Experimental Evaluation of the Effectiveness of Tide Pods versus Liquid Tide Detergent

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I. Introduction

There have been a number of recent television and online advertisements about a new Tide product, Tide Pods. It has been marketed as a superior and more efficient product, however, it is sold for a higher price. Tide sells 50 ounces of its original scented detergent, or 32 loads, for $6.89 and a pack of 16 Tide Pods for $6.29. This makes Tide pods almost twice the price as liquid Tide detergent. Is this price just a façade or are Tide Pods really worth the money? With this experiment, consumers will hopefully be able to make an educated decision when shopping for household detergent.

II. Statistical Question

First Test ($\mu_1 - \mu_2$)

Is there a difference between one Tide Pod and an equivalent amount of Tide detergent (24mL) in the effectiveness of removing stains?

Hypothesis:	Definitions:
$H_0 : \mu_1 - \mu_2 = 0$	$\mu_1 =$ the mean numerical intensity of using one Tide Pod as a treatment
$H_\alpha : \mu_1 - \mu_2 \neq 0$	$\mu_2 =$ the mean numerical intensity of using an equivalent amount of Tide detergent, 24 mL, as reported by Tide[1]

Second Test ($\mu_3 - \mu_4$)

Is there a difference between two Tide Pods and two equivalent amounts of Tide detergent (48mL) in the effectiveness of removing stains?

Hypothesis:	Definitions:
$H_0 : \mu_3 - \mu_4 = 0$	$\mu_3 =$ the mean numerical intensity of using two Tide Pods as a treatment
$H_\alpha : \mu_3 - \mu_4 \neq 0$	$\mu_4 =$ the mean numerical intensity of using two equivalent amounts of Tide detergent, 48 mL, as reported by Tide[2]

[1] "Compaction | Sustainability - Tide." https://tide.com/en-us/about-tide/sustainability/compaction.
[2] "Compaction | Sustainability - Tide." https://tide.com/en-us/about-tide/sustainability/compaction.

Third Test (μ_1 - μ_4)

Is there a difference between one Tide Pod and two equivalent amounts of Tide detergent (48mL) in the effectiveness of removing stains?

Hypothesis:	Definitions:
$H_0 : \mu_1 - \mu_4 = 0$	$\mu_1 =$ the mean numerical intensity of using one Tide Pod as a treatment
$H_\alpha : \mu_1 - \mu_4 \neq 0$	$\mu_4 =$ the mean numerical intensity of using two equivalent amounts of Tide detergent, 48 mL, as reported by Tide[3]

Fourth Test (μ_2 - μ_3)

Is there a difference between two Tide Pods and an equivalent amount of liquid Tide detergent (24mL) in the effectiveness of removing stains?

Hypothesis:	Definitions:
$H_0 : \mu_2 - \mu_3 = 0$	$\mu_2 =$ the mean numerical intensity of using an equivalent amount of Tide detergent, 24 mL, as reported by Tide[4]
$H_\alpha : \mu_2 - \mu_3 \neq 0$	$\mu_3 =$ the mean numerical intensity of using two Tide Pods as a treatment

A significance level of $\alpha = 0.05$ was used for all four tests in this experiment

[3] "Compaction | Sustainability - Tide." https://tide.com/en-us/about-tide/sustainability/compaction.
[4] "Compaction | Sustainability - Tide." https://tide.com/en-us/about-tide/sustainability/compaction.

III. Data Collection

The purpose of this experiment was to investigate and experimentally determine if there is a difference in the effectiveness of regular Tide detergent and Tide Pods. There were four treatment groups of 30 squares of fabric: one group washed with one Tide Pod, one group washed with an equivalent amount of Tide detergent (24 mL),one group washed with two Tide Pods, and one group washed with double the amount of regular Tide (48 mL).

Our samples were 120 equally sized squares of fabric, obtained by cutting three identical t-shirts cut into 120 pieces of 5 inches by 5 inches. They were then laid out on saran wrap on the floor of a room of constant lighting and temperature. The saran wrap was used to ensure that stainer would be absorbed by only the shirts. The squares were dyed with the same amount of tea (1 teaspoon) in the same area on the fabric and left to dry for an hour before being washed with the treatment. Figure 1 demonstrates how the fabric was laid out on the floor, and the equal amounts of dye used.

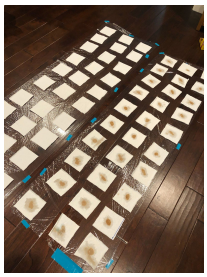

Figure 1. The fabric laying out and drying on the floor.

To randomly assign the first treatment, we assigned each piece a number from 1-120, wrote the numbers 1-120 down on separate, equally sized pieces of paper, and randomly chose 30 slips of paper without replacement from a hat. The corresponding 30 pieces of fabric to these first 30 numbers picked was assigned to be washed with one Tide Pod, the next 30 picked was

assigned to be washed with 24 mL of Tide detergent, the next 30 was assigned to be washed with two Tide Pods, and the last 30 was assigned to be washed with 48 mL of Tide detergent.

For the 24 mL of Tide detergent treatment, we used the "Quick Wash" feature on the washing machine and washed the chosen 30 pieces of fabric with 2 large white towels for 30 minutes. After the cycle was finished, we took pictures of the stains on the 30 pieces of fabric from that treatment. We made sure that the lighting was consistent and used the same camera for all of the pictures. In order to convert the images into numerical values, we used a program called ImageJ. This program converted the image into grayscale and measured the integrated density of the stain. A lighter stain had a larger integrated density value and a darker stain had a darker integrated density value. The values from each of the stains were recorded in a spreadsheet. This process was repeated for the three other treatments. ImageJ and the data analysis features are displayed in Figure 2. Table 1 demonstrates the raw data collected through this experiment, with the corresponding treatments. The numerical intensity values of each of the pieces of fabric were used to demonstrate the effectiveness of the Tide Pods and regular Tide detergent at removing stains.

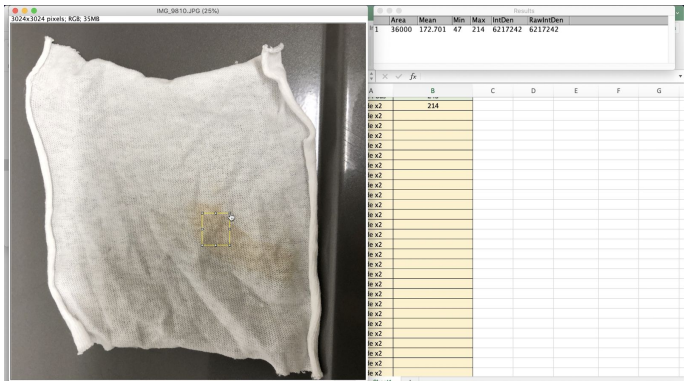

Figure 2. A snapshot of how ImageJ was used to measure the intensity of the stain after washing.

Treatment	Numerical Intensity (High = Greater Stain)
Tide	207
Tide	214
Tide	219
Tide	215
Tide	201
Tide	215
Tide	202
Tide	220
Tide	219
Tide	210
Tide	215
Tide	225
Tide	217
Tide	223
Tide	228
Tide	211
Tide	215
Tide	213
Tide	220
Tide	204
Tide	217
Tide	229
Tide	211
Tide	215
Tide	222
Tide	209
Tide	218
Tide	212
Tide	203
Tide	225
Tide Pods	235
Tide Pods	224
Tide Pods	223
Tide Pods	223
Tide Pods	216
Tide Pods	217
Tide Pods	225
Tide Pods	219
Tide Pods	218
Tide Pods	219
Tide Pods	223
Tide Pods	225
Tide Pods	225
Tide Pods	225
Tide Pods	223
Tide Pods	225
Tide Pods	219
Tide Pods	223
Tide Pods	210
Tide Pods	217
Tide Pods	218
Tide Pods	215
Tide Pods	213
Tide Pods	216
Tide Pods	225
Tide Pods	225
Tide Pods	221
Tide Pods	225
Tide Pods	222
Tide Pods	223
Tide x2	214
Tide x2	193
Tide x2	199
Tide x2	219
Tide x2	190
Tide x2	189
Tide x2	218
Tide x2	208
Tide x2	220
Tide x2	212
Tide x2	198
Tide x2	208
Tide x2	212
Tide x2	200
Tide x2	184
Tide x2	212
Tide x2	203
Tide x2	210
Tide x2	214
Tide x2	193
Tide x2	199
Tide x2	213
Tide x2	192
Tide x2	203
Tide x2	210
Tide x2	208
Tide x2	198
Tide x2	215
Tide x2	189
Tide x2	200
Tide Pods x2	199
Tide Pods x2	215
Tide Pods x2	223
Tide Pods x2	222
Tide Pods x2	218
Tide Pods x2	215
Tide Pods x2	218
Tide Pods x2	210
Tide Pods x2	224
Tide Pods x2	227
Tide Pods x2	227
Tide Pods x2	230
Tide Pods x2	226
Tide Pods x2	220
Tide Pods x2	200
Tide Pods x2	220
Tide Pods x2	211
Tide Pods x2	202
Tide Pods x2	190
Tide Pods x2	205
Tide Pods x2	200
Tide Pods x2	190
Tide Pods x2	198
Tide Pods x2	211
Tide Pods x2	202
Tide Pods x2	191
Tide Pods x2	209
Tide Pods x2	198
Tide Pods x2	220

Table 1. The raw data collected in this experiment.

IV. Data Display

Treatment	n	Mean	SD	min	Q_1	med	Q_3	max
Tide	30	215.133333	7.375	201	211	215	220	229
Tide pods	30	220.9	4.196	210	218	223	225	225
Tide x2	30	204.1	10.135	184	198	205.5	212	220
Tide pods x2	30	210.6	12.353	185	200	211	220	230

Figure 3. Summary statistics.

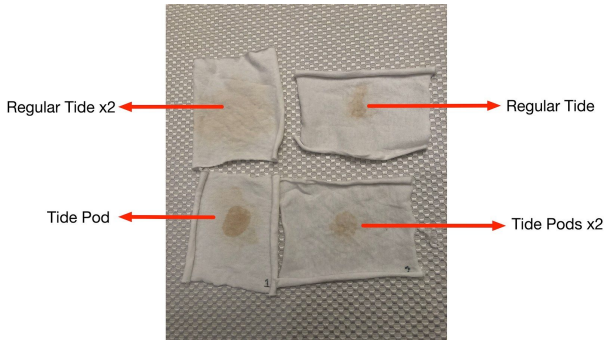

Figure 4. An image that displays a representative fabric pieces from each group; notice how Regular tide is clearly more effective, and the fabric treated with a Tide Pod is less effective.

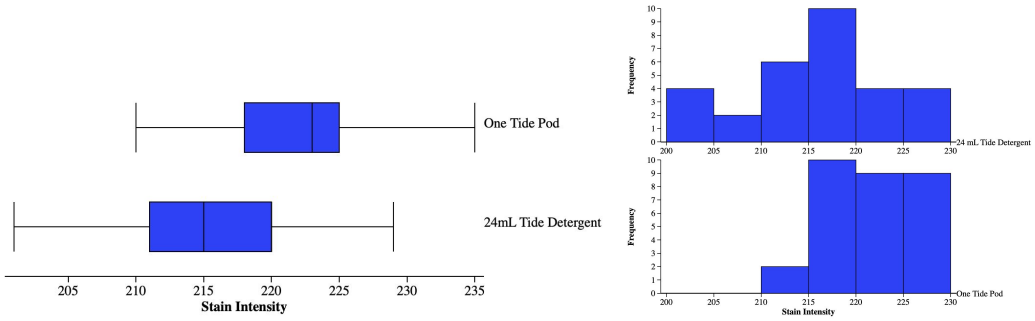

Figure 5. A boxplot and histogram of the stain intensity after the one Tide Pod versus the 24 mL of Tide detergent treatments; notice how one tide pod has a greater median, they both appear to have about the same spread, they do not have any outliers, and about the same shape.

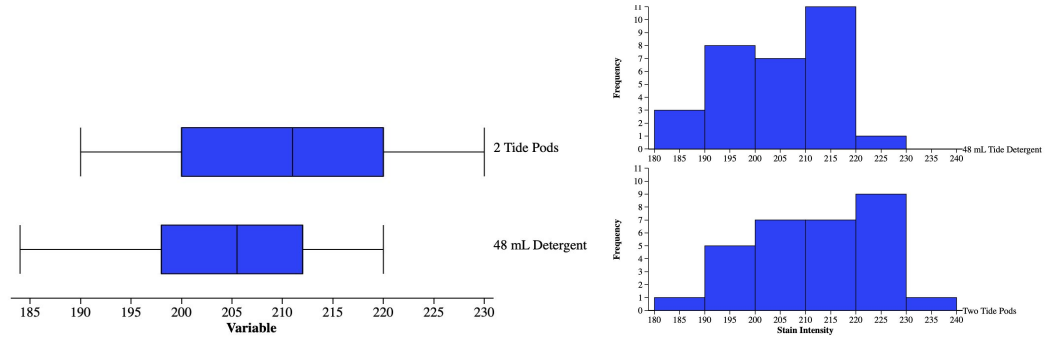

Figure 6. A boxplot and histogram of the stain intensity after the two Tide Pod treatment versus the 48 mL of Tide detergent treatments, which shows similar trends as the other two treatment groups.

V. Data Analysis

Conditions for all four significance tests:

Random → The fabric pieces of equal sizes were randomly assigned to all four treatments

Independence → The results of one piece of fabric does not affect the results of another piece of fabric due to random assignment. This is true for pieces of fabric in all four treatments.

Large/Normal Sample → A sample of 30 was used ($n \geq 30$) for all four treatments

	First Test	Second Test	Third Test	Fourth Test
t statistic	3.722	2.228	8.389	1.72
p-value	0.000537	0.0299	3.097×10^{-10}	0.0909
df	45.996	55.868	38.660	47.344

*p-value = the probability of getting a difference of the point estimate used to calculate the t statistic or greater in either direction between the mean numerical intensities of the fabrics in the two treatments

VI. Conclusion

First Test

Since the p-value of 0.000537 is less than the significance level, we reject the null hypothesis. There is convincing evidence that there is a difference between the mean numerical intensity of fabrics in the one Tide Pod treatment and the mean numerical intensity of fabrics in the equivalent amount of Tide Detergent treatment.

Second Test

Since the p-value of 0.0299 is less than the significance level, we reject the null hypothesis. There is convincing evidence that there is a difference between the mean numerical intensity of fabrics in the two Tide Pods treatment and the mean numerical intensity of fabrics in the two equivalent amounts of Tide Detergent treatment.

Third Test

Since the p-value of 3.097×10^{-10} is less than the significance level, we reject the null hypothesis. There is convincing evidence that there is a difference between the mean numerical intensity of fabrics in the one Tide Pod treatment and the mean numerical intensity of fabrics in the two equivalent amounts of Tide Detergent treatment.

Fourth Test

Since the p-value of 0.0909 is greater than the significance level, we fail to reject the null hypothesis. There is not convincing evidence that there is a difference between the mean numerical intensity of fabrics in the equivalent amount of Tide Detergent treatment and the mean numerical intensity of fabrics in the two Tide Pods treatment.

VII. Reflection

We found convincing evidence that there is a difference between the stain's mean numerical intensity after using one Tide Pod to wash the fabric versus an equivalent amount of Tide detergent. We also found convincing evidence of difference between using two Tide pods and 48 mL of Tide detergent and between using one Tide pod and 48 mL of tide detergent. From

the fourth significance test, it can be concluded that there is no convincing statistical evidence of a difference between 24 mL of original Tide and two Tide pods.

While conducting the experiment, we ran across some problems. One was that the staining patterns were not consistent. When pouring the stainer onto the pieces of fabric, we did not have a method to keep the shape and area of the stain uniform. This meant that some pieces of fabric had stains that were originally more concentrated and, therefore, darker before going into the wash. However, this was mainly accounted for with the use of random assignment and replication. Random assignment ensured that the possible effect of confounding variables such as staining pattern were spread evenly throughout all four treatments. Replication through the use of many experimental units in each treatment worked to distinguish the effects of the treatments from differences due to chance variation. We also did not have a completely flat surface for all the squares to dry on. We tried our best to find an environment with a large enough area to contain all of the squares that also had constant lighting and temperature conditions throughout. To do this, we chose to use the floor of a bedroom that had grooves for the wood tiles, meaning that the plastic wrap the fabrics were drying on was not completely flat. In the future, a change of location may be beneficial to the experimental design.

There are also limitations to the inferences we can make about our results. For stains like those in our study, we were able to infer which detergent, regular Tide detergent or Tide Pods, was more efficient in removing a stain. However, we were limited to inferring only about the washing machine we used and about the white cotton shirts from the brand we chose. As an extension to this experiment, different types of stainers and detergents could be used to conduct additional significance tests.