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P4 2 Steve's La-la-la-lava Chicken: A Salmonella Attack

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Abstract

In "A Minecraft Movie", submerging a chicken in lava is a technique which Steve employs in his local business to create "crispy and juicy" chicken meals. In this paper, we investigate how this reaction would translate into real world physics. Using dry transient conduction, we find that during this cooking process $\sim 7\%$ of the chicken's volume is cooked, leaving $\sim 80\%$ undercooked and $\sim 13\%$ burnt.

Introduction

In "A Minecraft movie", Steve has a small business where he fully submerges a chicken into lava to create a crispy snack. The chickens cooking time lasts for the duration of his business jingle, and serves the four other characters in the movie scene. In this paper, we aim to test how uniformly the chicken is cooked using transient conduction.

Results

Thermal properties of the lava chicken system - Initially, we find properties for the chicken and lava (Table 1), assuming the former is a sphere of chicken breast and the latter is basaltic.

We first approximate the mass of the chicken to be 1.75 kg [11] as the film shows the chicken serving five people. Since we have the density (Table 1), we calculate the radius of our spherical chicken, $r = 73$ mm.

Values for α and e in Table 1 are obtained using equation 1 [1] and equation 2 [2].

$$\alpha = \frac{k}{\rho c} \qquad (1) \qquad\qquad e = \sqrt{k\rho c} \qquad (2)$$

Quantity	Chicken (Ch)	Lava (L)
Initial temperature, T_0 /°C	41 [3]	1160 [4]
Thermal conductivity, k /W m^{-1} K^{-1}	0.509 [5]	1.4 [6]
Density, ρ /kg m^{-3}	1050 [7]	2645 [6]
Specific heat capacity, c /J kg^{-1} K^{-1}	3521 [5]	1450 [8]
Thermal diffusivity, α /m^2 s^{-1}	1.4×10^{-7}	3.7×10^{-7}
Thermal effusivity, e /W s$^{1/2}$ m^{-2} K^{-1}	1400	2300

Table 1: Thermal properties and initial conditions for chicken and lava.

Using values in Table 1, we find the initial contact temperature of the chicken surface, T_{sc}, with the lava using equation 3 [9],

$$T_{sc} = \frac{e_{\mathrm{Ch}} T_{0,\mathrm{Ch}} + e_{\mathrm{L}} T_{0,\mathrm{L}}}{e_{\mathrm{Ch}} + e_{\mathrm{L}}} \qquad (3)$$

giving $T_{sc} = 740\,^{\circ}\mathrm{C}$.

Heat conduction into the chicken - We assume ideal contact between the chicken and the lava, so there are no gaps or cavities, and the temperatures are equal at the surfaces. Therefore, radiative transfer is absent and only transient conduction is at play. Radiation itself still needs to be accounted for, and that is included in k_{lava}. We calculate the heat conduction into the chicken using the 1D transient heat conduction

equation [10],

$$\frac{\partial T}{\partial t} = \alpha \frac{\partial^2 T}{\partial x^2}, \tag{4}$$

where the temperature, $T(x,t)$, is a function of space and time. The solution to this equation is derived in [10] and adapted to our lava chicken concept,

$$T(x, t = 25) = T_{\text{sc}} + (T_{0,\text{Ch}} - T_{\text{sc}})\ \text{erf}\left(\frac{x}{\sqrt{4\alpha_{\text{Ch}} t}}\right) \tag{5}$$

where

$$\text{erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2}\, dt\,. \tag{6}$$

Equation 5 describes the temperature within the chicken as a function of depth and is plotted in Figure 1. We define the cooking time for the chicken to be t = 25s.

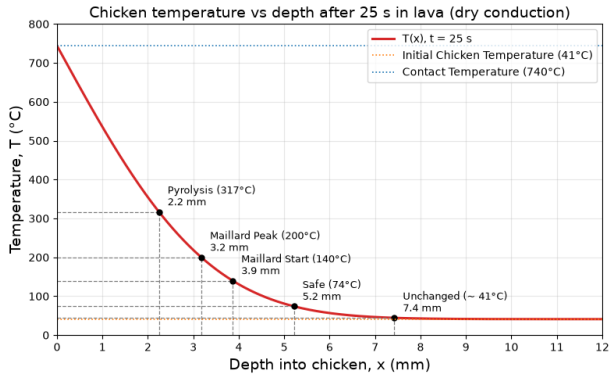


Figure 1: Temperature within the chicken (radius 73 mm) [11] as a function of depth after 25 s in contact with lava. Temperature thresholds associated with pyrolysis [12], the Maillard reaction [13] and safe eating [14] are indicated.

The thermal penetration depth [15] of the chicken,

$$x_p = 4\sqrt{\alpha_{\text{Ch}} t} = 7.4 \text{ mm}, \tag{7}$$

shows that beyond 7.4 mm the temperature of the chicken remains almost unchanged.

Volume of "edible" chicken - To calculate the volume of "edible" chicken (safe to Maillard Peak), we use the radius of the chicken $r = 73$ mm to find the shell volumes of the different sections, shown in figure 2.

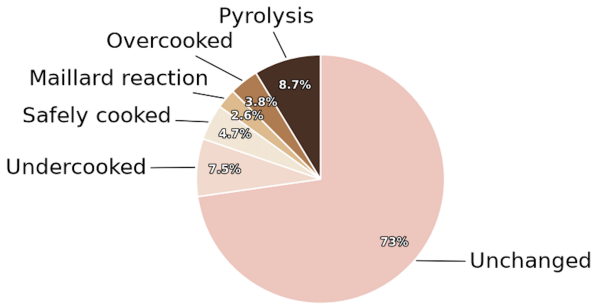


Figure 2: A pie chart displaying the percentage (2 s.f.) volume of chicken (radius 73 mm) [11] that has undergone various cooking thresholds presented in figure 1. We consider safely cooked and Maillard reaction volumes suitably edible.

Discussion and Conclusions

We find that submerging a chicken in 1160 °C basaltic lava, only 7.3% of its volume will be suitable for consumption. Whilst 19.8% could be considered edible if we include overcooked or pyrolysis volume, it would not align with Steve's definition of it being 'crispy and juicy'. Therefore, we deem cooking chicken in lava an unhygienic practice, being unsafe for human consumption. Additionally, our calculation is an overestimate. For simplicity, we assumed a spherical chicken breast whilst keeping the properties in Table 1 constant throughout the exposure to the lava. In reality, these parameters will decrease as the chicken is heated, due to the evaporation of water within the flesh and the Maillard reaction altering the chemical properties of the meat. Assuming ideal contact means there are no gaps, which is unrealistic when cooking a chicken as steam creates pockets. This means less of the heat would reach and cook the chicken. Overall, these assumptions mean the amount of cooked chicken is even less than we calculated. The outer charred layer alone would significantly hamper the internal heating of the chicken, with its much lower specific heat capacity and conductivity of 840-1300 J kg^{-1} K^{-1} and 0.05-0.10 W m^{-1} K^{-1} respectively (taking the charred layer as charcoal) [16], instead insulating it to the high temperature of the lava.

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