**Background**

World coffee export is a 19-billion-dollar market. [[1]](#endnote-1) $19,000,000,000 is a lot of cups of morning Joe! Just the sheer volume of the market demands a closer inspection of coffee’s developmental process. Coffee beans are grown all over the world, in differing elevations and climates, usually growing best on the hillsides of volcanic mountains. Once grown, harvested and processed, the coffee bean is shipped and finally ready for roasting. Coffee beans contain moisture within their body. Much like popcorn popping, when heat is applied to unroasted coffee beans (called “greens”), they undergo many chemical reactions. They also take on color changes from green to straw to tan before they take on the distinctive brown color and become what we traditionally think of as coffee. A major chemical reactive milestone that every green bean goes through is called “1st Crack”. At this point the bean has changed from green through yellow and is beginning to brown. Inside the bean, water content is rapidly diminishing and the oils that we think of as coffee are reacting as well. Most importantly, with the start of 1st Crack, the beans are changing from reacting exothermically to endothermically. Consequently, first crack must be noted and monitored by professional roasters so too much heat isn’t lost or the entire roast risks “stalling” or baking the beans rather than roasting them. Recognizing and noting, 1st Crack is one of the few travel signs on the road to coffee roasting. And, it is in a roaster’s colloquial knowledge that a host of different variables (heat, geography, bean varietal) all effect the timing of 1st Crack. However, not much research exists on this.

The closest research I found was a study by Dwi Nugroho, et al. They researched the “Physical Bean Quality of Arabica Coffee (Coffee Arabica) Cultivated at High and Medium Altitude”. Their findings published in The Coffee and Cocoa Research Journal found “altitude showed significant effect on all of physical quality of bean variables”. Using their study as a springboard, my study attempted to determine whether the altitude of bean growth shows a statistically significant effect on the time to roast to 1st Crack.

**Methodology**

Using a Behmor 1600-Plus Coffee Roaster, I purchased and roasted nineteen, ¼-pound increments of coffee beans grown at a *minimum of 1,800 meters* (considered a high elevation) and recorded the time it took for the beans to get to 1st crack. Then, in contrast, I roasted nineteen, ¼-pound increments of coffee beans grown at a *maximum of 1,200 meters* (considered a low elevation) and recorded the time it took for them to get to 1st crack, as well. High and low elevation beans were the two exploratory variables under study with the time time it took for each to reach 1st Crack being the response variable.

In order to mitigate lurking variables that could also affect the time to 1st crack, I took the following precautions. First, I made sure I purchased the same bean varietal with the same processing system (washed in this cased) but grown at two different elevations. Next, in attempts to add some level of sample randomization, I alternated roasting between high and low elevation batches (1st low elevation bean, then high elevation; then high elevation bean, followed by low). Finally, I roasted at least one high and one low elevation batch during the same session (to offset changes in ambient temperature). Minimizing these lurking variables was the attempt to focus any potential significant variation upon the true variable under study. Put another way, minimizing lurking variables allowed a clearer answer to the question “how does time to 1st crack respond to the exploratory variable of growth elevation of coffee bean.”

**Results**

After 25 hours of data gathering through 38 separate coffee roasts (data sheets provided in appendix), the initial descriptive statistics showed the mean time to 1st Crack for the low elevation and high elevation grown beans was indeed different, 7.928 minutes versus 7.628 minutes or a difference of 18 seconds between the two roasts.

|  |  |  |
| --- | --- | --- |
| Statistic | low elevation | high elevation |
| Nbr. of observations | 19 | 19 |
| Minimum | 7.470 | 7.200 |
| Maximum | 9.500 | 8.250 |
| 1st Quartile | 7.750 | 7.500 |
| Median | 7.820 | 7.630 |
| 3rd Quartile | 8.000 | 7.700 |
| Mean | 7.928 | 7.628 |
| Variance (n-1) | 0.172 | 0.054 |
| Standard deviation (n-1) | 0.415 | 0.232 |

However, a view of the side by side box plots indicated an outlier for both test groups.

Could the outliers be the true cause of the difference between the mean? Or could the difference between the two means be caused by sampling error, or even a combination of both sampling error and outliers? Reviewing my roasting notes I had taking during the process, I had *indeed* indicated both roasts as anomalies. During both roasts I had been distracted causing me to preheat the roaster far beyond the normal 200 degrees required for the “roast profile” (the recipe I created for how I was to roast these beans). To try to compensate for lthe ong pre-heats, I tried cooling down the roaster which both times resulted in far too long roast times.

The normal probability plot supported what the box plots had shown, neither the plotted line for the low elevation (left) or the high elevation (right) appeared very linear.

The correlation coefficients put the nails in the coffin. Neither came close to reaching the critical values. My samples, as they stood, were not normal. The search for the next step led to Data Triming.

Wikipedia gives a good desciption of process of Data Trimming under the title Trimmed Estimator:

In statistics, a trimmed estimator is an estimator derived from another estimator by excluding some of the extreme values, a process called truncation. This is generally done to obtain a more robust statistic, and the extreme values are considered outliers.[[2]](#endnote-2)

By trimming the top and bottom 5 or 10% of each sample, the outliers could be removed while still maintaining much of the data’s integrity. The following chart shows the sorted roasts with the upper and lower 5 and 10% colored in to show what values would be trimmed off.



Trim Off

Trim Off

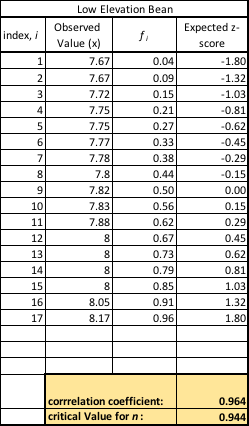
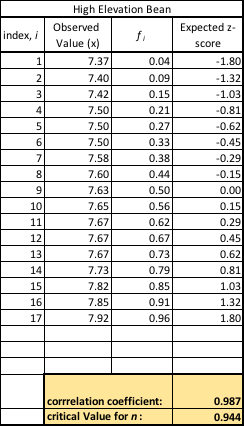
Starting with trimming off the upper and lower 5%, the remaining values were resubmitted for analysis.

|  |  |  |
| --- | --- | --- |
| Statistic | Low elevation bean mean (mins) | High elevation bean mean (mins) |
| Nbr. of observations | 17 | 17 |
| Minimum | 7.670 | 7.370 |
| Maximum | 8.170 | 7.920 |
| 1st Quartile | 7.750 | 7.500 |
| Median | 7.820 | 7.630 |
| 3rd Quartile | 8.000 | 7.670 |
| Mean | 7.862 | 7.616 |
| Variance (n-1) | 0.022 | 0.025 |
| Standard deviation (n-1) | 0.147 | 0.158 |

Initial descriptive statistics of the new trimmed data showed the mean time to 1st Crack for the low elevation and high elevation grown beans was also different, 7.862 minutes versus 7.616 minutes or 15 seconds between the two roasts (3 seconds less difference than before). Unlike last time however, this time the box plot showed no outliers.

And, unlike the last time, the plots this time appeared more linearly.

Most importantly, the correlation coefficients for both roasts now passed the critical value for a normal probability plot:

The nails were removed from the coffin! With the trimmed down samples, I could now proceed to see whether the difference between the two means was significant.

In order to determine whether there was a statistically significant difference between mean times to 1st Crack for low elevation grown coffee beans as opposed to high elevation grown coffee beans, a 2-sample *t*-test was run.

Low Elevation Beans: = 17 = 7.862 min = 0.147 min

High Elevation Beans: = 17 = 7.616 min = 0.158 min

I) : = vs. : two-tailed test

II) = 0.05

III) = = 4.700 *P=* 4.7944 x

IV) If *P-*value , reject ; 4.7944 x 0.05, reject

V) There is sufficient evidence at the = 0.05 level of significance to reject the belief that the mean time to reach 1st Crack for a low elevation grown bean is the same as for the same as a high elevation grown bean; there is a statistically significant difference in their times!

So, in summary, a statistical significance was shown between the mean times to 1St Crack of two of the same coffee beans grown at different elevations. Though shown statistically significant, is the difference practically significant? Could this significance serve a purpose? Yes, the purpose it serves (in the short run) is that it is supportive evidence contributing to the initial study by Dwi Nugroho, et al where they stated, “altitude showed significant effect on all of physical quality of bean variables”. This research supports that study in that one of the physical qualities of bean variables that altitude shows a significant effect upon is the bean’s chemical reaction time to applied heat in the form of the time interval it takes to get to 1st Crack.

In the long run, a study like this (that shows a significant difference between two sample mean times) encourages other researchers to *continue searching* for other “physical qualities of bean variables” that might also be influenced by growth altitude. Findings from those research projects could ultimately lead to better choices by coffee farmers on the allocations of their plots of land for their bean crops based on altitude of beans that are most responsive to those particular site’s elevation. As a farmer you can decide to plant this bean versus that bean on this plot of your farm as opposed to that plot of your farm that is at a different elevation, confident that data driven research supports your choice. When farmers have the best available research data on hand, they have the opportunity to grow the best crop, garner the best price for their crop and ultimately provide us all the best tasting cup of morning Joe.

1. <https://www.politifact.com/global-news/statements/2017/may/08/starbucks/no-coffee-not-second-most-traded-commodity-after-o/> [↑](#endnote-ref-1)
2. <https://en.wikipedia.org/wiki/Trimmed_estimator> [↑](#endnote-ref-2)