How to cook a perfect egg

As an egg cooks, the proteins first denature and then coagulate. When the temperature exceeds a critical point, reactions begin and proceed faster as the temperature increases.

• In the egg white the proteins start to coagulate for temperatures above 63 °C, while in the yolk the proteins start to coagulate for temperatures above 70 °C.

• For a soft boiled egg, the white needs to have been heated long enough to coagulate at a temperature above 63 °C, but the yolk should not be heated above 70 °C.

• For a hard boiled egg, the center of the yolk should be allowed to reach 70 °C. The following formula expresses the time t it takes (in seconds) for the center of the yolk to reach the temperature Ty (in Celsius degrees):

$$t = \frac{M^{2/3} c \rho^{1/3}}{K \pi^2 (4\pi/3)^{2/3}} ln[0.76 \frac{T_o - T_w}{T_y - T_w}]$$

Here, M, ρ, c, and K are properties of the egg:

• M is the mass,

• ρ is the density,

• c is the specific heat capacity,

• K is thermal conductivity.

• Relevant values are ρ = 1.038 g cm−3, c = 3.7 Jg−1 K−1, and K = 5.4 10−3 W cm−1 K−1

Constants

Density of Egg

$\rho_{egg} = 1.038 \frac{g}{cm^3}$

Specific Heat Capacity of egg

$c_{egg} = 3.7 \frac{J}{g\ K}$

Thermal Conductivity of Egg

$K_{egg} = 5.14 \cdot 10^{-3} \frac{W}{cm\ K}$

Inputs

Temperature of water

$Temp_{Water} = 353.15\ K$

Temperature of Egg

$Temp_{egg} = 283.15\ K$

Temperature of yolk

$Temp_{Yolk} = 343.15\ K$

Range of mass of egg

$Mass_{egg} = [0.047, 0.05..0.067]\ kg$

Calculations

Vectorizing function for different range of mass to get time

$$\overrightarrow{t = \frac{Mass_{egg}^{\frac{2}{3}} \cdot c_{egg} \cdot \rho_{egg}^{\frac{1}{3}}}{K_{egg} \cdot \pi^{2} \cdot \left(\frac{4 \cdot \pi}{3}\right)^{\frac{2}{3}}} \cdot \ln\left(0.76 \cdot \left(\frac{Temp_{egg} - Temp_{Water}}{Temp_{Yolk} - Temp_{Water}}\right)\right)}$$

Outputs

Range of Mass of Egg

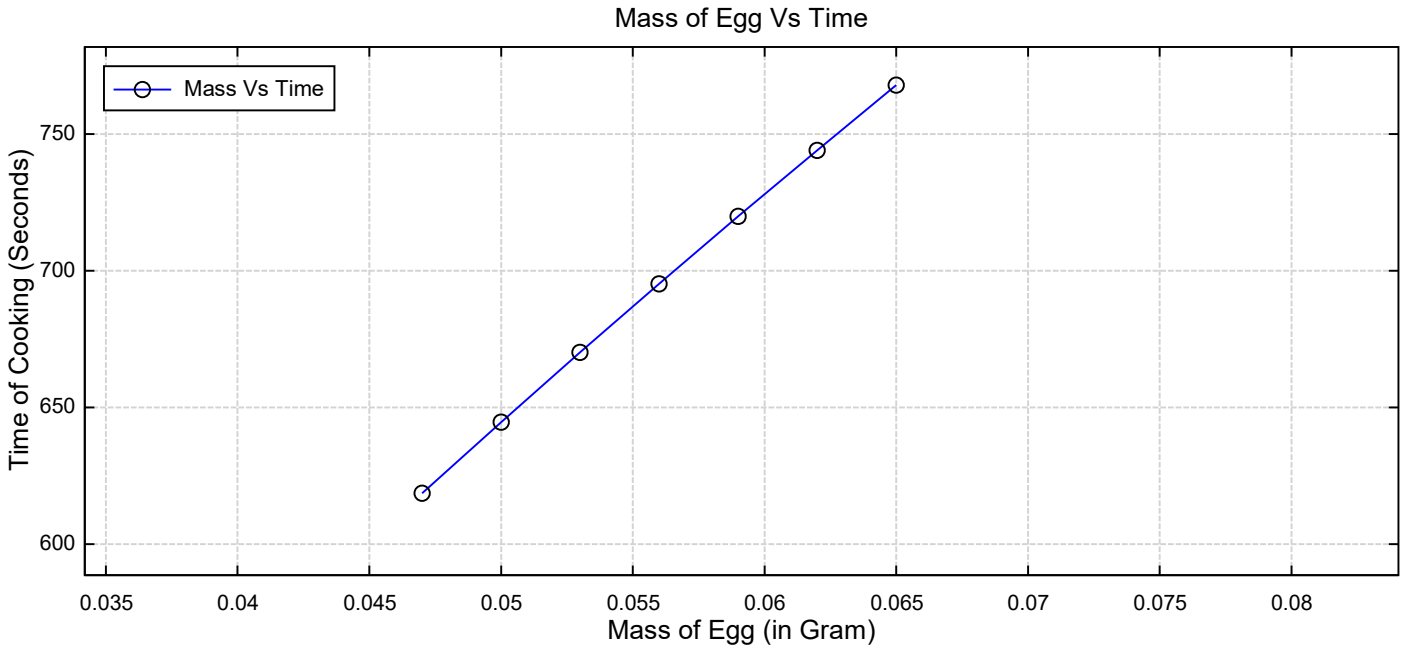
$$Mass_{egg} = \begin{bmatrix} 47 \\ 50 \\ 53 \\ 56 \\ 59 \\ 62 \\ 65 \end{bmatrix} \text{ g}$$

Specific cooking time for corresponding value of mass of Egg

$$t = \begin{bmatrix} 10.3108 \\ 10.745 \\ 11.1706 \\ 11.5883 \\ 11.9985 \\ 12.4019 \\ 12.7988 \end{bmatrix} \text{ min}$$

Graphical Output

$$Plot = \text{augment}\left(Mass_{egg}, t\right)$$



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In [ ]:
```
import numpy as np
import matplotlib.pyplot as plt
```

In [ ]:
```
Mass_of_egg = np.linspace(0.047,0.067,50) #Chicken egg mass
rho = 1038 #Basis
c = 3700 #Basis
K = 5.4*10**-1 #Basis
Temp_of_egg = 283.15 # Inputs in kelvin
Temp_of_water = 353.15 # Inputs in kelvin
Temp_of_yolk = 343.15 # Inputs in kelvin
```

In [ ]:
```
t = Mass_of_egg**(2/3)*c*rho**(1/3) / (K * np.pi**2 * (4*np.pi/3)**(2/3))
```

In [ ]:
```
Log_temp = np.log(0.76 * ((Temp_of_egg-Temp_of_water)/(Temp_of_yolk-Temp_of_water)))
```

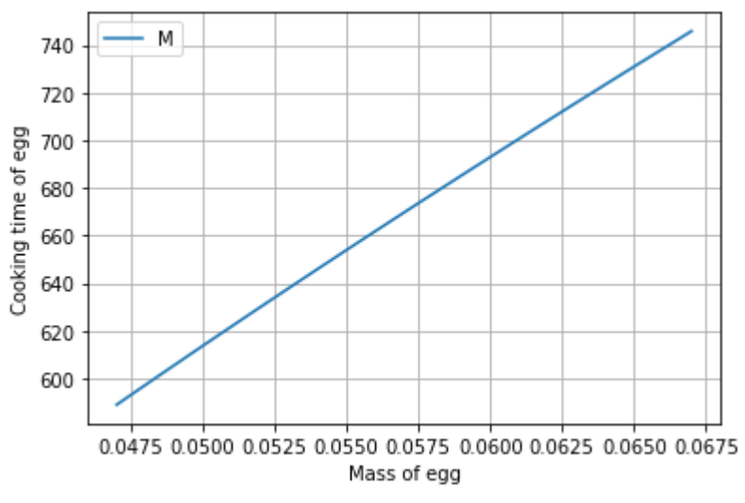
In [ ]:
```
# t
```

In [ ]:
```
egg_cooking_time = t*Log_temp
```

In [ ]:
```
egg_cooking_time
```

Out[ ]:
```
array([588.86120985, 592.26553565, 595.66010539, 599.04502998,
       602.42041809, 605.78637631, 609.14300913, 612.49041905,
       615.8287066 , 619.15797043, 622.47830731, 625.78981223,
       629.09257842, 632.38669739, 635.672259  , 638.94935148,
       642.21806149, 645.47847414, 648.73067304, 651.97474034,
       655.21075677, 658.43880165, 661.65895295, 664.87128733,
       668.07588013, 671.27280546, 674.46213617, 677.64394391,
       680.81829917, 683.98527128, 687.14492846, 690.29733783,
       693.44256543, 696.58067626, 699.71173431, 702.83580255,
       705.95294298, 709.06321666, 712.16668368, 715.26340325,
       718.35343367, 721.43683236, 724.51365588, 727.58395998,
       730.64779954, 733.70522869, 736.75630072, 739.80106819,
       742.83958289, 745.87189586])
```

In [ ]:
```
plt.plot(Mass_of_egg,egg_cooking_time)
plt.xlabel('Mass of egg', fontsize = 10)
plt.ylabel('Cooking time of egg', fontsize = 10)
plt.legend("Mass of egg v/s time")
plt.grid()
plt.show()
```



In [ ]:
```
```