

PURGING CARBON DIOXIDE FROM CUCUMBER BRINES TO PREVENT BLOATER DAMAGE—A REVIEW

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ABSTRACT

Purging is a simple, practical means of preventing bloater damage in brined cucumbers. In the procedure, dissolved carbon dioxide in the fermenting brine is removed by bubbling nitrogen, inert gas, or air through the brine. Nitrogen or inert gas is recommended for use in purging brines; air will effectively prevent bloater damage, but its use may cause problems with brine-stock quality such as poor texture and off flavors and colors.

This review gives background information on development of the purging concept, explains the principle of purging, and gives guidelines and precautions for a successful purging operation. Areas that are not fully understood are discussed with the intent of stimulating further research.

INTRODUCTION

Bloater damage has been a source of serious economic loss to the pickle industry for decades. The problem has increased in the last 15 years or so due largely to increased demand for large cucumbers and the trend toward mechanical harvesting with resultant harvest of larger cucumbers. Large cucumbers are more susceptible to bloater damage than small ones. Bloater damage is caused by a buildup of carbon dioxide (CO_2) in the brine, which results in gas pockets inside the cucumbers. Carbon dioxide in the brine originates from the cucumber tissue and from microbial activity in the brine.

Controlled fermentation and purging of brines to prevent bloater damage are recent developments which have received considerable attention within the pickle industry. Although further research and engineering are needed to realize the full potential of these developments, the industry already is being influenced significantly from the farm level through processing and marketing of the finished pickle products. Higher yields of brine-stock cucumbers can now be expected from the larger sizes of cucumbers, which heretofore were extremely susceptible to bloater damage. Thus, these recent brining methods are timely for the farmer who has been forced to harvest more large fruit because of the current limitations of mechanical harvesters. Briners are being pressured to consider using these methods because of the improved quality and yields. Buyers of brine-stock cucumbers are now asking if the stock was purged, and if so, how, and if controlled fermentation was used.

Purging of CO_2 from brines, in particular, has received much attention since its introduction into the industry in 1972, especially by quality control supervisors and brine yard superintendents. Since then, the volume of brined cucumbers that is purged has increased annually. It is estimated that over half of the large cucumbers brined in the United States are now purged. Diminished, perhaps, is the mystique of the "old brine master" who tasted brines to determine if things were progressing satisfactorily and kicked the sides of the brining tanks to determine if the bubbles breaking the surface would yield to him insights that were not readily obvious to those who held him in such awe. The new generation of briners can show results in dollars and cents, which impresses the board of directors whether or not they understand the scientific basis for purging and controlled fermentation.

Briners must exercise caution, however, to avoid pitfalls that often attend new developments. In the food industry, the effect of even the smallest change in a product on the quality and wholesomeness for human consumption must be considered first; only then can economics be considered.

The purpose of this review is to give background information on development of the controlled fermentation process, with emphasis on purging which is an integral part of the original process. General scientific principles, advantages and precautions that should be considered by users or potential users of purging will be discussed. The review will deal only briefly with economic and engineering aspects of purging. Other aspects of the controlled fermentation process, including use of cultures and buffer additives, will not be dealt with fully herein.

PRINCIPLE OF PURGING

Carbon dioxide can be effectively removed from fermenting cucumbers by bubbling nitrogen (N_2) gas through the brine. Air and other gases will also efficiently remove CO_2 from the brine, but N_2 is recommended.

As N_2 is introduced near the bottom of the brine solution, bubbles of N_2 rise through the solution, absorbing dissolved CO_2 (Fig. 1). Carbon dioxide diffuses from the brine into the

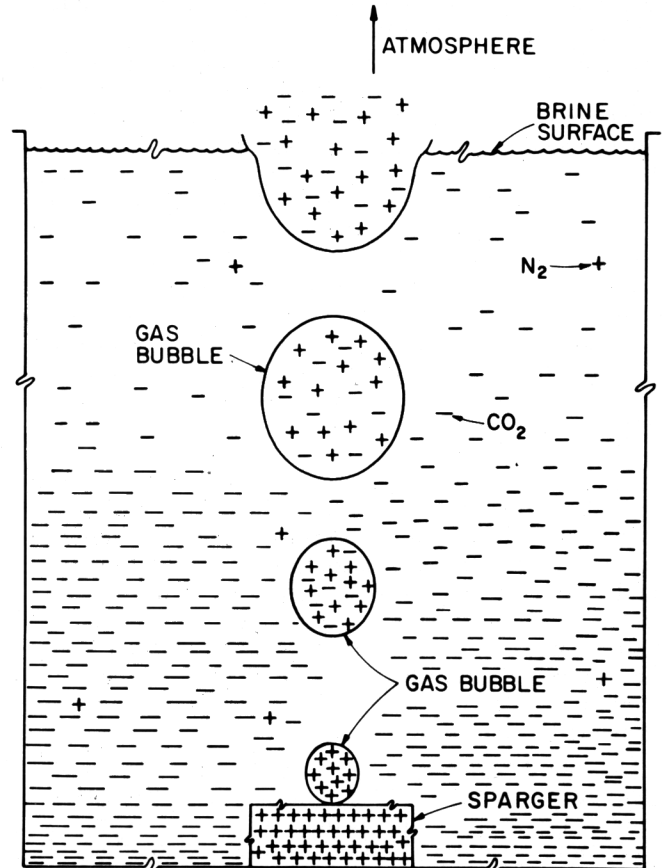


Fig. 1. Schematic view of CO_2 removal from brine by N_2 purging.

N_2 bubble. Since N_2 is only sparingly soluble in brine (its solubility is about 1/80 that of CO_2 at 27°C), only a relatively small amount of N_2 dissolves in the brine. Thus, the gas bubbles, with CO_2 entrapped, burst at the brine surface and N_2 and CO_2 are released into the atmosphere. Several factors that influence the efficiency of CO_2 removal from the brine will be discussed later.

HOW PURGING GOT STARTED

It may seem strange that such a simple procedure as purging brines to prevent bloaters required so long to be discovered. Our only consolation is that many discoveries, when viewed retrospectively, seem simple and long overdue. Numerous scientists deserve credit for uncovering scientific principles that led to the purging development.

In 1939, Veldhuis and Etchells (1) reported that gas trapped inside bloated cucumbers was of the same approximate composition as the gas that evolved from the brines. They concluded that gas was produced within the cucumbers and by microorganisms in the brine. Then, in 1943, Etchells and Jones (2) reported that salting at high brine strengths caused limited growth of

lactic acid bacteria, but extensive growth of yeasts and certain salt-tolerant coliform bacteria. Low levels of salt favored growth of lactic acid bacteria, with limited growth of yeasts. In a concurrent paper (3), they reported that high salt treatments resulted in low levels of acid, high amounts of CO₂, and a comparatively large proportion of bloaters. They concluded, therefore, that yeasts were the cause of bloating, due to production of large amounts of CO₂. Numerous studies on the types of yeasts active in fermenting brines followed (4-7). In the 1950's, several researchers reported means of controlling yeast growth by the addition of sorbic acid (8-13).

In 1968, however, Etchells et al. (14) reported that certain gas-forming lactic acid bacteria also can cause bloater damage. In a study on bloater damage in over-nite dill pickles, yeasts were excluded from the brines by the addition of sorbic acid, but numerous gas-forming lactic acid bacteria were present. Recalling the earlier advent of pure culture fermentation of cucumbers in 1964 (15), Etchells et al. (unpublished) theorized that a sure means of controlling bloater damage was at hand. Well, the theory held if one added "non-gas-forming" lactic acid bacteria to pasteurized small cucumbers in capped glass jars, as was done in the pure culture process. It was deemed impractical, however, to heat the large amounts of cucumbers necessary for bulk brining in commercial operations. Therefore, we chose to control growth of natural microflora in the cover brine and cucumber surface with the use of chlorine and acetic acid. In a critical brining experiment under the supervision of Dr. J.L. Etchells (Doc) in the fall of 1969 (unpublished), cucumbers were sanitized, acidified, and brined in a 40-gal plastic onion drum and inoculated with a pure culture of *Lactobacillus plantarum*. Only the added culture was detected in the fermentation brine; no yeasts or other bacteria were observed. The fermented cucumbers were severely bloated!

Doc had the mixed reaction of surprise, shock, and excitement, realizing on the one hand that we had not reached the promised land, but on the other hand that some more variables had been eliminated and others obviously had not been considered. His enthusiasm pervaded the laboratory as we were determined to learn more about the mechanism of bloater formation. We were still convinced that CO₂ produced during brining caused bloater damage. Two questions occupied our immediate attention: How can we measure CO₂ in the brine? Where does the CO₂ originate?

Previously, CO₂ produced during fermentations was measured by trapping the gas that evolved from the surface of brines (1). In the present instance, however, the fermentation did not appear to be of the vigorous, "gassy" type with bubbles breaking the surface. Thus, it became obvious that we should measure the dissolved CO₂ in the brine. Initially, we used the method of the Association of Official Analytical Chemists (16) recommended for alcoholic beverages. The method was time-consuming and awkward for our purposes, however, so we eventually developed our own procedure for laboratory use (17). Somewhat later we adapted the Harleco method, which is now used extensively by the pickle industry for monitoring commercial brines (18).

We determined that CO₂ in fermenting cucumbers originates from two previously ignored sources (Fig. 2): the non-gas-forming lactic acid bacteria and the cucumbers themselves (19). The CO₂ from these sources

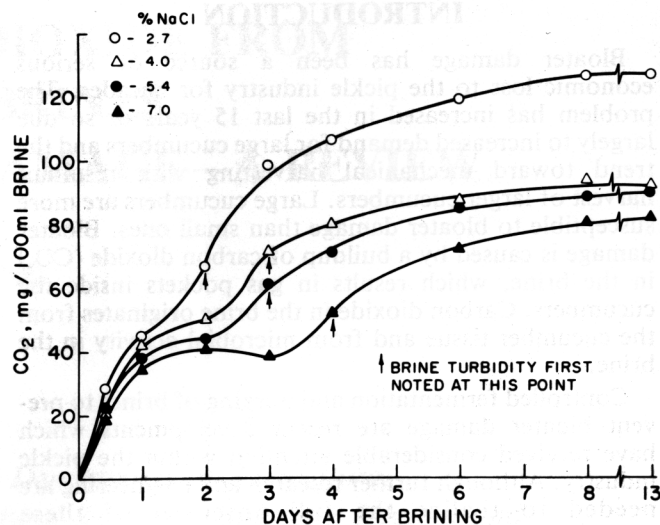


Fig. 2. Production of CO₂ in the fermentation of brined cucumbers. CO₂ appears in the brine from two sources: first CO₂ diffuses from the cucumbers and then is produced by microbes in the brine (from Fleming et al., 19).

was shown to be sufficient to cause bloater damage (20). Although *Lactobacillus plantarum* is loosely classified by microbiologists as a "non-gas-former," it produces sufficient CO₂ in cucumber fermentations to be significant.

In commercial fermentations, however, the yeasts remain an extremely important source of CO₂, since they may proliferate under conditions favorable for their growth. Thus, yeasts and lactic acid bacteria are two major microbial sources of CO₂ in fermenting cucumbers. Products of their fermentation are listed in Table 1.

TABLE 1.

Products from the fermentation of cucumbers by lactic acid bacteria and yeasts.^a

Fermentable sugars	Microorganism	Products
Glucose and Fructose	Lactic acid bacteria	Lactic acid (CH ₃ CHOHCOOH) Acetic acid (CH ₃ COOH) Ethyl alcohol (CH ₃ CH ₂ OH) Carbon dioxide (CO ₂)
	Yeasts	Ethyl alcohol (CH ₃ CH ₂ OH) Carbon dioxide (CO ₂)

^aLactic acid is by far the major product from growth of *Lactobacillus plantarum* (a homofermentative bacterium), which is sold in cultures for fermenting cucumbers. However, this bacterium also produces small amounts of the other compounds listed, including CO₂. Certain other lactic acid bacteria, called the heterofermentative type, produce lactic acid as the major product, but also relatively high amounts of CO₂ and other compounds shown. Yeasts, if grown in the absence of air, as in cucumber fermentations, produce large amounts of ethyl alcohol and CO₂. If grown aerobically, yeasts produce primarily CO₂.

