



# Ripening Bananas

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## Experiment Goal

- Evaluate the effectiveness of household methods in accelerating the ripening of bananas
- Assess how these methods impact both the ripeness and taste of the fruit



## Control and Treatment

**Control Group:** Bananas that ripen under standard conditions (e.g., room temperature) without any intervention.

**Treatment Groups:** Bananas exposed to

- A brown paper bag
- Baking at 300 F for 5 minutes

Explore the impact of these methods on taste.



## Measurable Variables:

**Ripeness:** Evaluated visually based on peel color, firmness, and the appearance of brown spots.

**Starch Content:** Measured using Lugol's iodine test, which indicates the conversion of starch to sugar as bananas ripen.

**Taste:** Assessed by participants, focusing on sweetness, texture, and flavor changes.



# Environmental Control

External factors that can potentially influence the results are controlled for all bananas:

- Temperature
- Humidity
- Light exposure
- ...



## Experimental Design: Set Up

- Factorial design with the two treatments
  - Control for brown bag is sitting on the countertop
- 9 bunches of 4 bananas were chosen based on...
  - comparative under ripeness
  - similarity to other bunches for visual traits
  - bunches were not chosen randomly due to experiment limitations



## Experimental Design: Set Up

- Each bunch was randomly assigned to a number 1-9 to allow for easy identification
- Each banana in the bunch was randomly assigned to a letter/ treatment
- The letter number combo was written at the top of each banana



## Experiment Design: Blocking

Assumption: within the brunch, the bananas are similar in all aspect of ripeness.

Minimize nuisance covariate effect such as

- initial ripeness
- banana size
- producer





## Experimental Design: Baking the Bananas

To prevent introducing confounders all of the following were done for the banana baking process.

- Only the top rack was used
- Only 1 sheet at a time
- The same banana orientation & layout was used
- Sheets were allowed to cool in between rounds
- Oven was allowed to reach temperature again
- Timers were used and followed to the second
- Time in between rounds was minimal



# Experimental Design: Baking the Bananas

## Initial Observations

- Banana charred and blackened where it touched the sheet
- It did not leak

Thoughts: 200 for 8 minutes might have been better

Problem: Banana could ripen/ taste uneven within a slice leading to erratic evaluations



# Experiment Design: Evaluation

Bananas are evaluated for 6 consecutive days to track the progress of ripening and changes in taste.

Each day, a bunch is selected randomly, and the bananas in that bunch assigned different treatments are evaluated for both ripeness and taste. Participants are required to

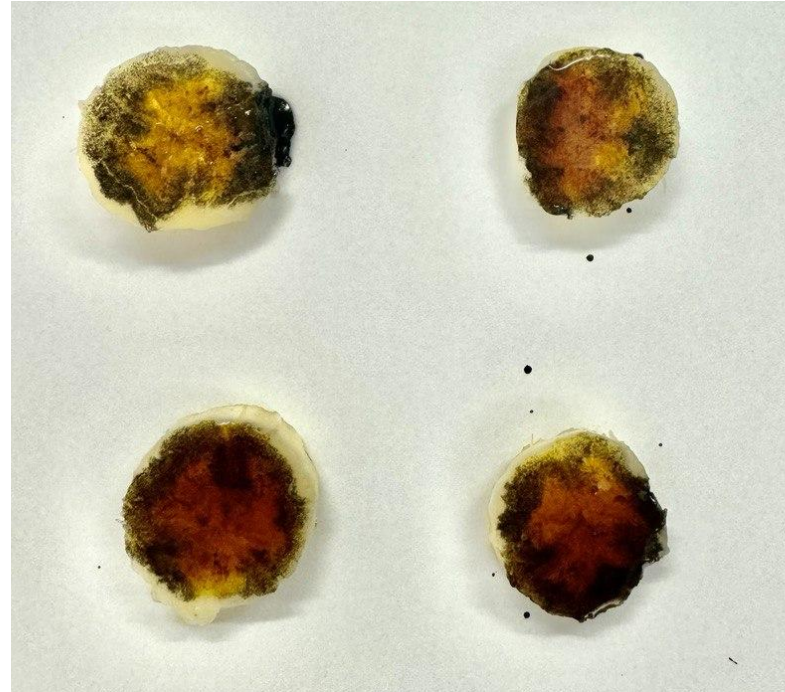
- taste of the top half in a randomized order, judging by sweetness, creaminess...
- assess the ripeness of the bottom half, judging by the peel, color...

The chemical measure of ripeness is determined by the starch content, indicated by the color change in the Lugol's iodine test.

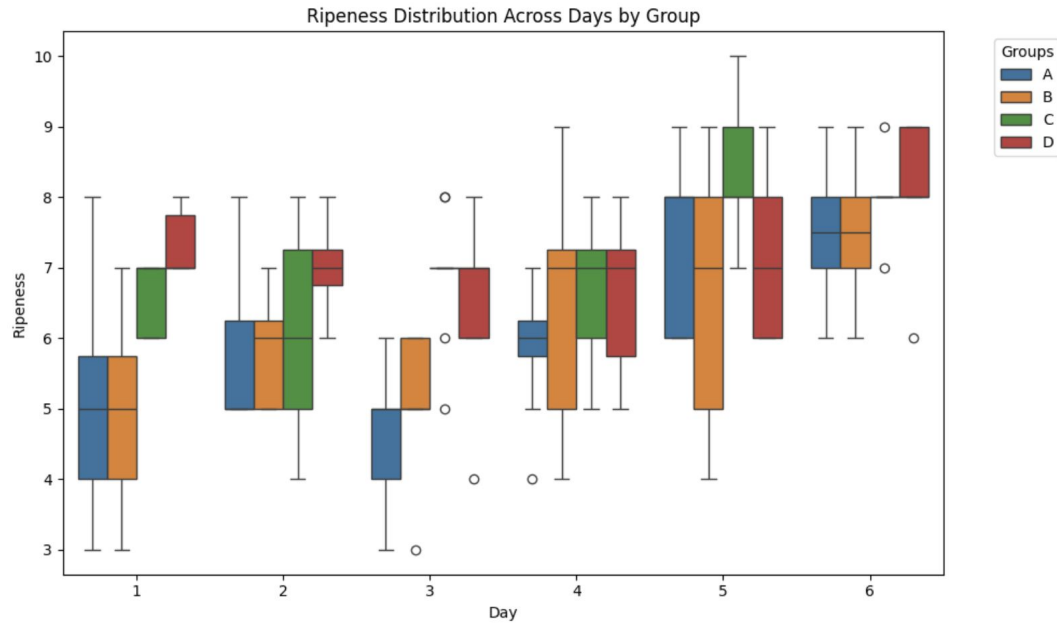
## Exploratory Data Analysis - Iodine Test



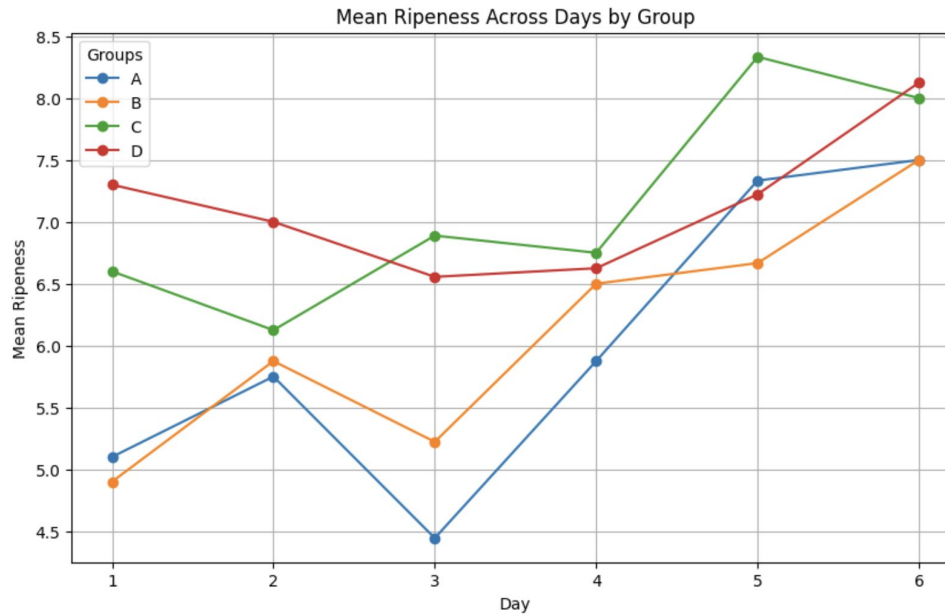
Day 1 (left)  
and  
Day 6 (right)  
iodine's test  
results



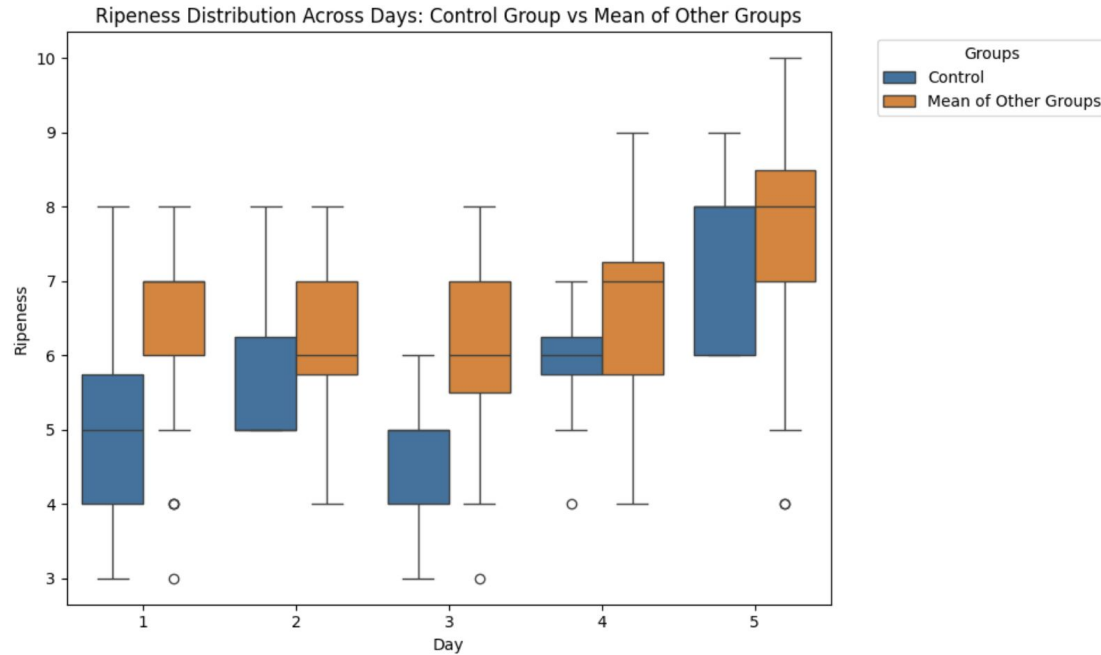
# Exploratory Data Analysis - Ripeness



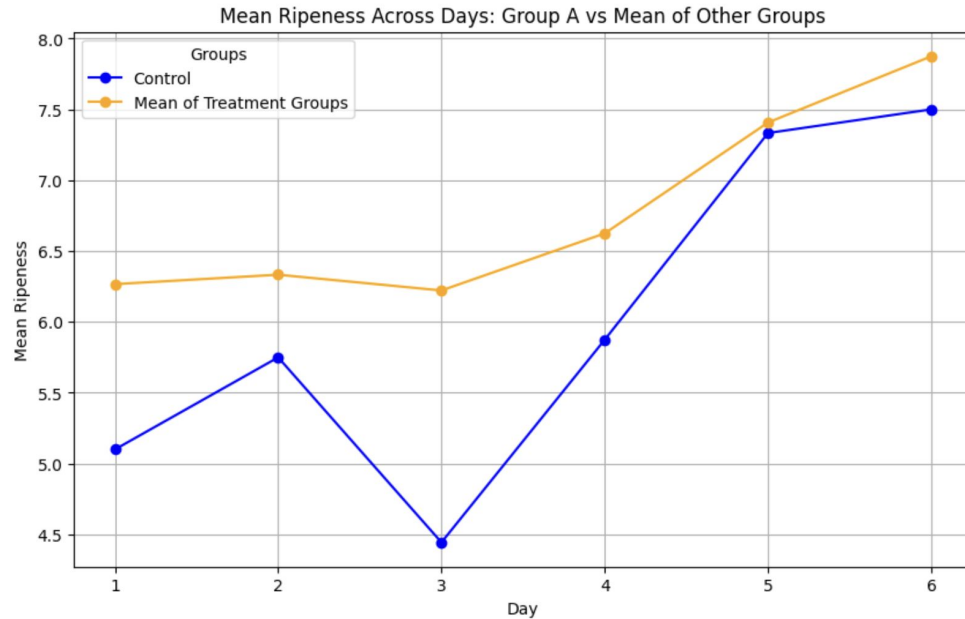
# Exploratory Data Analysis - Ripeness



# Exploratory Data Analysis - Ripeness

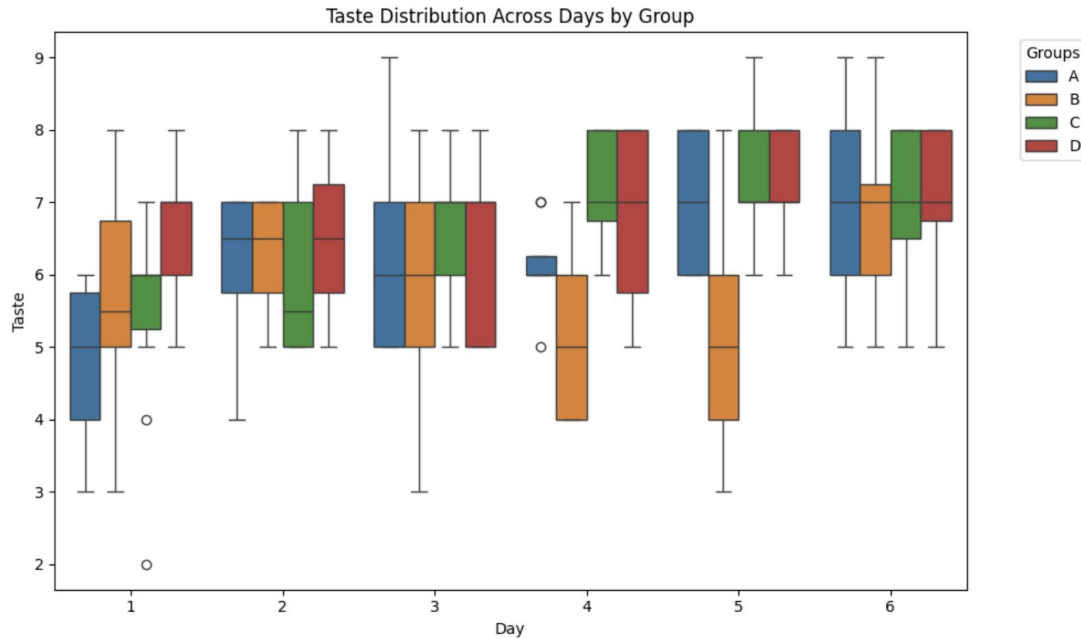


# Exploratory Data Analysis - Ripeness

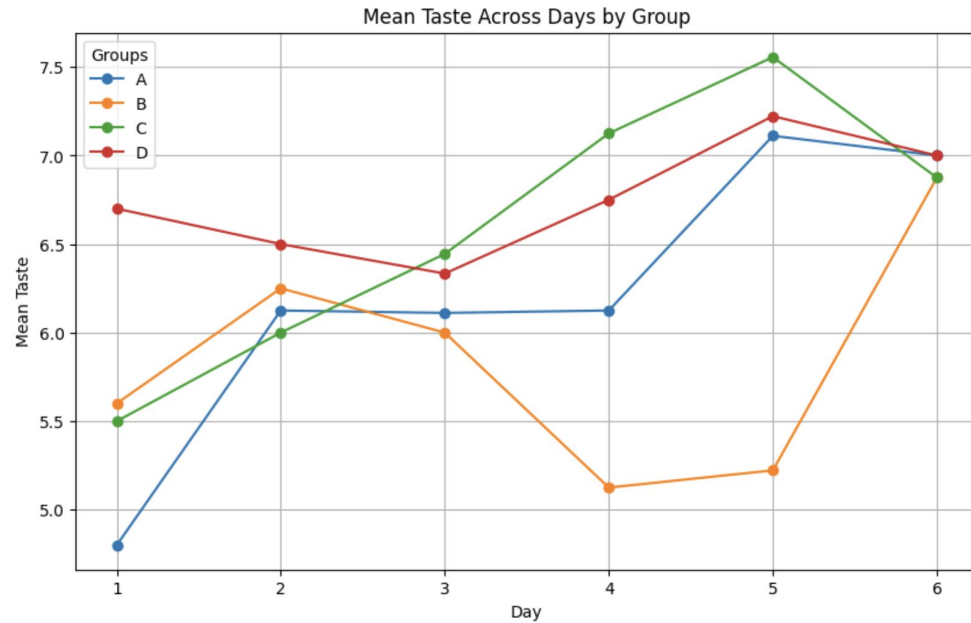




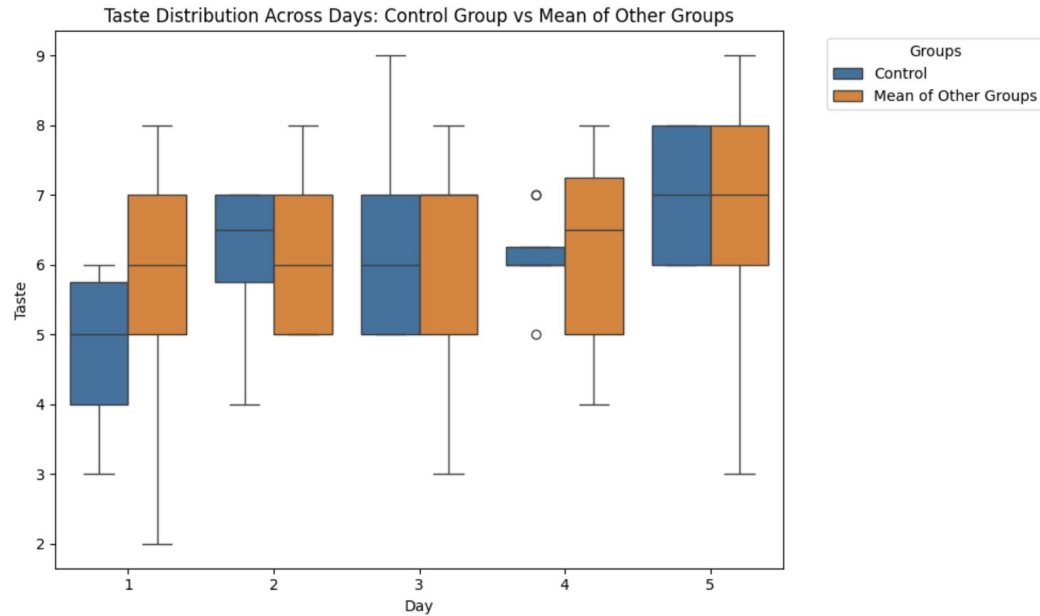
# Exploratory Data Analysis - Taste



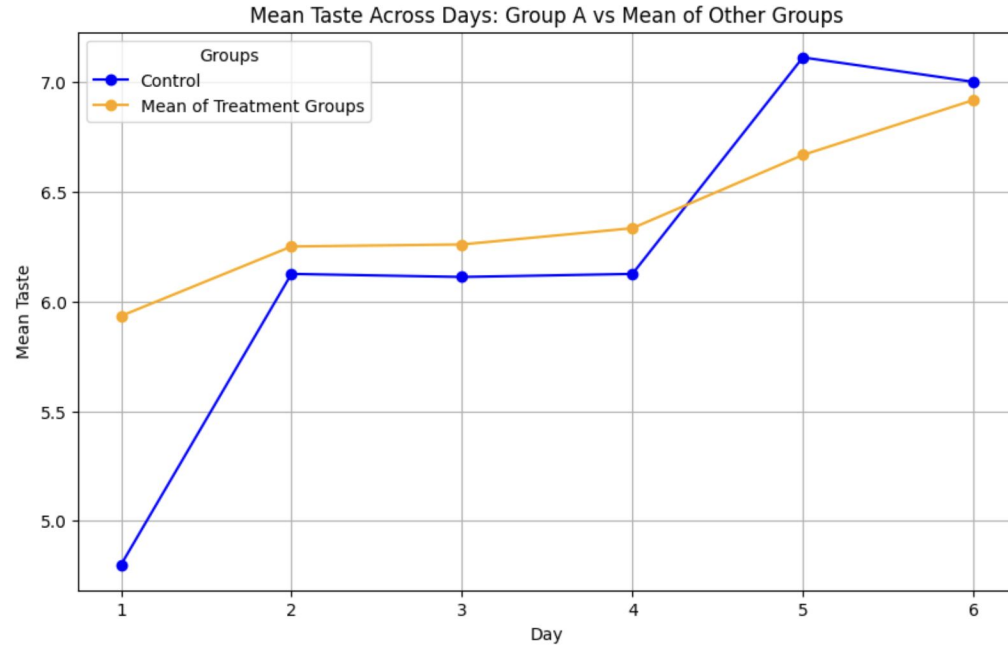
# Exploratory Data Analysis - Taste



# Exploratory Data Analysis - Taste



# Exploratory Data Analysis - Taste





# Data Analysis: Rank Permutation Test

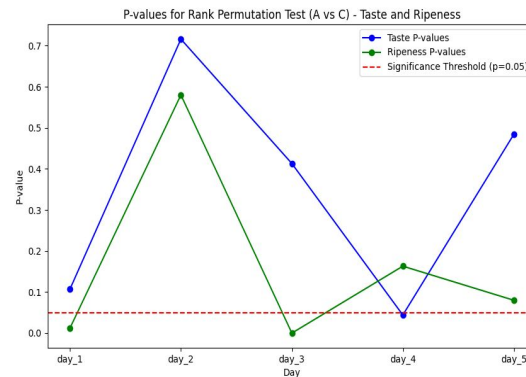
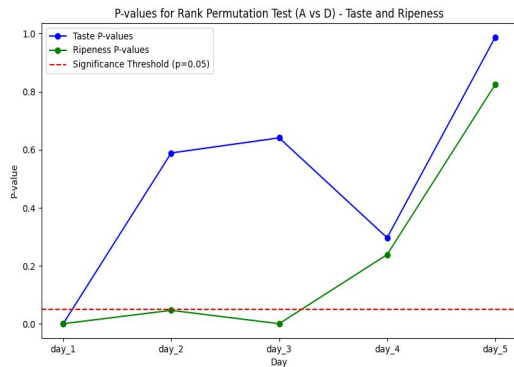
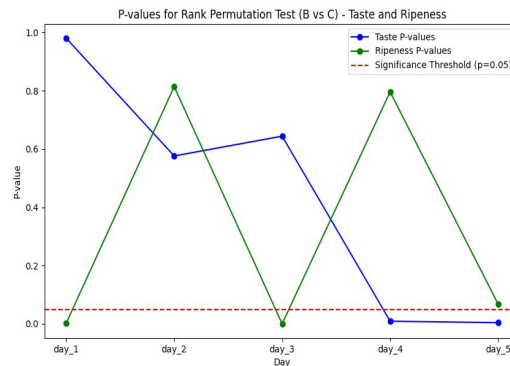
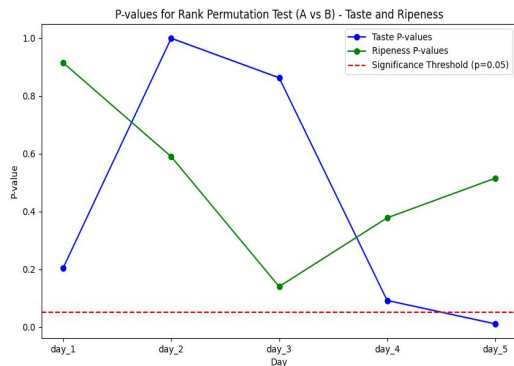
Since we used blocking to have bananas from the same bunch being tested every day, we use a blocked permutation test where we permute the treatments for the four bananas within a single bunch.

Rank permutation tests are non-parametric statistical methods used to compare groups by assessing the differences in their distributions without making strong assumptions about the underlying data.

Reasons:

- based on the ranks
- useful in small sample sizes
- No assumption in distributions

# Data Analysis: Rank Permutation Test





# Data Analysis: Propensity Score Matching

Propensity Score Matching (PSM) is a statistical method used to reduce bias in causal inference by matching treated and control groups based on other observed outcomes.

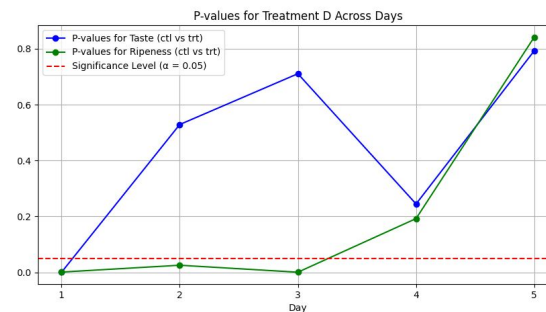
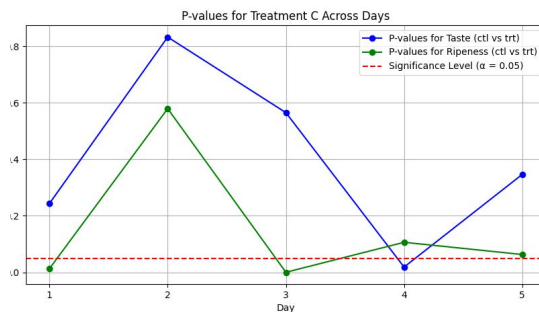
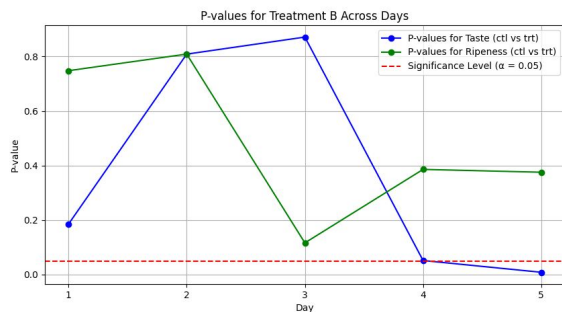
Advantages:

- Efficient Use of Data
- Reduction of Bias
- ...

# Data Analysis: Propensity Score Matching

First, we treat taste as the target outcome and match the ripeness scores to create comparable groups. We then apply PSM to evaluate the treatment effect on taste.

In the second study, we switch our focus and use ripeness as the target outcome. Here, we match the taste scores to establish comparable groups and again apply PSM to assess the treatment effect on ripeness.





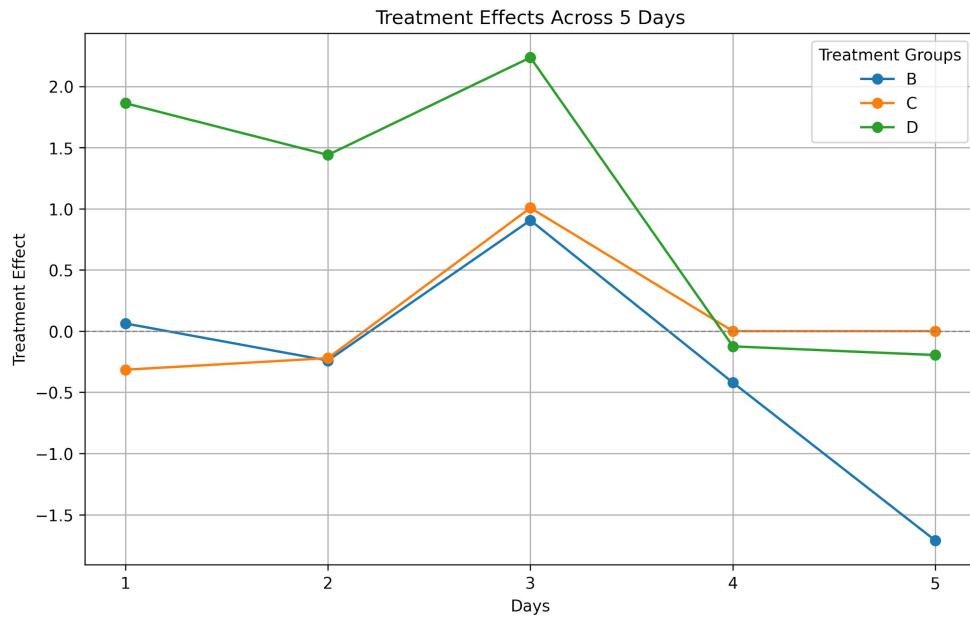


## Data Analysis: Causal Forests

Causal Forest is an advanced machine learning technique used to estimate heterogeneous treatment effects in observational data. It is an extension of the random forest algorithm, specifically designed to uncover how treatment effects vary across different subpopulations by utilizing a combination of tree-based methods and causal inference principles.

- Heterogeneous Treatment Effect Estimation
- Flexibility
- ...

# Data Analysis: Causal Forests





## Conclusion

- The oven treatment demonstrates a significant effect on ripening, despite these challenges, in general.
- The treatment effects of the oven method on banana ripening are not clearly evident on the first and last days of the experiment, particularly on the third day.
- There was considerable variability in the scores, as some participants did not provide consistent evaluations.



## Further work

- Increase the sample size by including more than one banana bunch per day.
- Use a more objective method to measure the visual appearance of the bananas instead of relying on subjective color assessment.
- Perform conditional analysis, considering participants' individual preferences in the evaluation.