

Independent Research Project

Change in Height of Breads Baked by Different Type of Leavening Agents

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Abstract

Leavening is an inevitable and natural outcome in process of baking breads regardless of having chemical agents in the dough or not. Leavening causes gas bubbles that soften and rise the dough. The gas bubbles produced are mostly carbon dioxide or water vapor. Leavening agents are largely classified into three categories: chemical, biological, and mechanical. In this research five different leavening agents are tested throughout the baking process of bread to find out which leavening agents rise the dough more. The five leavening agents used in this experiment are air, baking soda, instant dry yeast, egg whites, and sourdough starter. This baking experiment is done over one week with a hypothesis that if five leavening agents are categorized into different characteristics of leavening process, then there will also be certain differences in the change of the height of each leavening agent type. Baking ingredients are limited to 400g of all-purpose flour, 240g water, and 8g salt to prevent any possible variables that may affect the results. The results are recorded by measuring the height of the dough center before and after the baking to obtain the change in height. Bread baking processes are conducted twice per each leavening agent to get a mean value of the change in height. In order to compare the height change of breads from five leavening agents and test the hypothesis of statistically significant difference of the height change, one-way ANOVA analysis is performed by GraphPad Prism 8. The result from a one-way ANOVA shows a $p\text{-value} < 0.0001$ ($p < 0.05$), therefore it indicates that the results have statistically significant difference in each group. Furthermore, a Tukey Test, post-hoc test, is performed to find out whether these significant differences from the ANOVA results are mutual among each group. According to the Tukey Test results, each leavening agent has statistically significant differences amongst others except for sourdough vs instant yeast. Further research may be required to test the leavening in more controlled and highly limitation-prevented environment would show same results from multiple types of leavening agents.

Introduction

One of the most essential factors in baking is leavening. Leavened bread has been regarded as well baked and qualified bread since human being had noticed about baking. Leavening is the expansion process of doughs by gas molecules occurred through different chemical reaction (Alfaro, 2020). Two main leavening reactions are done by carbon dioxide (CO_2) gas and water vapor gas (H_2O). They occur via different types of chemical reactions but one simple thing they share is the dough rises more as more gas occurs.

The goal of this experiment is to determine which type of bread leavening agents make more rise among numerical leavening agents (Encyclopedia Britannica, 2019). This is aimed to bake breads with five typical leavening agents: air, baking soda, eggs, instant dry yeast, and sourdough starter to compare how each agent affects the leavening height of bread after baking. Amongst numerous leavening agents, they are categorized within three types which are chemical, biological, and mechanical.

A typical chemical agent is baking soda which releases carbon dioxide as it works with heat or moisture. Biological leavening agents digest sugars to produce carbon dioxide through fermentation process and typical agents are yeast and sourdough starter. Mechanical leavening agents have rather simple mechanism as they release gas which is trapped in the dough. An example of mechanical agent is eggs, in this case beaten egg whites (Ozimek, 2014). Air and eggs use the mechanism of water vapor whereas baking soda, instant yeast, and sourdough starter use the mechanism of CO_2 gas.

In case of air and eggs, while the dough is exposed to high heat in the oven and approaches to water boiling point, moisture that was trapped or contained in the dough becomes evaporated and water turns into steam.

Baking soda is commonly used with vinegar as a leavening agent. When baking soda reacts with vinegar, it produces carbon dioxide. Vinegar generally contains 5% of acetic acid (CH_3COOH). When the acid reacts with the base, in this case baking soda, also known as sodium bicarbonate (NaHCO_3), CO_2 is produced. Produced CO_2 gas leavens the dough to increase its height. This is general acid-base chemical reaction of producing CO_2 gas

(Helmenstine et al., 2020): $\text{NaHCO}_3(\text{s}) + \text{CH}_3\text{COOH}(\text{l}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) + \text{Na}^+(\text{aq}) + \text{CH}_3\text{COO}^-(\text{aq})$

Yeasts are single cell organisms that consume simple sugars, monosaccharides which include glucose, and break them down into alcohol and carbon dioxide (CO_2) through a chemical mechanism called fermentation: $\text{C}_6\text{H}_{12}\text{O}_6 (\text{aq}) \longrightarrow 2\text{C}_2\text{H}_5\text{OH} (\text{aq}) + 2\text{CO}_2 (\text{g})$

Instant dry yeast is designed to actively digest glucose from flour to produce CO_2 gas. As this gas is formed the dough rises with its volume and height (Lawandi, 2015).

Sourdough is the most ancient type of baking bread and sourdough starter is a fermented mixture of flour and water which enables the sourdough bread being fermented with naturally contained wild yeast and lactic acid bacteria (Hamelman, 2004). These natural yeasts metabolize glucose and maltose from starch of flour to produce carbon dioxide (CO_2) gas, leavening the dough. The fundamental chemical mechanisms of producing CO_2 gas is same as the instant yeast. Since these yeasts are naturally occurring, they need a longer amount of time for leavening, approximately 12 hours in total, compared to commercial instant yeast because the wild yeasts are less active (Peterson, 2002).

Since each leavening agent uses different biological, chemical, and mechanical mechanisms to rise the bread dough, the height change will show certain difference between breads using different types of leavening agents. Thus, this hypothesis can be put as the change in height of the bread will show significant difference between different leavening agents.

Method

Five different leavening agents are tested: air, baking soda, eggs, instant yeast, and sourdough starter. Ingredients for baking are limited to all-purpose flour, water and salt in order to minimize the possible variables which may affect the differences in leavening. Every bread except for sourdough starter has 400g of flour with 240g of water and 8g of salt as basic ingredients. According to Michael Ruhlman's book, he mentions the proportions of the ingredients as 5:3, flour to water with two percent (2%) of salt (8g) to the weight of the flour. Every baking process is done twice per each leavening agent in order to obtain the mean

values of the change in height.

Baking with air as a leavening agent is conducted with three basic ingredients. Measure the height at the center of the dough before putting the pan into oven and place the pan in the 400 °F oven for 30 minutes. After baking is done, measure the height at the center of the dough again.

Baking with baking soda is also conducted with 400g flour, 8g salt, and 172g water with 1 teaspoon of baking soda (4.8g) and 68g of vinegar, the molar balanced amount to the baking soda so that 172g water plus 68g vinegar becomes 240g of liquid. This molar balanced amount of vinegar to baking soda was referred from the Cake Lab of Lab 3. The batter is then placed in a loaf pan, the height at the center is measured before and after baking in the 400 °F oven for 30 minutes.

Baking with eggs has 400g flour, 8g salt, 106g of egg white, and 134g water so that sum of egg white and water comes to 240g of liquid. Egg white are beaten well before it gets mixed with other ingredients. Once the dough is well mixed, place it in a loaf pan, the height at the center is measured before and after baking in the 400 °F oven for 30 minutes.

Baking with instant yeast is as simple as air. Mix 400g flour, 240g water, 8g salt, and 1 teaspoon of instant dry yeast (3.1g) together. Once the dough is well mixed, place it in a loaf pan, the height at the center is measured before and after baking in the 400 °F oven for 30 minutes.

Baking with sourdough starter has an exceptional process since it uses 230g of sourdough starter as a leavening agent, therefore this baking process requires longer time. Mix 400g water, 8g salt and 240g water with the 240g starter. Then the dough needs a couple of turning and a couple of kneading processes with 30 minutes of resting in between each process plus additional 6 hours of fermenting time. The oven temperature needs 430 °F with 45 minutes. Measure the height of the dough center before and after baking.

After the five baking processes are done, calculate the change in height of the dough center for each leavening agent. Then the collected data are analyzed to test the hypothesis that there is a significant difference between leavening agents. Statistical analyzing method is

called one-way ANOVA which analyzes the differences between the means three or more independent groups (Kim, 2002). This is performed using GraphPad Prism 8 software to obtain F and p-value and this allows us to determine whether the differences among the means of group are greater than the expectation. The hypotheses of these statistical results tell whether it would have statistically significant differences based on the p-value of 0.05 ($p < 0.05$). If the ANOVA test gives significant results, this may require another step called Tukey Test, a post-hoc test. This test enables to see if these significant results have the interaction among each group is mutually significance (Glen, StatisticsHowTo.com)

Results

Each leavening agent baking process was done twice in order to reduce the variables of single test bias.

	Air	Baking Soda	Instant Yeast	Egg	Sourdough
1st Baking	1.0	3.3	4.1	1.9	4.5
2nd Baking	0.9	3.4	4.4	2.1	4.5

Table 1: The height changes of the dough center for each leavening agent before and after the baking. Units in centimeter (cm)

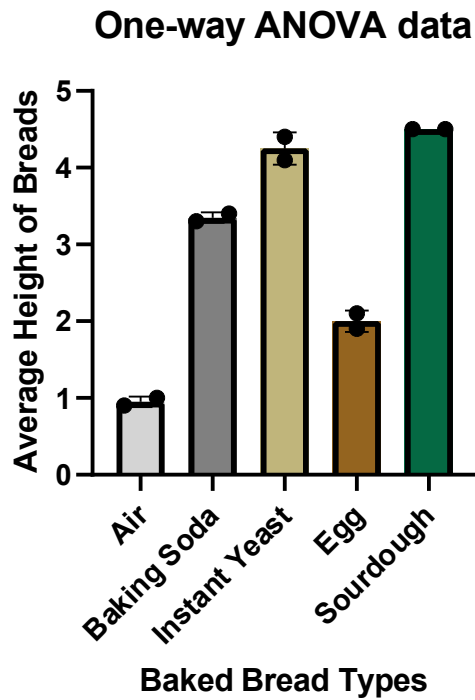


Figure 1: Average height changes of each bread. Air, baking soda, instant yeast, egg, sourdough with 0.95 cm, 3.35 cm, 4.25 cm, 2.0 cm, 4.5 cm respectively. As seen in figure 1, air has the lowest average height change while sourdough has the highest average height change.

The collected data for each leavening agent were then analyzed by GraphPad Prism 8 to perform the ANOVA analysis and to obtain F and p-value.

ANOVA Summary	
F	304.6
P Value	<0.0001
R squared	0.9959

Table 2: One-way ANOVA analysis summary with F, p-value, and R squared from baking with different leavening agents

P value has a result of $p < 0.0001$ which was much less value than 0.05 ($p < 0.05$).

Tukey's multiple comparisons test	Mean Diff.	95.00% CI of diff.	Significant?	Summary	Adjusted P Value	
Air vs. Baking Soda	-2.400	-2.891 to -1.909	Yes	****	<0.0001	A-B
Air vs. Instant Yeast	-3.300	-3.791 to -2.809	Yes	****	<0.0001	A-C
Air vs. Egg	-1.050	-1.541 to -0.5587	Yes	**	0.0019	A-D
Air vs. Sourdough	-3.550	-4.041 to -3.059	Yes	****	<0.0001	A-E
Baking Soda vs. Instant Yeast	-0.9000	-1.391 to -0.4087	Yes	**	0.0039	B-C
Baking Soda vs. Egg	1.350	0.8587 to 1.841	Yes	***	0.0006	B-D
Baking Soda vs. Sourdough	-1.150	-1.641 to -0.6587	Yes	**	0.0013	B-E
Instant Yeast vs. Egg	2.250	1.759 to 2.741	Yes	****	<0.0001	C-D
Instant Yeast vs. Sourdough	-0.2500	-0.7413 to 0.2413	No	ns	0.3647	C-E
Egg vs. Sourdough	-2.500	-2.991 to -2.009	Yes	****	<0.0001	D-E

Figure 2: Tukey's Test to check whether the result of ANOVA analysis ($p < 0.0001$) has mutually statistically significant differences among each leavening agent. Each group has statistically significant differences with only exception of instant yeast vs. sourdough starter ($p = 0.3647 > 0.05$).

Discussion

As the ANOVA analysis results come with the P value of $p < 0.0001$, which is less than 0.05 ($p < 0.05$), it can reject the null hypothesis: the change in height of the bread will show no difference between different leavening agents.

As ANOVA shows the statistically significant difference among the leavening agents, Tukey Test, the multiple group comparisons test is required to indicate the comparison of the change in height between each leavening group. Tukey Test shows there is a mutually statistical significance between each group (Figure 2) except for instant yeast vs. sourdough as it has a p-value of 0.3647 ($p > 0.05$). This means the leavening function of instant dry yeast and sourdough has no statistically significant difference from each other in terms of the change in height, although their p-values are slightly different (Table 1), but it also indicates that sourdough starter and instant yeast has meaningful statistically significant differences of the change in height in compared to other leavening agents.

This may refer to chemical leavening agents such as instant yeast and sourdough starter are likely to make the dough rise higher than other types of leavening agents. This also may be due to the net molecular amount of leavening agents function of producing leavening gas. Eggs have limited capacity of trapping the air bubbles by total weight of eggs used, and baking soda with vinegar also has limited capacity of producing CO_2 gas depending of their balanced amount used. Instant yeast and sourdough starter, on the other hand, are fed by glucose from starch to produce CO_2 gas, so they may tend to have more capacity of leavening

the dough. This consumption would be another start point of hypothesis for broadening the research.

This contrasts with the experimental results done by Manthey, the largest increase in height was yeast and baking soda. Also, the sourdough starter and the air showed the lowest leavening in his results. However, his experiment was purely gone by height, size and the volume measurement about the leavening agents without any statistical analysis. Thus, further research to test about the height change affect done by leavening agents is required to test in more variable-controlled environment.

Also, each leavening agents were tested only twice to obtain average values, therefore larger number of trials should bring more reliable means of each group. Moreover, each leavening agent weight was not identical, baking time was not identical due to the specificity of sourdough starter recipe, but only the best controlled quantity was identical amount of flour and liquid. These arguable procedures may had affected the results of the height changes, and it would be another limitation to be improved in further research. If this experiment would be performed in sufficiently controlled environment, more accurate value of leavened bread height by different type of leavening agents would be expected as well.

Conclusion

There was certain statistically significant difference among the leavening agents, and there was also mutually significant difference as ANOVA analysis and Tukey Test indicated. This shows that the hypothesis which stated the change in height of the bread will show difference between different leavening agents may correct. Although it means this result rejects the null hypothesis and fails to reject the alternative hypothesis, there were limitations and uncontrolled variables. The properly controlled experimental environment will allow us to overcome those variables in further experiment.

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