The Effect of Different Leavening Agents on the Volume of the Produced Cake

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Abstract

Chemical leavening is a process that is utilized in many baked goods in order to develop the properties that make them so coveted. Volume is one of the properties of a cake that can determine its quality. Leavening agents can help determine the final volume of a cake depending on which agents are used. In this investigation we conducted samples consisting of 3 different combinations of leavening agents in order to determine their effect on the volume of cakes. Our combinations consisted of (1) citric acid and baking soda, (2) baking powder as a stand-alone, and (3) vinegar and baking soda. Mean volumes were found to be 1537 cm^3, 1742 cm^3, and 1184 cm^3 respectively. Statistical analysis determined a significant difference ($P<0.05$) between the volumes of each sample. Samples that used baking powder as the leavening agent produced the highest calculated volume per cake falling within expectations. Citric acid and baking soda also produced higher volumes than vinegar and baking soda which was used as a control group. In order to determine optimal conditions to produce a cake of quality, other properties other than volume must be investigated, however baking powder shows great promise towards producing the most volume per cake.

1. Introduction

Bakery goods are an integral part of many cultures around the world often shared during celebration. Cakes are arguably the most famous desserts among bakery goods and therefore are important in regards to optimizing its quality. Chemical leavening is a process that involves the reaction between an acid and a bicarbonate to facilitate the release of carbon dioxide gas (Brodie & Godber, 2007). The gas is used for aeration of the batter during the baking process which gives light fine-grained structure that is seen in most cakes. The acid allows the bicarbonate to release CO_2 gas upon contact with moisture. Baking powder acts as a complete leavening system as it contains the bicarbonate and acid components all in one.

Double-acting baking powder, a prevalent component in almost all cake recipes, will produce CO_2 gas twice during the baking process. Once when added to a liquid, and another when exposed to heat. Outside of baking powder, other combinations of leavening agents can

be substituted in to achieve the same result. In terms of an acid, the reactivity and temperature at which the acid will react determines its ability in leavening for cakes.

Qualities of cakes can be evaluated visually by its volume, contours, and texture. Leavening agents play a role in determining the final height of a cake after the baking process. In order to determine the extent at which leavening agents play a role in producing the final height, and thereby volume, of a cake, we conducted an investigation of different combinations of leavening agents. The objective of this study is to evaluate the optimal leavening agents to use in cake production in terms of highest volume per cake. Previous studies from Pop (2007) suggested that lack of baking powder resulted in poor volume of cakes. Therefore we can expect that our sample with baking powder will yield the highest mean volume.

2. Methods

For this investigation we used King Arthur's Original (Hamel, n.d.) cake recipe as a baseline and substituted 1 tablespoon vinegar and 1 teaspoon baking soda with combinations: (1) citric acid and baking soda, (2) baking powder. However ingredients such as cocoa powder and espresso are excluded in order to minimize potential points of error on leavening agents and final volumes examined.

2.1 Measurements of leavening agents

Samples containing the combination of citric and baking soda consisted of approximately 195.15 mL of freshly squeezed orange juice with 45 mL cold water. Amount of baking soda used followed the amount suggested in the recipe: 1 teaspoon. All other ingredients followed the suggested amount in the recipe with the exception of water as our orange juice contained citric acid and water.

Our rendition of baking powder substituted for baking soda+vinegar saw that we utilized 3 teaspoons of baking powder with 1 cup of water. Other ingredients are kept consistent with the recipe and other samples.

Our third sample served as our control (vinegar + baking soda) and it strictly followed the recipe with the exclusion of cocoa powder and espresso.

2.2 Cake preparation

For the formulation of cakes, a batter consisting of 180g of all-purpose flour, 198g of sugar, ½ teaspoon of salt, 1 teaspoon of vanilla, ⅓ cup vegetable oil, and measurements of leavening agents as previously mentioned was poured into a 9 inch cake pan. Batter mixes were whisked thoroughly until a consistent texture was seen. Each sample was repeated 3 times and placed into an oven heated at 350°F for 35 minutes each. This will reduce single-test bias.

2.3 Volume measurement

Observations were taken through the baking process. Upon completion of anointed time in the oven, each cake was carefully transferred to a separate medium in order to have measurements taken. Measurements of radius and height were recorded to allow for area and volume calculations.

2.4 Statistical analysis

Statistical treatment was carried out using a one-way ANOVA with type of leavening agents as a factor. A comparison of mean volume was implemented using a Tukey test with a

5% significance level. Data was also compiled into mean, standard deviation, and 95% confidence intervals.

3. Results

The mean volume for each sample was calculated (Table 1 and Figures 1 and 2). The control sample (vinegar and baking soda) has a mean of 1184.0167±101.4149223 cm^3. The second sample (orange juice and baking soda) has a mean of 1537.8533±154.9192733 cm^3, and the third sample (baking powder) has a mean of 1741.9967±211.1239286 cm^3.

Table 1: Mean, Standard Deviation, and 95% Confidence Interval of each leavening agent

	Sample size	**Mean (cm^3)**	**Std. dev. (cm^3)**	**95% (cm^3)**
Vinegar and Baking Soda (A)	3	1184.0167	40.825	101.4149223
Orange Juice and Baking Soda (B)	3	1537.8533	62.3634	154.9192733
Baking Powder (C)	3	1741.9967	84.9888	211.1239286

One-way ANOVA and Tukey tests were performed on volume to determine significance (Table 2 and 3). A p-value of 0.00013 was calculated from a one-way ANOVA test and Tukey test revealed critical values of 163.5371 for each pair.

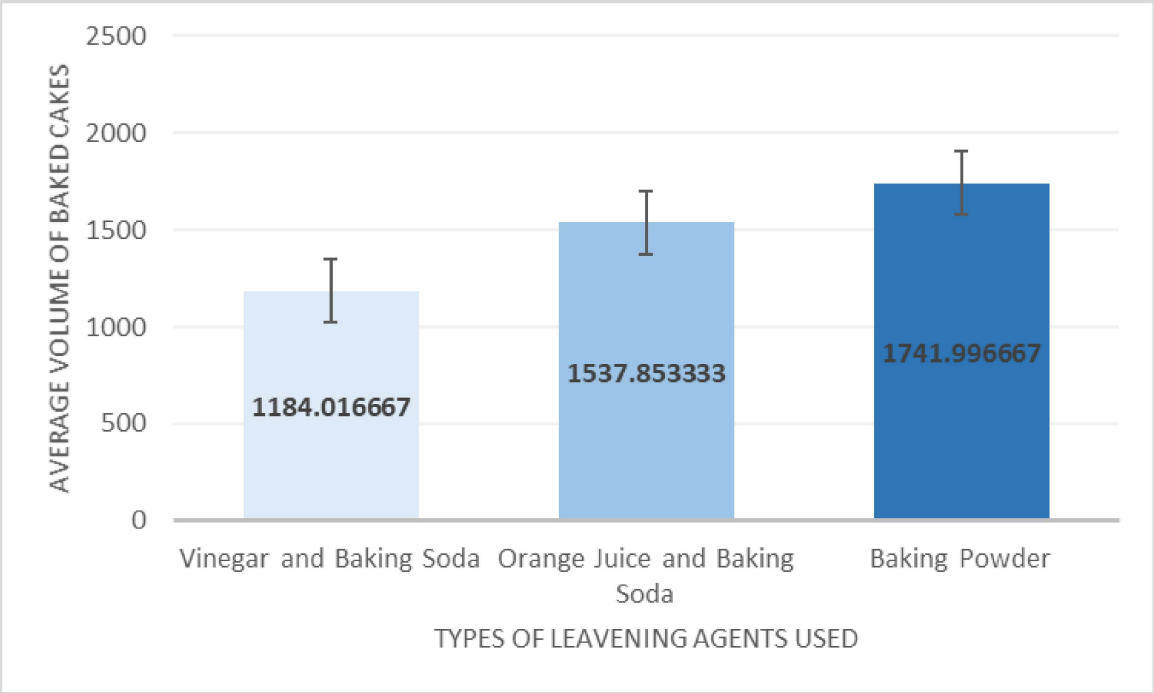

Figure 1: Bar graph with error bars comparing different combinations of leavening agents used in each sample and resulting mean volume (cm^3), (n=3). Error bar represents a 95% confidence interval.

Table 2: One-Way Anova Summary:

F-statistic value	**56.13323**
P-value	**0.00013**
Degree of freedom	**6**
Q-value	**4.34**
Mean Square MS	**4259.6568**

Table 3: Tukey Test / Honest Significant Difference

Pairs	**|mean1-mean2|**	**Critical value**	**Significant at 5%**
A-B	353.8366	163.5371	Yes
A-C	557.9800	163.5371	Yes
B-C	204.1434	163.5371	Yes

The colour and texture of the baked cakes also varied between each type of leavening agent. The vinegar and baking soda cakes were observed to be a light golden-brown colour and had no visible air pockets. The orange juice and baking soda cakes were a nice golden- light orange colour with crispy edges, more height, and visible air pockets. The baking powder cakes were a light yellow, had the most height and visible air pockets (Figure 2).

Figure 2. Cake Section of each sample for colour and texture analysis. The top picture shows sample A: vinegar and baking soda. The picture in the middle shows sample B: orange juice and baking soda. The picture at the bottom shows sample C: baking soda

4. Discussion

The results from this investigation indicate that the type of leavening agent used when baking a cake has drastically affected the outcome of the baked cake. For example, the cakes varied in height and volume for the three treatment groups: vinegar+baking soda, orange juice+baking soda and baking powder. In addition, the Tukey Test / Honest Significant Difference results indicate statistically significant size differences among the three treatment groups (Table 3). Furthermore, the results from the one-way ANOVA tests indicate a P-value of 0.00013 (Table 2), which is less than the alpha value of 0.05. Thus the null hypothesis can be rejected.

The initial prediction stated that the cakes baked with baking powder would have the highest volume compared to cakes baked with vinegar and baking soda or cakes baked with orange juice and baking soda. The analytical results with the bar graphs (Figure 1) show that the mean cake volume varied between all three treatment groups; the highest mean volume of the cakes baked was when baking powder was used. This is due to the baking powder being a complete leavening system in one product. It consists of sodium bicarbonate, one or more leavening acids, and a diluent, typically starch or calcium carbonate (Brodie & Godber, 2007). The baking powder used in this experiment is a double-acting baking powder that contains a fast-acting acid and a slow-acting acid. The fast-acting acid gets activated when mixed with the cake batter, releasing about 20% carbon dioxide. The rest of the carbon dioxide gets released in the oven as the slow-acting acid gets activated in the heat, creating more air pockets, which give the cake its volume (Otero-Guzmán et al., 2020). Compared to the other two samples (vinegar+baking soda and orange juice+baking soda) with fewer air pockets and less volume, the carbon dioxide in these two samples was only released during the mixing process and none in the baking process. A study done by Shin (2015) investigated citrus peel powders in search for an optimal percentage of citrus peel powder to use to produce quality cakes in terms of

taste, weight, and visuals. They found that 10% citrus peel powder produced the most optimal conditions for a sponge cake. Comparatively, our study saw that the combination of citric acid and baking soda produced the second best results. This is consistent with Shin's study as our sample contained approximately 1.5% citric acid and produced cakes similar in visual presentation.

Though most of the possible measurement and instrumental variation were controlled using exact measurements with the exact kitchen glassware throughout the experiment, potential sources of error could have affected our results. One of the sources is the small number of replicates in this experiment. Having a small sample size will not give the most accurate results, increasing the number of replicates and performing more than one trial would provide more accurate mean values and a smaller margin of error in the data. Sample A with vinegar and baking soda appear a little undercooked therefore skewing the volume obtained. Expected height for this sample is similar to sample with citric acid acid and baking soda.

Thus, further research is required to examine the effect of different leavening agents on the volume of the baked cake requires more control of the variables as well as more frequent trials.

5. Conclusion

Ultimately, this experiment used different leavening agents in combination to investigate the effect of these agents on the volume and quality of the baked cake. Results showed a significant difference in the outcome regarding the size (volume) of each cake produced. Analysis of the data led to the rejection of the null hypothesis, which states that there is no difference between the leavening agent used and the size of the cake as the tests performed on the collected data (Turkey test and the one-way ANOVA test) showed a significant size difference between the treatment groups. The results also prove the initial prediction that baking

powder has a significant effect on the outcome of the cake in the sense of the greater air pockets and the volume produced.

Acknowledgements

We would like to thank Professor Celeste Leander for allowing us to conduct this investigation and providing conceptual assistance, UBC for the opportunity to be part of Biol 342 and Musqueam people for allowing us to learn on their traditional land. We also want to acknowledge this paper's co-authors: Maryam Alkaloo and Calvin Cao.

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