Rice Cooking Time Mean Comparisons: An Application of One-Way Completely Randomized Design

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1. Objectives and Background:

Rice is considered as a main food staple for more than 3.5 billion people around the world, particularly in Asia, Latin America, and parts of Africa. As both of us belong to Asia so having it regularly is common for us. Time management is crucial for graduate students; thus, we are trying to save our time from daily activities and spend that on studying. This thinking evokes a question in our mind that how can we reduce our rice cooking time? To answer this particular question, we will perform a confirmatory experiment based on the result of the exploratory experiment where we have studied which factor levels plays important role for reducing cooking time. The goal of this experiment is to compare the treatment means of cooking time and find which treatments will provide least cooking time.

2. All Sources of Variation:

We will use the treatment combination as a factor for our confirmatory experiment. We will have a total of 4 treatments. The factor is the combination of rice cooking ingredients such as water amount, temperature, and amount of oil. We selected four treatments that produce the least cooking time from the exploratory experiment. The possible treatments that can make least cooking time as follows:

The first treatment is $\{Temp = 45, Water = 960, Oil = 0\}$. The second treatment is $\{Temp = 45, Water = 960, Oil = 15\}$. The third treatment is $\{Temp = 45, Water = 1120, Oil = 0\}$. The fourth treatment is $\{Temp = 45, Water = 1120, Oil = 15\}$.

The variations of the amount of rice for cooking can affect the cooking time. However, we will not use this as a factor for this experiment. As a student, we usually cook rice for one person each time. So, we'll set this variation as constant with 3 cups of rice.

A rice cooker would be another factor that could affect cooking time. So, if we use multiple rice cookers for this experiment, we should set the rice cookers as a blocking factor. However, we will use only one rice cooker "Aroma" we already have used. In order to keep the same condition for the rice cooker as possible as we can, we will have enough cooling time for the rice cooker after each run.

3. Response Measurements:

Our response is the time (seconds) required to cook rice. We will measure the time using a stopwatch on a smartphone. As long as we press a start button on the rice cooker, we will start the stopwatch to measure elapsed time. We will stop the stopwatch when the rice cooker makes a beeping sound for completion.

4. Analysis Strategy:

In the exploratory experiment, we had $2^3 \times 2$ full factorial design. The working model we found is

$$\widehat{Cooking\ Time} = 1408.06 - (77.56 \times \text{Temperature}) + (55.94 \times Water) - (17.06 \times \text{Oil}) + (29.56 \times \text{Temperature} \times Water) + (13.56 \times \text{Temperature} \times \text{Oil}) - (15.19 \times Water \times \text{Oil})$$

According to the model, we can see that the interaction terms are effective. So, in this confirmatory experiment we will focus on how much the mean difference between the levels of combination: treatments with one-way completely randomized design.

We will first perform power analysis to find an appropriate sample size by setting a meaningful time difference. We will calculate a non-centrality parameter for power function and use R software for power computation. After that we will use the *Tukey* adjustment method in order to analyze the mean difference between the treatment that we selected by using SAS proc mixed.

5. Pilot Experiment:

The main ingredients of cooking rice are amount of water, it's amount and amount of oil. So, in our exploratory experiment, we have selected these three factors and define two levels for each factor. We have taken 2 replications for each of them. Then we have performed $2^3 \times 2$ factorial experiment for finding out interesting factor levels which will gives us less cooking time than the others. We have fitted a full factorial model including the interaction terms and kept only the significant terms by using F-test. We have used this fitted model for getting idea about our desired factor levels. Finally, the *Tukey* adjusted treatment comparisons is implemented for verifying our results and got some detailed idea about the significant difference between the considered treatment combinations.

6. Reflect on Pilot Experiment:

In our fitted model, we have observed that the three factor interactions are insignificant. However, the studentized residuals plots exhibits that all the standard assumptions hold. The fitted model suggests that select the high level of Temperature, high level of Oil, and low level of Water will give us minimum cooking time. From our analysis, we have observed that $\{Temperature = 45, Water = 960, Oil = 0\}$ and $\{Temperature = 45, Water = 960, Oil = 15\}$ treatment combinations are different than the other considered treatment combinations and producing the minimum cooking time. We have also got the other two treatment combinations $\{Temperature = 45, Water = 1120, Oil = 0\}$ and $\{Temperature = 45, Water = 1120, Oil = 15\}$, though they are producing higher cooking time than the previous two considered treatment combinations but they are significantly different than the others, and comparison between them is insignificant. Thus, we can use these four treatments for this experiment as they are satisfying our goal.

7. The Experimental Design:

We will perform an one-way completely randomized design with one factor with four treatments to compare. Here, our factor is the combination of rice cooking ingredients such as

water amount, it's temperature and amount of oil. We have selected the four treatments from the knowledge of our exploratory experiment. We have considered $\{Temp = 45, Water = 960, Oil = 0\}$, this as our treatment 1 and similarly the remaining treatments 2,3 and 4 are $\{Temp = 45, Water = 960, Oil = 15\}, \{Temp = 45, Water = 1120, Oil = 0\}$, and $\{Temp = 45, Water = 1120, Oil = 15\}$ (Ref. Table 1). We have selected these four treatments because in our exploratory experiment, we have seen that they are producing less response time comparative to the other treatments. Thus, we are performing this completely randomized design to compare their mean response time.

To randomize our design, we will use a R function "sample". The randomization order along with the response is provided in the following:

Run Orders	1	2	3	4	5	6	7	8
Treatments	Trt4	Trt3	Trt2	Trt4	Trt1	Trt1	Trt3	Trt2
Cooking Time	1400	1460	1258	1423	1234	1258	1432	1270

For the power analysis part, we set the meaningful difference time as 180 seconds (3 mins) to find an appropriate sample size. This is because our apartments are 3 minutes away from Upham hall by bus. So, 3 minutes is as valuable as time to commute from home to school. Based on the power analysis, we selected sample size 2 for each treatment. When we set $n_i = 2$ treatment and all other assumptions are true, then if two treatment means are 180 seconds apart and others equal, the F test will have a $p - value < 0.05$ almost all the time. The details are provided in Appendix.

8. Experimental Procedure and Challenges:

This experiment will be conducted in Sheikh Yasir Arafat apartment. This is because the group member has all factors we will use for the experiment in his home, and he cooks rice at least twice a day. For the first two runs, we will do the experiment together. After that, Sheikh Yasir Arafat will conduct it by a protocol. We will leave the rice cooker on a table in the kitchen. The protocol is as follows. First, we wash 3 cups of rice exactly twice with normal water (20 degrees Celsius) in the rice cooker pot. Second, we measure the temperature of water by using a thermometer and the amount of water with a measuring cup. Third, we put the water into the rice cooker pot. Fourth, we put the amount of oil into the pot with a measuring cup. Fifth, we press a cooking button on the rice cooker and start a stopwatch simultaneously. Sixth, we prepare to stop the stopwatch when the rice cooker shows 1 minute left for cooking on the monitor. Seventh, we press the stop on the stopwatch when we hear the second beeping sound. Eight, we wash the pot and have around 6 hours for cooling. Ninth, we do the next run.

9. Analysis And Conclusions:

We have performed the completely randomized design with one factor. From Table 2, we have observed that the F statistic results a value of 0.0005, we have strong evidence that at least

one of the treatments has a different mean than the others. As our aim is to compare the treatments means so, regardless the value of the F statistic we will perform the *Tukey* adjusted treatment comparisons. From the comparisons, we have seen that treatment 1 is significantly different than treatment 3 and 4. However, the difference between treatment 1 and treatment 2 is producing higher adjusted p-values which implies they are not different. Similarly, treatment 2 is significantly different than treatment 3 and treatment 4. Finally, we have also seen that treatment 3 and treatment 4 provides an insignificant difference (Ref. Table 4). The residuals plot also suggests that the assumptions are satisfied such as residuals are approximately normally distributed, and variance is constant (Ref. Figure 1).

From the above analysis, we can conclude that treatment 1 and treatment 2 are producing less cooking time and they are significantly different than others. The least square estimates also support that treatment 1 gives less cooking time than all the considered treatments (Ref. Table 3). In addition to this, treatment 2 contains oil which we personally don't prefer. Thus, treatment 1, $\{Temp = 45, Water = 960, Oil = 0\}$ is our suggested treatment for cooking rice and this aligns with our objective of the experiment which is extracting the treatment that provides less looking time.

10. Reflection:

This experiment trained us to think about the sources of variation and conduct the experiment in such a way that the unnecessary variations can't affect the results. We have also learnt how to select the factor levels and number of replications logically. For calculating the response, we are actually dependent on the signal of the rice cooker, and we are not sure whether any electrical malfunction exists or not. If we could perform this experiment manually like cooking rice in a pot instead of a rice cooker which may help us to overcome this problem. We have figured out a treatment for cooking rice in less amount of time which will help us for future cooking time.

Appendix:

Power Analysis:

Performing the theoretical power analysis assuming the following: $\Delta = 180\ seconds\ (3\ minutes)$, $\alpha = 0.05$, $\sigma^2 = 352.19$, and $n_i = 2,\ i = 1,2$. (Δ is selected from the experimenter interest and σ^2 is the MSE of the full model which the experimenter fit in the exploratory part of the experiment).

Here,

$$F_{0.05,3,4} = 6.59$$

$$\delta^2 = \frac{n \times \Delta^2}{2 \times \sigma^2} = \frac{2 \times 180^2}{2 \times 352.19} = 91.995$$

So, the power is $P\left(F_{0.05,3,4,91.995} > 6.59\right) \cong 1$.

R code:

```
qf(0.05,3,4,lower.tail = FALSE)
1-pf(6.59,3,4,91.995)
```

Table 1: Treatments.

Class Level Information		
Class	**Levels**	**Values**
trt	4	trt1 trt2 trt3 trt4

Table 2: Analysis of Variance Table.

Type 3 Analysis of Variance								
Source	**DF**	**Sum of Squares**	**Mean Square**	**Expected Mean Square**	**Error Term**	**Error DF**	**F Value**	**Pr > F**
trt	3	61892	20631	Var(Residual) + Q(trt)	MS(Residual)	4	81.18	0.0005
Residual	4	1016.500000	254.125000	Var(Residual)	.	.	.	.

Table 3: Least Square Estimate of Treatments.

Least Squares Means									
Effect	**trt**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Alpha**	**Lower**	**Upper**
trt	**trt1**	1246.00	11.2722	4	110.54	<.0001	0.05	1214.70	1277.30
trt	**trt2**	1264.00	11.2722	4	112.13	<.0001	0.05	1232.70	1295.30
trt	**trt3**	1446.00	11.2722	4	128.28	<.0001	0.05	1414.70	1477.30
trt	**trt4**	1411.50	11.2722	4	125.22	<.0001	0.05	1380.20	1442.80

Table 4: Treatment Comparisons.

Differences of Least Squares Means									
Effect	**trt**	**_trt**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Adjustment**	**Adj P**	**Alpha**
trt	**trt1**	**trt2**	-18.0000	15.9413	4	-1.13	0.3220	Tukey	0.6939	0.05
trt	**trt1**	**trt3**	-200.00	15.9413	4	-12.55	0.0002	Tukey	0.0008	0.05
trt	**trt1**	**trt4**	-165.50	15.9413	4	-10.38	0.0005	Tukey	0.0017	0.05
trt	**trt2**	**trt3**	-182.00	15.9413	4	-11.42	0.0003	Tukey	0.0012	0.05
trt	**trt2**	**trt4**	-147.50	15.9413	4	-9.25	0.0008	Tukey	0.0026	0.05
trt	**trt3**	**trt4**	34.5000	15.9413	4	2.16	0.0964	Tukey	0.2747	0.05

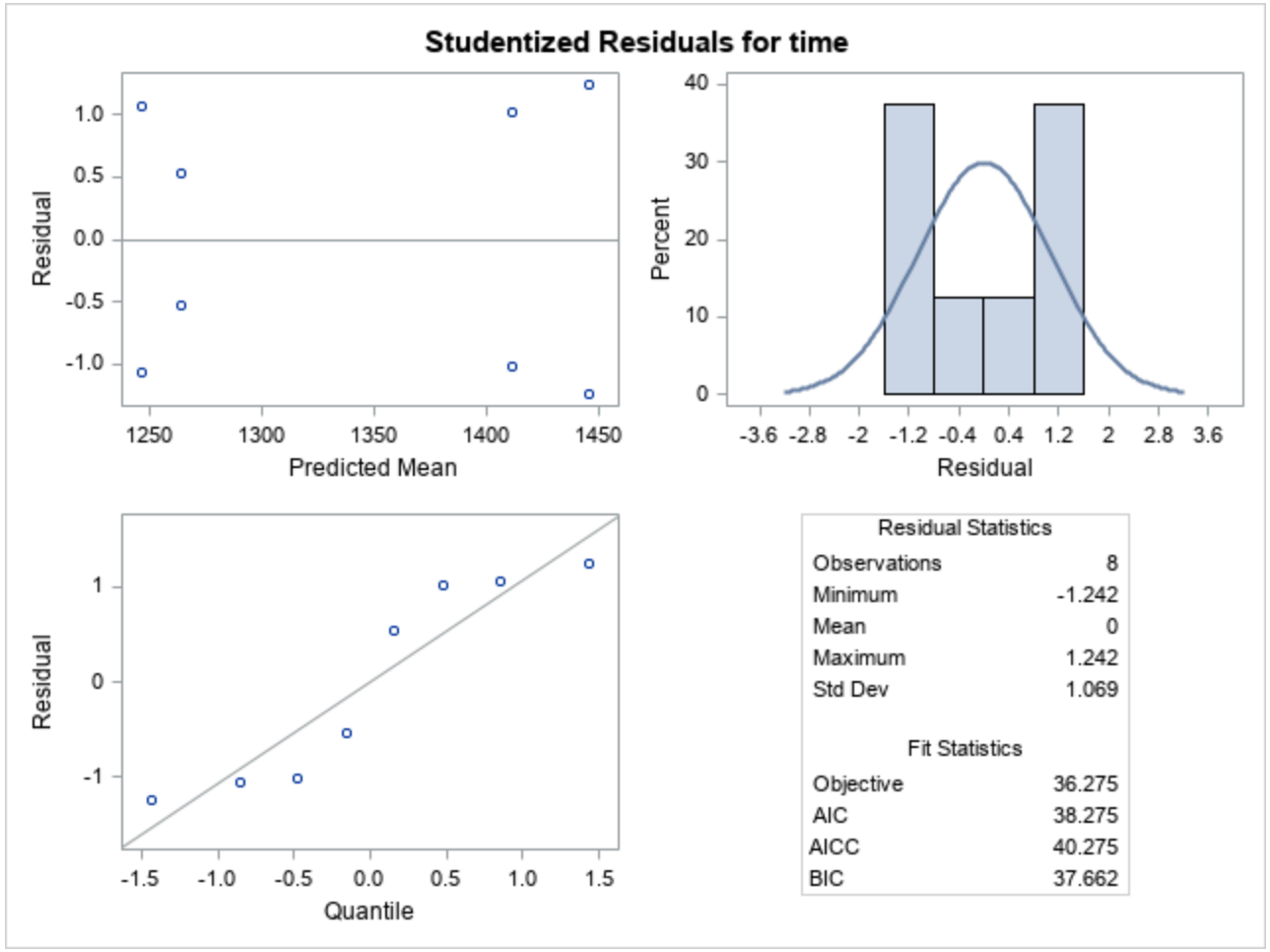

Figure 1: Studentized Residuals Analysis.