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Differences in Leavening Between Chemical and Biological Leaveners

Abstract

This study is an experiment into examining the differences that chemical and biological leaveners have on the final product of a baked good. To accomplish this, three recipes of bread (each with a different leavener (baking soda, baking powder, and yeast)) were baked with a standardized amount of dry ingredients. After baking these loaves were measured to find their overall density, and then later these densities were compared between recipes. The initial hypothesis was that biological leaveners would be better at leavening compared to chemical leaveners due to the biological leavening process that takes place. After baking 9 different bread loves and conducting a one-way ANOVA test, we concluded that there was a significant difference in density when the biological leaveners were compared to the chemical leaveners. This aligns with previous research indicating that biological leaveners incorporate more gas into bread doughs.

Introduction

Leaveners have been used in baked goods since the times of Ancient Egypt [2], but how much is really known about the properties of leaveners? This paper will explore how different leavening products can affect the overall texture and density of baked goods by comparing some common home leaveners and their respective baked goods. Although there has been much previous research on specific leaveners and their properties [1], not much peer-reviewed research has been done on comparing the differences that arise in baking from using specific leaveners instead of others. This experiment aims to solidify the effects of using certain leaveners compared to others by trying to maximize the chemical processes that arise from these leaveners while keeping ingredient volumes consistent across the trials.

Because of previous research [1], we should believe that if a leavener reacts more within a dough to create air bubbles, then the bread will have a larger volumetric area (cm^3) once baked because more air bubbles will be present inside the dough to help it expand outwards. And due to the biological mechanism of yeast as a leavener, we should expect yeast leavener to create larger loafs than chemical leaveners.

Methods and Materials

Materials used for baking:

All-purpose flour	Salt	Butter	Baking Soda
Granulated white sugar	Water	Buttermilk	Bread Yeast
Rectangular loaf-pan	Tin foil	Milk	Baking powder
Whisk	Rubber spatula	Oven	Oil

Each loaf of bread is baked in a specific manner to maximize the leavener's potential reaction, but all recipes use the same amount of flour, sugar, salt, and oil. In order to maximize each leaveners chemical reaction potential, differences are made in the kind of liquids used in each bread, but volumes of liquids used are consistent. To further standardize each loaf, dough is weighed before baking.

Bake each of the following breads using the same loaf-pan for each loaf of bread:

1. ***Bread using Yeast as a leavener*** [5]

In a large bowl, whisk together ¼ cup of whole milk (warm), 1 cup of water (warm), 2tbsp of sugar, and 2.25tsp of bread yeast. Cover and let sit for 5 minutes. Next, add ¼ cup of melted butter to the yeast mixture along with 1tsp of salt and 1 cup of flour. Mix everything together with rubber spatula until mildly incorporated, then add another cup of flour. Repeat once more adding the final third cup of flour. Take the dough out of the bowl onto a cleaned work surface and knead by hand for 2-3 minutes. Once fully kneaded, grease another large bowl with oil and place the dough inside making sure to coat all sides of the dough in oil. Cover and let sit in a warm place for 1-2 hours until the dough has doubled in size. Finally grease the loaf-pan with oil, take the dough out of the bowl and punch out some of the air from the dough, and then place it into the loaf-pan. Let it rise again in the loaf-pan for another hour until it is almost rising out of the loaf-pan. Bake at 350F for 30-35 minutes until the top is golden brown. Remove and let cool for 20 minutes before removing and measuring volume.

2. ***Bread using Baking Soda as a leavener*** [4]

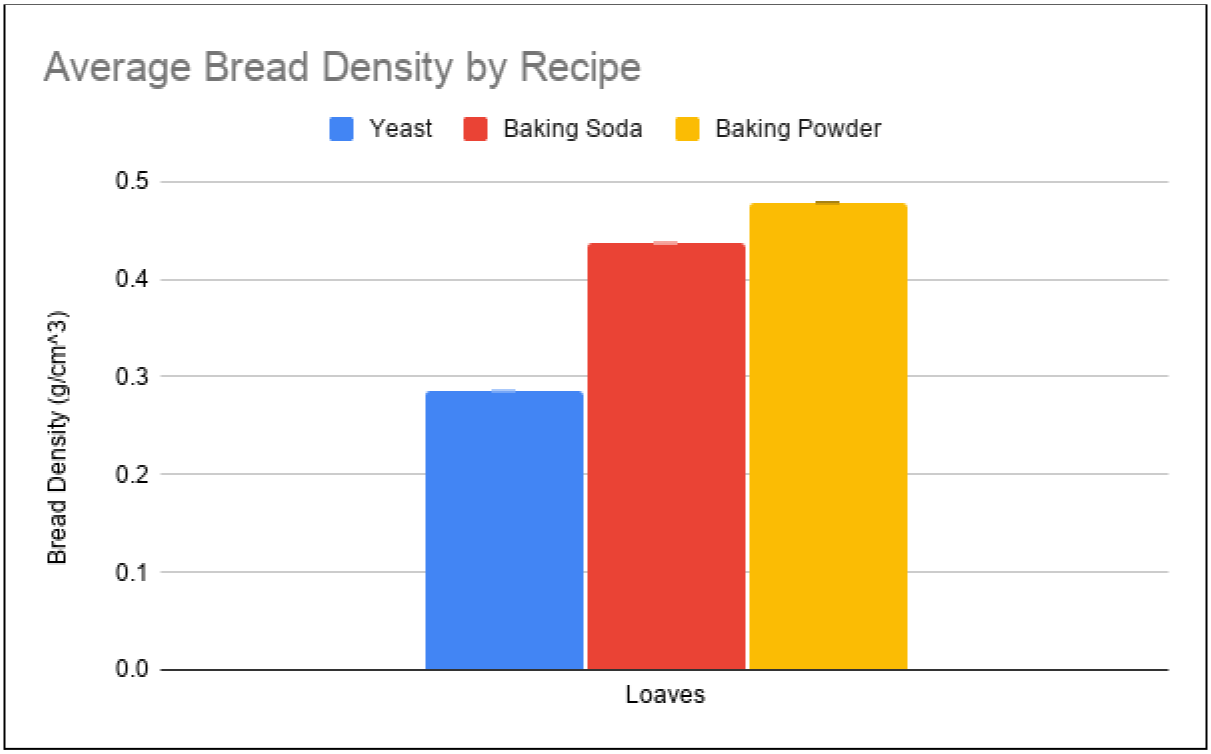
Whisk together 3 cups of flour, 1tsp of salt, 2tbsp of sugar, and 1.5tsp of baking soda in a large bowl. Next, pour in ¼ a cup of melted butter and whisk together again. Slowly mix in 1 and ¾ cups of buttermilk until a shaggy dough forms. Once formed, pour out onto a clean work surface and knead into a ball. Form this ball into the shape of the loaf tin and place inside after greasing the tin. Bake the bread at 400F for 45 minutes, covering with tin foil halfway through to prevent burning on the top. Remove from the oven and let cool before removing from the tin and measuring volume.

3. ***Bread using Baking Powder as a leavener*** [3]

Whisk together 3 cups of flour, 1tsp of salt, 2tbsp of sugar, and 8tsp of baking powder in a large bowl. Next, slowly pour ¼ a cup of oil and 1 and ¾ cups of warm milk into the dough and mix together until flour is fully incorporated. Immediately after, scrape dough into the loaf-pan using a rubber spatula. Bake the bread for 30 minutes at 430F. Then remove from the oven, cover with tinfoil, and put back in the oven at 390F for 20 minutes. Take the bread out and let cool before removing from the tin and measuring volume.

Once each loaf of bread is baked and cooled, they will be measured for their volumetric areas. Weighing of a standardized volume of each bread will also be done at this stage to determine relative density of the loaf compared to the others. These two readings should give an excellent indication of if different leaveners have different effects on a bread's composition. After acquiring raw data, perform a single factor ANOVA test on the Bread Density using Excel's ANOVA functionality to determine significance.

Results



*(**Figure 1:** The Average Bread Density of all baked loaves (g/cm^3) grouped based on which bread recipe and leavening type was used (n=3, 3, 3))*

*(**Figure 2:** Photos of some bread loaves showing the overall shape and texture of each loaf of bread. a) Baking Soda. b) Yeast. c) Baking Powder.)*

Each of the three recipes was baked three separate times, totalling to 9 different bread loaves. The volume and weight of each loaf was measured and the averages for each are displayed above in Figure 1. Alongside these two measurements, a third variable was calculated to give each loaf a density ratio (g/cm^3), which we will refer to as 'Bread Density'. The average Bread Density was also calculated and is displayed above in Figure 1.

Because of this relatively low sample size, there is not much variance inside each experimental group's data. Each recipe had a variance that was less than 0.001BD (BD=Bread Density), indicating that each group's loaves had similar density between baking attempts.

After performing a one-way ANOVA test on the raw BD data using a significance value of ($p < 0.05$), it was found that there is a significant difference in bread density between the three recipes. This statistical conclusion comes from a relatively high F value of $F = 55.1$ (which indicates that there was significant variation between the experimental group's means), and a low p-value of $p = 0.00013$ which is far below the required significance level.

Discussion

Because of the results of the statistical test, which indicate significant variation between experimental groups, we can conclude that the type of leavening that is used in a baked good has a significant impact on the final density of the baked good. Therefore, because of the low Bread Density of the yeast bread compared to the baking soda and baking powder bread, we can conclude that biological leaveners such as yeast incorporate more gas into bread doughs than chemical leaveners.

This conclusion is consistent with our initial hypothesis that biological leaveners would incorporate more gas into the dough when compared to chemical leaveners because of its leavening mechanism. But what is this biological mechanism that allows for yeast to outperform chemical leavening alternatives? The answer comes in the form of the alcoholic fermentation process.

The alcoholic fermentation (also known as ethanol fermentation) process is a biological process in which an organism converts sugar molecules (such as glucose, sucrose, and fructose) into pyruvic acid through glycolysis, and then those pyruvic acid molecules into ethyl alcohol and carbon dioxide gas [6]. Yeast organisms use this process to acquire more energy and to grow, so they are constantly absorbing sugars and producing carbon dioxide and alcohol. This means that as the yeast colony grows, it produces more and more gasses.

That is why in the procedure we let the yeast bread rise for almost 2-3 hours before baking. This long timespan before baking allows the yeast to grow and produce gas through the alcoholic fermentation process inside of the dough. The longer time to let it rise, the more gas that is eventually incorporated into the dough through fermentation, and thus the lower the bread density will be. This is also why the baking soda and baking powder breads didn't have as low of a density. These chemical leaveners, when put into the dough, react with acids in the dough to create gasses. Once all the base has reacted with all the acid, there is no more gas to be created, and thus there is a finite amount of gasses that can be incorporated into the bread.

Overall, these findings are consistent with previous research, but future experimentation could be done to determine intricacies of each leavener. Although we have determined that biological leaveners are more effective at incorporating gas into bread loaves, we did not do any other tests on other baked goods. To fully conclude that biological leaveners are the most effective leaveners for incorporating gas into baked goods, more tests should be carried out under similar parameters to this one but with different baked goods being baked. This type of test could be utilized to conclude the overall effectiveness of chemical vs biological leaveners in a variety of baked goods, and could possibly determine the benefits of using certain leaveners in certain situations. This type of future experimentation could also benefit from an increase in sample size compared to the relatively small sample size of this experiment.

In conclusion, biological leaveners produce less dense loaves of bread as they allow for more gasses to be incorporated into the dough compared to chemical leaveners.

<u>References</u>

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<u>Appendix</u>

Bread Density

Bread Density	Yeast	Baking Soda	Baking Powder
Loaf 1	0.2858	0.4589	0.4485
Loaf 2	0.2748	0.4484	0.4979
Loaf 3	0.2978	0.4042	0.4896

Bread Weight

g	Yeast	Baking Soda	Baking Powder
Loaf 1	787	831	882
Loaf 2	804	823	860
Loaf 3	779	848	873

Bread Volume

cm3	Yeast	Baking Soda	Baking Powder
Loaf 1	2753.03	1810.77	1966.45
Loaf 2	2925.09	1835.35	1727.2
Loaf 3	2615.38	2097.54	1782.91