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Research Questions and Hypothesis

Research Questions

What are the symptoms and causes of edema, especially those that might be related to food?

↳ From edema research, I found that limiting salt (i.e., sodium) in foods is a lifestyle change to avoid edema. Therefore, the following question arose:

How will limiting sodium in the cookie affect the cookie: its texture, taste, and any other internal chemistry?

Hypothesis

If the table salt (NaCl) is removed from the recipe, then the cookie will be drier, denser, and smaller (in height and diameter) due to the lack of salt's ability to retain water and strengthen gluten bonds (which better contain carbon dioxide and therefore increase cookie volume).

(Sodium is present mainly in two ingredients: table salt (NaCl, ~5g) and baking soda ($NaHCO_3$, ~5g), as well as much smaller amounts in butter (~2mg), egg (~62mg) and nuts (~7mg, but it depends on the nut and whether there is added salt). However, because they are both already in small concentrations, because baking soda is more important to the chemistry of baking, because the concentration of sodium in salt is constant compared to some of the other substances such as eggs and nuts, and so as to avoid manipulating two variables, I focused my hypothesis solely on eliminating table salt to attempt to create a more directed, more reproducible experiment.)

Background Research

Research

(underlined notes probably are most relevant to Cookie Project)

Edema

- Edema is the medical term for swelling from injury or inflammation by fluid; ranges from a small area to the entire body
    - Usually has underlying causes, not a medical condition in and of itself, needs separate treatment
- Limiting sodium intake can help reduce swelling, but it likely will not stop the underlying problem

"Edema." *Mayo Clinic*. Mayo Clinic for Medical Education and Research., 2016. Web. 19 Jun. 2016. <http://www.mayoclinic.org/diseases-conditions/edema/basics/definition/con-20033037>.

"Edema Overview." *WebMD*. WebMD LLC., 2016. Web. 19 Jun. 2016. <http://www.webmd.com/heart-disease/heart-failure/edema-overview>.

Salt's Effects on the Cookie

- Salt slows down the rate of expansion by strengthening the gluten bonds, thus controlling the rate of bubbles forming and lowering the possibility of holes to form. This means that less gas will escape, so that the dough will be fluffier
- Salt is also hygroscopic, which means that it will keep water in the cookie, increasing the moisture and improving the texture of the cookie
- When yeast is used (it is not in this recipe), adding salt can be used to control the rate of yeast fermentation (more salt = less fermentation, and vice versa). Slowing down yeast fermentation also increases amount of sugar left over, which allows for more Maillard reaction and more browning and aroma
- (Non-chemical importance: it adds to the flavor, not letting the baked goods taste as bland)

"Ask the Experts … About Salt." *Home Baking Association*. Home Baking Association, N.d. Web. 26 Jun. 2016. <http://www.homebaking.org/foreducators/askexperts/salt.html>.

"How Salt Affects Baking." *Progressive Baker*. Cargill, Incorporated, 2016. Web. 26 Jun. 2016. <http://www.progressivebaker.com/tips_tools/salt_affecting_baking.html>.

"Salt." *King Arthur Flour*. King Arthur Flour Company, Inc., 2016. Web. 26 Jun. 2016. <https://www.kingarthurflour.com/professional/salt.html>.

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Cookie Project Part 2
Materials and Procedure

Previous steps

1. Preliminary Research
2. Project Variable (Accomodationg Edema)
3. Hypothesis, Questions, and Directed Research

Materials

The Recipe**

- 532mL (2 1/4 cups) all-purpose flour
- 2.46mL (1/2 teaspoon) salt*
- 4.93mL (1 teaspoon) baking soda
- 237mL (1 cup (2 sticks)) butter, softened
- 177mL (3/4 cup) granulated sugar
- 177mL (3/4 cup) packed brown sugar
- 4.93mL (1 teaspoon) vanilla extract
- 100g (2) large eggs
- 473mL (2 cups (12-oz. pkg.)) Nestlé Toll House Semi-Sweet Chocolate Morsels
- 237mL (1 cup) chopped, unsalted* walnuts****

- 1 measuring cup
- 4 bowls (2 large, 2 small)
- 1 hand whisk***
- 1 ice cream / cookie scoop
- 2 ungreased baking sheets

* note the halved amount of table salt and unsalted nuts
** Ingredients and recipe from Very Best Baking
*** Anolon brand hand whisk used in my experiment, due to a lack of electronic mixers
**** Only walnuts were used in this experiment to maintain consistency and clear ambiguity of "nuts" present in original recipe.

The Experiment

- 1 (millimeter) ruler
- 1 (gram) scale

Procedure

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Recipe modified from Very Best Baking to make two half-batches of cookies:

1. Gather materials.
2. Preheat oven to 191° C.
3. Mix with whisk half of flour (1 1/8 cups) and half of baking soda (1/2 teaspoon) in small bowl.
4. Mix with whisk half of butter (1/2 cup), half of granulated sugar (3/8 cup), half of brown sugar (3/8 cup), and half of vanilla extract (1/2 teaspoon) until creamy for 2 minutes in large bowl.
5. Add one egg, mixing well.
6. Mix in flour and baking-soda mixture slowly with whisk.
7. Mix in half of chocolate chip morsels (1 cup) and nuts (1/2 cup) with whisk.
8. Measure out 30g of batter. Mold it into a round shape using the ice cream / cookie scoop and put onto baking sheet.
9. Label the sheet as the experimental group.
10. Repeat steps 3 through 9, this time adding all of the salt (1/2 teaspoon) and putting the cookies on a different sheet labeled as the control group.
11. Bake all cookies for 10 minutes.
12. Remove from oven and leave out for 10 to 20 minutes until entirely cooled.
13. Clean up materials and wash utensils.

Measuring Size and Density Differences

14. Take ten cookies from each group (experimental and control).
15. Measure the height and diameter of every cookie. Record in the chart below under "Cookie Height" and "Cookie Diameter."
16. Calculate and record the approximate* cookie volume using the formula for the volume of a cylinder:

$$V = \pi r^2 h$$

17. Measure the mass of every cookie. Record in the chart below under "Mass."
18. Calculate the density of every cookie. Record in the chart below under "Density."

* Approximate volume calculated because more exact measuring methods such as water-displacement might be destructive to the cookies (which are necessary in the next step) and would be difficult with the materials I have at hand. The volume is calculated as a cylinder, which is closest to a cookie's shape.

Measuring Moisture Levels

(Use the same 20 cookies from the previous section)

17. Dehydrate all of the cookies by putting them back in the oven at 66° C (or, if not applicable, its lowest setting) for 6 hours.*
18. Let cookies cool for 10 to 20 minutes until entirely cooled.

19. Measure the mass of every cookie again. Record in the chart below under "Dehydrated Mass."
20. Calculate the percent mass of water in each cookie. Record in the chart under "% Water." The formula for percent water is:

$$\%\ mass_{H_2O} = \frac{initial\ mass - dehydrated\ mass}{initial\ mass} \times 100\%$$

* Dehydration recommendations from here.

Data Table Layout

Experimental Group Data

Cookie	Height (mm)	Diameter (mm)	Approximate Volume (mm^2)	Mass (g)	Density (g/mm^2)	Dehydrated Mass (g)	Percent Water
EXP1							
EXP2							
EXP3							
EXP4							
EXP5							
EXP6							
EXP7							
EXP8							
EXP9							
EXP10							
Average							

(Make a copy for the control group, but with "CTL[ID]" format for the "Cookie" field instead.)

Points of Comparison

Hypothesis:

> If the table salt (NaCl) is removed from the recipe, then the cookie will be drier, denser, and smaller (in height and diameter) due to the lack of salt's ability to

retain water and strengthen gluten bonds (which better contain carbon dioxide and therefore increase cookie volume).

As per the hypothesis, compare the following fields between the two groups: volume, % water, and density, with an expected decrease in the former two and an increase in the latter of the mentioned fields from the control group to the experimental group.

Trial	Cookie	Height (mm)	Diameter (mm)	Approximate Volume (mm^3)	Mass (g)	Density (g/cc)	Dehydrated Mass (g)	Water Percent Composition
Control Batch 1	C1	20.0	61.0	*58400*	28.3	*0.485*	25.5	*10.0%*
	C2	20.0	63.0	*62300*	28.3	*0.455*	25.5	*10.0%*
	C3	21.0	62.0	*63400*	28.3	*0.447*	25.5	*10.0%*
Control Batch 2	C4	14.0	79.0	*68600*	25.5	*0.372*	25.5	*0.00%*
	C5	15.0	82.0	*79200*	28.3	*0.358*	25.5	*10.00%*
	C6	15.0	80.0	*75400*	31.2	*0.414*	31.2	*0.00%*
Control Batch 3	C7	17.0	77.0	*79200*	28.3	*0.358*	28.3	*0.00%*
	C8	13.0	84.0	*72000*	31.2	*0.433*	31.2	*0.00%*
	C9	14.0	90.0	*89100*	28.3	*0.318*	28.3	*0.00%*
	Avg.	16.6	75.3	*71956*	28.7	*0.404*	27.4	*4.4%*
Experimental Batch 1	E1	23.0	60.0	*65000*	22.7	*0.349*	19.8	*12.5%*
	E2	24.0	59.0	*65600*	25.5	*0.389*	25.5	*0.00%*
	E3	26.0	55.0	*61800*	25.5	*0.413*	25.5	*0.00%*
Experimental Batch 2	E4	18.0	65.0	*59700*	22.7	*0.380*	22.7	*0.00%*
	E5	20.0	64.0	*64300*	28.3	*0.441*	25.5	*10.00%*
	E6	18.0	66.0	*61600*	25.5	*0.414*	25.5	*0.00%*
Experimental Batch 3	E7	20.0	69.0	*74800*	31.2	*0.417*	28.3	*9.09%*
	E8	18.0	66.0	*61600*	28.3	*0.460*	25.5	*10.00%*
	E9	19.0	69.0	*71000*	25.5	*0.359*	25.5	*0.00%*
	Avg.	20.7	63.7	*65044*	26.1	*0.402*	24.9	*4.6%*
P-Values		0.468	0.017	0.034	0.104	0.130	0.453	0.443

(↑ p-values generated by independent t-test between both groups)

General Observations (qualitiative)

The control group cookies were flatter, shorter, more brown, and more consistent (the experimental gro
The batters between a control/experimental batch pair were visually similar (could not pick out differenc
The cookies and batter from the first group (control and experimental) were noticeably harder than thos
There was no noticeable difference in the tastes between the two types of cookies

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Cookie Project Data Analysis

(Data is located here.)

According to the data table, the control batches had an average of 16.6mm height, 75.3mm diameter, 28.7g, and 27.4g when dehydrated. This gave an estimated 73800mm^3 volume per cookie, 0.404g/cm^3 density, and 4.4% water composition.

The experimental data, had very similar results, having an average of 20.7mm height, 63.7mm diameter, 26.1g, and 24.9g when dehydrated. This gave an estimated 65800mm^3 volume per cookie, 0.402g/cm^3 density, and 4.6% water composition.

This means that the experimental data cookies were on average taller, smaller in diameter, and had a slightly greater water composition. They were also observed paler in color, while the control group cookies were browner. They also were more uneven in texture, with the chocolate chips and walnut chunks more extrusive, while the cookies from the control group had a more flat, even texture.

There were many possible sources of error in the experiment. Several have been listed above regarding the data values and calculations that should not be used in the analysis. In the experiment, most instruments were common kitchen equipment with limited precision. The tool used to measure the volume in teaspoons was a little cup with measurements with precision ±0.5tsp. The tool used to measure the volume in cups was a measuring cup with measurements with precision ±0.25cup. The tool used to measure height was a common millimeter ruler, with precision ±1mm. The tool used to measure the masses was a US Postal Office weight scale, measured in ounces, with precision ±0.1oz. Out of these instruments, the largest sources of error were likely from the cup measurement (for the recipe), because of the small precision, and with the scale. The scale measured in tenths of an ounce, which were not very precise; as a result, many of the cookies reported having no change in mass when they could very possibly have had a change in mass that was under one-tenth of one ounce and therefore was undetected by the machine. Dimension measurements were taken to the highest point for height and the smallest diameter, in order to maintain consistency and provide a middle ground for the volume calculation; however, this may have lost accuracy as well. Out of the cookies, the first batch (control and experimental groups 1) were noticeably taller and less wide than those of the following batches; these values may all be outliers. Lastly, it is important to note that I, the baker, have never baked cookies before, and that my limited experience may have made errors unknown to myself along the way.

In general, the data was statistically unimportant. As determined by an independent t-test, the height, mass, density, dehydrated mass, and the water percent composition had p-values of 0.468, 0.104, 0.130, 0.453, and 0.443, respectively — greater than 0.05 (the chosen significance level). This means that the data supports the null hypothesis: the differences are not significant and likely due to error. Only the diameter and approximate volume metrics had p-values lower

than 0.05 — 0.017 and 0.034, respectively. Even though these had low p-values (and therefore a high statistical significance), their accuracy is not guaranteed — the volume was calculated on the premise that the cookies were highly cylindrical, which they proved not to be. This affected the subsequent density calculation, which is highly unlikely (according to the data, on average they are less than half the density of water, when they would be roughly the same density as water).

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Cookie Project Conclusion / Future Investigations

(Data analysis is here.)

The experiment did not provide strong evidence to show the hypothesis that the elimination of table salt (sodium chloride) in the cookies would decrease the size of the cookies, increase their densities, nor would it make the cookies more dry (smaller percent water composition). Although the control batch (with the table salt) was larger in volume on average, the control group also had a slightly greater density and a slightly lower percent water composition on average. This was also made statistically insignificant by high p-values (over 0.05) on most of the data sets (height, mass, density, water composition) and a high potential for inaccuracies for the volume calculation.

Although this experiment did not seem to yield much significant data, it would likely do so if the instruments were more exact. As previously stated in the data analysis portion, low precision on the instruments used leave wide margins of error (±0.1oz rather than ±0.01g that can be obtained with a centigram scale for volume and ±0.25cups rather than ±0.1mL that can be obtained with a graduated cylinder for volume in a laboratory setting). A more controlled laboratory setting would be the first step to producing significant results.

For future investigations, testing volume via a water displacement method may be a more accurate method to calculate volume due to the non-regular shape of the cookie. This may reduce inaccuracies in the volume and density calculations (also mentioned in the data analysis), and again make the data more significant.

Another interesting variable to test would be to eliminate baking soda (sodium bicarbonate) from the cookie. There is a similar amount of sodium in sodium bicarbonate as there is in sodium chloride in the cookie, and the sodium is the primary reason that the table salt was eliminated in the first place (sodium being a contributor to edema, which was the initial affecting factor of the entire experiment). Sodium bicarbonate has important properties in baking (especially dough leavening during the baking process), so this would likely greatly affect the cookie in interesting ways.