IMPACTING
BETTER FOOD™

Leavening - It's a Simple Equation

Discover the science & innovation behind **ICL Bakery Ingredients.**

Table of Contents

What is Chemical Leavening?

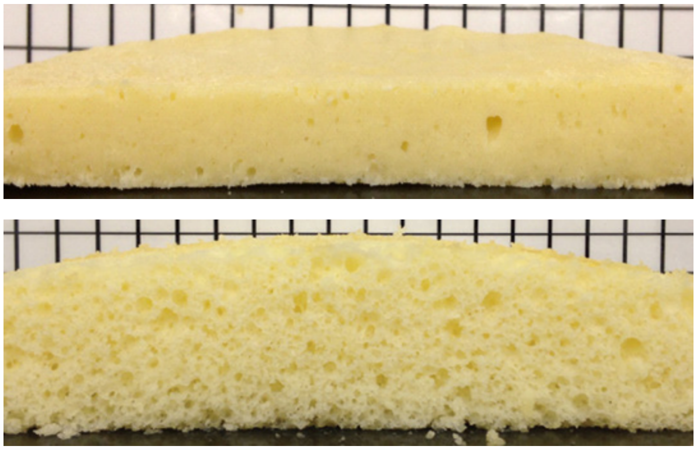
Chemical leavening can be a complex and challenging topic for many bakery formulators. Perhaps it's because there can be numerous calculations involved, which go beyond simply adding an ingredient. Or maybe it's because the many choices of leavening acids can be overwhelming. The critical role of leavening in determining the final quality and texture of baked products underscores its importance in formulation.

Formulators in the food industry, have access to a diverse array of ingredients, which can be both advantageous and challenging. Unlike home baking, where leavening options are typically limited to store-bought baking powder, buttermilk or even vinegar, and preparation is straightforward, baking for industrial formulations require careful consideration of specific formulations and manufacturing processes to determine an optimal custom leavening system.

Chemically leavened baked goods primarily consist of flour and water, along with other functional ingredients. Flour provides structure to the baked product by trapping air bubbles as the product sets. Water is essential in the leavening process as it activates the leavening agents, enabling them to generate the gas necessary for achieving the desired texture. The flour-to-water ratio is a critical factor influencing the range of chemically leavened products. From high-moisture cake batters to low-moisture tortilla doughs, each formulation and processing condition demands the appropriate leavening system to produce an optimal product.

Components of Chemical Leavening

A cake without leavening is dense and gummy with limited cell structure. However, it can be transformed with the addition of the right ingredients.



All the components of the leavening equation are contained in a box of baking powder (Table 1). At home, a simple "baking powder" can be made by combining baking soda with a readily available acid such as buttermilk (which contains lactic acid), lemon juice (citric acid) or vinegar (acetic acid). These acids react very quickly with the baking soda, producing gas immediately. This reaction is similar to the "volcano" experiment, where mixing baking soda and vinegar creates an effervescent reaction that children find entertaining.

When this same reaction occurs in a batter or dough, the gas produced is retained by the flour-water system. Upon heating, the gas expands, and the components of the flour (starch and protein) begin to change, forming a matrix that traps the gas, resulting in a chemically leavened baked good.

Table 1: Composition of Baking Powder

Ingredient	Function
Corn Starch	Keeps acid and base from reacting prematurely
Baking Soda	Source of carbon dioxide
Monocalcium phosphate	First reaction of double action – during mixing
Sodium acid pyrophosphate	Second reaction of double action – during baking

Baking Soda

The baking soda component of the leavening equation has minimal variations, primarily in particle size. This ingredient is the source of carbon dioxide (CO_2) gas. Sodium bicarbonate dissolves quickly in a batter or dough.

Leavening Acid

There are many types of leavening acids available in the ICL Food Specialties portfolio (Table 2). These acids react at different times and in different ways, allowing for the selection of the appropriate acid for each specific application (Table 3). The leavening acid is crucial for manipulating the leavening reaction, so it is important to understand how to select the right acid for your baking needs.

Monocalcium phosphate (H.T.® MCP) is a very fast-acting acid that reacts rapidly with baking soda to release carbon dioxide gas. MCP is ideal for use in double-acting baking powder and in mixes that require a two-stage leavening action, such as pancakes. However, MCP can sometimes be too fast, particularly for food service applications, so a delayed-reacting anhydrous MCP, known as Py-Ran®, is available.

ICL Food Specialties also offers a complete portfolio of different sodium acid pyrophosphates (SAPPs) grades. These SAPP grades vary in the proportion of gas formed during mixing versus baking, with higher numbers indicating a faster rate of reaction (gas production). The available grades include:

- SAPP RD-1
- SAPP 26
- SAPP 28
- SAPP 40
- SAPP 43

A newer group of available leavening is the calcium acid pyrophosphates (CAPP), which is trademarked as Levona®. Similar to SAPP, CAPPs vary in the amount of leavening that occurs early (ideally in the mixing bowl) and the CO_2 that is released later.

The order of reactivity from fastest acting to slowest is as follows: Levona® Allegro, Levona® Brio, and Levona® Opus. The Levona® family of leavening acids has the added benefit of being sodium-free, adding calcium to the formula, and contributing to a no-aluminum claim.

Heat-activated leavening acids are useful because they do not produce gas until heating occurs during baking. The main type of acid in this category is sodium aluminum phosphate (SALP – Levn-Lite®). Because gas production in the oven alone can often result in a less optimal baked good, Levn-Lite® has been formulated in combination with a faster-acting acid – these blends are called Pan-O-Lite® and Stabil-9®. Pan-O-Lite® is especially effective in white cake mixes due to its added structure resiliency, crumb whiteness, and baking tolerance.

Stabil-9® is a double-acting leavening phosphate used primarily in self-rising flours, self-rising cornmeal, and biscuit mixes to ensure a full-volume, light product.

Dicalcium phosphate dihydrate (DCPD) is a unique heat-dependent leavening acid with a late reaction, making it suitable for high-set temperature products such as cakes with high sugar content. It reacts very late in the baking cycle and is typically used with other leavening acids or for specialty results, such as creating cracks in the top crust or inducing late cracking in cookies.

The Levona® family of leavening acids have the added benefit of being sodium-free. Depending on the formulation, they may also contribute to a calcium claim.

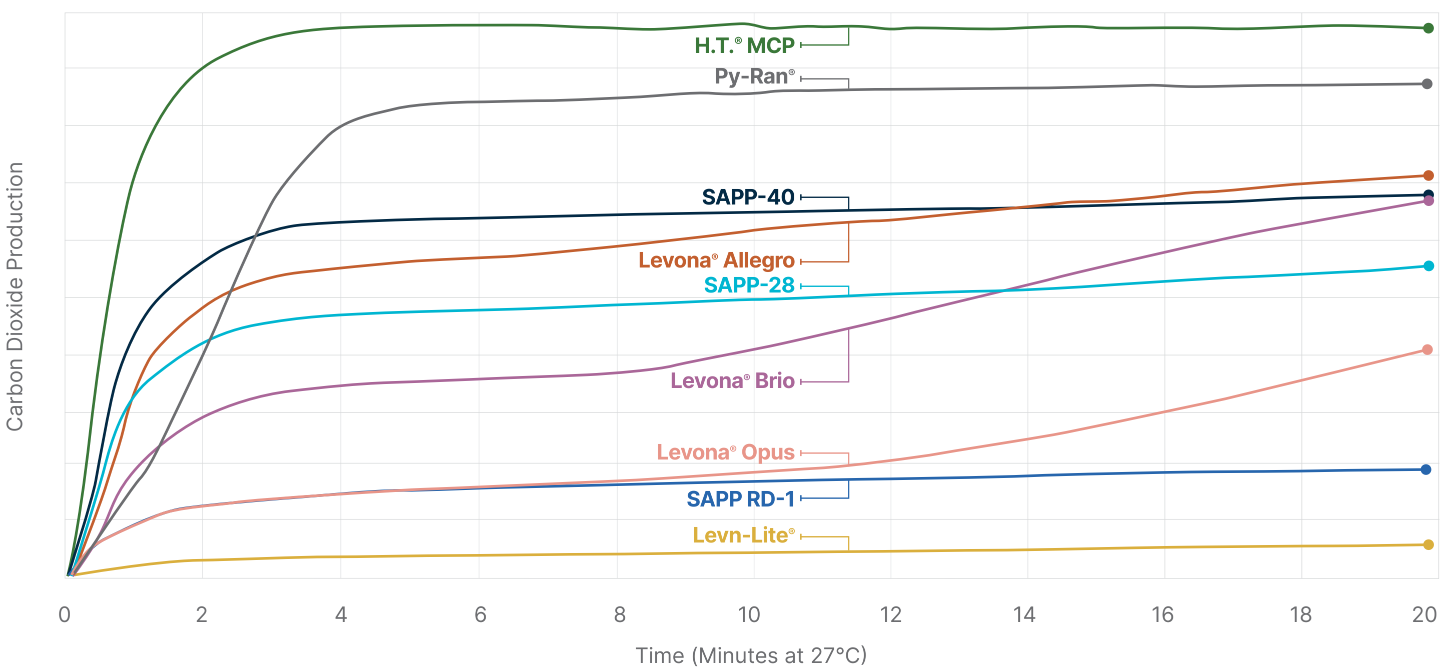
How to Use Leavening Acids

Selecting a Leavening Acid

The selection of a leavening acid is based on the rate of carbon dioxide release in your dough or batter mixture, which is crucial for a successful application. Figure 1 illustrates the relative gas production for ICL leavening acids in a model dough system, determined through a Dough Rate of Reaction (DRR) test. This test measures carbon dioxide release during mixing and the holding stage at a constant temperature.

The DRR test provides a useful comparison of the reactivities of different leavening acids and serves as a guide for selecting the appropriate acid for an application by showing typical reaction curves of the various acids. Since the test uses a simple formula, it provides information to allow bakers and formulators to understand gas production for their specific "critical zone"—the point in the preparation process where gas release is desired.

Figure 1: Relative Gas Production for ICL Food Leavening Acids in Model Dough System



Calculating Leavening Acid Amount

The Simple Chemical Leavening Equation

$$\underset{\text{Acid Salt}}{HX} + \underset{\text{Sodium bicarbonate}}{NaHCO_3} \xrightarrow[\text{Water}]{\text{Heat}} \underset{\text{Neutral Salt}}{NaX} + \underset{\text{Water}}{H_2O} + \underset{\text{Carbon dioxide}}{CO_2}$$

Chemical leavening is an acid base reaction, as shown in the Chemical Leavening Equation. Water is the solvent that allows the two ingredients to dissolve and react. As the temperature increases (during mixing or baking) the reaction will proceed faster. Cooler temperatures (such as frozen storage) will slow the reaction. The properties of the acid will also impact the timing of the production of water and carbon dioxide (as shown in Figure 1). The acid salt will remain in the final baked product. The water can become steam, a gas like the carbon dioxide, which will give the expansion during baking to produce the volume and appearance desired.

The reactants of the Chemical Leavening equation must be combined in the correct proportions for a successful baked product. Once the type of leavening acid has been determined, the amount of acid to use must be calculated.

Typically, when developing the leavening in a formula, the amount of soda is determined first; a good starting point is 2% of the flour. Then calculate the amount of leavening acid. The amount of leavening acid needed to react with the soda is a unique property called the neutralizing value (NV); this is provided in Table 2. Because the NV is different for each acid, they cannot be equally exchanged in a formula.

The equation that is used for calculating the amount of acid, based on the known values of soda and NV is provided below.

Calculating Leavening Acid Amount

$$\text{Amount of leavening acid} = \frac{\text{Amount of soda} \times 100}{\text{Neutralizing Value (NV)}}$$

ICL Bakery Portfolio

Table 2: Leavening Acids

Chemical Name (Abbreviation)	Trade Name	Neutralizing Value	Reaction Mechanism
Monocalcium phosphate monohydrate (MCPM)	H.T.® MCP	80	Hydration
Monocalcium phosphate anhydrous (MCPA)	Py-Ran®	80	Delayed Hydration
Sodium acid pyrophosphate (SAPP) RD-1, 26, 28, 40, 43	—	72	Time Delayed, Heat Accelerated
Calcium acid pyrophosphate (CAPP)	Levona® Allegro	73	Time Delayed, Heat Accelerated
Calcium acid pyrophosphate (CAPP)	Levona® Brio	63	Time Delayed, Heat Accelerated
Calcium acid pyrophosphate (CAPP)	Levona® Opus	60	Time Delayed, Heat Accelerated
Sodium aluminum phosphate – anhydrous (SALPA)	Levn-Lite®	100	Heat Activated
Sodium aluminum phosphate blend	Pan-O-Lite®	100	Hydration and Heat Activated
Sodium aluminum phosphate blend	Stabil-9®	93	Hydration and Heat Activated
Dicalcium phosphate dihydrate (DCPD)	—	33	Heat Activated

Applications

Table 3: ICL leavening acid options for bakery applications

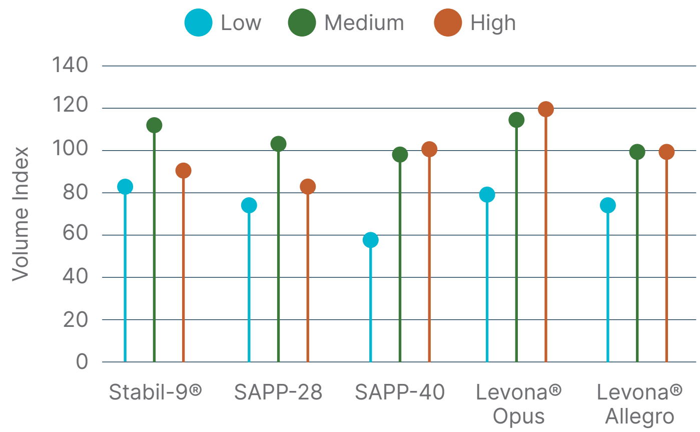
The table below outlines the uses and levels of sodium bicarbonate and ICL leavening acids best suited for each bakery product. Generally, a combination of acids is selected to achieve the desired release

Baked Good	Soda Level (% Flour)	Acid
Cake, Layer	2.5 - 3.5	SAPP-40, Stabil-9®, Pan-O-Lite®, Levona® Opus
Cake, Sponge	1.5 – 2.0	SAPP-28, Stabil-9®, Pan-O-Lite®, Levona® Allegro
Muffin	1.7	Stabil-9®, DCPD, Levona®
Pancake/Waffle	5.0	Stabil-9®, Pan-O-Lite®, SAPP-40
Biscuit	2.5 – 3.0	Stabil-9®, Pan-O-Lite®, Levona® Allegro, Levona® Opus, SAPP-28
Tortilla	0.6 – 1.0	Levn-Lite®, SAPP-28
Doughnut	1.7-2.0	SAPP-28, SAPP-40, SAPP-43, Levn-Lite®
Cookies	0.0 – 0.7	Stabil-9®, SAPP RD-1, H.T.® MCP, SAPP 28, Levn-Lite®
Crackers	0.5 – 1.8	H.T.® MCP, Py-Ran®, SAPP 28
Refrigerated Dough	2.0 – 2.5	SAPP RD-1, SAPP 26, Levn-Lite®, Pan-O-Lite®, Levona®

Yellow Cake

Each leavening acid is unique, resulting in differences in the baked products. A research project at ICL Food Specialties measured the Volume Index (AACC method 10-91) of yellow cakes made with three different levels of soda neutralized by five different types of leavening acids. The results (Figure 2) show that too little leavening gives a small volume cake, and increasing the amount of leavening can be beneficial. However, if the leavening system is increased too much, there is no additional benefit, as the cakes do not always get larger. Levona® Opus produced the largest cakes, with Stabil-9® showing similar results at the medium soda level.

Figure 2: Volume Index of Yellow Cakes at Three Levels of Baking Soda



When evaluating cake symmetry or the evenness of the crust shape, significant differences were observed based on the leavening acid used (Figure 3). At low soda levels, the cakes were nearly flat. As the soda level increased, the cakes became more rounded, with Stabil-9® and Levona® Allegro providing the best shape. At the highest levels, some cakes fell in the center, but SAPP-40 and Levona® Opus maintained a desirable rounded top.

The characteristics of the cake crumb are also influenced by the selection of leavening acids. The amount of force required to bite the cake varies with each acid (Figure 4), as does the crumb's cohesiveness (Figure 5). Stabil-9® and SAPP-28 produced the softest crumb, while Opus resulted in the most cohesive crumb.

Figure 3: Symmetry Index of Yellow Cakes at Three Levels of Baking Soda

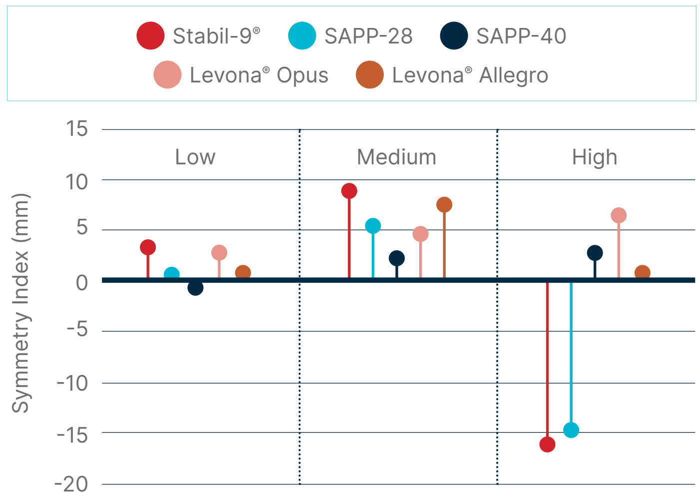


Figure 4: Force to Compress Yellow Cakes

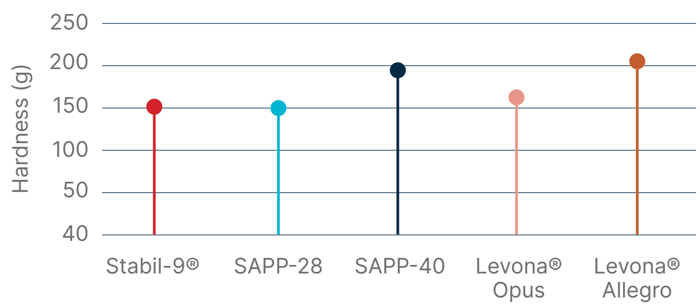
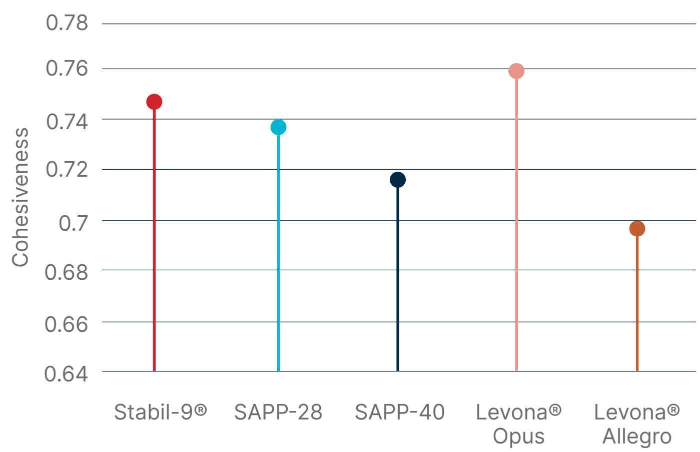


Figure 5: Cohesiveness of Yellow Cakes



Tortillas

In contrast to the high-sugar fluid batter system of a cake, the developed dough for tortillas is also influenced by the leavening acid. Table 4 presents the physical properties of tortillas made with different leavening acids. Tortilla properties such as diameter and height are affected by the choice of leavening acid as is the strength of the tortilla. In experiments conducted by ICL Food Specialties, tortillas containing Levn-Lite® required the least force to break, indicating a more tender product. It is possible to formulate tortillas to be fluffier and softer or more resilient with better rollability and cohesiveness.

Table 4: Tortilla Properties by Leavening Acid

Acid	Diameter (cm)	Stack Height (mm)	Force (g)
Levn-Lite®	16.8	33.9	768
SAPP-28	16.1	34.8	851

Impact of Leavening on Alternative Ingredient Baked Products

When formulation changes are made for nutritional purposes or to meet consumer demand for plant-based and alternative ingredients, it is valuable to evaluate different leavening agents in these specific formulations as they relate to the volume, texture, and characteristics of the final product.

The addition of whole wheat to a muffin formula changes the properties of the final product compared to using all-purpose flour. Data shows that in a simple formula, Levona® Opus produced larger whole wheat muffins than other acids, while SAPP-28 resulted in the softest texture (Table 5).

Formulating bakery products to meet keto standards, which require low carbohydrate levels, creates a unique system with higher fat and protein content than traditional wheat flour baked goods. Application testing of keto muffin formulations showed that the addition of DCPD (the slowest acting leavening acid) with other acids was beneficial.

Testing in the ICL bake lab demonstrated different effects on volume and softness with Stabil-9®, SAPP-28, Levona® Opus, and Levona® Allegro. The combination of Levona® Allegro and DCPD was found to be optimal for the keto muffin formulation.

Gluten-free (GF) formulas are another category that deviates from using wheat flour as the main ingredient. There are many GF ingredients available, often used in combinations rather than alone. Any of the ICL leavening acids can produce a great final product, but they need to be evaluated in the specific application to determine the optimal choice and usage level to achieve the desired product characteristics.

Table 5: Muffin Properties as Impacted by Flour Type and Leavening Acid

Acid	All-Purpose		Whole Wheat	
	Specific Volume (ml/g)	Force (g)	Specific Volume (ml/g)	Force (g)
Levona® Opus	2.48	476	2.42	580
Stabil-9®	2.34	564	2.34	590
SAPP-28	2.25	416	2.27	500

Trends & Innovations

Health and wellness, along with sustainability, drive innovation in the bakery and cereal market. Consumer preferences for nutritious, tasty options drive demand for ingredients like whole grains, natural sweeteners, and plant-based fats. Allergen concerns also impact consumer choices, with many opting for gluten-free or nut-free options. High fiber, high protein, no added sugar, no gluten, no lactose, reduced/no allergens, organic, non-GMO, and other clean label claims are increasingly important. The clean labeling trend emphasizes transparency in food ingredients and sustainability, leading to conscious food choices from consumers.

As a result of these evolving consumer preferences, the rise of keto and gluten-free products, and the use of upcycled ingredients, ICL scientists can help identify the right leavening for unique formulas. Customers are provided with resources and services to tailor formulations and optimize the sensory experience. The ICL portfolio offers ingredients to solve product development challenges while delivering innovation.

- Health & Wellness
- Allergen-Free
- Clean Label
- Sustainable
- Specialty Diets
- Custom Formulations
- Innovation

Experience the Future of Food

ICL Food Specialties is an ingredient solutions provider with over 80 years' experience in the food and beverage industry. We combine the power of a global leader with the passion of an agile team of experts to help you create solutions that impact the future of food.

iclfood.com

Ready to Formulate?

Follow these basic steps:

1. Begin by identifying the specific baked product you want to create, and the ingredients required for the formulation. Consider the nutritional and marketing goals.
2. Determine the amount of baking soda to use in your formulation. A good starting point is to use 2% of the flour weight.
3. Choose two or three leavening acids or blends that will react at different stages of the baking process.
4. Do calculations to determine the amount of each leavening acid needed to react with the baking soda.
5. Make the product and evaluate its performance characteristics, such as volume, texture, and overall appearance.
6. Assess how well the leavening system works. Based on these evaluations, make any necessary adjustments to optimize the product attributes.
7. Contact our bakery applications technical team at ICL Food Specialties to discuss next steps at 855-425-7732 or foodexperts@icl-group.com