A Comparison of Leavening Agents

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Abstract

There are many different leavening agents available to the baker. These include active dry yeast, sourdough starter, baking soda (sodium bicarbonate), baking powder (baking soda, calcium phosphate, and sodium aluminum sulfate), potash (potassium bicarbonate) or pearl ash, and bakers' ammonia (ammonia carbonate). Each of these leaveners was tested by making a biscuit containing flour, water, and the leavening agent. In addition, a home-made potash was tried. For baking soda and the home-made potash, an alternate set of biscuits were made with vinegar and water instead of just water. Another set of biscuits contained only flour and water for use as a control.

Three biscuits were made of each sort. Each was baked in a standard home oven. The resulting baked biscuits were measured in diameter and height. Variations in smell and taste are noted.

The yeast produced the largest biscuits. Many leavening agents produced comparably tall biscuits, with the bakers' ammonia producing the tallest. The worst rising biscuits were the unleavened ones, followed very closely by the home-made potash and the sourdough.

Introduction

The home-baker has access to several different leaving agents. Baking soda, baking powder, and active dry yeast are the three most common. Specialty shops sell sourdough starter and bakers' ammonia. Historically pearl ash or potash was used between at least the 1790s and the 1840s when it was replaced by baking soda. Potash can still be obtained, though there are also instructions on how to make it at home.

Although the comparative effect of baking soda and baking powder is often discussed, there does not seem to be any more general comparison with other leaveners. The following experiments make this comparison and also examine the use of home-made potash.

A total of ten different sets of biscuits were made to test seven different leaving agents. These were:

- Unleavened
- Baking soda
- Baking soda with vinegar
- Baking powder
- Bakers' ammonia
- Potassium bicarbonate
- Home-made potash
- Home-made potash with vinegar
- Active dry yeast
- Sourdough starter

Each of the leaving agents is detailed below.

The Leavening Agents

Baking Soda

Baking soda is also known as sodium bicarbonate or $NaHCO_3$. The baking soda used for these tests was Arm and Hammer brand, purchased at the local grocery store.

Figure 1: The box of baking soda and a sample of the soda

Baking Powder

Baking powder is a combination of baking soda and a powdered acid. For these tests, Davis double-acting baking powder was used, as purchased from the local grocery store. This contains cornstarch as a filler, sodium bicarbonate, calcium phosphate, and sodium aluminum sulfate. Calcium phosphate is $Ca(H_2PO_4)_2$, and sodium aluminum sulfate is $NaAl(SO_4)_2$.

Figure 2: The can of baking powder and a sample of the powder

Bakers' Ammonia

Bakers' ammonia is ammonium carbonate or $(NH_4)_2CO_3$. It is an astonishingly noxious smelling substance. The bakers' ammonia was purchased from King Arthur Flour, a mail order baking supply company. It was manufactured by Lorann Oils.

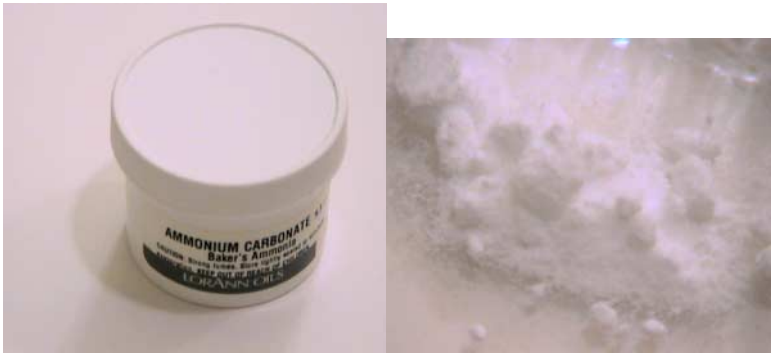

Figure 3: The jar of bakers' ammonia and a sample of the ammonia

Potassium Bicarbonate

Potassium bicarbonate is one of the substances known as potash. This, as well as potassium carbonate, is also known as pearl ash. It is $KHCO_3$. The potassium bicarbonate used in these tests was purchased at a home brewery supply store. It is manufactured by Crosby and Baker, Ltd.

Figure 4: The jar of potassium bicarbonate and a sample of the powder

Home-made Potash

Figure 5: A sample of the home-made potash

As per the instructions found at the *Caveman to Chemist* website (http://cator.hsc.edu/~kmd/caveman/projects/potash/), some potash was manufactured.

This was done by starting with wood ash made in a wood-burning stove. Mixed hardwoods were used and the ash was collected from the ash grate. 250 g of ash were placed in a glass bowl with 2500 g of hot tap water (approximately 50°C/120°F). This was stirred to mix thoroughly, then allowed to settle for 12 hours.

The bowl now contained a sandy-looking precipitate, a small quantity of charcoal floating on the surface, and some fairly clear but slightly colored liquid (most likely tan, though the observer is incapable of distinguishing color due to Daltonism). 1250 g of the colored liquid was withdrawn from the bowl and placed in a stainless steel pot.

The liquid in the pot was brought to a roiling boil. It was boiled until all liquid had evaporated and only a greyish residue remained. This residue was scraped out of the bowl. A total of 22 g of residue was obtained.

Active Dry Yeast

Yeast is readily available in a granulated form. The yeast used in these tests was the Fleischmann brand, purchased at a local grocery store.

Figure 6: The jar of yeast and a sample of the yeast

Sourdough Starter

Sourdough starter is generally a colony of wild yeast that is periodically fed on flour and water. In this case, the starter has been actively maintained and used for decades by the author.

Figure 7: A sample of the sourdough starter

Making Biscuits

To test the various leavening agents, a set of biscuits was made with each agent. These biscuits consisted only of flour, water, and leavening. As a control, a set of biscuits was made without any leavening. As the common conception is that baking soda requires an acid to properly rise, an additional set of biscuits was made with flour, baking soda, water, and vinegar (acetic acid). As the home-made potash had very poor leaving on its own, it too was tried with vinegar.

For all biscuits, the flour used was King Arthur unbleached all-purpose white flour. Water was common tap water. Where used, vinegar was distilled white vinegar with 5% acidity.

The basic biscuit recipe was as follows:

50 ± 0.5 g flour
35 ± 0.5 g water
2.7 ± 0.2 g leavening

For the unleavened biscuits, the same amount of flour and water was used but the leavening was left out. For biscuits that used vinegar, the recipe was:

50 ± 0.5 g flour
32 ± 0.5 g water
3 ± 0.5 g vinegar
2.7 ± 0.2 g leavening

All measurements were done by weight using a Acculab V-6000 scale.

Three biscuits were made with each of the ten leavening combinations. Each biscuit was formed by hand into an approximate disk with a height of 20 ± 1 mm. The biscuits were baked in a pyrex dish for 12 minutes (± 2 seconds) at 205°C/400°F in a conventional home electric oven. Based on the readings of a Fluke thermocouple, the oven averaged this temperature with swings of ± 20°C/36°F.

After baking, the biscuits were removed from the pyrex dish using a thin-bladed stainless steel spatula and placed on a wooden board to cool. All measurements and analysis was done on the room temperature biscuits (17°C/63°F).

Results

The height of each biscuits was measured to an accuracy of ± 0.5 mm. While the biscuits were intended to be round, most were roughly oval. The minimum and maximum diameter of each biscuit was measured to an accuracy of ± 2 mm. The low accuracy was caused by the

irregular edges of some biscuits. The heights and diameters are listed in a table after the commentary on the biscuits.

In addition to measuring the biscuits, one biscuit of each type was tasted, and the aroma of the biscuits was noted. These are very subjective notes, completely dependent on one researcher. Any other significant properties of the biscuits are noted.

An overall view and a cross section of each biscuit is shown. The overall view was taken with a 640x480 resolution digital camera, while the cross section was scanned at 300 dpi using a flatbed scanner.

Unleavened

The unbaked dough of the unleavened biscuit was mildly sticky. Baked, it was still a bit damp, indicating that more baking was desirable.

The smell was very plain and ordinary, more of flour than anything else. The taste was damp, bland, and doughy.

Figure 8: The unleavened biscuit

Baking Soda

This biscuit looked and felt very much the way a dough is expected to behave.

The smell was a bit like pretzels. The taste was chewy, acrid, and in need of salt. Taste-wise, the biscuit has too much baking soda in it.

Figure 9: The baking soda biscuit

Baking Soda and Vinegar

The dough of this biscuit was a bit stickier than the plain baking soda biscuit. Additionally, the dough rose a bit prior to baking.

The smell was very similar to the plain baking soda biscuits, though a bit more pleasant. The taste was indistinguishable from the plain baking soda biscuits.

Figure 10: The baking soda and vinegar biscuit

Baking Powder

This biscuit was the closest to the archetypal biscuit. The dough was pleasant to work with and the final biscuit was one of the most attractive.

The smell is what one imagines a biscuit should smell like, while the taste was nearly like that of bread.

Figure 11: The baking powder biscuit

Bakers' Ammonia

The bakers' ammonia has a strong noxious smell. This made the dough unpleasant to work with.

The smell of the baked biscuit has occasionally whiffs of ammonia, which largely block a slight floury-smell. The taste is mildly chemical with an occasional pungent ammonia bit. Overall, this was vile and disgusting.

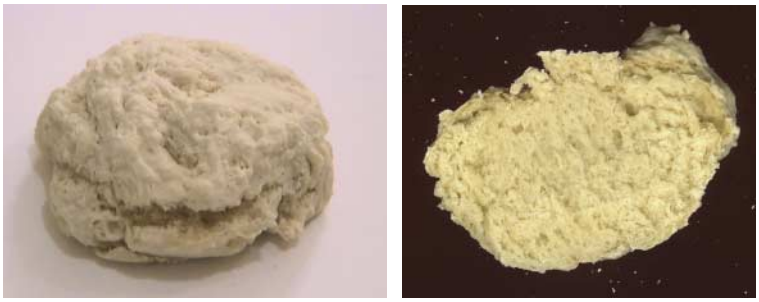

Figure 12: The bakers' ammonia biscuit

According to the sales literature that accompanied the bakers' ammonia, this compound is supposed to dissipate in the baking process. In the researcher's limited experience, this never fully happens, and any baked good always has pockets of noxious smelling and tasting ammonia.

Additionally, the biscuits left dark stains on the wooden board where they were set to cool.

Potassium Bicarbonate

The potassium bicarbonate biscuit dough was nearly indisting-uishable from that of the baking soda biscuit.

The smell was flat and damp. There was almost no taste at first. There was a slight acrid aftertaste. This probably indicates that too much leavening was used. The biscuit is in need of salt.

Figure 13: The potassium carbonate biscuit

Home-made Potash

The dough was nearly identical to that of the baking soda biscuit. The biscuit didn't rise very much at all.

After baking, the smell was damp and doughy. The taste was nearly identical to the unleavened biscuit, but there was a faint flat aftertaste.

Figure 14: The home-made potash biscuit

Home-made Potash with Vinegar

Aside from some initial frothing in the dough, this biscuit appeared identical to the home-made potash without vinegar biscuit.

Figure 15: The home-made potash and vinegar biscuit

Active Dry Yeast

The dough of this biscuit was a bit wet, and therefore hard to shape. The dough was left to rise for 60 minutes after the biscuits were formed. Most of the rising occurred in this time.

The smell was yeasty. The taste was very similar to french bread excepting that it was a bit yeasty.

Figure 16: The yeast biscuit

Sourdough

The sourdough starter looked insubstantial within the dough of this biscuit. The dough was left to rise for 90 minutes after the biscuits were formed.

The resulting biscuits did not rise much. There was almost no smell. The taste was chewy and very slightly yeasty.

In general, much more

Figure 17: The sourdough biscuit

sourdough starter is used when making a baked good. Using an ounce of sourdough starter would have produced more desirable results.

Measurements

The table below lists all biscuits and the measured values for each. In addition to measuring the height and diameter, the area and volume of each biscuit was computed. This was done using the cavalier assumption that the biscuits were oval in area and ellipsoidal in volume; while this is certainly not the case, it should provide a valid comparison to determine which biscuits are largest.

Table 1: Biscuit Measurements and Calculated Values

Leavening	Height (mm)	Min. Diam. (mm)	Max. Diam. (mm)	Area (mm^2)	Volume (cm^3)
Unleavened	26.0	62	75	3652	63.3
	26.5	66	81	4199	74.2
	25.5	63	72	3563	60.6
Baking soda	41.0	76	77	4596	125.6
	44.0	72	78	4411	129.4
	39.5	67	79	4157	109.5
Baking soda and vinegar	42.5	67	82	4315	122.3
	41.0	73	77	4415	120.7
	42.0	74	82	4766	133.4
Baking powder	40.5	75	90	5301	143.1
	42.0	72	86	4863	136.2
	40.0	75	86	5066	135.1
Bakers' ammonia	45.0	72	84	4750	142.5
	48.5	67	80	4210	136.1
	46.0	63	83	4107	125.9
Potassium bicarbonate	38.0	73	77	4415	111.8
	40.5	69	76	4119	111.2
	40.0	68	71	3792	101.1
Home-made potash	27.0	66	67	3473	62.5
	27.0	64	74	3720	67.0
	26.0	66	84	4354	75.5
Home-made potash with vinegar	29.0	63	73	3612	69.8
	30.0	70	77	4233	84.7
	28.0	70	77	4233	79.0
Yeast	39.0	88	92	6359	165.3
	41.5	86	91	6147	170.1
	38.0	86	98	6619	167.7
Sourdough	25.0	64	90	4524	75.4
	27.0	74	81	4708	84.7
	27.5	65	78	3982	73.0

Rankings

It is useful to examine which leaving agents rose highest, produced biscuits with the greatest volume, and generated the widest biscuits. For these purposes, the values of the three biscuits for each leaving agent were averaged together. Tables 2 through 4 rank the various leavening agents based on average height, area, and volume.

Based solely on height, bakers' ammonia produced the tallest biscuits. Of the other leavening agents, baking soda with and without vinegar, baking powder, potassium bicarbonate, and yeast all generated roughly equally high biscuits. Home-made potash with vinegar showed a slight increase in height, while the home-made potash without vinegar and the sourdough biscuits failed to rise appreciably more than the unleavened biscuits. Unsurprisingly, the unleavened biscuits were the shortest, though even these increased from 20 mm to 26 mm.

Yeast raised biscuits had the largest area by a significant factor. Of the rest, the baking powder biscuits were also significantly larger, though much smaller than the yeast biscuits. Baking soda with and without vinegar, sourdough, and bakers' ammonia all produced similarly sized biscuits. Potassium bicarbonate wasn't as larger. The home-made potash was scarcely better than the unleavened biscuits, though the vinegar helped a slight amount.

Volumetrically, the yeast raised biscuits were clearly the largest. Baking powder and baker's ammonia came next. Baking soda, with and without vinegar were smaller, but still respectable in size. Potassium bicarbonate also produced a significant increase in volume. The home-made potash and sourdough biscuits showed only a slight increase over the unleavened biscuits.

Table 2: Leavenings listed based on average height

Leavening	Avg. Height (mm)
Bakers' ammonia	46.5
Baking soda and vinegar	41.8
Baking soda	41.5
Baking powder	40.8
Potassium bicarbonate	39.5
Yeast	39.5
Potash with vinegar	29.0
Home-made potash	26.7
Sourdough	26.5
Unleavened	26.0

Table 3: Leavenings listed based on average area

Leavening	Avg. Area (mm^2)
Yeast	6375
Baking powder	5077
Baking soda and vinegar	4498
Sourdough	4405
Baking soda	4388
Bakers' ammonia	4356
Potassium bicarbonate	4108
Potash with vinegar	4026
Home-made potash	3849
Unleavened	3804

Table 4: Leavenings listed based on average volume

Leavening	Avg. Volume (cm^3)
Yeast	167.7
Baking powder	138.1
Bakers' ammonia	134.9
Baking soda and vinegar	125.5
Baking soda	121.5
Potassium bicarbonate	108.1
Potash with vinegar	77.8
Sourdough	77.7
Home-made potash	68.3
Unleavened	66.0

Conclusion

Active dry yeast provided the largest increase in volume of any of the leavening agents tested. Although bakers' ammonia produced the highest rising biscuits, the noxious fumes that it releases are enough of a drawback, that its use cannot be recommended. Baking powder was the next best quick rising agent, with baking soda and potassium bicarbonate serving adequately.

The addition of vinegar to biscuits with baking soda or home-made potash increased their height and area to a small extent. The home-made potash was a dismal failure as a leavening agent. The biscuits were larger than the unleavened variety, and thus the home-made potash wasn't wholly worthless. Neither the home-made potash nor the addition of vinegar appear to be worth the effort of using them.

The tests used an identical baking time, an identical weight of leavening agent, and an identical quantity of liquid for each biscuit. As a result, some biscuits were underdone (such as the unleavened biscuits) while some were adequately cooked. Some biscuits tasted of excess leavening (such as the baking soda and potassium bicarbonate biscuits) while others did not have enough leavening to rise much at all (specifically the sourdough biscuits). Some biscuits had a sticky wet dough, while others had a dryish dough. It would be useful to repeat some of these tests with biscuits that had been more optimized for taste, texture, baking time, and leavening.