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A3 2 Steak du Soleil

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Abstract

In this paper we have explored the possibility of cooking the perfect steak using only solar radiation and have posed the question: How close to the Sun would you have to be to cook the perfect steak? We found that you would need to be approximately within $220,000,000$ km of the Sun, which is approximately the distance between the Sun and Mars. We concluded that using solar radiation was not a viable method of cooking a steak.

Introduction

Many chefs around the world have endeavoured for as long as beef has been a common staple, to cook the perfect steak. Sous vide, reverse sear, open flame, all of the previous are common methods but why hasn't anyone tried cooking their steaks in space? The question we pose in this paper is thus: What are the perfect conditions to cook a steak in space, using solar radiation?

Methodology

First of all, we made assumptions about the steak to begin our calculations. The assumptions made were as follows: we would model a standard size 6 oz. steak (0.17 kg), take the perfect steak temperature to be 55°C [2], assume the steak is a perfect square of homologous beef with specific heat capacity 1,670 J $kg^{-1}K^{-1}$ [3] and surface area 0.1 m^2. We also negated the effects of the steak freezing due to being subject to a vacuum, and suggested the cooking process would start from a fridge temperature of 3°C.The starting calculation we made was to find the required energy to cook the steak to the perfect temperature, which means to cook the steak perfectly, the temperature must increase by 52 K. Using the specific heat capacity equation [4]:

$$\Delta E = mc\Delta T, \tag{1}$$

Where ΔE is the change in thermal energy, m is the mass of the steak, c is the specific heat capacity of the beef, and ΔT is the change in temperature. We substituted our values for these variables to find a value for the energy required. We found the energy required to increase the temperature of the steak by 52 K to be 14,762.8 J. Next, we had to formulate an equation where the power radiated from the Sun was a function of distance from the Sun. To do this we started with the Stefan Boltzmann law [1]. This states the luminosity (P_{rad}) is the product of the emissivity (ϵ), the surface area of the star ($4\pi R_s^2$), the temperature (T) to the power of four and the Stefan-Boltzmann constant (σ):

$$P_{rad} = \epsilon\sigma 4\pi R_s^2 T^4, \tag{2}$$

In this equation the emissivity of the Sun is approximated to be 1 and so can be ignored in further manipulation of this equation. From this equation we required the flux per meter squared at a distance. To do this we divided the Stefan-Boltzmann Law by the surface area of a new sphere with radius r distance from the Sun. This gives the equation:

$$F_{rad} = \frac{\sigma R_s^2 T^4}{r^2}, \tag{3}$$

This gives us the inverse square law, where F_{rad} is the flux of the radiation, shown by:

$$F_{rad} = \frac{E_{tot}}{t A_{steak}} \tag{4}$$

Where E_{tot} is the energy previously stated (14,762.8 J), t is cooking time and A_{steak} is the area of the steak. We assumed infrared radiation was the main source of radiation for the cooking process. As a result, we plotted a model using Planck's Law of Radiation to map the intensity of the Sun's radiation against wavelength to show a blackbody curve at 5,700 K (the temperature of the Sun). From this we marked two lines showing the infrared section of the model. We then calculated the area under the curve for the infrared section as a percentage of the total intensity. The result was 51.11%, this will then be factored in to [eqn.3] so the equation represents the total infrared radiation flux.

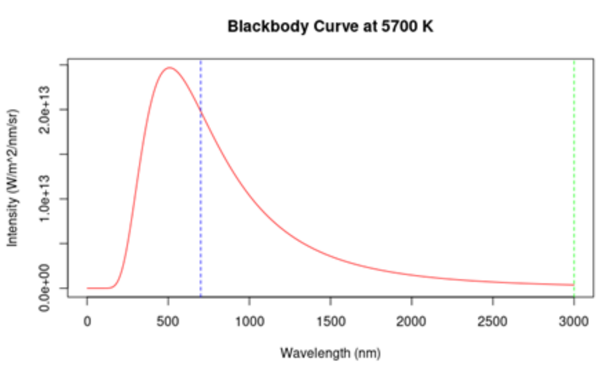

Figure 1: A plot showing intensity of radiation against wavelength of radiation at a blackbody temperature of 5,700 K. Also shown is the region of the curve consisting of infrared radiation between the two vertical lines.

Factoring this into our expression for radiated flux of infrared radiation:

$$F_{IR} = \frac{\sigma R_s^2 T^4}{r^2} 0.51, \tag{5}$$

The perfect time to cook a steak to medium rare is 4 minutes per side (240s). Given the 480s cooking time and substituting [eqn.4] we can rearrange [eqn.5] to find the distance from the Sun required to cook the steak to 55°C.

Results and Conclusions

The value for r we calculated was 2.2×10^{11} m or 220,000,000 km from the Sun. 220,000,000 km is 8 million kilometers shy of the distance from the Sun to Mars [5]. Although by no means close to the Sun's surface, the intensity of the radiation capable of cooking a steak in 8 minutes would also begin to start cooking the chef and as such, they would require adequate shielding between themselves and the steak. Not to mention the costs of getting to Mars to cook the steak. We concluded from this, that this method of cooking a steak is not to be attempted by the amateur cook or for that matter any human being without proper equipment or training.

References

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