distribution function of Equation (15) for the cooling process can be obtained as

$$U(r,t) = T_L - 2u_0 \sum_{n=1}^{\infty} \frac{1}{\mu_n^{(0)} J_1\left(\mu_n^{(0)}\right)} J_0\left(\frac{\mu_n^{(0)}}{R} r\right) e^{-\alpha\left(\frac{\mu_n^{(0)}}{R}\right)^2 t}. \tag{16}$$

**Figure 3** shows the temperature distribution of rice noodles as a function of radius $r$ for different preheating times, where the horizontal coordinate is the radial distance $r$ of the rice noodles in the cylindrical coordinate system, and the vertical coordinate is the temperature of the rice noodles $U$. The vertical dashed line corresponds to the location of the rice noodle cross-section radius $R$. The red, green, blue, light blue, purple, and dark blue lines indicate the internal temperature distributions of the rice noodles when the preheating time is $t = 1$ s, 3 s, 5 s, 10 s, 15 s, and 20 s, respectively. From **Figure 3**, it can be seen that the temperature at each point inside the rice noodles decreases with the increase in time. Meanwhile, the temperature at the core of the rice noodles is always at its highest, and with the prolongation of the cooling time, the radial temperature of the rice noodles gradually converges to the environmental temperature, $T_L$.

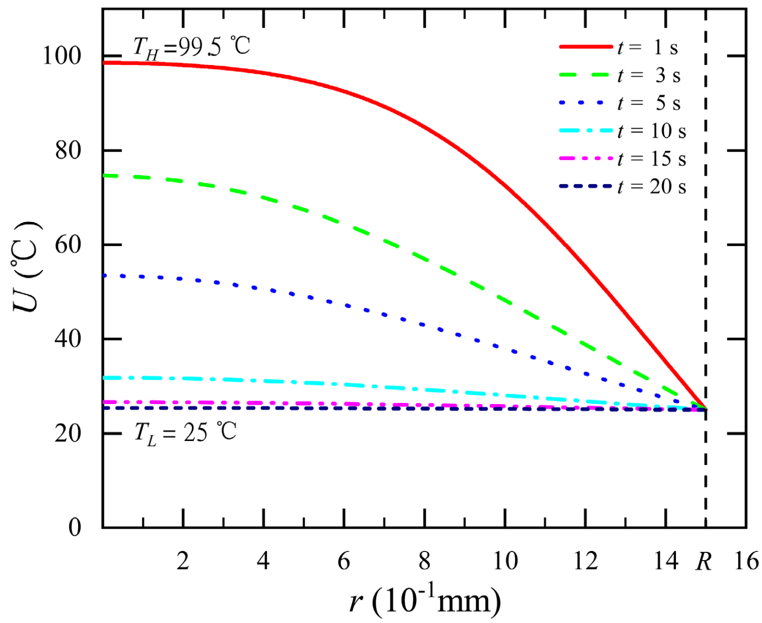


**Figure 3.** Same as **Figure 2**, but for the cooling process.

### 3.6. Results Analysis

The rice noodles' cooking process with sterilising effect includes the preheating and the cooling processes. From the analyses mentioned above, it can be seen that during the preheating process of Guilin rice noodles and next to the cooling process, the rate of temperature variation at the core of the rice noodles is the slowest compared to the other parts. Therefore, the complete inactivation of *Pseudomonas cocovenenans* subsp. farinofermentans in rice noodles can be determined by examining the sterilising effect at the core of the rice noodles. By combining Equations (10) and (16) and setting $r = 0$, the temperature distribution function with time at the core of Guilin rice noodles in the cooking process can be obtained, as shown in **Figure 4**, where the horizontal coordinate is the cooking time $t$ and the vertical coordinate indicates the temperature distribution function $U$ at the core of rice noodles. The shaded area indicates the time ranges in which the sterilisation conditions are met at the core of rice noodles. The sections designated as I, II, III, and IV represent the specific time of the preheating process (beginning from the left) and the cooling process (beginning from the right), where the internal temperatures at the core of rice noodles are 60˚C - 70˚C, 70˚C - 90˚C, 90˚C - 99.5˚C, and 99.5˚C (as shown in **Table 2**), respectively. And the labels $t_1 \sim t_8$ on the horizontal coordinate indicate the time required to reach each temperature range, respectively.

The total sterilisation effect is expressed as follows

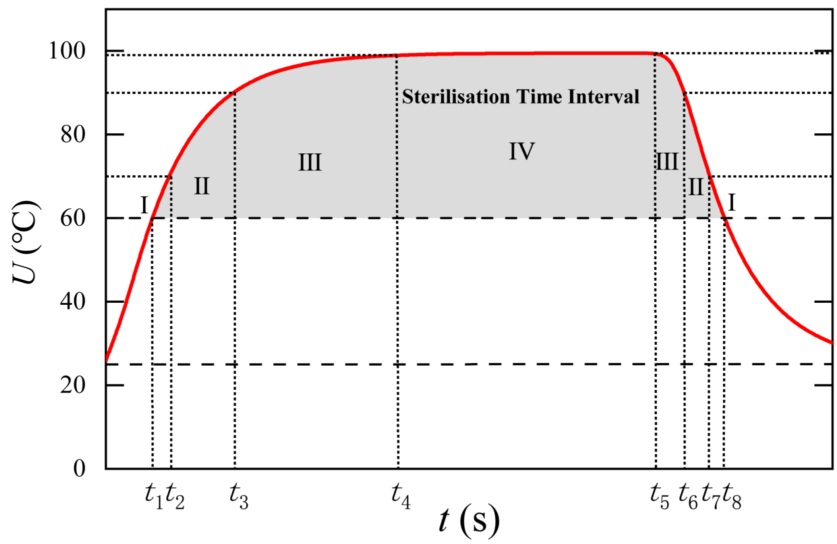


**Figure 4.** Temperature of Guilin rice noodle core with time during the cooking process. The shaded area indicates the time region when the temperature of the rice noodles core reaches the sterilisation condition. I, II, III and IV, starting from the left, correspond to the time regions in which the temperature of the rice noodles core is preheating at 60˚C - 70˚C, 70˚C - 90˚C, 90˚C - 99.5˚C, and 99.5˚C, respectively. And I, II III, starting from the right, correspond to time regions where the sterilisation conditions are met at the rice noodles core during the cooling process. $t_i\left(i=1,\cdots,8\right)$ on the horizontal axes indicates the moments at each temperature interval, respectively.

$$\eta=\eta_{0i}\times\Delta t_j=\eta_{0i}\times\left(t_{j+1}-t_j\right), \tag{17}$$

where $i$ = I, II, III, IV, and $j=1,2,\cdots,8$. The values of $\eta_{0i}$ are shown in **Table 2**, and $i$ and $j$ are shown in **Figure 4**. Combined with **Figure 4**, the time ranges corresponding to the sections I, II, and III (beginning from the left) in the preheating process can be strictly obtained from Equation (10), so that the value of $t_j\left(j=1,2,3,4\right)$ can be determined. In the same way, the time ranges corresponding to the sections I, II and III (beginning from the right) in the cooling process can be obtained by using Equation (16), so that the time ranges from $t_5$ to $t_8$ can be determined. Based on the fact that the total effect $\eta$ must be greater than 100%, the IV-th time interval (*i.e.*, the value of $t_5-t_4$) can be obtained. When the total time range $t=t_8-t_1=34.57$ s, *i.e.*, the preheating time $t_5=30.28$ s, the sterilisation effect of the cooking process reaches 100%. The sterilisation time and effect for each temperature interval are shown in **Table 3**. It can be concluded that the time of the preheating process of Guilin rice noodles should sustain at least 31 s before the possible existence of *Pseudomonas cocovenenans* subsp. farinofermentans in Guilin rice noodles can be considered to be completely inactivated.

## 4. Conclusion

Guilin rice noodles, as one of the representative delicacies of Guilin's traditional culture, have received widespread attention. Nowadays, shops of Guilin rice

Table 3. Sterilisation time and sterilisation effect in each temperature range.

| cooking process | time interval | $\Delta t$ (s) | $\eta$ (%) |
|---|---|---|---|
| pre-heating process | I | 1.19 | 1.58 |
| | II | 3.94 | 6.58 |
| | III | 10.01 | 23.32 |
| | IV | 15.14 | 60.56 |
| cooling process | III | 1.80 | 4.19 |
| | II | 1.55 | 2.59 |
| | I | 0.94 | 1.25 |
| total | | 34.57 | >100 |

noodles have been both domestically and internationally scattered. In order to further promote this "Guilin Classic" to the world, the safety of the cooking process should be further regulated. In this paper, the problem of whether Guilin rice noodles are effectively sterilised in the cooking process before consumption is investigated. Based on the actual parameters of the rice noodles such as thickness, length, diffusion coefficient and some external factors of the environmental conditions of the preheating and cooling processes, the three-dimensional heat conduction model is established, and the relationship between the internal temperature of the rice noodles and the time during the preheating and cooling processes is analytically obtained. By analyzing the inactivation characteristics of *Pseudomonas cocovenenans* subsp. farinofermentans in Guilin rice noodles with temperature, the minimum preheating time (about 31 s) required to completely inactivate the strains is obtained. This result provides an important reference of standardizing the cooking process of Guilin rice noodles.

## Acknowledgements

This work was supported by Guangxi Key R&D Project (Guike AB24010296), Central Government Guides Local Scientific and Technological Development Funds of China (Guike ZY22096024), Scientific Research and Technology Development Project of Guilin (20210104-2), and National Natural Science Foundation of China (No. 12065003).

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

## References

[1] Zhou, S.R., Su, L.T., Huang, S., Long, S.H. and Zhang, J.C. (2023) An Empirical Study on the Dissemination Strategy and Path of Guilin Rice Noodle Culture towards ASEAN: A Case Study of Thailand. *Culture Industry*, **1**, 156-159.

[2] Huang, W.L. (2022) Rice Noodles: Nostalgia among the People of Guilin. *Chinese*

*Three Gorges*, **4**, 60-67.

[3] Chen, L.S., Liang, Q.M., Yao, Z.J. and Lin, Y. (2022) Research Status and Prospect of Rice Noodles Quality Evaluation and Manufacture. *Science and Technology of Cereals, Oils and Foods*, **30**, 71-79.

[4] Wang, D. (2019) A Preliminary Analysis of the Contemporary Functions of Traditional Handcrafted Guilin Rice Noodles. *Marketing Circles*, **28**, 125-127.

[5] Chen, H.J., Chen, R.Q., Zhu, W.X., *et al.* (2021) Using Rice Soaking and Rinsing to Remove *Pseudomonas cocovenenans subsp. farino fermentans* during Wet Flour Production. *Modern Food Science and Technology*, **37**, 320-325.

[6] Yan, Q.Y., Le, L.S., Sun, Y.H., *et al.* (2023) Analysis of Toxin Production and Acidity of One Strain of *Pseudomonas cocovenenans subsp. farino fermentans* in Wet Rice Noodles Matrix. *Journal of the Chinese Cereals and Oils Association*, **38**, 164-168.

[7] Liu, X.M. (1996) An Analysis of the Trend in the Prevalence of Food Poisoning Caused by *Pseudomonas cocovenenans subsp. farino fermentans* in Fermented Rice Products in China. *Chinese Journal of Preventive Medicine*, **6**, 54-56.

[8] Su, M.Z., Ding, Q.L., Zeng, X.C. and Su, Z.T. (2023) Research on the Inactivation Means of *Pseudomonas cocovenenans subsp. farino fermentans*. *Food Safety Guide*, **15**, 128-136.

[9] Shentu, P.P., Zhu, J.H., Xu, X.M., Lü, G.J., Wang, C.R. and Tao, Z.Y. (2019) A Food Poisoning Incident Caused by *Pseudomonas cocovenenans subsp. farino fermentans*. *Shanghai Journal of Preventive Medicine*, **31**, 466-478.

[10] Wang, M.D., Qin, H.Y., Wei, W., *et al.* (2020) Hygienic Specification for of Guilin Rice Noodle. Guilin Market Supervision Administration.

[11] Ju, W., Tang, Z.M., Xu, G.J., *et al.* (2020) Hygienic Specification for the Production of Guilin Fresh Wet Rice Noodle. Guilin Market Supervision Administration.

[12] Qin, H.Y., Wang, M.D., Wei, W., *et al.* (2020) Specification for Production and Operation of Pre-Packed Guilin Rice Noodle. Guilin Market Supervision Administration.

[13] Wang, D.X. (2016) Methods of Mathematical Physics. 4th Edition, Science Press.

[14] Li, L.T. and Chen, M.H. (2000) Production and Research Status of Rice Noodle. *Food and Machinery*, **3**, 10-11.

[15] Jia, X.X., Xu, M.H., Hu, G.H., Liu, J., Lu, H. and Liang, Z. (2014) Numerical Method for Three-Dimensional Heat Conduction in Cylindrical and Spherical Coordinates. *Journal of Chongqing University of Technology* (*Natural Science*), **28**, 33-37.

[16] Antonov, D.V., Shchepakina, E.A., Sobolev, V.A., Starinskaya, E.M., Terekhov, V.V., Strizhak, P.A., *et al.* (2024) A New Solution to a Weakly Non-Linear Heat Conduction Equation in a Spherical Droplet: Basic Idea and Applications. *International Journal of Heat and Mass Transfer*, **219**, Article ID: 124880. https://doi.org/10.1016/j.ijheatmasstransfer.2023.124880

[17] Wu, D., Tao, Y. and Ren, H. (2023) The Laplace Transform Shortcut Solution to a One-Dimensional Heat Conduction Model with Dirichlet Boundary Conditions. *Axioms*, **12**, Article No. 770. https://doi.org/10.3390/axioms12080770

[18] Kunsen, L. (2009) Methods of Mathematical Physics. 4th Edition, Higher Education Press.

[19] Anhui Education (1986) The Relationship between the Boiling Point of Water and Altitude. *Anhui Education*, **12**, 44-45.

[20] Li, W.B., Zhu, H.L., Wang, Y.Y., Fan, Z.Z. and Qi, G.C. (2017) Analysis of Soil Fer-

tility Variation across Different Topographic Zones in the Urban Area of Guilin City. *Southern Horticulture*, **28**, 46-49.

[21] Zhen, X. (2000) Research of Thermal and Physical Properties of Food during the Freezing Process. *Journal of Wuhan Polytechnic University*, **4**, 4-8.