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Lab experiment: Leavening

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Course: Nut 106

Lab: TR 9:00 a.m to 11:50 a.m

Introduction:

Leavening agents play an essential role in baking products such as cake, scones, or bread. It is because leavening agents can increase the air and water interaction inside baking products. It means that the leavening agents increase gas-producing ability to expand the volume of bakery products.[1] When there is more air and steam inside the dough, it provides more space for volume expansion.

Physical, biological, and chemical leavening agents are always to be used for baking products. The ways to distinguish these three major types of leavening agents are based on what leavening is added to baking products for expansion. Butter, shortening, or cream cheese are physical leavening agents that use aerate fat to increase volume. Yeast is the representative of biological leavening agents which use some eukaryotes to cause expansion. Moreover, chemical products not found in nature, such as baking powder and baking soda are classified as chemical leavening agents. lecture note

After using physical leavening with sugar into baking ingredients is more effective to trap air insider baking products for size expansion. Only physical leavening is based on the incorporation of air to increase volume, but biological and chemical leavening generates carbon dioxide to increase size expansion. In biological leavening, carbon dioxide will be generated when sugar is added with yeast due to fermentation. In chemical leavening, more carbon dioxide is produced when it reacts with acidic ingredients during the reaction. Lecture note Furthermore, because of the reaction between carbon dioxide and bicarbonate for aeration of dough, it is beneficial to provide porous cell desirable texture and appearance for bakery products. [2]

The leavening agents and different mixing methods (biscuit method, muffin method, and conventional method) can affect the textual qualities of final products. Using the biscuit method

can create flakey texture qualities because the biscuit method uses solid fat to spread out leaving space during melting in the oven. It provides enough space for the interaction of baking powder, steam, and carbon dioxide to expand. The liquid fat is included by the muffin method. This mixing method provides moist, crumbly, coarse, and open texture because there are many liquid ingredients to interact with baking powder to contain appropriate gluten developing to support baking products. Lastly, using a hard fat with sugar for creaming is considered to be a conventional method. Because of the high amount of sugar and fat, more air can be trapped (incorporation of air) so that the volume of the baking product increases during baking in the oven. [Lecture note]

Methods:

Leavening agents

Four graduated cylinders were labeled with BP (baking powder), and each of the two graduated cylinders was also labeled HW (hot water) and CW (cold water). Meanwhile, one of the labeled HW and CW graduated cylinders were labeled “Acid.” After all graduated cylinders were labeled, one teaspoon of baking powder was added to all BP cylinders. Two of the graduated cylinders, marked with CW and HW, added 20 mL hot water and cold water and recorded the observations after three seconds. The rest of the two graduated cylinders, marked with CW and HW, added hot water with acid and cold water with acid into HW and CW labeled cylinders. The observation was recorded after 3 seconds and 5 minutes. Repeating the same procedure to BS (baking soda).

Cake

Using the convection bake setting to preheat the oven to 350 Fahrenheit. All of the assigned cake ingredients were combined together in a bowl. The oil, water, and vanilla extract were added at the same time and mixed it. It was beneficial to use the non-stick cooking spray for cake unmolding. The cake was baked for 32-35 minutes and cut into 16 pieces after it cooled. The cake appearance, texture, and flavor were recorded.

Scones

The oven was preheated to 400 Fahrenheit with a convection bake setting. The cold butter had to be cut to small pieces about 10-12 pieces and added to the scones' flour mixture. When the cold butter resembled breadcrumbs, milk and sour cream were added to the mixture. Since the scones ingredients were done, it was baked for 15-20 minutes. The scones' appearance, texture, and flavor were noticed after the scones were cooled.

The purpose of the leavening agent's experiment is to investigate the impact of leavening agents on water volume when baking soda and baking powder interact with heat and acid. Because baking powder can be double-acting which can produce more carbon dioxide, I hypothesize that using more baking powder can produce more leavening and higher volume than baking soda. Moreover, the purpose of the cake and scone experiment is to investigate how chemical leavening agents affect the appearance, texture, and flavor of baked cake and scones. I hypothesize that baking soda with cornstarch and cream of tartar should have a similar appearance, texture, and flavor rather than other leavening agents because baking powder

ingredients contain acid, baking soda, and cornstarch even though their amounts may be different.

Statistical Data analysis:

Leavening agents

To measure the validity of the % increase in the volume of the water for each assigned variation, formula ((highest volume peak - initial water volume) / initial water volume) x 100% was used to figure out what the % water increment in each assigned conditions. Moreover, ANOVA: single-factor could determine whether there was a significant difference between these % water increments in each experimental condition. It should be at least one significant difference if the p-value is less than alpha 0.05. On the contrary, there is no significant difference that is similar if the alpha is greater than alpha 0.05 between each experimental condition.

Example: ((39-20) /20)* 100 = 95% increase of the volume

Result:

Leavening agents

Table 1: The Average and Standard Deviation of % Baking Soda and Baking Powder in 3 Seconds

		Baking Soda (3 seconds)				% Baking Soda (3 seconds)			
station	Initial volume (mL)	Hot water	Cold water	Hot water with acid	Cold water with acid	Hot water	Cold water	Hot water with acid	Cold water with acid
B	20	28	20	28	37	40	0	40	85
C	20	23	26	29	23	15	30	45	15
F	20	20	20	48	40	0	0	140	100
					Average	18.33333333	10	75	66.66666667
					SD	20.20725942	17.32050808	56.34713835	45.36885863
		Baking Powder (3 seconds)				% Baking Powder (3 seconds)			
station	Initial volume (mL)	Hot water	Cold water	Hot water with acid	Cold water with acid	Hot water	Cold water	Hot water with acid	Cold water with acid
B	20	38	20	33	25	40	0	65	25
C	20	23	27	30	30	15	35	50	50
F	20	30	23	59	52	50	15	195	160
					Average	35	16.66666667	103.3333333	78.33333333
					SD	18.02775638	17.55942292	79.73915809	71.82153809

Briefly explanation:

Using the formula ((highest volume peak - initial water volume) / initial water volume) x 100% to measure the % increase in the volume of the water for baking soda and baking powder in 3 seconds. After that, there was an average and standard deviation, which was calculated. The

standard deviation was represented in the standard deviation error bars, which indicated whether there was a significant difference between different baking soda and baking powder conditions after 3 seconds.

Table 2: The ANOVA Single Factor with P-Value of % Baking Soda and % Baking Powder in 3 Seconds

ANOVA: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Hot water	3	55	18.33333333	408.3333333		
Cold water	3	30	10	300		
Hot water with acid	3	225	75	3175		
Cold water with acid	3	200	66.66666667	2058.333333		
Hot water	3	105	35	325		
Cold water	3	50	16.66666667	308.3333333		
Hot water with acid	3	310	103.3333333	6358.333333		
Cold water with acid	3	235	78.33333333	5158.333333		
ANOVA						
ource of Variati	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	25462.5	7	3637.5	1.608475357	0.2035654209	2.6571966
Within Groups	36183.33333	16	2261.458333			
Total	61645.83333	23				

Briefly explanation:

The ANOVA single factor demonstrated the p-value of % increase in the volume of the water for baking soda and baking powder conditions. The p-value was 0.20, which was greater than the 0.05 alpha standard point, so there was no significant difference between the different baking soda and baking powder conditions after 3 seconds.

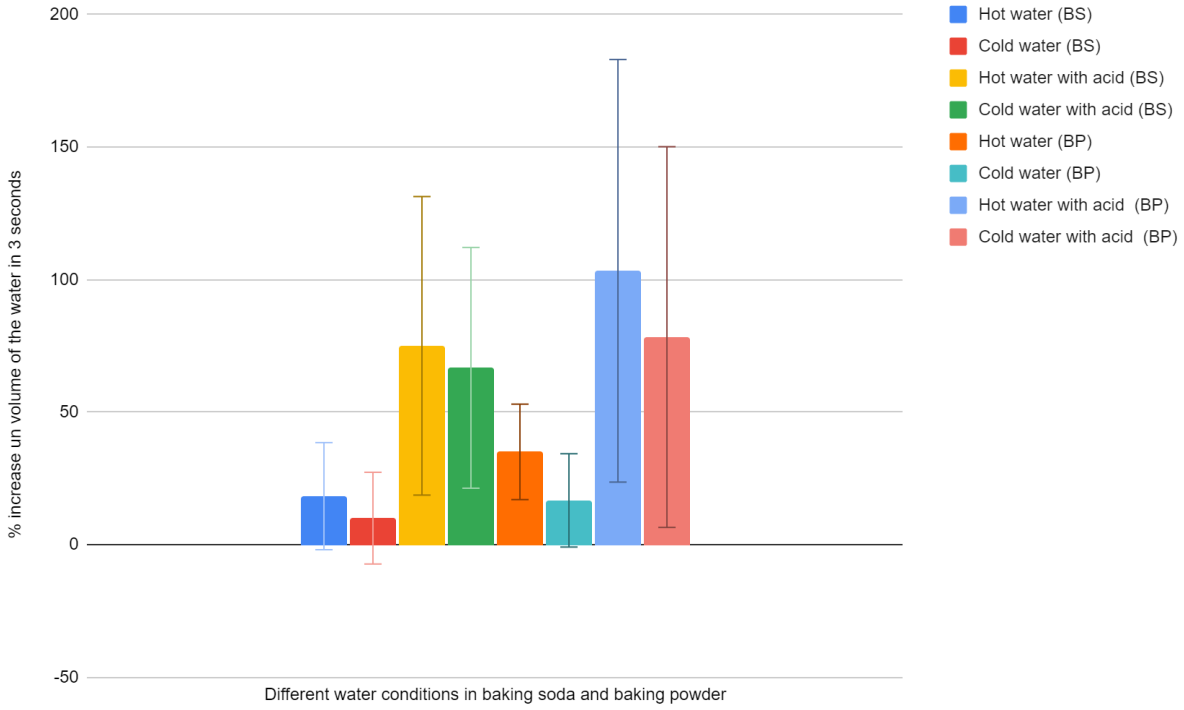

Figure 1: Average % increase in the volume of the water for different baking soda and baking powder conditions after 3 seconds. The values were average ± standard deviation. ANOVA was used to compare % increase in the volume of the water between different baking soda and baking powder conditions after 3 seconds. ($p = 0.20$)

Briefly explanation:

The one-way ANOVA revealed a significant difference between the % increase in the volume of the water for different baking soda conditions (figure 1). The overlap of standard

deviation error bars indicated whether there was at least one significant difference between different baking soda conditions. There were no standard deviation error bars between "baking soda and baking powder with acid" and "baking soda and baking powder without acid" after 3 seconds, demonstrating at least one significant difference between these conditions. On the other hand, there were standard deviation error bars between "the hot water baking soda with acid and the cold water baking soda with acid" and "the hot water baking powder with acid and the cold water baking powder with acid" after 3 seconds. Moreover, standard deviation error bars between "the hot water baking and the cold water baking soda" and "the hot water baking powder and the cold water baking powder" were overlapped after 3 seconds. Thus, it indicated that there was no significant time for these conditions. The p-value of 0.20 was greater than the standard alpha value of 0.05, so it was no significant difference in different "baking soda and baking powder with acid" and "baking soda and baking powder without acid" after 3 seconds even though there were overlap error bars to show the difference.

Table 3: The Average and Standard Deviation of % of Baking Powder and % Baking Powder after 5 minutes

		Baking Soda (5 minutes)				% Baking Soda (5 minutes)			
station	Initial volume (mL)	Hot water	Cold water	Hot water with acid	Cold water with acid	Hot water	Cold water	Hot water with acid	Cold water with acid
B	20	20	19	20	20	0	5	0	0
C	20	22.5	26	27	23	12.5	30	35	15
F	20	20	20	23	24	0	0	15	20
					Average	4.166666667	11.66666667	16.66666667	11.66666667
					SD	7.216878365	16.07275127	17.55942292	10.40833

	Baking Powder (5 minutes)				% Baking Powder (5 minutes)				
station	Hot water	Cold water	Hot water with acid	Cold water with acid	Hot water	Cold water	Hot water with acid	Cold water with acid	
B	20	18	18	18	0	10	10	10	
C	21	22	28.5	18	5	10	42.5	10	
F	12	18	23	24	40	10	15	20	
				Average	15	10	22.5	13.33333333	
				SD	21.79449472	0	17.5	5.773502692	

Briefly explanation:

The formula ((highest volume peak - initial water volume) / initial water volume) x 100% was used to determine the % increase in the volume of the water for baking soda and baking powder after 5 minutes. After measuring an average and standard deviation of % increase water volume in the baking powder and baking soda conditions, the standard deviation was represented in the standard deviation error bars, which indicated whether there was a significant difference between different baking powder and baking soda conditions.

Table 4: The ANOVA Single Factor with P-Value of % Baking Powder and % Baking Powder after 5 Minutes

ANOVA: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Hot water	3	12.5	4.166666667	52.08333333		
Cold water	3	35	11.66666667	258.3333333		
Hot water with acid	3	50	16.66666667	308.3333333		

Cold water with acid	3	35	11.66666667	108.3333333		
Hot water	3	45	15	475		
Cold water	3	30	10	0		
Hot water with acid	3	67.5	22.5	306.25		
Cold water with acid	3	40	13.33333333	33.33333333		
ANOVA						
ource of Variati	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	594.7916667	7	84.9702381	0.4409266409	0.8620689322	2.6571966
Within Groups	3083.333333	16	192.7083333			
Total	3678.125	23				

Briefly explanation:

The ANOVA single factor demonstrated the p-value of % increase in the volume of the water for baking soda and baking powder conditions. The p-value was 0.86, which was greater than the 0.05 alpha standard point, so there was no significant difference between the different baking soda and baking powder conditions after 5 minutes.

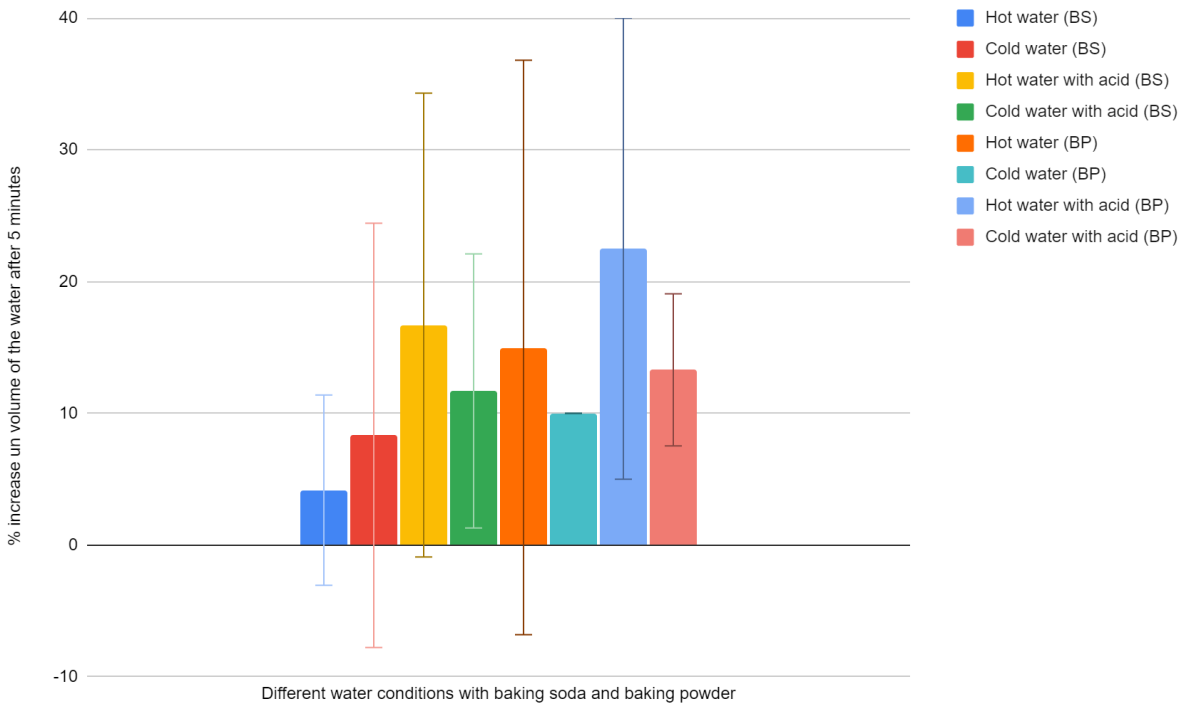

Figure 2: Average % increase in the volume of the water for different baking powder and baking powder conditions after 5 minutes. The values were average ± standard deviation. ANOVA was used to compare % increase in the volume of the water between different baking powder and baking soda conditions after 5 minutes. ($p = 0.86$)

Briefly explanation:

The one-way ANOVA revealed a significant difference between the % increase in the volume of the water for different baking powder conditions (figure 2). The overlap of standard deviation error bars indicated whether there was at least one significant difference between different baking powder and baking soda conditions after 5 minutes. The standard deviation error bars of "hot water baking powder condition" overlapped to all different assigned conditions after

5 minutes, except "hot water baking powder with acid conditions." Hence, there was no significant difference between these experimental conditions. Nevertheless, there were standard deviation error bars between "hot water baking powder with acid," "cold water baking powder," and "cold water baking powder with acid." It indicated that there was no significant difference between these conditions after 5 minutes. Meanwhile, "hot water baking powder with acid" had at least one significant difference "hot water baking soda," "cold water baking soda," "hot water baking soda with acid," and "cold water baking soda with acid" conditions after 5 minutes due to the lack of overlap error bars. The p-value of 0.86 was greater than the standard alpha value of 0.05, so it was no significant difference in different baking powder conditions although there were overlap error bars.

Sensory Evaluation of cake:

Using baking soda and baking powder could provide different results in appearance, texture, and flavor. The cake which was made of baking powder contained a medium-dark brown appearance and had a soft fluffy texture. Furthermore, it contained a low sweetness content in the cake. On the other hand, the cake which was made of baking soda had a deep darker brown color than baking powder cake; it was smooth and had less moisture content and dense. Moreover, it did not taste sweet, even bitter than baking powder cake when there was too much baking soda in the cake.

Even though the cake used the same leavening agents, different appearances, textures, and flavors were also different. More baking powder was added to a cake with a darker brown color and higher moisture content. It also tasted a flour-like flavor. Meanwhile, more amount of baking soda was added to the cake that contained darker brown color and spongy texture. The

cake's sweetness content would decrease which was not sweet, even bitter. The cake which used the same amount of leavening agent but different flour also contained different appearances, textures, and flavors. The all-purpose baking soda cake had a very dark flaky appearance and dry texture than cornstarch baking soda cake and gluten-free flour baking soda cake. After that, the cornstarch baking soda cake contained the strongest and sweetest chocolate flavor. It also had the lightest brown color. The gluten-free flour baking soda cake had the highest moisture and sticky texture than gluten-free flour baking soda cake and all-purpose baking soda cake which contained the same amount of baking soda. The cornstarch baking soda with cream of tartar was a preferable cake variation.

Sensory Evaluation of scones:

The different leavening agents provided other appearances, textures, flavor scones. None leavening agent's scone and gluten-free flour baking powder's scone also had a light yellow color, but the none leavening agent's scones had a smooth surface. The baking soda scones were the darkest yellow color. Moreover, the baking powder scone and baking soda scones had a rough and coarse surface. The inside of cream of tartar scones and no leavening agent scones seemed not completely cooked. The non-leavening agent had the smoothest texture and was similar to the undercooked pastry. Although the gluten-free baking powder sconces and baking soda scones both was cakey, the gluten-free scones were fluffy and higher moist. After that, the all-purpose flour baking powder scones was the driest texture, but it was not airy. Moreover, when the baking soda was added with cream of tartar, it caused the airy crisp texture inside the scones. Without the baking soda, the scones which only used cream of tartar were crunchy.

In addition, only the baking soda scones were bitter, and the cream of tartar scones was sour. The gluten-free baking soda scones, cream of tartar with baking soda scones, all-purpose baking powder scones, and non-leavening agents scones were also sweet. Nonetheless, the gluten-free baking soda scones contained buttery flavor, cream of tartar with baking soda scones was very sweet and all-purpose baking powder scones were savory. As a result, gluten-free baking soda, all-purpose baking powder, and cream of tartar with baking soda were preferable to the scone variations.

Discussion:

When the cold water was added to the baking soda, there was a weak reaction between the water and baking soda which released a few bubbles and baking soda still left on the bottom. There was no change in the cold baking soda conditions and only a few bubbles on the side in hot baking soda conditions. Nonetheless, a reaction immediately released bubbles when the baking powder reacted with hot and cold water. Over time, the volume of cold baking powder condition was decreased, and it became a curdled milky thick appearance. Moreover, the volume of hot baking powder condition had a decrease and was the milky color.

When additional acid was added to baking soda and baking powder, the volume of baking soda conditions and baking powder conditions had increased higher volume than without adding acid which increased almost a double volume. Even though acid could increase reaction, some baking soda still stayed in the hot and cold water conditions, and the volume of hot and cold baking soda conditions increased. Moreover, higher temperature caused a faster reaction increased the amount of water volume. It had a similar appearance and color with hot and cold baking powder conditions without acid. After these baking powder conditions stayed for a while,

its water volume had slightly decreased. However, it still had a higher water volume than without acid.

Using different amounts of baking soda could affect the appearance, texture, and flavor. The cake, which was made with 24 g baking soda, was the darkest brown (almost dark color) which seemed to burn out appearance. It was a spongy texture and even tasted bitter. On the other hand, the 6 g baking soda cake was lighter brown color than the 24 g baking soda cake. It was soft and airy. It was slightly sweet but also not bitter. Although all-purpose and gluten-free contained both 6 g of baking soda, there were some differences between these variations. The all-purpose variations were darker than gluten-free variations. The texture was dry and less dense which dissolved easily. On the contrary, the gluten-free variations were sticky, moist, and mushy. Based on the above observations, adding more baking soda seemed not acceptable to make a cake.

For example, the 4 g of baking powder cake was media brown color, fudgy pastry texture, and sweeter than 16 g baking powder cake. On the other hand, the 16 g baking powder had a darker brown color than the 6 g baking powder cake. It was soft, squishy, and moist. It did not taste sweet and also contained some flour taste. Adding 4 times baking powder was acceptable because it was just more moist than 4 g baking powder bake and contained a slight flour taste. Therefore, the baking powder could replace baking soda. When baking powder was added to either hot water or cold water conditions, most baking powder almost completely dissolved, which reacted to water. Hence, the cake did not taste bitter and had a dry texture. Conversely, the baking soda did not completely dissolve into the dough even though it was mixed with some acidic ingredients. Some baking soda was left in the dough, so using more baking soda to make a cake caused a bitter flavor and spongy texture.

In addition, the 16 g of baking powder most closely resembled cornstarch, baking soda, and cream of tartar as the leavening agent. The components of baking powder are included baking soda, acid, and cornstarch. There was a similar amount of cornstarch (2.5 g), baking soda (6 g), and cream of tartar (6.8 g) which closed to 16 g baking powder. Thus, it should be the closest cake variation.

After that, the all-purpose with baking powder scones and gluten-free with baking powder both had a light yellow color, but the gluten-free variations had brown color on top. Moreover, it was more moist, cakey, and fluffy than all-purpose variations. The gluten-free cake also contained a buttery flavor, but the all-purpose cake was savory. The baking soda leavening agent was the darkest yellow color. Moreover, non-leavening agent scones were dense, but their surface texture was smooth. The baking soda with cream of tartar was airy and crisp. Conversely, the all-purpose variations were dry and flakier than other leavening agents. Meanwhile, the gluten-free variations were the moistest and fluffiest. Many of the leavening agents were sweet, but there was some exception. The baking soda variations tasted bitter, and the cream of tartar variation was sour, similar to the lemon flavor. Even though the all-purpose and gluten-free variations used baking powder, gluten-free variations were more moister and fluffy than all-purpose variations.

And then, the scones which were made of baking soda with tartar cream leavening agents was similar to baking powder scones because it was similar ingredients to baking powder. Even though there was no cornstarch in the baking soda with cream of tartar scones, some carbon dioxide was produced when the baking soda interacted with acid and high temperature. Therefore, it could make a similar texture, appearance, and flavor to baking powder scones.

Not only leavening agents but also some mixing methods also can affect the characteristic of bakery products. For instance, the biscuit method is used to make the scones because the solid butter was cut into small pieces and covered by dry ingredients. When the scones were baked in the oven, the small pieces of butter were melted and created space to expand the volume of scones via the interaction of steam, carbon dioxide, and baking powder. Thus, the scones were flakey. If the sconces are overmixed, the scones will be tough and humping because there is flour in the scones. When the flour is over-kneaded, the gluten is produced which makes the scones tough. Furthermore, the scones become stickier and moist because the gluten will over-develop and too much liquid in the dough. lecture note

In addition, the gluten-free variation mainly provided higher moisture content, so the gluten-free cake was moist, sticky, soft, and mushy. Moreover, gluten-free scones were moist and fluffy than all-purpose variations because there is no gluten in the dough. Conversely, the texture of cake and scones which were made of all-purpose flour, was dry and broke down readily because the all-purpose flour only has 8-11% protein to react with the gluten after mixing butter and water. Lecture note

There were some differences between chemical leavening agents and biological leavening agents: the bread was using yeast-leavening, its texture was soft but elastic. It was chewy and not broken down easily because of a higher amount of gluten. On the other hand, its texture was smooth, mushy, and soft when using chemical leavening to make other bakery products. The cake and scones were easily to dissolve. Moreover, when there was too much chemical leavening agent, it caused bitter flavor and darker color. After that, when the gluten-free variations were mixed with yeast-leavening, the bakery products were more dense, gummy, flour-like taste and aroma. Conversely, when the gluten-free variations were combined

with chemical leavening, the bakery products were smooth, soft, sticky, mushy, and fluffy. There are differences between chemical and biological leavening agents because the reaction of chemical leavening was limited. Since baking powder had reacted entirely with other ingredients, the response has stopped. Nonetheless, the biological leavening agents (yeasts) could keep releasing carbon dioxide until the dough was baked in the oven. Hence, biological leavening agents provide a chewy and gummy texture than chemical leavening agents.

Reference

1: Baomiao Ding, Quanhui Zheng, Xiangzhou Yi, Minhsiung Pan, Yishiou Chiou, Fengwei Yan, Zhenshun Li, Microencapsulation of Sodium Bicarbonate Based on Glycerol Monostearate and Konjac Glucomannan Wall Systems by Phase Separation, Food Science and Technology Research, 10.3136/fstr.24.249, 24, 2, (249-255), (2018).

2: Chung, Frank H. Y.「Bakery Processes, Chemical Leavening Agents」. *Kirk-Othmer Encyclopedia of Chemical Technology*, American Cancer Society, 2000. *Wiley Online Library*, https://doi.org/10.1002/0471238961.0308051303082114.a01.