Measurement Statistics: Color Distribution in M&Ms

Required Reading D.C. Harris***, Quantitative Chemical Analysis*** (9th ed., W. H. Freeman, NY, 2016) pp. 64-80 . Data rejection and Data Reporting sections of the ***Analytical Lab Manual***.

This experiment will introduce the student to some of the basic statistics that will be used in the lab.

M&M'S are produced by a method known as panning. Panning involves coating candies by rotating them in a coating material in a revolving pan. The principle, briefly, is to coat the center with a layer of material, which on evaporation leaves an even layer or shell of dry substance. This process is repeated several times until the desired thickness is acquired.

The colors are panned separately, then mixed before the final process is completed. Regardless of the color, the flavor remains the same. The 'm' is printed on the candies by a machine specially designed to handle this delicate process without cracking the thin sugar shell. This process is similar to offset printing. About 400 million M&M'S CHOCOLATE CANDIES are made daily. The color blends were selected by conducting consumer preference tests, which indicate the assortment of colors that pleased the greatest number of people and created the most attractive overall effect. According to the manufacturer, each package of Milk Chocolate M&M's should contain 24% blue, 13% brown, 16% green, 20% orange, 13% red, and 14% yellow M&M's on average.[1]

Materials

Each student will be given a package of M&M's (plain). Each student is to count the number of each color and determine the fraction (# color / # total) of each color for his or her pack of M&M's **before they are eaten.**

After you have entered these calculations in your notebook, when you are finished, enter your data into the Excel spreadsheet so we can tabulate the results for the entire lab.

[1] Note, interestingly the color distributions are not the same for the other types of candies:
M&M'S PEANUT: 23% cyan blue, 23% orange, 15% green, 15% bright yellow, 12% red, 12% brown.
M&M'S KIDS MINIS: 25% cyan blue, 25% orange, 12% green, 13% bright yellow, 12% red, 13% brown.
M&M'S DARK: 17% cyan blue, 16% orange, 16% green, 17% bright yellow, 17% red, 17% brown.
M&M'S PEANUT BUTTER and ALMOND: 20% cyan blue, 20% orange, 20% green, 20% bright yellow, 10% red, 10% brown.
M&M'S PRETZEL: 20% each of red, green, orange, blue and brown.

The sheet will look like this:

Student #	Brown	Blue	Red	Orange	Yellow	Green
1	.55	.10	.50	.12	0.00	.18
2						
3						
4						
.						
.						
.						

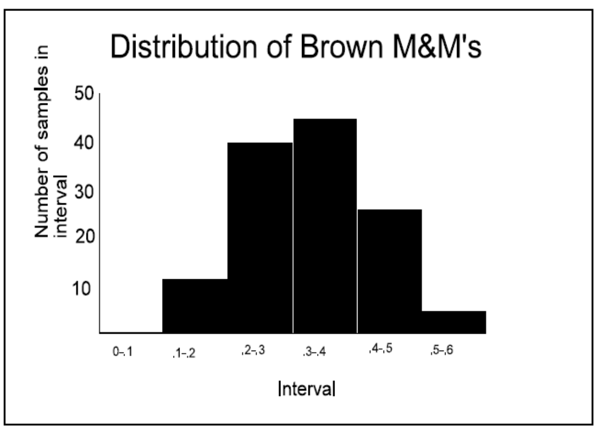
Use your numbers, and those of the next 3 higher groups as 4 experimental determinations of fraction color. (Students with the highest group will cycle to groups 1 and 2)

For this lab you will do the following eight statistical calculations (I would suggest using Excel):

1. Determine the mean, standard deviation, and relative standard deviation (Coefficient of Variation) for each color fraction based on your four measurements.

2. Looking at your data (4 measurements) do you have any you think should be rejected? If so, does the Q test allow it to be rejected? (Even if you don't think you need to, try the Q-test on at least two sets of data.)

3. A few years ago the distribution of brown M&M's based on all the data collected looked like this:



Using the data from the entire lab make two similar plots, one for the distribution of brown M&M's and one for the distribution of blue M&M's. On each plot mark the mean and standard deviation you determined for the set of data you collected and for your three samples. How do these values compare to the observed distributions?

4. Using data from the entire lab, what is the mean and the 95% confidence interval around the mean for each color? How do the values compare to those reported by the manufacturer?

5. I like the red M&M's. If I made each person in the lab give me 2 red M&M's before the lab started, what kind of error would that place on our numbers. Likewise, what would have happened if I told everybody to eat 5 M&M's before they started counting, what would have happened to our error. (This is not a calculation, identify the kind of error)

6. Assume that I went through and randomly took a single M&M from your sample or added an M&M. This introduces some uncertainty into your fraction numbers. When you report your fraction color, how many significant digits should you use to represent this uncertainty? Why? (Show me a calculation to prove your answer)

7. I wish to use the fraction Brown and fraction Blue in the following strange calculations. Using what you were taught about propagation of random error, what is the uncertainty in the outcome of these calculations, based on your experimental data? (Use the LAB data average values for fraction brown and fraction blue, and use the standard deviation as the uncertainties in these values.)

Fraction dark = fraction brown + fraction blue

ratio = fraction blue / fraction brown

8. A previous classes results were as follows:

	Color Mean	Standard Deviation	
Brown	.323	.093	
Blue	.067	.047	
Red	.201	.075	
Orange	.113	.076	
Yellow	.212	.086	
Green	.086	.054	n=127

Use the appropriate statistics to see if M&M's have changed their color distributions for Brown, Orange, or Green since the above data was collected. (Do all three cases. Use a 95% confidence interval. If N is too large for a given table, use the highest N available on your table)