The Use of Potassium Bromate by the Commercial Baking Industry

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Over the past several years, much work has been done to determine how potassium bromate, a highly effective oxidizing agent, can continue to be used in a safe manner in bakery applications. This article provides information on the history of potassium bromate, its current status, and its potential for continued future use.

- In spite of the issues raised, potassium bromate remains a highly effective oxidizing agent when used in bakery products. It possesses unique capabilities that are difficult or, at best, expensive to replace. The continued ability to utilize this functional additive, with an emphasis on doing so in a safe and responsible manner, could be very beneficial to the baking industry.
- The wholesale baking industry continues to work to find ways to keep potassium bromate available.
- It is essential that companies choosing to use potassium bromate in their products follow the recommendations provided in the *Commercial Baking Industry Guide.*

A Century of Use

Potassium bromate has been used as an oxidizing agent by the U.S. baking industry since 1914, following the issuance of a patent by the U.S. Patent Office. Regulations pertaining to potassium bromate include the May 1941 approval by the U.S. Food and Drug Administration (FDA) for the use of potassium bromate at 50 parts per million (ppm) in bromated flour (standards of identity for flour) and the May 1952 approval for its use in bread at a level of 75 ppm based on flour (standards for bread and rolls). Under provisions covered in the Code of Federal Regulations (12) potassium bromate is prior-sanctioned (i.e., approved for a specific use by the FDA or the USDA before September 6, 1958) for use in baked goods and flour.

Many years ago, flour was packaged and transported from the mill to the bakery in cloth bags. Because the bags were air permeable, the flour was oxidized during extended storage periods by the oxygen in the surrounding air. This oxidation step was highly important in producing good quality products. With the advent of bulk flour handling system usage, however, this mode of oxidation was no longer available. Thus, additives that worked as oxidizing agents became very important. The actions of potassium bromate were particularly needed in enclosed mixing systems, such as continuous mixing and the Chorleywood process, because the dough is not exposed to air during these types of processing (11). Additionally, low-grade flours that result from poor crop years have an increased need for effective oxidation (3).

As an oxidizing agent, potassium bromate appears to act on the thiol groups of the flour protein. The resulting cross-linked network of protein molecules impacts the dough structure and rheology, being particularly important for dough strength during mixing and extensibility during moulding. Through its effect on dough-handling properties, potassium bromate also contributes to a product's volume, grain, and texture. These effects of potassium bromate occur during the dough mixing, proofing, and baking steps (3). As an oxidizing agent in baked products, potassium bromate is converted to potassium bromide (10).

Key Issues

Beginning in as early as 1948, numerous studies were conducted to determine the potential health consequences associated with the intake of potassium bromate (5,9,16). These studies involved the use of a range of animal test species, including rats, mice, hamsters, dogs, and monkeys, and tested bromate that had been provided to the animals through its incorporation into flour, bread, drinking water, or through subcutaneous or intravenous injections. Additional studies included microbial assays and chromosome aberration and micronucleus tests. While results were often inconclusive or contradictory, many of the studies indicated that potassium bromate was nephrotoxic, ototoxic, carcinogenic, and weakly mutagenic. As a result, the World Health Organization International Agency for Research on Cancer classified potassium bromate as a Group 2B—possibly carcinogenic to humans (16).

It is important to note, however, that those studies testing potassium bromate, that had been incorporated at recommended levels into flour or bread, showed no adverse effects on the test animals. Additionally, the most recent research indicates that there may be a threshold level below which no adverse effects are detected (6,17). Work continues on this line of research.

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Summary of Major Recommendations from the *Commercial Baking Industry Guide for the Safe Use of Potassium Bromate*[a]

- Potassium bromate should be used in products or production methods in a manner such that residue levels remain below the level of 20 ppb in the finished product.
- To control levels of addition, potassium bromate should be added at the mill on the baker's instructions or by the baker, but not by both.
- A single source of bromate in a formula is highly preferred as opposed to multiple sources.
- Four critical "Check Points" are to be monitored during product development and production:
  - Product formulation
  - Ingredient delivery
  - At the mixer
  - At the oven
- Portions of GMP procedures may require modification:
  - Quality control
  - Training
  - Ingredient control
  - Receiving, storage, and shipping
  - Traceablity and recall
  - Inspection of the facility
- Product should be tested, using HPLC or equivalent methodology, at two critical stages:
  - Following product formulation (prior to production)
  - On the first day of product production and periodically (no less than every four months) thereafter
- AIB International is a resource of information and services:
  - Inspection service or consultation
  - Training programs/materials
  - Testing services/procedures ("Quick Test" Method)
  - Information support

[a] *Source: The American Bakers Association and AIB International (1).*

Because early results implicated potassium bromate with having detrimental health effects, some countries and organizations took a precautionary approach, limiting its usage or removing it from the list of approved dough conditioners. Notable among these was the United Nations Joint Food and Agriculture Organization/World Health Organization Expert Committee of Food Additives, which withdrew approval (15) of previously allowed (13,14) acceptable levels of potassium bromate treatment of flour. Countries which have restricted the use of potassium bromate include most of Europe (including the United Kingdom), Canada, China, Peru, Brazil, Nigeria, Sri Lanka, and others.

Many American bakers have also chosen to eliminate potassium bromate from their products. For some, the elimination of bromate resulted from the desire to have "clean labels" on their products. Others chose to eliminate the additive because of being located in California, for which California's Proposition 65 would require store-level consumer warnings about the presence of a known carcinogen in their products (6). While some bakeries have discontinued the use of potassium bromate, there is still an advantage to having this option available for future use if needed.

In spite of the issues raised, potassium bromate remains a highly effective oxidizing agent when used in bakery products. It possesses unique capabilities that are difficult or, at best, expensive to replace. The continued ability to utilize this functional additive, with an emphasis on doing so in a safe and responsible manner, could be very beneficial to the baking industry.

Substitutes

Because of the restrictions on or prohibited use of potassium bromate in baked products, attempts to find suitable substitutes have been made (6,11). Various other oxidizing agents, such as potassium iodate, azodicarbonamide (ADA), and ascorbic acid (vitamin C), are used in bakery applications, though issues have also been raised with some of these, and the FDA now requires the labeling of ADA. These additives are classified as fast or intermediate acting in comparison to the slow-acting potassium bromate. Thus, the timing and, subsequently, some of the effects of these alternative oxidizers differ from those of potassium bromate. In addition, some applications require the use of both fast- and slow-acting oxidizers.

Some positive results have been obtained by replacing potassium bromate using a combination of ascorbic acid and/or ADA with fungal enzymes, and an encapsulated form of ADA has also been used. Additionally, certain mechanical alternatives, including the application of a vacuum and/or high pressure, the use of different headspace gasses, and changes in impeller speeds, have shown potential for certain applications (6).

Costs, formulation and/or processing changes, and potentially negative processing side effects must certainly be considered when making these substitutions or processing changes. As a result, the wholesale baking industry has continued to work hard to find ways to keep potassium bromate available.

Testing for Residues

It has long been known that during the oxidation process the heat of a baking oven converts the potassium bromate added to a product into the relatively harmless potassium bromide. Early regulation of the amount that could be added acknowledged this fact. Most of the later concern regarding the safe use of potassium bromate in bakery applications revolves around the question of whether all of the potassium bromate added is converted or whether some residues remain at the end of the baking process.

To make this determination, it was first necessary to develop an accurate method of analyzing products for residual levels of potassium bromate content. In the early 1990s, researchers at FDA, the Yamazaki Baking Co. Ltd. (YBC, Tokyo, Japan), and the Dead Sea Bromine Group (Beer Sheva, Israel) worked to develop and improve

Table I. Factors impacting the levels of residual bromate in bakery products[c]

Reduce Residual Bromate	Increase Residual Bromate
Lower levels of added bromate[a]	Higher levels of added bromate
Added ascorbic acid	Added azodicarbonamide
Added ferrous sulfate enrichment	Added reduced iron enrichment
Use of bleached flour	Use of unbleached flour
Lower dough pH[b]	Higher dough pH[b]
Longer fermentation time	Shorter fermentation time
Higher bake temperature	Lower bake temperature
Longer bake time	Shorter bake time

[a] <30ppm.
[b] pH 5.2 vs. 5.7.
[c] Source: The American Society of Bakery Engineers (4).

methods of analysis. By 1997, collaborative efforts between YBC and the FDA led to the publication (7) of a method for analyzing potassium bromate in finished baked foods that used high performance liquid chromatography (HPLC) instrumentation that was accurate to 3 parts per billion (ppb). This method later received AOAC International peer-verified status (8). Continued work by YBC and the FDA has led to the development of a "quick test," in which chemiluminescence is used to detect the presence of residual bromate, and levels greater than 20 ppb can be measured using this method of analysis.

Understanding the Process

In 1994, the Food Technical Regulatory Affairs Committee (FTRAC) of the American Bakers Association (ABA) established the Potassium Bromate Subcommittee (2). Comprised of representatives from ABA, AIB International, and the baking industry, this group has worked in conjunction with the FDA and other groups to establish ways in which the baking industry can continue to safely use potassium bromate.

Based on results from certain toxicological tests of potassium bromate, the FDA conducted a risk analysis and subsequently identified 20 ppb as a safe upper limit for residual bromate in baked goods (5). One of the efforts undertaken by the FTRAC Potassium Bromate Subcommittee involved a series of studies (3,5,6) examining formulation and processing factors that impact residual bromate levels. These studies were an effort to determine parameters that would help maintain residues below the 20 ppb level established by the FDA. Collaboration among the various participating bakeries, the FDA, YBC, and the Dead Sea Bromine Group led to investigations involving a variety of bakery products, mixing methods, processing conditions, additives, and treatments. The parameters of the studies that were generally found to influence the levels of residual bromate in the final bakery products are summarized in Table I (4). Interestingly, the mixing methods tested—straight dough, sponge and dough, and continuous mix—appeared to have no effect on the residue levels.

Additional cooperative efforts between the FDA and the U.S. wholesale baking industry have been made to address potassium bromate concerns and needs through an effective, voluntary approach. Consultations between the two groups in the 1990s led to voluntary reductions in the amount of potassium bromate being used. The legal limit of 75 ppm was voluntarily reduced first to 50 and then later to 30 ppm for a one-pound (454-g) loaf of bread (5). This reduction in usage level contributes to lower residual bromate levels in bakery products.

Developing an Industry Guide for Safe Use

To address safety issues regarding bromate usage, the *Commercial Baking Industry Guide for the Safe Use of Potassium Bromate* (1) was jointly issued by the ABA and AIB International in September 2008 at the AACC International Annual Meeting. This guide emphasizes the need to use potassium bromate in a safe and responsible manner such that residual levels in finished products are maintained below 20 ppb and personnel handling the additive are protected.

Information in the guide includes a brief history of bromate use and concerns, as well as voluntary guidelines for the proper use, testing, and monitoring procedures for the development and production of bakery

products to which potassium bromate is added. It also addresses minor modifications that must be made to Good Manufacturing Practices (GMP) procedures that companies should follow when using potassium bromate. Additionally, it specifies the role of AIB International as a resource to the baking industry in providing inspections, training, testing, and information that will contribute toward continued safe use of potassium bromate. A summary of some of the major recommendations made in the guide (are shown in the Side Bar) and copies of the complete document may be obtained at both the ABA and AIB websites (1).

One of the main components of the *Commercial Baking Industry Guide* is for periodic testing of potassium bromate-containing products throughout their formulation and production. Two methods of analysis are recommended, each having different applications in the voluntary monitoring of residual potassium bromate levels. The first method uses HPLC technology and is a highly accurate procedure that has a detection limit of 3 ppb. This is the methodology (or its equivalent) that is to be used to test for residual bromate levels at the end of product formulation (prior to production) and then periodically (at least every four months) during production. Analysis of finished products following this methodology is available through the Food Science and Technology Department at the University of Nebraska-Lincoln by contacting Vicki Schlegel (vschlegel3@unl.edu).

The second method is the "quick test," which was developed through cooperation between researchers at YBC and the FDA. It uses chemiluminescence of bread extracts as its means of detection, and residual bromate amounts greater than 20 ppb can be measured. The purpose of the quick test is for "spot check" purposes at various points during product formulation and between the official HPLC methodology checks during production. Analysis of samples or copies of the method for companies wishing to use it in their on-site laboratories can be obtained through the AIB International Research Department by contacting Bryan Glaser (bglaser@aibonline.org).

Outlook

For the past several years, the FDA has conducted a monitoring program in which it collects commercially available bakery products and tests them for residual bromate. This program is anticipated to continue. Thus, it is essential that companies choosing to use potassium bromate in their products follow the recommendations provided in the *Commercial Baking Industry Guide*. These recommendations are practical and well within the operating capabilities of a modern baking plant.

By restricting usage of bromate to <30 ppm and rigorously adhering to formula and processing parameters that reduce residual bromate levels, finished product residues can be consistently maintained below the critical 20 ppb limit. Safe handling by bakery personnel is also important, and training in the proper procedures is required.

While the guidelines apply in most cases, it must also be remembered that certain factors, such as flour quality, product types (e.g., flat breads), and bromate form, may have a significant influence on potential bromate residues. The Japanese baking industry has been particularly active in researching these factors and developing precise control methods and procedures. This underscores the need for routine analytical testing of products that are formulated to contain bromate. Labeling of potassium bromate on product ingredient legends is also mandatory.

Diligence in these matters is essential in order to maintain the credibility of the industry and to continue having access to an ingredient that provides bakers with so many beneficial characteristics.

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