



Ozone use in flour milling

Researchers aggressively testing the chemical compound as a replacement for chlorine gas in controlling microbial contamination

by Jeff Gwirtz

Chlorine gas has been used for some time in the United States in treating soft wheat flours for various baking applications. High ratio cake flour, which is used in cakes containing a higher level of sugar than flour, is most often associated with chlorine gas treatment. In this application, chlorine gas has two major effects: whitening and functional improvement with respect to cake production.

The application of chlorine gas is typically two ounces per hundredweight of flour. The level is monitored and controlled by measuring the flour pH. Recently, chlorine gas has been extended to include chlorination of the wheat tempering water, thereby reducing microbial counts on the surface of the tempered grain and in the milling process itself.

Independent of the intended purpose, storage and use of chlorine gas is quite dangerous, but the demand for lower microbial loads in wheat- and grain-based flour products is more intense than ever. As a result, an increasing number of millers are using ozone to treat flour.

MICROBIOLOGY IN FLOUR MILLING

Food-borne disease outbreaks in the United States are caused by the following (with percent of frequency): bacteria (66%), chemicals (25%), viruses (5%) and parasites (4%). Very few food-borne illnesses are the result of contaminated flour.

Bacteria are everywhere in our environment including soil, water, air, dust, edible plants and plant products, animals and animal products, the intestinal tracts of man and animals, employees' hands and contaminated food utensils and equipment. In most cases where dangerous contamination exists in grain or grain-based products, it is usually the result of human engagement in the storage, handling or processing of the product.

Bacteria have specific nutritional and environmental needs in order to survive and reproduce. They are: food, moisture, proper atmosphere, pH, temperature and inhibitory substances. Grain and flour, of course, are a tremendous food source for material, yeast and molds. There must be adequate moisture for bacteria to grow. The amount of moisture needed is defined by the term "water activity."

Locations in the mill with a high level of humidity or water activity (0.90 plus) will support rapid bacterial growth. However, lower relative humidity areas that remain dry and have a lower water activity (less than 0.85) will not. In older mills or in locations where cool air can move across a spout containing warm stock, condensation is known to occur and shortly thereafter the population of yeast and mold increases, forming a dark smelly mass which continues to inoculate passing stocks.

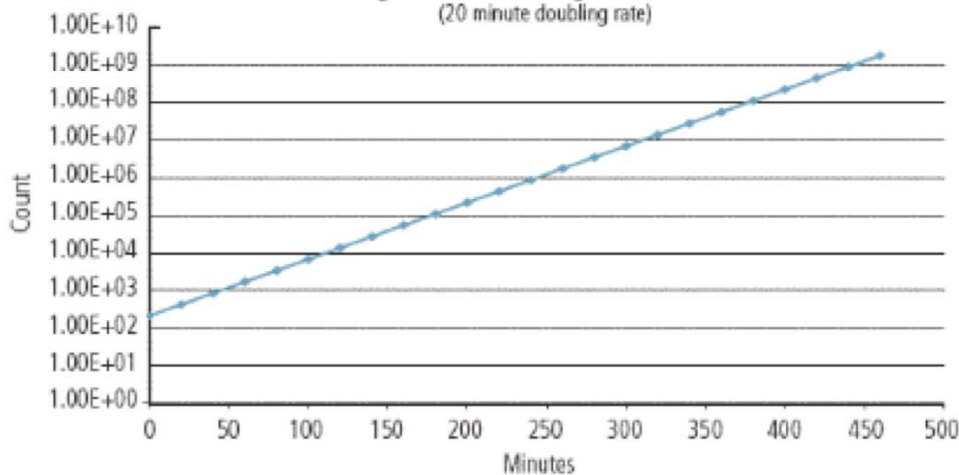
Bacillus species have been implicated in food spoilage and poisoning problems. As endospores, these mesophilic species resist a wide temperature range. Therefore, in baked products the spores germinate and damage the bread product. *B. subtilis* and *B. licheniformis* are associated with a food spoilage known as ropey bread. Most bacteria of public health concern grow best at pH values 4.6 to 7.5. The pH of freshly milled flour is often in this range with an average of 6.1 to 6.3.

Those spoilage bacteria of public health concern grow best between 60 degrees and 120 degrees F. The growth of bacteria, yeast and mold is nothing short of phenomenal. Figure 1 (page 76) shows the growth of 216 initial cells with a doubling rate of 20 minutes.

FLOUR MICROBIOLOGICAL INDICATORS

The most common microbiological indicators in flour and

Figure 1: Bacteria growth curve
(20 minute doubling rate)



baked products are total aerobic count (often referred to as total plate count), coliform/enteric bacteria count, and yeasts and mold counts.

Total aerobic count refers to a total count of microbe colonies growing on the media plate from the sample. Coliform or enteric bacteria count is a subset of the total aerobic microbe colony count and is often used as an indicator of direct or indirect fecal contamination. Yeasts and mold counts are not included in total aerobic counts, although they are also often subject to maximum tolerances. Their main relation to food safety is the potential to produce mycotoxins, which are toxic compounds produced by fungi that contaminate plants.

It has been reported that microbial counts found in a flour mill will vary widely, depending on a number of factors such as initial counts in the grain from crop conditions, milling practices, post-milling handling, moisture content of flour and storage conditions.

Typical microbiological counts in flour are 1.5×10^4 for total aerobic count; 200 for coliforms; 120 for yeasts and 800 for molds. Significant correlations have been observed between all microbial indicators and some quality criteria (e.g. test weight) and grading factors (e.g. wheat grade number, vitreous kernel content). A weak but significant correlation has also been reported between the total plate count and the moisture content of grain.

MILLING ENVIRONMENT AND MICROBIOLOGY

Warm temperatures are required for the successful separation of bran germ and endosperm to prevent bran shattering and improve ease of endosperm reduction. Moreover, the energy input dissipates in the form of heat, driving moisture off the milled product within the process.

While temperature and relative humidity of the milling room are important, it is the temperature and humidity inside the milling processing environment where bacteria, yeast and mold may cause problems. The optimal relative humidity and temperature for milling is approximately 75 degrees F (plus or minus 10 degrees F) and 65% relative humidity (plus or minus 10%), respectively.

Figure 2 (page 78) presents the relative humidity inside various break sifters and on the sifter floor during a mill run in the Kansas State University Pilot Flour Mill. Notice that the room relative humidity is less than the relative humidity measured inside the sifter, which is besides the roller mill and purifier in which the wheat processing environment exists. In some locations, constantly elevated humidity and/or rapid increases in humidity cause sifting, handling and general flow problems for the miller. Temperature and relative humidity conditions outside the optimal range have significant and negative economic and technical consequences. Rapid cooling

and condensation create conditions for microbial growth.

Some management practices can be employed to reduce microbial loads in the mill environment. Reducing microbial load on the wheat surface through addition of chlorine in tempering water has been reported to effectively reduce microbial load in the milling process and ultimately the flour.

In automated mills, there is a considerable temptation to simply shut down the unit when the load is taken off the milling unit. However, many automated mill programmers have extended set shutdown time periods, allowing mill shake down while pulling aspiration or suction to reduce humidity in the system where condensation onto product and processing surfaces could occur. Such practice assists in reducing surface condensation and caking, which lead to microbial development and start-up challenges. While the building and unit are warm, condensation may not be an issue. But it is best to let it cool down and dry out before shutting it down.

Another tool often used in older mills is dragging or cleaning the spouts to prevent active mold colony build-up.

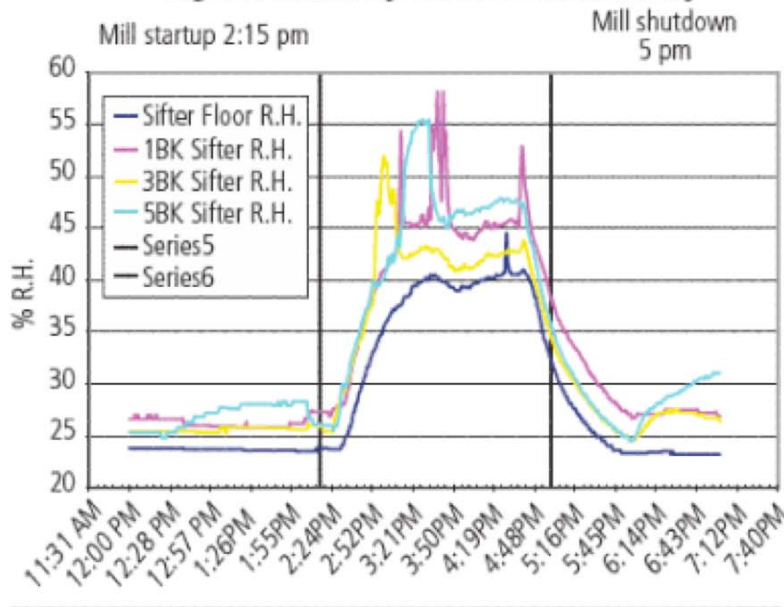
OZONE PRODUCTION AND CONTROL

The following steps have been identified for the use of ozone in a primarily aqueous system and apply to milling when used in tempering water.

- Oxygen/feed gas preparation. Produce clean, dry 95% pure oxygen from the air to improve efficiency and protect the ozone generator. It requires 50% to 75% less energy to produce ozone with purified air.
- Ozone generation: Control input oxygen concentration, increase voltage and lower feed gas flow rate to optimize ozone output.
- Mass Transfer: This was generally applied to the use of ozone in the aqueous phase, which would not be applicable to use of gas on flour. Ozone transfer in PVC piping is not recommended since a portion of the ozone is lost when it reacts with the PVC pipe. Stainless

MILLING OPERATIONS

Figure 2: Break system relative humidity



steel, such as 304 or 316, has been suggested for use in ozone transfer systems.

- **Monitoring and Control:** Control of oxygen concentrations, flow rates, voltage, etc., should be adequate for monitoring and control. However, any or all of these could be adjusted based on production rate, product moisture and temperature to

optimize addition and provide control.

Exposure to ozone is hazardous to humans. Like chlorine gas, it attacks the respiratory tract. Standards set by the Occupational Safety and Health Administration in the United States allow a permissible exposure level of less than 0.1 milligrams per liter (mg/L) on a time-weighted average for an eight-hour work period and a maximum single exposure of 0.3 mg/L for less than a 10-minute duration. Ambient air should be tested for safety using monitors which operate on the basis of UV light absorption being a function of ozone concentration.

OZONE-CHLORINE REPLACEMENT

Ozone, zanthan gum, L-cysteine, malto-dextrins, heat, combinations of heat and ozone, chlorine and ozone blends are being studied as chlorine replacements with varying degrees of success. Ozonation was studied as an alternative to chlorination for cake flour. Flour was treated with ozone at the rate of 0.06 liters per minute for 10 and 36 minutes using 5 pounds of flour. Ozonation of cake flour decreased pH and increased the lightness (L value) of flour. Baking studies using a high-ratio white layer cake formulation showed that the volume of cakes significantly increased ($p < 0.05$) as ozonation time increased, and cakes were softer than those made with

chlorinated or control flours. The cell brightness and number of cells measured by image analysis (C-Cell) of cakes from ozone-treated flour for 36 minutes exhibited similar values to those from chlorinated flour.


The optimum ozonation time was about 8 to 11 minutes with the temperature range between 36 and 46 degrees C. Increase in Mixograph peak time, peak viscosity, and water retention capacity were observed as ozonation time increased. Ozonated flour was reported to have a strong odor that affected the odor and flavor in the cakes. Volatile gases dissipated when ozonated flour was stored under a fume hood, suggesting that additional research needs to be focused on how to decrease the strong odor in flours by using processing techniques or other methods.

OZONE AND UV-MICROBIAL LOAD REDUCTION

A study to investigate the feasibility of using ozone and UV light as a substitute for chlorinated tempering water for bacteria and mold control in a wheat flour mill was conducted. In the study, microbiological test data of flour samples after milling show that the use of ozone results in a reduction in bacteria of approximately 75% to 80% compared with grain treated with chlorinated water.

Visual inspection of equipment and lines indicates a similar reduction in mold growth. Data gathered during the project indicate a potential 75% to 80% reduction in total plate count bacteria in comparison to conventional treatment with chlorinated water. The average anaerobic plate count (APC) of one group of flour samples from grain treated with chlorinated water averaged 181,675 colony forming units per gram (cfu/g). In comparison, the average APC for flour from ozone-treated grain is 42,627 cfu/g, a reduction of 77%.

The last data collected on 195 samples of flour processed showed 75 lots (38%) with APC of less than 10,000 cfu per gram. Although the project did not include mold counts to quantify the effectiveness of ozone over chlorine in mold abatement, visual inspection of equipment and lines by plant staff indicates a similar reduction of mold growth in the equipment.

International use of ozone to reduce or control microbial contamination threats appears to be growing rapidly in all food sectors. Grain-based products, because of their low moisture and water activity and the non-deleterious nature of their general microbial contaminants, make this product group one of the last to be treated with ozone for microbial control. Use of ozone to replace chlorine gas driven by both safety and residue concerns continues to be aggressively pursued. 

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