Salt reduction is a hot topic not only for commercial and artisanal bakeries, but for consumers worldwide. Many recent conferences have addressed the importance of reducing salt in all areas of food production. Salt, which has been branded a “silent killer,” has been linked to a significant increase in the prevalence of heart attacks, strokes, and other medical conditions associated with high blood pressure and hypertension (1,6). It is found in a wide variety of foods worldwide, and quantities are particularly high in processed foods (5). A high level of salt means a high level of sodium—the mineral responsible for the negative health effects associated with salt consumption. It is not only processed foods that contain high levels of salt, however; bakery products can also contain high levels of sodium in ingredients that may not be obvious to consumers. The action group World Action for Salt and Health (WASH) has called for more awareness to be given to reducing salt consumption, stating that products need better labels (6). The detrimental effects of high sodium intake on health have motivated many food companies to develop innovative ideas and ingredients to help reduce salt in their products. It has also inspired an increase in research into sodium, its effects on the body, and possible ways to reduce its overall consumption.

Salt and Sodium

Salt is made up of sodium chloride, and it is the sodium component that is responsible for the physiological effects of salt. Many familiar baked goods, such as bread and sweet bakery products, contain large amounts of sodium. Salt not only affects the flavor of products, to which we have become very accustomed, but it is an extremely important contributor to an extended shelf life. Sodium is a fundamental component of numerous chemical interactions that are used to produce modern baked products.

Sodium reduction is not simply a case of removing it entirely from the diet. Sodium is an important mineral in the diet and is vital to maintaining healthy function of the body (5). In the body sodium works synergistically in conjunction with potassium to help regulate blood pressure (4). These two minerals must be in balance in the body to regulate fluid levels and, in turn, blood pressure (4,5). Modern diets are often deficient in potassium but very high in sodium, leading to an imbalance that can result in an increase in blood pressure. This imbalance is something medical professionals are trying to address to improve health. Using innovative ingredients to bring these minerals back into balance is one way to help lower blood pressure and assist in reducing the prevalence of hypertension-related medical conditions such as heart attacks and strokes (5,8). Understanding the vital interaction between sodium and potassium within the body is critical to developing a strategy for reducing sodium in baked goods.

Salt is not the only component that contributes to the sodium levels found in sweet baked goods such as cakes and muffins. A number of other less recognized sources also exist. A large proportion of the sodium found in baked goods comes from the baking powder or leavening agents used. Baking powder is a complete leavening system that causes baked products to rise. It typically consists of acid and alkali components that react with each other to produce carbon dioxide gas bubbles, which cause the baked product to rise and expand. Most commonly, the alkali component is sodium bicarbonate, and the acid component is a phosphate leavening acid. In commercial bakeries, the phosphate tends to be sodium acid pyrophosphate (SAPP). Both components contribute significantly to the sodium content of baked goods: sodium bicarbonate is 27.4% sodium, and SAPP is 20.4% sodium.

Sodium Bicarbonate

For many years, sodium bicarbonate has been the primary source of carbonate used by the baking industry (10). Its stability as a powder, pleasant flavor, and good functionality when used in a balanced leavening blend has ensured that it has remained the primary choice for bakers (7). It is also extremely versatile and is available in many different grades that are suitable for a wide variety of applications. Various grades with different particle size distributions are routinely used in the baking industry. The variety of available particle sizes allows bakers flexibility in choosing the grade that is most suitable for an application. Additionally, for bakery applications sodium bicarbonate can be treated with conditioners to obtain a free-flowing quality (FFQ). A very fine particle size combined with an FFQ is suitable for dough-type products in which there is less water available, because it provides full dispersion throughout the dough. A standard grade has a fine particle size distribution that is suitable for cake batters in which more water is available to hydrate the particles. Although stable and versatile, the high sodium content of sodium bicarbonate has prompted a search for effective replacements.

Early sodium reduction strategies involved bakers simply removing added salt from their formulations. Although this reduced the sodium content, it had drastic, negative effects on the shelf life and flavor of the end products (10). Salt is one of the most efficient means of extending and enhancing shelf life because it draws out moisture, preventing food spoilage micro-
organisms from growing (11). As a result, alternative methods of reducing sodium without having to remove added salt are required to maintain shelf life. If sodium from other sources can be reduced or removed from formulations, added salt can continue to be used to influence flavor, texture, rise, and other attributes of the finished product.

**Potassium Bicarbonate**

In the drive to decrease sodium consumption, potassium bicarbonate has become increasingly popular as an alternative source of carbonate. Like its sodium counterpart, potassium bicarbonate is able to react with acidulants to generate carbon dioxide gas (3,10). Until recently potassium bicarbonate was only available as a coarse grade that had a particle size larger than the industry standard for sodium bicarbonate (10). In addition, the hygroscopic nature of potassium bicarbonate and its inherent instability made it difficult to manufacture grades with finer particle sizes that would be suitable for use in the baking industry. Surface spotting, which results from the use of coarse potassium bicarbonate, is visually unacceptable. It is caused by partial dissolution of the carbonate, which leads to areas of high alkalinity (Fig. 1). This high alkalinity also decreases shelf life by increasing pH, which allows the acceleration of mold and bacterial growth.

Significant improvements in the stability of potassium bicarbonate have resulted in the creation of a variety of grades for bakery applications, similar to those available for sodium bicarbonate, that can be used to maximize end-product quality. Potassium bicarbonate with FFQ, similar to its sodium counterpart, has a very fine particle size that allows full dispersion and dissolution in drier doughs in which less water is available. A fine grade has a particle size more suitable for batters in which more water is available to hydrate the particles. The improved solubility of the finer grades of potassium bicarbonate ensures maximum dissolution in the dough or batter, allowing for maximum rise of baked goods and eliminating any unsightly spots associated with uneven dissolution caused by coarser grades of potassium bicarbonate (Fig. 2).

**SAPP and Potassium Biocarbonate.**

Use of potassium bicarbonate allows the continued use of SAPP, which is multifunctional and versatile and is available in a wide variety of reaction speeds that suit different bakery applications and provide more control over the baking process (3). Fast-reacting SAPP begins reacting sooner in the bakery process, as soon as it comes in contact with liquid, and can be beneficial when maximum gas evolution is required during a short bake time (10). Slower reacting SAPP begins reacting much later in the baking process and offers more process tolerance when used in applications with longer production cycles (10).

Utilizing different reaction speeds means that gas release can be manipulated to occur at specific points in the development of product structure to maximize and maintain product volume, shape, and internal structure (3,10). Although they offer lower sodium levels than SAPPs, calcium phosphates do not have the same versatility in terms of reaction speeds. They tend to react quickly and, as a consequence, to react during the processing stage rather than the baking stage. Calcium phosphate can be used in combination with slower reacting leavening acids. The use of potassium bicarbonate with SAPP within a leavening system allows for sodium reduction while still utilizing the versatile functions of these phosphates.

**Gas Value.** The gas value is the amount of carbon dioxide released per gram of bicarbonate. Potassium bicarbonate has a slightly lower gas value (0.44 g of CO₂/g) than sodium bicarbonate (0.52 g of CO₂/g). This may be considered a negative when replacing sodium bicarbonate with potassium bicarbonate, because theoretically more potassium bicarbonate must be added to obtain the same effect. However, potassium bicarbonate dissolves more readily than sodium bicarbonate. In addition, more often than not, there is little benefit to increasing the addition of potassium bicarbonate so the gas values match those of sodium bicarbonate, because a slightly acidic product can be beneficial in terms of flavor and shelf life.

**Sodium Reduction Strategies Using Potassium Bicarbonate**

Initially, issues with potassium bicarbonate properties and stability caused concerns regarding its suitability for use in bakeries. Potassium bicarbonate is very hygroscopic; it readily absorbs moisture, which causes it to form solid blocks and renders it unusable, leading to problems with transportation and handling of potas-

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**Fig. 1.** A scone (American biscuit) made with coarse potassium bicarbonate (A) exhibits uneven pH. The universal indicator shows areas of high alkalinity (dark green) caused by areas of unreacted bicarbonate. A scone made with potassium bicarbonate with a fine particle size (B) exhibits a more acidic and even pH. Even pH is a result of full dispersion and dissolution of the potassium bicarbonate.

**Fig. 2.** A, Scones made with coarse potassium bicarbonate (note the unsightly spots and poor volume); and B, scones made with fine potassium bicarbonate.
sium bicarbonate powder. In addition, there is the potential for loss of carbon dioxide through release, which results in a shorter shelf life and poor product volume. Processing aids can be added to maintain the free-flowing characteristics of the potassium bicarbonate powder and increase the inter-particle space. This helps prevent caking during storage by inhibiting moisture absorption and particle sintering. Markedly improved stability means that potassium bicarbonate that is similar to sodium bicarbonate in terms of stability.

When used as a sodium reduction solution, some bakers have noted unsatisfactory flavor qualities. Initially this was thought to be due to the use of potassium bicarbonate; however, there are many factors that can affect product flavor when trying to reduce salt. Changes in flavor can be avoided or moderated using several methods:

1) When replacing sodium bicarbonate with potassium bicarbonate, added salt can be left in the formula. This causes little or no change in the flavor of products while still achieving salt reduction targets.

2) Coarse particle size in potassium bicarbonate causes the formation of carbonate spots in baked goods, which, in turn, causes localized areas with high alkalinity and very strong metallic flavors. This can be avoided by using finer grades of potassium bicarbonate that can be fully dissolved and dispersed throughout the dough.

3) Some bakeries have tried to go too far in reducing sodium—replacing all of the leavening components, including acidulants, with sodium-free versions. Sodium-free products are not required to meet sodium reduction targets. Simply reducing sodium by 50% allows for a healthier product without compromising the flavor of the finished product.

Sensory research has been performed by a food research association on behalf of one of the United Kingdom’s leading leavening agent suppliers. An assessment of differences in flavor was made between products containing potassium bicarbonate and those containing sodium bicarbonate; both products had a particle size similar to a baker’s-grade sodium bicarbonate such as USP #1. The results obtained showed that independent taste-test professionals could not detect any significant difference between product types or any unpleasant aftertaste.

Potassium bicarbonate with a fine particle size matches the required functionality of sodium bicarbonate in terms of carbon dioxide release and exceptional stability. It is also available in a range of grades suitable for bakery applications and can be used in products without affecting the quality, texture, flavor, appearance, or rise of baked goods. Replacement of sodium bicarbonate with potassium bicarbonate can achieve up to a 50% reduction in sodium levels.

Health Benefits of Potassium Bicarbonate

One major advantage to using potassium-based ingredients is the recognized health benefits associated with potassium in the diet. Potassium is a naturally occurring mineral that is abundant in many fruits and vegetables such as bananas, prunes, tomatoes, and potatoes. It is the third most abundant mineral in the body and is essen-
tial for health and well being. Apart from being closely involved with sodium in maintaining healthy blood pressure, potassium can be used to reduce hypertension in sodium-sensitive individuals (1,2,5,9). Potassium has also been recognized for its role in helping to maintain healthy muscles (including the heart) and a healthy and efficient nervous system and in helping to reduce anxiety and stress levels in susceptible individuals (1,4,5,9).

Use of potassium bicarbonate in baking powders enables bakers to not only reduce sodium, but to incorporate an ingredient with potential health benefits. Simply producing a scone (American biscuit) with potassium bicarbonate rather than sodium bicarbonate may provide consumers with as much potassium as eating one-third of a banana (based on calculations of the potassium content of both products). Another major benefit of replacing sodium with potassium bicarbonate is that it contributes to the balance between the two minerals. Replacing only 50% of the sodium in a baked product with potassium will help in balancing these two minerals (9).

Conclusions
Exchanging sodium bicarbonate for potassium bicarbonate can help bakers reach their salt reduction targets and create healthier baked goods. Recent advances in technology have improved this carbonate source so it now matches its sodium counterpart in functionality and versatility. Although potassium bicarbonate is hygroscopic and can be difficult to handle, advances in potassium bicarbonate product formulations have led to a powder that is very stable, free flowing, and available in a wide range of particle sizes.

The future of potassium bicarbonate in the baking industry should not be underestimated. It can not only help bakers to reduce salt in their baked products without compromising product quality, but can also provide added health benefits by increasing the amount of potassium in the diet.

References