Factors Influencing the Cooking time of Eggs

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Introduction

Although the consumption of eggs is common worldwide and considered a staple in many households due to its richness in protein, the cooking time of an egg is widely disputed. The question of how to maximise the cooking time of an egg often crosses the mind but is often neglected due to the lack of consensus worldwide. It is this exact question that we set out to investigate and shed light onto with our experimental study. In particular, we aim to answer the question of whether factors such as water temperature and water salinity influence the internal temperature of an egg given a controlled 10 minutes of boiling time. The results that can be obtained from this study are essential as it will reveal what factors impact the cooking time of an egg and help individuals boil their eggs to perfection.

Methodology

Variables

In the experiment, three variables were considered: two explanatory (independent variables) and one response (dependent variable). The explanatory variables were the salinity and the starting temperature of the water in which the egg was boiled. The salinity of the water was binary, with two possible levels: 0 grams/litre or 50 grams/litre, making it a categorical variable. Similarly, the starting temperature of the water was categorical, with two possible levels: 10 degrees Celsius or 20 degrees Celsius. The response variable which was measured was the internal temperature of an egg in degrees Celsius after being boiled, which is a quantitative variable, this was measured with a digital thermometer. To measure the salinity of the water, 37 grams of salt was measured with a cooking scale and then added to 750ml of water, otherwise the water was left unsalted.

The Experiment

Forty large sized eggs were randomly selected and boiled one at a time in a pot containing 750ml of water with four possible treatments. After placing the egg into the pot of water, the pot was placed onto a preheated hot plate set at medium high heat, and a 10 minute timer was started. After 10 minutes had elapsed, the egg was removed from the pot and allowed to rest for thirty seconds in a bowl at room temperature. The temperature was then measured using a digital instant read thermometer by inserting the probe approximately 11 millimetres into the bottom of the egg. Since the temperature fluctuated constantly, the temperature was recorded for two minutes and the maximum reading was taken as the result for that specific treatment.

To prevent nuisance factors, randomization, replication, and control were employed in the experiment. As all experimental units were homogeneous, blocking was not applicable for this study. Randomization was used as all forty eggs were numbered one to forty and using a random number generator in R without replacement a number was selected from this range. Once the number was selected that corresponding egg was assigned a treatment. The randomly selected eggs were assigned treatment one then two then three and finally four then the cycle was repeated, once this process was over there were ten randomly selected eggs in each treatment group. This is also demonstrative of treatment level replication as each treatment group contained 10 randomly selected

experimental units or eggs. Finally, a multitude of control variables were considered and kept constant throughout the experiment. These consisted of using the same pot and initial pot temperature, hotplate top and hotplate temperature, constant volume of water at 750 ml per egg, egg size and brand of egg, constant egg starting temperature, boiling one egg at a time, checking the egg was not expired, cooking time at ten minutes, placing the egg in the same location in the pot, type of salt, and finally the same thermometer was used Throughout.

Discussion/Results

Overall, there were three main methods that were used to analyze this data. First, two-way ANOVA was used on a model that tested the 'interaction effect' between water salinity and the water temperature. This was ultimately a test to determine if both water salinity and water temperature had any combined effect on the internal temperature of an egg. Next, two-way ANOVA was again used, now on an 'additive model'. This was ultimately a test to determine if water salinity and water temperature had their own respective effects on the internal temperature of an egg, given that varying levels of these 2 factors in combination with one another would not have any effect on the internal egg temperature. Finally, some further comparisons of various treatments, known as a post hoc analysis, were then tested using Bonferroni correction, a method used to limit potential incorrect conclusions that any treatments have an effect on the internal egg temperature.

We began by testing the combined effect of water temperature and water salinity on the internal temperature of an egg using Two-way ANOVA. Our hypotheses for the test were as followed:

1. **Null Hypothesis**: The interaction between water salinity and water temperature has no effect on the internal temperature of an egg

2. **Alternative Hypothesis**: The interaction between water salinity and the water temperature has an effect on the internal temperature of an egg

After conducting this test, we confirmed, with 95% certainty, that there was no evidence of an interaction effect between water salinity the water temperature on the internal temperature of an egg.

Thus, as the interaction effect was insignificant, we proceeded to test the individual effects of water salinity and water temperature on the internal temperature of an egg using two-way ANOVA on an additive model. To administer this, we determined the following hypotheses:

1. **The hypothesis to test the effect of water temperature:**

    a. **Null Hypothesis**: water temperature has no effect on the internal temperature of an egg
    b. **Alternative Hypothesis:** water temperature has an effect on the internal temperature of an egg
2. **The hypothesis to test the effect of water salinity:**
    a. **Null Hypothesis**: water salinity has no effect on the internal temperature of an egg
    b. **Alternative Hypothesis:** water salinity has an effect on the internal temperature of an egg

After testing our first hypothesis regarding water salinity, we determined, with 95% certainty, that water temperature has a significant effect on the internal temperature of an egg. Similarly, for our second hypothesis regarding water salinity, we determined, with 95% certainty, that water salinity has a substantial effect on the internal temperature of an egg.

3.2.1: Post Hoc Analysis

The goal of this post-hoc analysis is to draw some directional conclusions about the different treatments (which are varying levels of water salinity and water temperature applied together) in this experiment. Please refer to Table 4 given below for treatment specifications.

Treatment 1	Treatment 2	Treatment 3	Treatment 4
(10C, unsalted)	(20C, unsalted)	(10C, salted)	(20C, salted)

For this test, we tested the following hypotheses:

1. **Testing the average internal temperatures of the experimental units of treatment 4 vs the average internal temperatures of the experimental units of treatment 1:**
    a. **Null Hypothesis:** the average internal temperatures of the experimental units of treatment 4 is less than the average internal temperatures of the experimental units of treatment 1
    b. **Alternative Hypothesis:** the average internal temperatures of the experimental units of treatment 4 is greater than the average internal temperatures of the experimental units of treatment 1

2. **Testing the average internal temperatures of the experimental units of treatment 4 vs the average internal temperatures of the experimental units not in treatment 4:**
    a. **Null Hypothesis:** the average internal temperature of the eggs in treatment 4 is smaller than the average internal temperatures of the eggs not in treatment 4
    b. **Alternative Hypothesis:** the average internal temperature of the eggs in treatment 4 is larger than the average internal temperatures of the eggs not in treatment 4

After conducting our first test, it was determined, with 95% certainty, that the average internal temperatures of the experimental units of treatment 4 are greater than the average internal temperatures of the experimental units of treatment. Similarly, after conducting our second test, it was determined, with 95% certainty, that the average internal temperature of the eggs in treatment 4 is larger than the average internal temperatures of the eggs not in treatment 4

Limitations

There were various limitations to the study as expected, however there was one limitation which may compromise the validity of the conclusions made in this study. The source of this limitation came from equipment failure. The tool that was used to measure the internal temperature of the eggs(an instant read thermometer), failed with 8 trials to go. The thermometer was replaced with another instant read thermometer of a different brand due to local providers no longer carrying the original thermometer that was used. The new thermometer was then used in the last 8 trials. The problem is there is little reason to believe that the accuracy of the new thermometer is the same as the old one. This poses some issues in the data analysis because some measurements may not be as accurate as other ones.

Conclusion

The primary objective of this experimental study was to examine whether factors such as water temperature and water salinity had an influence on the cooking time of an egg. Our findings suggest that both the factors water temperature and water salinity had an impact on the cooking time of an egg. However, there were several limitations that impact the validity of this experimental study as previously discussed. The violation of normality in this study may be remedied by using non-parametric methods of data analysis. Furthermore, limitations introduced by equipment failure mentioned above will require data analysis methods that are robust to the violation of homogeneous variance within groups. The validity of this study may also be improved by increasing the number of eggs used for each treatment which would have yielded more accurate results. With the assistance of R code, we came to the conclusion that there was no interaction between the two factors, and that both factors on their own were statistically significant.