COOKING CHEMISTRY

FRANCINE G.

THE OXBOW SCHOOL

A CHEMICAL AND PERSONAL PERSPECTIVE ON COOKING

My earliest memories of working in the kitchen stem back to my Italian grandmother, Nonni. My sister, Cecilia, and I learned how to make traditional soups, sauces, and meatballs at a young age. As a Sicilian, food has always been important to me and my family. Many people eat to live. We live to eat.

I chose to take on a chemical perspective for my research. I typically use a scientific perspective to better understand the world around me. I researched how types of chemical properties are affected in cooking, how one can manipulate a recipe to their personal preferences; and, using the knowledge of chemistry, how ingredients are changed by different cooking methods, and how cooking methods affect the flavor and texture of the food. This research then led me to create my own experiment using chocolate chip cookie. The experiment studies the chemical properties in cookie ingredients, taking a chemical view on the methodology in baking, and assessing how these affect the overall cookie.

I chose to look at cooking and food from a personal perspective for my art. I created an art project that encapsulates each of my personal notions in relation to cooking. These associations are: nourishment, independence, bringing people together, and meditation as a coping mechanism for mental health. Nourishment is represented by the gnocchi and thumbprint cookies; the hand-carved wooden spoon demonstrates independence; the macarons reflect meditation; the wedding cake represents using cooking as a coping mechanism; and the presentation, eating, and installation are a platform for social gathering.

Francine G.
New Haven, Connecticut

Francine Giaimo
Final Paper
11 April 2018

my personal favorite is red sauce w/ cavatelli

Chemistry in Cooking

My earliest memories of working in the kitchen stem back to my Italian grandmother, Nonni. At a young age, my sister Cecilia and I learned how to make traditional soups, sauces, and meatballs. As a Sicilian, food has always been important to me and my family. Many people eat to live. We live to eat.

I chose to take on a chemical perspective for my research. I typically use a scientific perspective to better understand the world around me. My favorite subject in science, psychology, helps me to understand one of the most complicated pieces of our environment: people.

My research and food experiment have been addressing the questions:

- What types of chemical properties are affected in cooking?
- How can one manipulate a recipe to their personal preferences, using the knowledge of chemistry?
- How are ingredients changed by different cooking methods?
- How do cooking methods affect the flavor and texture of the food?

Through performing this experiment, I will be studying the chemical properties in cookie ingredients, taking a chemical view on the methodology in baking, and assessing how these affect the overall cookie. The experiment shall bring me to a level of knowledge that will allow me to manipulate the recipe to a certain taste preference.

I decided to test chocolate chip cookies on account to their numerous variables, simplicity in baking, and chemical complexity.

Methodology

This experiment sets out to test the effects of chemical properties in the ingredients for chocolate chip cookies. One variable of the cookie recipe will be changed in each batch. A standard batch of cookies will also be made as a control group.

<u>Standard Recipe/Control Group cookies:</u>

Ingredients:

- 6 ounces Semi-Sweet Chocolate Baking Chips
- ½ cup butter, softened (2 sticks)
- 2.4 ounces cup sugar
- 2.9 ounces cup brown sugar, packed
- 1 large egg (about 2 ounces)
- 1 teaspoons vanilla
- 4.7 ounces cups unsifted flour
- ½ teaspoon baking soda
- ¼ teaspoon salt

Not melted

Any type of chocolate will work, just depends on your preference

Directions:

1. Heat oven to 375°F.
2. Stir flour with baking soda and salt; set aside.
3. In large mixing bowl, beat butter with sugar and brown sugar at medium speed until creamy and lightened in color.
4. Add eggs and vanilla, one at a time. Mix on low speed until incorporated.
5. Gradually blend dry mixture into creamed mixture. Stir in chocolate chips.
6. Drop by tablespoon onto cookie sheets lined with parchment paper.
7. Bake for 5-8 minutes or until golden brown.
8. Wash your dishes:

It is easiest to stay tidy if you clean right after use.
One may need a quick break to reflect on the work created (eat, rest).
Perhaps one may also need the pans to soak a bit, or use a dishwasher, using the assistance of outside sources to make the task of cleaning less daunting. In the end, this person must still put in work to complete the job.
If one washes their dishes right after using them, they will not pile up. It is easier to clean a small pile than a large one. Building the pile in your sink can cause a dish to break. These broken pieces will be unredeemable.
It can feel good to clean your dishes. One can derive a sense of ownership and control. When one cleans immediately after use, the task is more conceivable than cleaning a large, built up pile. One can better motivate themselves to clean a small pile than start a long project. Cleaning a small pile can bring one gratification. A large pile building up creates stress. Clean your damn dishes.

Equipment:

- Oven
- Timer
- Mixing bowls
- Cutting board
- Knife
- Oven mitt
- Hand mixer

One of my favorite sensory experiences in baking derives from the hand mixer. If I use it for a while, I can still feel a slight buzzing in my wrist afterwards like a physical manifestation of a memory. In a memory, the event is no longer there, but the emotions it brought are. In this physical memory, the event is no longer there, but the physical attributes remain.

- Kitchen scale

Invest in a kitchen scale. It may be more expensive than plastic cup measurements, but it pays off. the accuracy of these measurements are far better than the plastic cups. It is much easier to use for sticky ingredients (such as honey) and prevents you from cleaning each individual plastic cup every time you cook.

- Metal cookie sheet
- Parchment paper

- 120 oz chocolate — & prefer semi-sweet
- 12 sticks of butter
- 48 oz white sugar
- 57 oz brown sugar
- 40 oz eggs
- 20 tsp vanilla
- 95 oz flour
- 10 tsp baking soda
- 5 tsp salt
- 1 tsp double acting powder
- 3.9 oz olive oil

Variables to be tested in the food lab:

1. Baking in a non-preheated oven
2. Testing baking temperatures 325, 350, 375 (control group), 400, 425
3. Testing sugars: 100% brown, 50/50(control group), 100% white sugar
4. Testing eggs: regular(control group), just yolks, just whipped whites (whipped until stiff peaks form)
5. Testing fat (saturated vs. unsaturated): Butter(control group), olive oil — for cookies, & use salted butter
6. Testing leavening: baking soda(control group), double acting powder

Variables to be kept consistent in the food lab:

- Amount of cookies in the oven

It is good to make multiple batches. While it may take longer, you have more attempts at making the cookies better. If you make one batch, but burn it, you lose your hard work. Be more well-rounded.

- Pan used
- Size of cookies
- Space between cookies
- Oven rack/ placement of the cookies in the oven — use middle rack

Documentation of the lab will consist of:

- Photographs of each batch of cookies (including profile view, side view, and cookie split in half to see the interior) — use natural lighting / take photos during the day
- Written notes in journal

Sometimes the only difference between playing with your food and science is whether or not you write it down.

Factors to be documented:

- Physical appearance of the cookies (color, thickness)
- Texture of the cookies
- Noticable difference in taste
- Details about each batch of cookies (temperature of oven, baking time, etc.)

<u>Hypothesis for each variable:</u>

1. Starting in a cold oven, rather than a preheated one

With lack of attention to preparation, one cannot expect the same results.

I hypothesize that these cookies will be flatter than the control batch, as a result of butter spreading. Butter is a fat with a sharp melting point.[1] A sharp melting point means that the substance melts completely over a narrow range of temperatures. Through baking the cookies over a longer period of time, the butter will melt, thus spreading the cookies.

2. Testing baking temperatures: 325, 350, 375 (control group), 400, 425

In an oven, heat is transferred through convection. Convection is the transfer from one solid body to another through the intermediary of a fluid.[2] With convection, the outside of the food is heated before the interior. The high temperature will crisp the outside before the interior can heat, thus giving the cookie a crunchy edge and softer inside. The cookies baked at 425 degrees will demonstrate this property clearly.In baking at temperatures lower than that of the control group, the cookies will spread more due to the butter. Similar to baking the cookies without a preheated oven, the sharp melting point of butter will cause the cookies to spread out. The cookies baked at 325 should be even flatter than those made at 350, due to a longer baking time. The cookies baked at higher temperatures than the control group will have crispier edges and soft middles. In an oven, heat is transferred through convection. Convection is the transfer from one solid body to another through the intermediary of a fluid.[3]

convection bake is especially important for making roasts

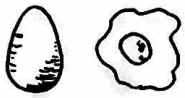
3. Testing sugars: 100% brown, 50/50 (control group), 100% white sugar

I hypothesize that using 100% brown sugar will produce chewy cookies that are dense and soft, with a thicker body. Brown sugar is slightly acidic, due to its molasses content, which contains acetic acid. This acid will react with the baking soda, creating carbon dioxide bubbles, water, and sodium citrate.[4] In the reaction between baking soda (sodium bicarbonate, $NaHCO_3$) and the citric acid in brown sugar ($C_6H_8O_7$), baking soda is the excess reactant.

$$C_6H_8O_7 + NaHCO_3 \rightarrow Na_3C_6H_5O_7 + 3H_2O + 3CO_2$$

The addition of more brown sugar will create more carbon dioxide bubbles. Brown sugar is more dense than white sugar, which will add to the chewy quality of the cookie. I hypothesize that the cookies with only white sugar will be flatter and crisper. Without the reaction between the baking soda and the acid in brown sugar, the cookies will not receive the carbon dioxide bubbles that act as a leavening agent.

4. Testing eggs: regular (control group), just yolks, just whipped whites (whipped until stiff peaks form)



---

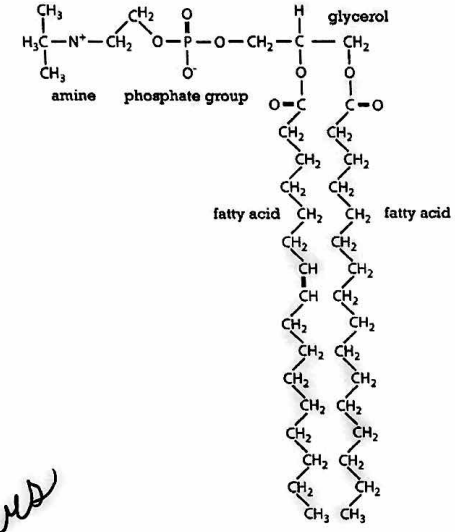
[1] Corriher, *CookWise.*

[2] Lopez-Alt, J. Kenji. *The Food Lab: Better Home Cooking through Science.*

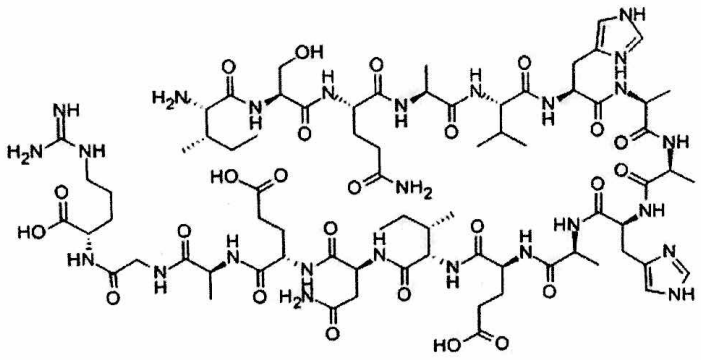
[3] Lopez-Alt, J. Kenji. *The Food Lab: Better Home Cooking through Science.*

[4] Parks, Stella, *Serious Eats.*

I hypothesize that cookies baked with only egg yolks will have a darker color and have a more dense and chewy texture. The color of the yolk is a consequence of the chemical compounds lutein and zeaxanthin. Both of these compounds are known as xanthophylls, and can also be classed as carotenoid compounds; they are hence members of the same chemical family as beta-carotene, the chemical that gives carrots their orange color.[5] These compounds will give the cookies a darker pigmentation. The egg yolk contains the phospholipid Lecithin, as pictured. With a hydrophilic head and a hydrophobic tail, Lecithin acts as an emulsifier.[6] The egg yolk is more dense than the egg white, containing far more fat and proteins. The emulsifying properties and density of the egg yolk will make the cookies more dense and chewy.



For the cookies with only whipped egg whites, I hypothesize that they will have a lighter color, be lighter in texture, and be more stiff/dry. The lack of the color pigmentation present in the egg yolk will make the cookies lighter in color. Egg whites are composed of about 90% water and 10% protein. Ovalbumin, as pictured below, makes up about 54% of the total proteins in egg whites.[7]
When egg whites are whipped, the proteins become denatured. As you beat the egg whites, you also whip bubbles into the mixture. The water molecules are attracted to each other and to the hydrophilic amino acids on the proteins. While trying to get close to each other and to the hydrophilic amino acids, the water molecules squeeze the hydrophobic amino acids out. The best place for the egg proteins is on the surface of the liquid, with their hydrophobic amino acids sticking out into the air. The surface of each bubble film becomes crowded with egg proteins. The water molecules are forced apart by these proteins. Since the attraction between water molecules decreases with distance, the water molecules don't stick together quite as well, so rather they can spread out and make a bubble film. Some of the proteins form bonds with each other to create a stable network that keeps the bubbles from popping. When heated, the



[5] *Compound Interest.*
[6] "The Accidental Scientist: Science of Cooking." *Exploratorium.*
[7] "The Accidental Scientist: Science of Cooking." *Exploratorium.*

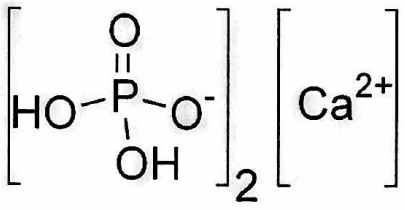
protein ovalbumin forms bonds that cause the egg to stiffen.[8] The bubble film and stiffening properties in egg whites will give the cookies a light texture and dryness.

5. Testing fat (saturated vs. unsaturated): Butter (control group), olive oil

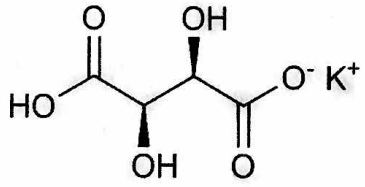
Cookies made with olive oil will have a more bitter taste and be flatter. The flavonoid polyphenols in olive oil are natural antioxidants that contribute to a bitter taste and astringency.[9] The cookie will be flatter due to the lack of aeration in the batter. When butter is creamed with the sugar, it provides aeration for the batter, making the cookies fluffier/thicker. Without this aeration, the cookies will be thinner.

6. Testing leavening: baking soda (control group), double acting powder

The addition of double acting baking powder will create cookies that are lighter in color and fluffier. The acidic content of a cookie affects how easily it browns. The more acid, the less browning.[10] In the chemical reaction between baking soda ($NaHCO_3$) and acid, baking soda is the excess reactant (see chemical reaction in the third hypothesis). Double acting powder contains both baking soda and calcium acid phosphate, $Ca(H_2PO_4)_2$. Calcium acid phosphate (pictured below) releases a small amount of carbon dioxide when mixed with baking soda and water, and much more when it is baked. With more acid content and carbon dioxide bubbles, these cookies will be fluffier and lighter in color.



Double acting powder also contains cream of tartar. The addition of cream of tartar will have a similar effect on the cookies. Cream of tartar, $KC_4H_5O_6$ (pictured below) will create carbon dioxide bubbles when combined with baking soda, making the cookies fluffier. This addition of acid will also make the cookies lighter in color.



Data:

Batch 1: Control Group

Standard does not necessarily mean best. By questioning what are thought to be truths, one may discover a better, more defined truth.

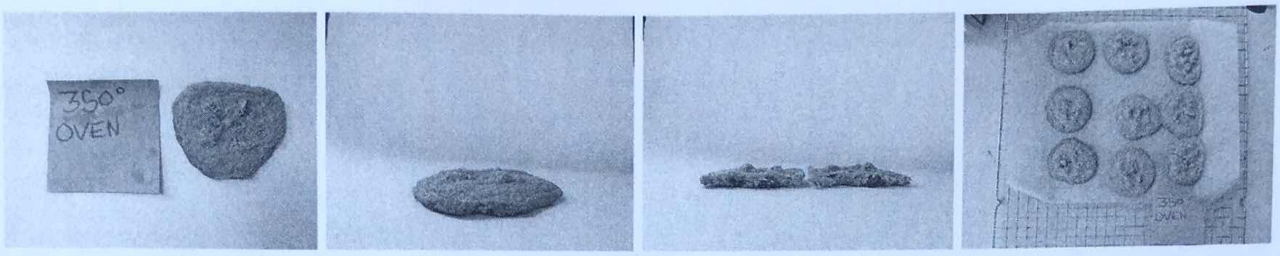
- Time baking: 6 minutes and 40 seconds
- Taste test notes:
  - Medium thickness
  - Generally soft

---

[8] "The Accidental Scientist: Science of Cooking." *Exploratorium.*

[9] "Chemical Composition of Olive Oil." *Clackline Valley Olives.*

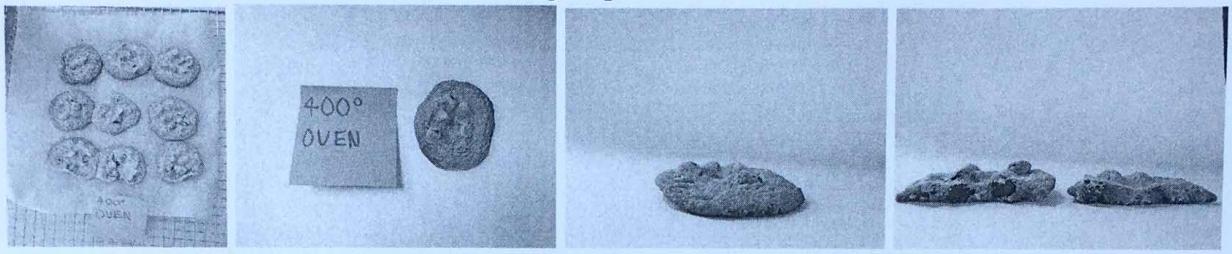
[10] Corriher, *CookWise.*



Batch 5: Baking at 400 degrees

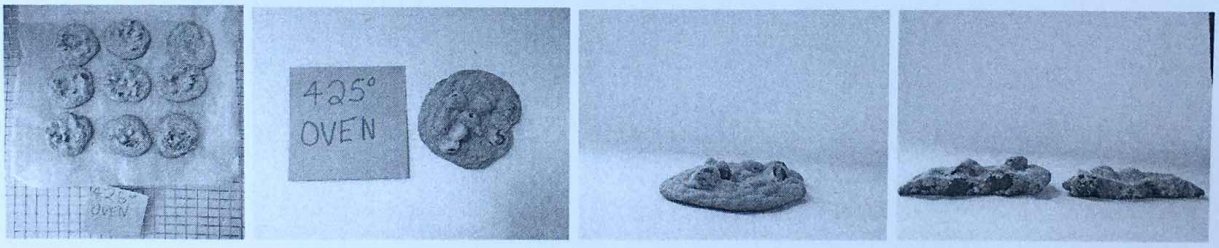
- Baking time: 5 minutes and 40 seconds
- Taste test notes:
  - Tougher edge, soft middle
  - A bit thicker than control group

both easy to burn (keep careful eye on the clock)



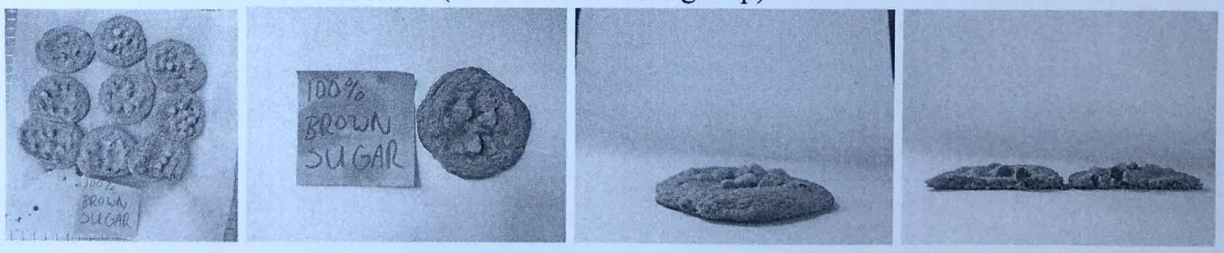
Batch 6: Baking at 425 degrees

- Baking time: 5 minutes
- Taste test notes:
  - Soft
  - A bit thicker than batch 5

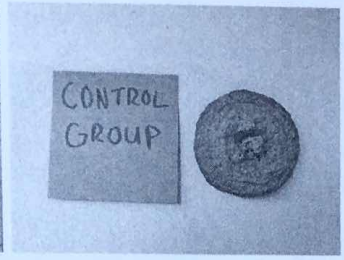


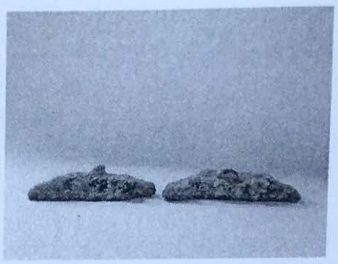
Batch 7: 100% Brown sugar — strong molasses flavor

- Baking time: 6 minutes
- Taste test notes:
  - Very chewy
  - Soft
  - Medium thickness (similar to control group)



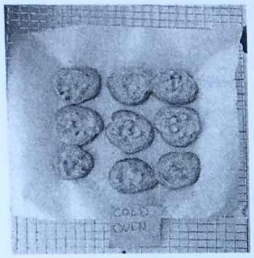
- Typical flavor — pretty good, but not my favorite batch

Batch 2: Non- Preheated Oven (starting in a cold oven) — I had to redo this batch a few times. The edges burned fast.

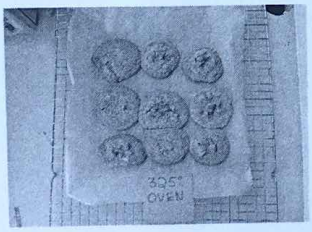
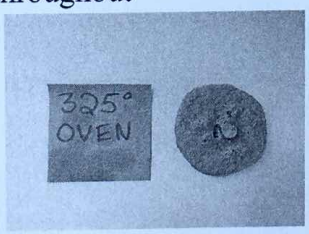
- Baking time: 6 minutes and 30 seconds
- Taste test notes:
  - Dry with a crunchy edge
  - Thinner than control group





Batch 3: Baking at 325 degrees

- Baking time: 9 minutes
- Taste test notes:
  - Thinner than control group
  - Tough texture
  - Cooked throughout


Batch 4: Baking at 350 degrees

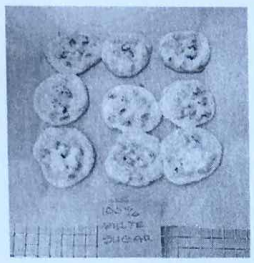
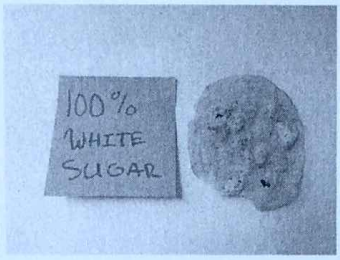
- Baking time: 7 minutes and 30 seconds
- Taste test notes:
  - Chewy, cooked throughout
  - Stiff/crunchy
  - Thinner than control group, thicker than batch 3

Good if you like a thinner cookie

Batch 8: 100% White sugar

- Baking time: 6 minutes
- Taste test notes:
  - Less flavorful
  - Crunchy
  - Light color
  - Thinnest cookie

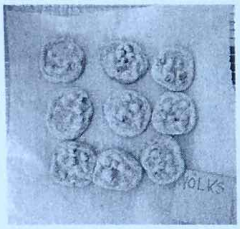
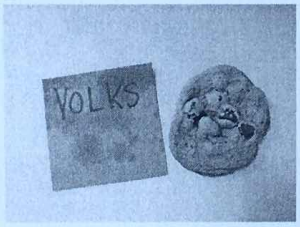
missing out on the honey/ molasses flavor in brown sugar


Batch 9: Just egg yolks

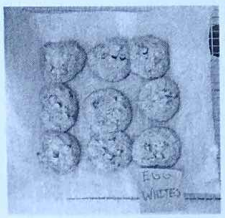
- Baking time: 7 minutes and 30 seconds
- Taste test notes:
  - Second thickest
  - Crisp outside, soft inside

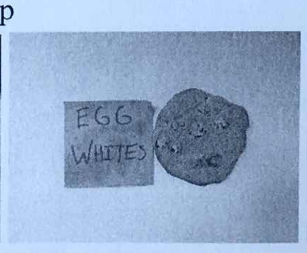
My personal favorite :)

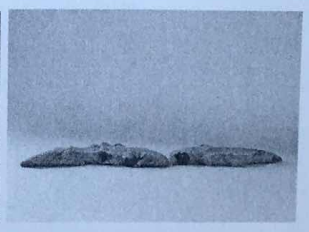




Batch 10: Just egg whites

- Baking time: 6 minutes 45 seconds
- Taste test notes:
  - Crisp/dry
  - Thinner than control group







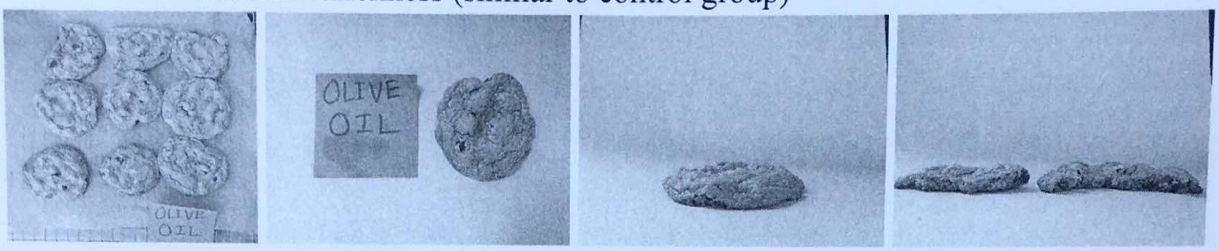
Batch 11: Olive oil replaces butter

- Baking time: 6 minutes and 30 seconds
- Taste test notes:
  - Shiny and wrinkled outside
  - Savory taste

- Smooth texture
- "It looks like my grandma"(Leo)... "it kind of tastes like her too"(Julia)

You know that you have artists as your taste-testers when you get comments such as this.

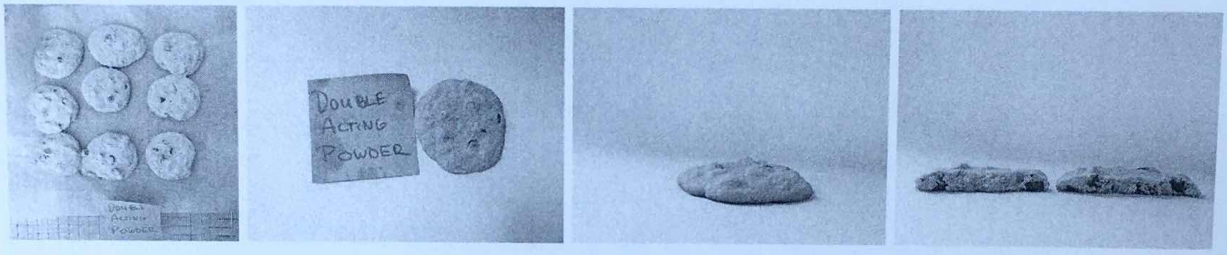
- Medium thickness (similar to control group)



Batch 12: Double acting powder replaces baking soda

- Baking time: 7 minutes
- Taste test notes:
  - Soft texture
  - Thickest cookie

The "cakey-est" batch



Discussion/Conclusion:

Hypotheses vs. Results:

Batch 1: Control group

This group of cookies followed the original recipe. They had a medium thickness, typical flavor, and soft texture. The following observations for these batches are in comparison to the control batch.

Batch 2: Non- Preheated Oven (starting in a cold oven)

For this batch, I hypothesized that these cookies would be flatter than the control batch because of butter's sharp melting point, which would cause the cookies to spread. This hypothesis proved to be correct. These cookies were also drier than the control group cookies, likely due to their extended baking time.

Batch 3 and 4: Baking at 325 degrees and 350 degrees

For these batches, I predicted that the cookies would be flatter than the control group. Similar to baking the cookies without a preheated oven, the sharp melting point of butter caused the cookies to spread. This hypothesis proved to be correct, for both batches created thin cookies. The batch baked at 325 degrees was thinner than the cookies baked at 350. This is likely due to the increased baking time for the cookies baked at 325. The extra time in the oven is what causes the butter's sharp melting point to affect the cookies, thus making batches 2, 3,

and 4 all thinner than the control group. The thinnest cookie among these batches was the one baked the longest (325 degrees, baked for 9 minutes).

less time for butter to melt = thicker cookie

Batch 5 and 6: Baking at 400 and 425 degrees

In these batches, I hypothesized that the cookies baked at higher temperatures than the control group will have crispier edges and soft middles due to convection heating. This hypothesis was accurate. It is also important to note that these cookies were thicker. This is likely because of the short baking time for these batches, which did not allow for the butter to melt and spread the cookie.

Batch 7: 100% Brown sugar

I hypothesized that the cookies baked with 100% brown sugar would be chewier, thicker, and softer. Brown sugar is slightly acidic, allowing it to react with baking soda and make carbon dioxide bubbles. Because acid is the limit in the reaction, the extra acid content gave these cookies more carbon dioxide bubbles. This factor gave this batch of cookies their soft chewy texture. This batch was, however, not as thick as predicted. I had previously hypothesized that the cookies would be thicker than the control group, but they turned out to be the same thickness. This may be due to the lack of aeration in the cookies. When the butter and sugar are whipped together, the mixture becomes aerated. Brown sugar is more dense than white sugar and it more water-absorbent. Because of this factor, the butter-sugar mixture in this batch was not able to whip as well, thus losing some aeration in the cookie dough.

Batch 8: 100% White sugar

I hypothesized that the cookies with only white sugar would be flatter and crispier. Without the reaction between the baking soda and the acid in brown sugar, the cookies did not receive the carbon dioxide bubbles that act as the leavening agent. This hypothesis proved to be correct. This batch created the thinnest and most crisp cookies in the experiment. It is also important to note the color of these cookies. Without the dark pigmentation of brown sugar, these cookies were the lightest in color.

My least favourite batch. Lacking flavour & chewiness

The most American, meaty texture.

Batch 9: Just egg yolks

For this batch, I hypothesized that cookies baked with only egg yolks would have a darker color and a dense, chewy texture. This hypothesis proved to be mostly correct. The cookies did have a dense and chewy texture, but the color of the cookies was not significantly darker. This is likely due to the strength of the brown sugar pigmentation on comparison to that of the eggs yolks. The pigmentation in brown sugar is more intense, thus overriding the effects of the egg yolk.

Batch 10: Just egg whites

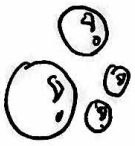
For the cookies with only whipped egg whites, I hypothesized the cookies would be lighter in color, feel lighter, and have a stiff to dry texture. This hypothesis was mostly correct. This cookies did have a light feeling and a dry texture, but the color was not affected much, for the same reason as the egg yolk batch.

Batch 11: Olive oil replaces butter

Wonderful if you like olive oil. Healthier too.

In this batch, I hypothesized that cookies made with olive oil would have a more bitter taste and be flatter. This hypothesis proved to be mostly true. The flavor in these cookies was much more bitter than the control group. The flavonoid polyphenols in the olive oil created a savoury aspect in these cookies. The cookies were not as thin as expected. The dough for these cookies was less viscous than the control group, but the cookies did not spread as much in the oven. Because there was no butter melting in the oven, this batch did not spread and get thin. This batch of cookies had a noticeably shiny and wrinkled texture. This is likely due to the lack of spreading in the oven, thus creating a wrinkled texture when the cookies cool. The nature of a liquid oil may have given these cookies their shiny appearance. Liquid oils act as a tenderizer in baking, coating flour and aiding in the process of gelatinization, thus giving the cookies a shiny exterior.

Batch 12: Double acting powder replaces baking soda



I hypothesized that the addition of double acting baking powder would create cookies lighter in color and have a fluffy texture due to the addition of acid. This hypothesis was correct. The batch of cookies was noticeably lighter in color than the control group, as caused by the acid content of cookie. These cookies were the thickest of any batch, also due to the acidic content.

Possible Sources of Error:

- The softness of the butter was not consistent in each batch
- The temperature of the pan was not completely consistent
- Heat fluxuations in the oven
- Size of the eggs was not perfectly consistent

Further Experimentation:

There are many more variables present in chocolate chip cookies that I was unable to test during this experiment. These variables include:

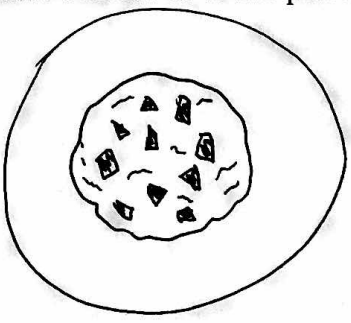
- Testing different pans (different types of metal, ceramic, glass)
- Testing chemical properties that contribute to preservation
- Testing different flours
- Addition of ingredients, rather than substitution

The "Best" Cookies:

There are more takeaways from this than new chemistry knowledge and 250 cookies: learning how to manipulate a cookie recipe to one's liking. Personally, I prefer cookies that are thick and chewy. Using this experiment, I have created a new recipe to make cookies fit to this preference:

Ingredients:

- 6 ounces Semi-Sweet Chocolate Baking Chips
- ½ cup butter, softened (2 sticks)
- 2.2 ounces cup sugar
- 3.1 ounces cup brown sugar, packed
- 3 egg yolks (about 2 ounces)
- 1 teaspoons vanilla
- 4.7 ounces cups unsifted flour
- ½ teaspoon baking soda



- ¼ teaspoon cream of tartar
- ¼ teaspoon salt

Directions:

- Heat oven to 400°F.
- Stir flour with baking soda and salt; set aside.
- In large mixing bowl, beat butter with sugar and brown sugar at medium speed until creamy and lightened in color.
- Add eggs and vanilla, one at a time. Mix on low speed until incorporated.
- Gradually blend dry mixture into creamed mixture. Stir in chocolate chips.
- Drop by tablespoon onto cookie sheets lined with parchment paper.
- Bake for 4-6 minutes or until edges appear golden brown.

If one prefers a crispier cookie, they can bake it at a lower temperature and for a longer period of time. They can also adjust the brown to white sugar ratio by adding more white sugar and a bit less brown sugar.

<u>Personal Reflection:</u>

Through my years of cooking experience, I have grown to associate 5 key components to food and cooking:

I. Bringing People Together: Let's Break Bread

Food and cooking can string people and families together. I am not afraid to admit that I have attended parties and gatherings only for the food, but in doing so discovered new companionship. Food can act as a platform for company and relationship building. What is a wedding without a cake?

II. Independence

I define independence as having the skills and resources to take care of oneself. To be able to cook and nourish the body is independence.

III. Coping Mechanism

Anxiety can distract one from the present moment; it makes one far more concerned with the future. With anxiety, it is difficult to sift through the multiple layers of fears and focus on one thing. One can feel as if they have no control over their life and environment. In cooking, one defines their role in the habit of the kitchen. One is given the ability to have control. Cooking allows you to decide what happens to your body. The meditation aspect I find in cooking appears in this association as well.

IV. Meditation

I view meditation as a practice in which I attempt to clear my mind of thought. If there is a thought that I cannot escape from, I allow it to stay and focus solely on it. I addressing its significance and decifier why my brain is occupied with it, and thus resolve it. In cooking, one can find themselves doing repetitive motions, methodical work, and practicing their patience. Each of these grants the chef with a platform to focus on one thing and the time to reflect.