What is the fastest way to cook rice?

Group 3 - Lec 9102

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Part I

Purpose of Study
The purpose of this experiment is to determine which method of cooking rice is the fastest.

Target Population
white basmati rice

Experimental Units
one standard ½ cup (64 grams) of white basmati rice

Question of Interest
What is the fastest way to cook white basmati rice?

Importance of Study
The purpose of the study is to find the quickest way to cook rice properly, this is important for cooks, and regular people who are in a rush and do not have much time to cook. Therefore the results of this experiment can help determine which method should be used to cook rice in a timely manner.

Part II

Response variables
The response variable is the amount of time that was needed to properly cook the rice, measured in minutes (Quantitative variable)

Explanatory variables
1) The quantity of water used to cook the rice - this variable consisted of two levels: 1:1 ratio (½ cup of water) and 2:1 ratio (1 cup of water)
2) Soaking the rice beforehand for 10 minutes - this variable consisted of two levels: yes or no

Sample Sizes
The sample size for each treatment was ½ cup (64 grams) of white basmati rice which was replicated six times for each of the four treatments, for a total of 6 cups (12 x ½ cups) of basmati rice.

Experimental procedure
To begin the experiment, a ½ cup (64 grams) of white basmati rice was measured out in a standard measuring cup and set aside while the pot was prepared for cooking. A standard

medium size cook pot was used, and either a ½ cup or 1 full cup of tap water, depending on the treatment, was boiled in the pot, with the stovetop set to medium flame. Also, depending on the treatment being experimented, the rice was soaked in a bowl for 10 minutes before it was cooked. Once the water had been brought to a boil, the rice was added to the pot, and a timer had begun. As the rice boiled, it was stirred every minute throughout the cooking process until the rice was thoroughly cooked. Once it was determined that the rice was properly cooked, through the means of trying (eating) a sample of the rice, the stove was turned off and the timer had been stopped. Afterwards, the time was noted, and the equipment was cooled off, washed and dried in order to repeat the experiment.

Principles

1) Control - This experiment controlled for soaking, by including this as a factor in the treatments. As soaking may play a role in the time it takes to cook rice, therefore extra treatments were added, which included soaking into the procedure, this allows the analysis to determine if it does indeed have an effect on the results. Also the type of stove was controlled for by only using electric (induction) stoves, that way the data will not be skewed by the use of both electric and gas powered equipment. The quality of the water was controlled by only using tap water to cook the rice, that way the minerals within the water will not affect the cook time of the rice. The same cooking pot was also used for each experiment, in this way the size, and material of the pot will not have any adverse effects on the result of the experiment. The pot was washed and left to dry until the temperature of the pot returned to the temperature of the room, this ensures the pot is the exact same at the beginning of the experiment. The same temperature was used to cook each sample of rice, as the stove was set to a level 4 (a medium flame), this helps keep another factor constant, which may affect the results if monitored improperly.
2) Blocking - Blocking was a principle which was left out of this experiment because the experiment itself did not include a factor that could not be controlled but observed. There is the factor that all did the experiments at home in different households. But we chose to not have this as blocking, and this will be further discussed in the limitations. One nuisance variable that could not be controlled for, is the heat lost due to checking whether the rice is cooked or not. As the pot cover is removed to check the rice, heat escapes and may affect the time to cook rice, albeit not by much. Since there is no way to effectively control for this variable, it was ignored, while all other nuisance variables were controlled for.
3) Randomization - salt was added to random experiments to determine if salt has an effect on the time it takes to cook the rice. As the salt was randomly added to some of each treatment test, this way, if the experiment which used salt has a shorter cook time, it can be implied that the added salt particles do indeed affect the cook time.

4) Replication - This experiment involved replication at the treatment level, meaning that the treatment was repeated six times to ensure the accuracy of the data and to gain the mean in order to use within the ANOVA analysis.

Part III

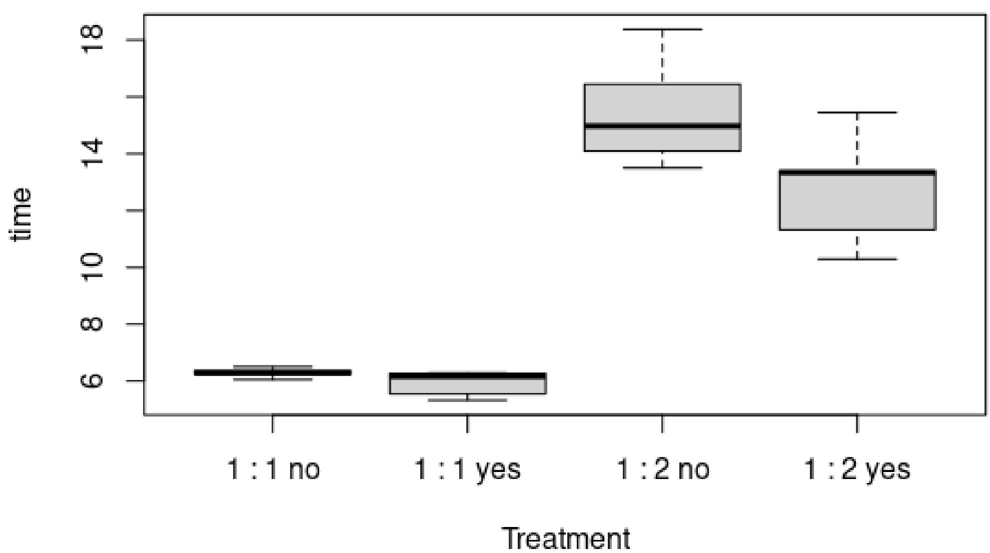
Methods

When conducting the analysis on the data received from the experiment, the two-way ANOVA test was used. Two-way ANOVA was used to determine if there is statistical evidence that the treatment means are significantly different from each other, using a 0.05 significance level.

H_0: $\mu_1 = \mu_j$ for i = 1,2,..,8 j=1,2,...,8 i=/=j

H_a: at least one pair of means does not equal each other

Analysis



From the boxplot, we can see that basmati rice with soaking yields a shorter cooking time regardless of the water ratio. Therefore, soaking could be the main factor of the cooking time. First of all, to check id cooking time depends on water ratio differently for different levels of soaking and vice versa, we will be checking the interaction effect between water ratio and soaking with a two-way anova.

Our model with interaction would be:

model_full: $time = \beta_0 + \beta_1 I_{ratio} + \beta_2 I_{soaking} + \beta_3 I_{ratio} * I_{soaking} + \epsilon$

$I_{ratio} = 0$ when water ratio is 1:1
$I_{ratio} = 1$ otherwise

$I_{soaking} = 0$ when rice is not soaked
$I_{soaking} = 1$ otherwise

```
> summary(model_full)

Call:
lm(formula = time ~ as.factor(ratio) * as.factor(soaking))

Residuals:
     Min       1Q   Median       3Q      Max 
-2.56667 -0.46500  0.08583  0.36083  2.97833 

Coefficients:
                                        Estimate Std. Error t value Pr(>|t|)    
(Intercept)                               6.2867     0.5284  11.898 1.58e-10 ***
as.factor(ratio)1 : 2                     9.1050     0.7472  12.185 1.04e-10 ***
as.factor(soaking)yes                    -0.3267     0.7472  -0.437   0.6667    
as.factor(ratio)1 : 2:as.factor(soaking)yes  -2.2083     1.0567  -2.090   0.0496 *  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.294 on 20 degrees of freedom
Multiple R-squared:  0.9234,	Adjusted R-squared:  0.9119 
F-statistic: 80.33 on 3 and 20 DF,  p-value: 2.491e-11
```

```
> anova(model_full)
Analysis of Variance Table

Response: time
              Df Sum Sq Mean Sq  F value    Pr(>F)    
ratio          1 384.08  384.08 229.2977 2.021e-12 ***
soaking        1  12.28   12.28   7.3334   0.01354 *  
ratio:soaking  1   7.32    7.32   4.3672   0.04962 *  
Residuals     20  33.50    1.68                       
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

From the anova table, we can see that water ratio explains a significant amount of variation in average cooking time. While soaking and the interaction effects explain a less significant amount of variation in average cooking time.

Hypothesis test for Interaction effect:

$$H_0 : \beta_3 = 0$$
$$H_a : \beta_3 ! = 0$$

$$F = \frac{MSRatio : Soaking}{MSE}$$
$$= \frac{7.32}{33.5}$$
$$0.218$$
$$p = p(F_{1,3} > 0.218) \simeq 0.04962$$

Therefore, the interaction effect is statistically significant on 0.05 level and we have sufficient evidence to reject H_0 and to conclude that the effect of water ratio on cooking time varies by if the rice is being soaked or not.

Since we have shown that the interaction effect is statistically significant in our model, we have to check which treatments give higher mean by doing Tukey's post-hoc analysis.

```
  Tukey multiple comparisons of means
    95% family-wise confidence level

Fit: aov(formula = lm(time ~ as.factor(ratio) * as.factor(soaking)))

$`as.factor(ratio)`
                diff     lwr      upr p adj
1 : 2-1 : 1 8.000833 6.89868 9.102987     0

$`as.factor(soaking)`
            diff       lwr      upr     p adj
yes-no -1.430833 -2.532987 -0.32868 0.0135378

$`as.factor(ratio):as.factor(soaking)`
                          diff        lwr       upr     p adj
1 : 2:no-1 : 1:no    9.1050000   7.013570 11.196430 0.0000000
1 : 1:yes-1 : 1:no  -0.3266667  -2.418097  1.764763 0.9713118
1 : 2:yes-1 : 1:no   6.5700000   4.478570  8.661430 0.0000001
1 : 1:yes-1 : 2:no  -9.4316667 -11.523097 -7.340237 0.0000000
1 : 2:yes-1 : 2:no  -2.5350000  -4.626430 -0.443570 0.0141160
1 : 2:yes-1 : 1:yes  6.8966667   4.805237  8.988097 0.0000001
```

This shows that the only non significant difference is for 1 : 1 water ratio either with soaking or without soaking. Therefore, we can conclude that on average, using 1 : 1 water ratio with soaking yields a faster cooking time on average compared to using 1 : 2 water ratio without soaking. And after comparing every treatment, we can say that using 1 : 1 water ratio with soaking yields a faster cooking time on average among all other treatments in our experiment. And this result matches our assumptions based on the boxplot in the beginning.

Difficulties with the data analysis

The original experiment had required 8 treatments, as salt was another factor used in the design. The analysis was going to be a three way ANOVA test with these 8 treatments, with factors being: ratio of water, soaked or not, and whether salt was added or not. Ultimately this proved too difficult and complex, so the salted treatments were removed to simplify the experiment. The new analysis was a two-way ANOVA, using four treatments, with the factors being: the ratio of water used, and whether soaking was conducted or not.

Part IV

Limitations

- Specifics of the pans used
    - While we tried our best to minimize the variance between cooking vessels used in the experiment, we did not all have exactly the same pot. This means there might be slight differences between the pans in capacity, depth, width, and material which could have been causes of error in our experiment.
- Ambient temperatures
    - The ambient temperatures of the storage of rice might have been slightly different before cooking for everyone. We also note that the ambient temperatures while soaking might have varied by a few degrees depending on the room temperature.
- Time constraints
    - Both of the above problems could have been solved by having one group member cook every sample for our dataset, however time and resource constraints prevented this from being an option and we had to share the load between the 6 of us.
- Ability to know exactly when the rice has finished cooking
    - We recorded the times for when the rice finished cooking by checking as often as possible so that we'd stop recording time as close to when the rice finished cooking as possible. While we are confident that our data properly represents the experiment, it is ultimately unavoidable that our data is not exact since there is no way for us to know the exact moment when the rice finishes cooking.

Conclusion

- From our data and analysis, we've found strong evidence that both the ratio of water and whether or not the rice is pre-soaked affects the cook time. Specifically, that a lower water to rice ratio and pre soaking the rice tend to lead to faster cook times. And that combining them is the fastest way to make rice.

- The least time is with a 1:1 ratio and soaking for 30 minutes. But we should note that this is the least time spent on the stovetop. If the soaking were to be included in the 'cooking' process, it would be the longer option since it would be an extra 30 minutes added to its average cook time of 9 minutes and 37 seconds.
- We conclude that salt did not have a bigger effect than soaking or water ratio on the cooking duration. We came to a significant p-value which means the randomized factors did not affect the results very much.
- The absorption process makes it skip those early minutes where dry rice absorbs in the non-soaking group.
- A lower water to rice ratio most likely cooks faster due to there being less water in the pot for the rice to absorb or evaporate. Rice is finished cooking when all the water is gone so naturally less water being in the pot to begin with should lead to a faster time. While decreasing the ratio too much might lead to undercooked or burnt rice, it seems as a general rule that rice will cook faster with less water in the pot.
- Important to consider our methodology is doing the best with what we have during the pandemic. In an ideal setting, this experiment would be repeated with much more similarities to counter most limitations.
- The findings may be good for time saving purposes, but there may be underlying differences in the end product besides simply the rice reaching the cooked stage. The food science aspect would be worthwhile to explore.

APPENDIX

Raw R-Code:

````
---
title: "Project code"
output: html_document
---
```{r}
data_24 <- read_excel("STA305 3-Way Anova Rice data_withSalt.xlsx")
data_24$ `Use of Salt` <- NULL
View(data_24)
attach(data_24)
names(data_24)[1] <- "ratio"
names(data_24)[2] <- "soaking"
names(data_24)[3] <- "time"
factor(data_24$ratio)
factor(data_24$soaking)
````
````

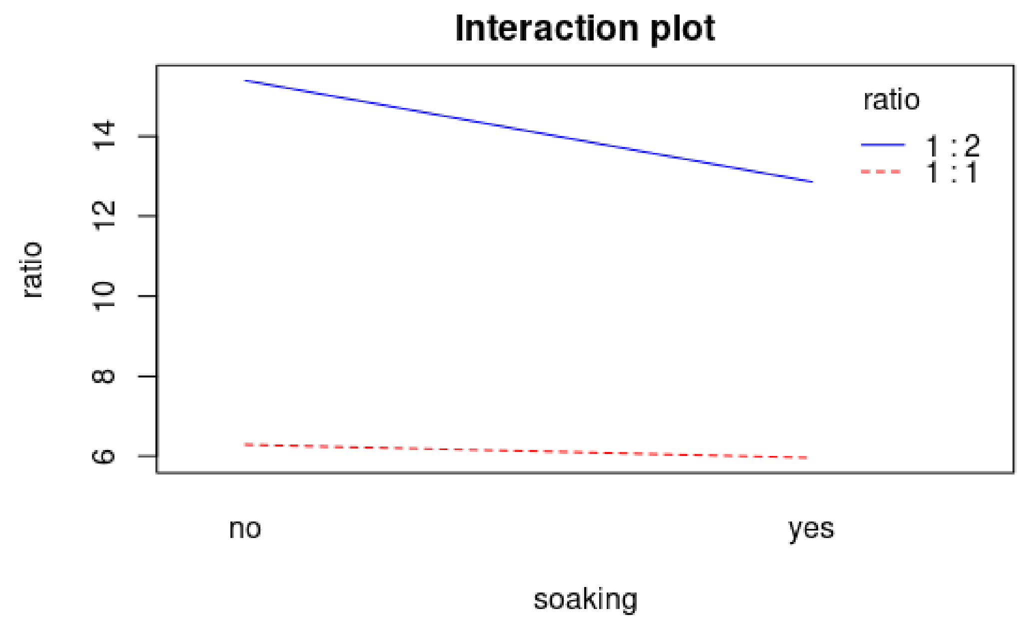
~~~
with(data_24, interaction.plot(soaking, ratio,time, col = c("red","blue"), main = "Interaction plot", xlab = "soaking", ylab="ratio"))
data_treat <- within(data_24, Treatment <- paste (ratio, soaking))
boxplot(time ~ Treatment, data = data_treat)
model_full <- lm(data_24$time~data_24$ratio*data_24$soaking)
anova(model_full)
model_treat <- lm(data_24$time~data_24$ratio:data_24$soaking)
anova(model_treat)
model_main <- lm(data_24$time~data_24$ratio+data_24$soaking )
anova(model_main)
```

```{r}
data <- read_excel("STA305 3-Way Anova Rice data.xlsx")

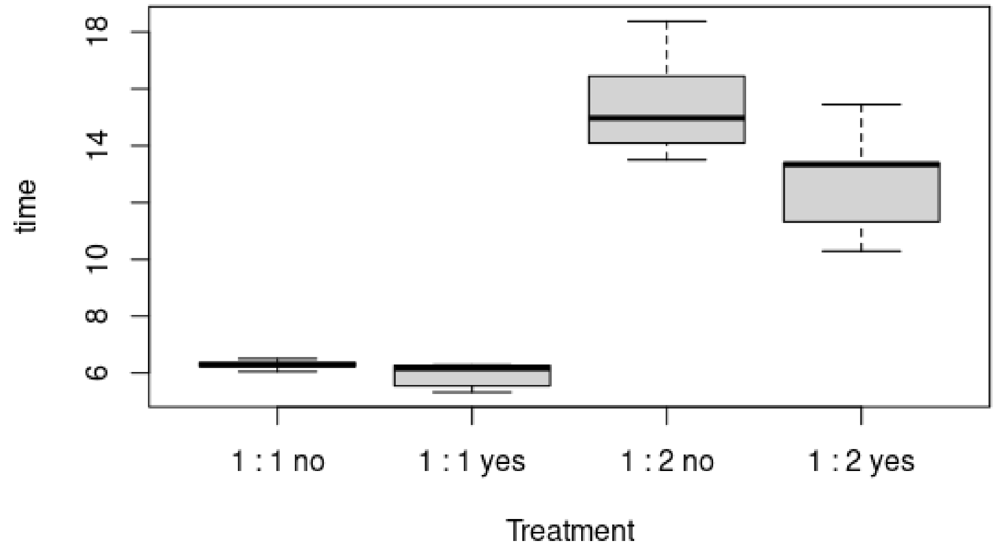
View(data)
attach(data)
names(data)[1] <- "ratio"
names(data)[2] <- "soaking"
names(data)[3] <- "time"
data_1 <- within(data, Treatment <- paste (ratio, soaking))
boxplot(time ~ Treatment, data = data_1)
```

```{r}
with(data, interaction.plot(soaking, ratio,time, col = c("red","blue"), main = "Interaction plot", xlab = "soaking", ylab="ratio"))
```
~~~

Interaction Plot:



<u>Box Plot:</u>



Photos from data collection process

Figure 1: a measurement of a ½ cup of basmati white rice before being cooked.

Figure 2: a standard cup of tap water, measured before being used to cook the rice.

Figure 3: The ½ cup of basmati rice is ready to be cooked inside a pot, using 1 cup of tap water, and the stove is set on medium.

Figure 4: The ½ cup of basmati rice after it has finished cooking.