Project Report

STAT 3113 — Engineering Statistics

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Due Date: November 30th, 2017

Contents

1 Objective

A useful tool in cooking is determining roughly how long it will take to boil water. There are several factors that might affect how fast water boils, including:

- Amount of salt in the water.
- The size of the pot.

This experiment will specifically determine how said factors affect how long it takes water to reach 100 °C.

2 Experiment Design

Below we will lay out the design of our experiment.

2.1 Factors and Levels

We design a two factor, three level experiment — a 3^2 factorial experiment. Please refer to Table 1 for a complete description.

Table 1: Factor and Level Definition

Factor	**Level 1**	**Level 2**	**Level 3**
Pan Size	$153.94\,\mathrm{cm}^2$	$254.47\,\mathrm{cm}^2$	$314.16\,\mathrm{cm}^2$
Salt Weight	No Salt	17 g	34 g

2.2 Response Variable

In our experiment, the response variable is the amount of time it takes for two cups of water to reach 100 °C.

2.3 Blocking Factors

There is only one possible blocking factor for our experiment: the initial temperature of the pot. We circumvent this by placing cold water in all of the pans initially and letting all the pans reach thermal equilibrium before starting the experiment.

2.4 Number of Replicants

Each treatment combination is replicated three times.

3 Experiment Plan

The following section will describe the layout of the experiment.

3.1 Letting Pans Reach Thermal Equilibrium

The first step is to ensure that all pans have the same initial temperature.

We accomplish this by placing cold water (5 °C) in both of the pans for 5:00 minutes. After this, we can proceed with the experiment.

3.2 Measure Out Salt

Note: This step does not apply to the treatment with no salt.

We measure out the salt on a scale to the desired weight (whether it be 17 g or 34 g).

After pouring said salt into all of the pans individually, we stir until we reach a homogeneous, saltwater mixture.

3.3 Conduct The Experiment

We proceed to set the temperature of all heating elements "high". We continually measure all pots to see if they have reached 100 °C.

If they have reached the desired temperature, take the pot off the heater and mark the time. Do so for all pots.

After all pans have finished, mark the recorded data — these notes can be found in Section 8

Figure 1: Timothy Ott Conducting The Experiment

4 Data Collection

All data collected can be summarized Table 2; additionally, Section 8 contains the data as it was collected during the experiment.

Table 2: Number of Minutes To Reach 100 °C (No Salt)

	No Salt			17 g Salt			34 g Salt		
Big	6:00.18	6:29.03	6:36.66	4:57.91	5:32.9	5:41.30	4:55.35	5:20.36	5:01.71
Medium	7:36.48	5:41.17	6:56.42	5:22.78	6:17.04	5:55.60	5:33.12	5:34.46	5:35.75
Small	8:15.79	6:57.90	7:13.85	6:08.14	6:34.02	6:47.33	6:03.25	6.08.36	6:04.19

5 Data Analysis

We entered the data of our experiment into the JMP software as shown below. The data can be viewed in Figure2

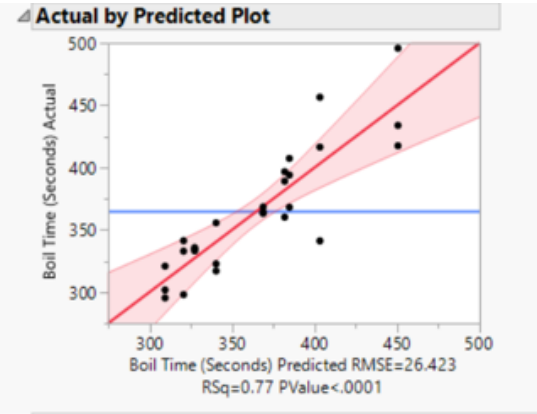
	Salt Weight	Pan Size	Boil Time (Seconds)
1	0	153.94	495.79
2	0	153.94	417.5
3	0	153.94	433.85
4	17	153.94	368.14
5	17	153.94	394.02
6	17	153.94	407.33
7	34	153.94	363.25
8	34	153.94	368.36
9	34	153.94	364.17
10	0	254.47	456.48
11	0	254.47	341.17
12	0	254.47	416.42
13	17	254.47	322.78
14	17	254.47	317.04
15	17	254.47	355.6
16	34	254.47	333.12
17	34	254.47	334.46
18	34	254.47	335.75
19	0	314.16	360.18
20	0	314.16	389.03
21	0	314.16	396.66
22	17	314.16	297.97
23	17	314.16	332.9
24	17	314.16	341.3
25	34	314.16	295.35
26	34	314.16	320.86
27	34	314.16	301.71

Figure 2: The Input Used By JMP.

To analyze the data we first needed to test for the presence of interaction effect.

$$H_0 : \gamma_{11} = \gamma_{12} = \ldots = \gamma_{IJ} = 0$$
$$H_1 : \text{at least one of the } \gamma_{ij} \text{ is nonzero}$$

Because the p-value of Salt Water*Pan Size is 0.7625 (Figure 3), which is greater than our significance level of 0.05, we fail to reject our null hypothesis and conclude that the interaction effect is not significant. Therefore, we can test for the main effects.



(a) The Actual by Predicted Plot

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Salt Weight(0,34)	1	1	26445.132	37.8780	<.0001*
Pan Size(153.94,314.16)	1	1	18460.811	26.4419	<.0001*
Salt Weight*Salt Weight	1	1	3749.167	5.3700	0.0307*
Pan Size*Pan Size	1	1	104.126	0.1491	0.7032
Salt Weight*Pan Size	1	1	65.435	0.0937	0.7625

(b) The Main Effects Table

Figure 3: The Results

6 Conclusion

To test the main effects we first need to define our null and alternative hypotheses. We will first consider pan size.

$$H_0 : \alpha_1 = \alpha_2 = \ldots = \alpha_I = 0$$
$$H_1 : \text{at least one of the } \alpha_i \text{ is nonzero}$$

The p-value for pan size is a number smaller than 0.0001 which is smaller than our significance level of 0.05. Therefore, we fail to reject our null hypothesis and conclude that pan size does have an effect on the time it takes for water to reach 100 °C.

We will now test for the main effect of salt weight.

$$H_0 : \beta_1 = \beta_2 = \ldots = \beta_J = 0$$
$$H_1 : \text{at least one of the } \beta_j \text{ is nonzero}$$

The p-value for salt weight is a number smaller than 0.0001 which is again smaller than our significance level of 0.05. Therefore, we fail to reject our null hypothesis and conclude than salt weight does have an effect on the time it takes for water to reach 100 °C.

7 Improvement Suggestions

There are still things that can be improved in our experiment; specifically, they are:

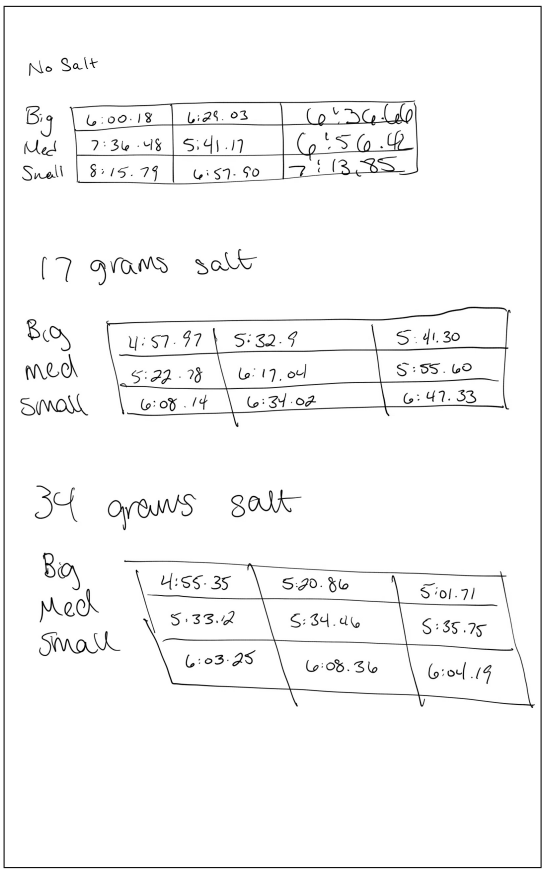
Filtered Water Using filtered water, as opposed to tap water, would also improve the accuracy of the experiment. Tap water naturally contains various minerals, ions, and other particles that vary greatly between samples. Filtered water would remove the interference of those particles, making the salt the only additive in the water.

Better Temperature Measurement Creating a rig to hold the thermometer in the water would also improve the accuracy of our results. Manually dipping the thermometer between the pots adds some variation between measurements, while having some method for holding the thermometer in the center of the pot would ensure consistent, unbiased results.

Atmospheric Pressure Controlling the atmospheric pressure at which the experiment was conducted would improve the accuracy of this experiment. The air pressure above the water changes the temperature/amount of time required to boil water, and since this experiment took place over the course of several hours, the atmospheric pressure is liable to change. Conducting the experiment in a controlled, pressurized environment would eliminate the variation in boiling pressures, thus producing consistent results.

8 Appendix

The following are notes collected from the experiment.



No Salt

Big	6:00.18	6:29.03	6:36.60
Med	7:36.48	5:41.17	6:56.42
Small	8:15.79	6:57.80	7:13.85

17 grams salt

Big	4:57.97	5:32.9	5:41.30
med	5:22.78	6:17.04	5:55.60
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34 grams salt

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