Stability of Sauerkraut Packaged in Plastic Bags

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ABSTRACT

Commercially processed sauerkraut, packaged in plastic bags, was evaluated for product stability following storage at 2, 20, 32 C. When stored at 2 C in the presence of benzoic acid and potassium metabisulfite, the product was stable for more than 8 months, whereas at 20 and 32 C the shelf life was reduced to 20 and 13 weeks, respectively. The reductions in shelf life were due to development of excessive discoloration (browning) and objectionable flavor formation. These defects appear to be caused by chemical rather than microbiological actions. In addition to serving as effective antimicrobial agents, the chemical preservatives (presumably sulfur dioxide) showed protective effects in retarding losses of naturally-occurring ascorbic acid found in sauerkraut. Under similar temperatures of storage, fresh sauerkraut containing no chemical additives had shelf life values of 22, 1.5, and 0.75 weeks, respectively. When stored at 32 and 20 C, the major defects (swollen or broken bags) were attributed to the actions of yeasts. Storage at 2 C markedly arrested and reduced viable yeasts counts, thereby extending the shelf life of the bagged product.

Food products have been packaged in containers constructed from flexible plastic films for a number of years, and sauerkraut is no exception. Based upon production estimates, (Personal communication, W. R. Moore, National Kraut Packers Association, Inc., St. Charles, IL), more than 42 million lb. of "bagged kraut" were produced by the industry during the past year. Although sauerkraut packaged in plastic bags appears to enjoy a modest volume of sales, less than 14% of the kraut produced in the United States is distributed in flexible packages. This lower acceptance rate of the packaged product is undoubtedly due to the processing methods used to preserve the final product, since naturally fermented sauerkraut serves as the ingredient common to both the canned and bagged product.

The canned product attains commercial sterility by the "hot-fill" method (2), whereas preservation of the packaged kraut relies upon the chemical treatment afforded by the additives (benzoic or sorbic acid and potassium bisulfite). In using such contrasting processes for achieving preservation, it is assumed that the physical and chemical characteristics and the anticipated shelf life of the products will be dissimilar.

Although numerous factors may influence the shelf life of a highly acid food, recent studies by Wagner (7) show that sauerkraut packed in plain electron bodies was stable for 12 months, whereas fully enameled cans provided a minimum shelf life of 18 months. However, with packaged kraut the parameters determining product stability remain to be defined. Therefore, this report describes the effect of time and temperature of storage on the keeping quality of packaged sauerkraut.

MATERIALS AND METHODS

Sauerkraut, packaged in polyethylene-mylar pouches (2 lb. capacities), was prepared under commercial processing conditions. The commercial grade samples (201 bags) were comprised of fresh sauerkraut, brine, and preservatives (sodium benzoate and potassium bisulfite). The untreated product or fresh sauerkraut (201 bags) was of similar composition but devoid of chemical additives.

Upon arrival at the laboratory, the chemically treated and untreated samples were divided equally into three lots (67 bags per lot), placed in conventional shipping cartons, and stored in 2, 20, and 32 C constant temperature rooms.

Drained weight analysis showed that the average contents of the bag were comprised of 70% solids and 30% brine. Using this distribution ratio, well drained solids (140 g) and kraut brine (60 g) were removed aseptically from each bag and added to a blender containing 100 g of sterile distilled water. Following 3 min of homogenization, aliquots of the blendate were removed for chemical and microbiological analyses.

The lactic acid bacterial population was determined by the methods and medium described by Etchells (1), whereas the viable yeast counts were established by plating on Potato-Dextrose Agar, pH 3.5.

Total titratable acidity (expressed as lactic acid) and salt (expressed as sodium chloride) were determined by the methods previously described (6). Ascorbic acid and free sulfur dioxide were determined by iodometric titrations (3).

During the first 6 weeks of storage, each bag was examined for physical intactness at weekly intervals and at bi-monthly and monthly periods thereafter. The latter schedules were adopted because of product stability and to conserve samples for prolonged testing purposes.

Microbiological and chemical analyses were done in triplicate at each designated test interval, i.e. bags were selected at random from each.
of the lots (treated and untreated) stored at each of the three
selected temperatures.

The color, flavor, and textural characteristics were evaluated by
persons knowledgeable with kraut grading procedures. The scoring
methods and the maximum allowable score points (color: 30, flavor: 30,
and texture: 10) used for evaluating product quality were similar to
those standards established for grading commercial kraut (6).

RESULTS AND DISCUSSION

Fresh sauerkraut, packaged without chemical preserv-
atives (benzoate and bisulfite) and stored at 20 and 32 C,
was extremely vulnerable to microbial spoilage. This
spoilage was visible as evidenced by the pronounced
distention of the bags and subsequent violent rupture of
the flexible plastic film.

As shown in Fig. 1, more than half (34 of 67) of the
bags incubated at 32 C ruptured within 18 h. The
remaining samples underwent similar types of destruc-
tion at sporadic intervals throughout the 5-day storage
period.

As might be expected, bags stored at 20 C showed
more reduced rates of spoilage than samples stored at
32 C. Under these conditions, simulating constant room
temperature, the 50% destruction value was reached at
the 5-day incubation interval, whereas an additional 7
days incubation were required to achieve complete
destruction of all test samples.

A further reduction in storage temperature (2 C)
decreased the incidence of spoilage most markedly; not a
single bag showed a "Bloater" defect following 8 months
of incubation. These observations suggest that low tempera-
ture storage can serve as an alternative method for chemical
additives; however, to achieve and maintain the control
of reduced temperatures throughout the complete
processing, distribution and consumer networks
appears at the present time to be an idealistic rather than
a practical solution to the preservation of bagged kraut.

It is well known that sauerkraut with its traditionally
high sal and acid contents poses a hostile environment
for many microorganisms; however, the fate and
endurance of the naturally-occurring, acid-tolerant
species in fresh kraut packaged in plastic bags and
subsequently stored at refrigeration temperatures is less
well defined. Therefore, the effects of such low-
temperature storage (2 C) upon the viability of lactic acid
bacteria and yeasts as well as the onset of undesirable
sensory characteristics (color, texture, and flavor) during
the 8-month storage term are shown in Fig. 2.

![Figure 2. Effects of low temperature storage (2 C) upon microbial viability and quality of sauerkraut packaged in plastic bags without chemical preservatives. --- Estimated viable count.](http://example.com/figure2.png)

Based upon viable cell counts, the lactic acid bacterial
population remained essentially unchanged (10^4 to 10^7
cells/g) throughout the 32-week incubation period. Since
no attempts were made to differentiate the dominant
species, the effects of low temperature storage upon the
viabilities of heterofermentative and homofermentative
lactic acid bacteria remain unknown. However, since the
plastic bags showed no visible evidence of "swells" and
the pH (3.40-3.62) and total titratable acid values
(1.17-1.39%) of the product remained essentially
unchanged throughout the course of this study, it
appears that low temperature storage effectively arrested
the major metabolic activities of the lactic acid bacteria.

On the other hand, the yeast population displayed both
growth and death characteristics during the above
conditions of storage. For example, the viable yeast
counts increased from 10^3 to 10^6 cells/g of product
during the first 3 weeks of storage; however, following 14
weeks of incubation less than 10 cells/g of product were
recovered.

Although the yeast population increased nearly 20-fold
during the first 3 weeks of incubation, the bags showed
no visual evidence of swelling. The failure to observe
perceptible swelling of the plastic bags may be due to
generation of CO2 at a reduced rate and its subsequent
diffusion through the flexible film. (The commercial
grade polyethylene-mylar film used for packaging these
sauerkraut samples does not provide a barrier totally

![Figure 1. Effect of temperature upon the burst rate of commercial sauerkraut packaged in plastic bags without chemical additives. Conditions: 97 bags were incubated at each of the respective temperatures. Initial temperature of product 12 C.](http://example.com/figure1.png)
impermeable to gaseous diffusion). Following 14 weeks of storage the yeast population declined to a level no longer detectable by the plate count method, i.e. 1.0-ml aliquots of sample yielded no viable cells when plated on PDA agar. Since methods for determining excessively low populations were not used, the maximal numbers of yeasts present remain unknown; however, the product was not devoid of viable yeasts following 20 weeks of storage at 2 C. This was demonstrated by removing four bags of product from low temperature storage and subsequently incubating them at 20 C. Following 21 days of incubation at the latter temperature each of the bags, previously showing no apparent abnormalities, developed perceptible “swell” characteristics and provided yeast counts in excess of 3 x 10^4 cells/ml.

Following 12 weeks of storage the untreated krauts began to develop a light pink color. Microscopic examination of the washed shreds indicated that this pink color was intimately associated with the shreds proper. Attempts to isolate pink yeasts or pigmented bacteria from the product resulted in consistent failure.

Following an additional 2 weeks of incubation, the discolored samples began to assume a buff or tan color characteristic which was accompanied by a loss in brilliance. This objectionable discoloration appears to be similar to that previously reported to occur in cabbage juice by Stamer et al. (5). Although color degradation was perceptible, the defect was minimal as the kraut scored 28 points (30 points, top quality) on the color scale used for grading canned sauerkraut.

The refrigerated product maintained excellent textural properties for more than 5 months. However, following 22 weeks of storage, the samples showed slight losses in crispness. Although the turbidity decreased throughout the remainder of the 32-week test period, the losses were not considered to be highly serious as the product received a score of 9 points (10 points, top quality) on the canned sauerkraut grading scale.

Flavor of krauts was judged to be of excellent quality following 7 months of storage. However, at the 8-month inspection interval, samples were judged to be highly unsatisfactory. The abrupt transition from an excellent to a sub-standard grade occurred without accompanying visible defects. The aroma of the product might best be described as “stale” with marked losses in pleasant bouquet, whereas the flavor was objectionably tart and accompanied by an extremely harsh, highly unpleasant, and lingering aftertaste.

The chemical additives, benzoic acid and sulfur dioxide or their salts, have been used for decades as preservatives of many foods and beverages. Although these compounds are frequently used for extending the shelf life of bagged kraut, their roles as antimycotic, antibacterial, and color-enhancing agents under various temperatures of storage are less well defined.

In examining the antimycotic properties of these chemicals, it was observed that yeasts were particularly vulnerable to these agents at each of the temperatures studied. For example, the initial viable yeast count, 9.4 x 10^4 cells/g, was reduced to less than 10 cells/g following 1 day of storage at 2, 20, and 32 C. Failure to recover viable yeasts throughout the course of the 8-month study period attests to the efficacy of these compounds as antimycotic agents for sauerkraut.

The effectiveness of these compounds as antibacterial agents appeared to be temperature dependent. For example, the population of lactic acid bacteria at the time of packaging was 4 x 10^4 cells/g; however, following 8 days of storage at 20 and 32 C, no viable cells were recovered. On the other hand, the samples stored at 2 C produced viable counts of 6.7 x 10^3 and 3.6 x 10^3 cells/g at the 8 and 14 day sampling periods respectively. However, no viable cells were recovered following 21 days and for the remainder of the study period.

Since the efficacies of the chemical additives upon microbial viability were measured as a function of two compounds (benzoate and SO_2), the effectiveness of each as a singular microcidal agent remains to be determined.

From a microbiological viewpoint, these data suggest that the currently recommended practice of immediately placing the freshly packaged kraut under cooler conditions of storage or refrigeration has little merit or need. Packaging and storing the product at ambient temperatures (20 C or less) for several days provides a simple means for reducing microbial populations without adversely affecting product quality and significantly reducing shelf life.

This is not meant to imply that temperature and time of storage do not play vital roles in directing biochemical deteriorations, because kraut, as many foods treated with chemical additives, is vulnerable to non-microbial degradation. The inverse relationship between stability of color and temperature of storage was quite apparent, i.e. the first visual defect (browning) occurred with those samples stored for 14 weeks at 32 C. The intensity of this browning response became so pronounced following 16 weeks of storage that the samples were judged to be completely unacceptable to the consumer. Likewise, effects of reduced temperatures upon extending color quality were quite apparent in that the onset of similar degrees of discoloration required 29 weeks of incubation at 20 C, whereas no significant changes in color were detected with those samples stored at 2 C for 32 weeks.

The most objectionable sensory defect encountered in these shelf life studies was that of “off-flavor.” Those samples stored for 16 weeks at 32 C developed highly aromatic, bitter, and medicinal flavor traits. These same undesirable flavor qualities were detected in those samples incubated at 20 C for 24 weeks; however, no flavor abnormalities were noted in those krauts held for 8 months at 2 C.

Of the sensory qualities evaluated, texture appeared to be the property least influenced by time-temperature relationships. Although undesirable flavor and color qualities dictated the time of sample rejection, all
samples held to their respective disposal dates possessed acceptable textural properties of firmness and crispness.

Since the sensory qualities (flavor, color, and texture) discussed above may singly or in concert establish final grade assignments to the product, the contributions of each factor and the effects of temperature upon the shelf life of sauerkraut are summarized in Table 1.

<table>
<thead>
<tr>
<th>Storage temperature (C)</th>
<th>Flavor</th>
<th>Color</th>
<th>Texture</th>
<th>Major defect</th>
<th>Maximum storage term</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>E/32</td>
<td>E/32</td>
<td>E/32</td>
<td>E/32 color</td>
<td>10</td>
</tr>
<tr>
<td>20</td>
<td>E/19</td>
<td>E/22</td>
<td>E/22</td>
<td>gas flavor</td>
<td>1.5, 20</td>
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<tr>
<td>32</td>
<td>E/13</td>
<td>E/13</td>
<td>E/22</td>
<td>gas color</td>
<td>&lt;0.75, 13</td>
</tr>
</tbody>
</table>

Polystyrene-mylar film; 2 lb capacities. Experiment terminated following 32 weeks storage.
Numerical values expressed as weeks.
(-) No additives
(+i) Additives (benzoic acid and sodium bisulfite)
E - Excellent; P - poor; VP - very poor qualities.

Since free SO₂ plays a vital role in producing and maintaining the desired color brightness in bagged kraut, the effect of temperature upon the fate of this highly reactive agent is shown in Fig. 3. As may be observed the SO₂ content was most rapidly depleted at 32 C, i.e. from 190 ppm (0.019%) to less than 10 ppm (0.001 %) following 14 weeks of storage, whereas the SO₂ content of the samples stored at 2 C was never less than 140 ppm throughout the storage term. A comparison of the degradation rates of SO₂ in those samples stored at 32 and 20 C indicates that the former temperature produced a 50% loss in free SO₂ concentrations following 5 weeks of storage, whereas 10 weeks of incubation at 20 C were required to achieve a similar level of disappearance.

![Figure 3](http://meridian.allenpress.com/jfp/article-pdf/41/7/525/1650141/0362-028x-41_7_525.pdf)

Figure 3. Effects of time and temperature upon the levels of free SO₂ in sauerkraut packaged in plastic bags.

Although the minimum levels of SO₂ required to maintain optimum color quality were not determined, it appears that discoloration was initiated at 32 C when the free SO₂ concentration was less than 20 ppm. (Estimated by comparing the time required for onset of discoloration, Table 1, to SO₂ levels obtained at a similar storage time, Fig. 3).

Since sauerkraut is a rich source of ascorbic acid, the effects of temperatures of storage and preservatives upon the lability of this naturally-occurring reductant were examined. As shown in Fig. 4, the ascorbic acid values (15 mg/100 ml brine) of those krauts stored at 2 C in the presence of benzoate and SO₂ remained essentially unchanged throughout the 32-week storage term. The effectiveness of refrigeration temperatures in extending the shelf life of vitamin C was very apparent in that storage at 20 and 32 C produced a 50% reduction in ascorbic acid content following storage periods of 12 and 3 weeks, respectively.

![Figure 4](http://meridian.allenpress.com/jfp/article-pdf/41/7/525/1650141/0362-028x-41_7_525.pdf)

Figure 4. Effects of preservatives and storage temperatures upon ascorbic acid content of sauerkraut packaged in plastic bags. (+i) benzoate and bisulfite added. (-) no additives.

The protective effects of the preservatives, benzoate and SO₂, on extending the shelf life of ascorbic acid were also noted. As shown in Fig. 4, the kraut samples stored at 2 C without preservatives suffered losses of 7 mg/100 g of product within 10 weeks, whereas the treated samples showed no apparent losses following 32 weeks of storage. Although the specific roles of the individual additives were not examined in this study, it is assumed that SO₂ rather than benzoic acid functioned as the active protectant for ascorbic acid since the former is known to serve as an oxygen scavenger in many biological systems.
Chemical Contaminants and Milk

Of all the foods on the market-place, few are more carefully regulated and scrutinized for safety than milk. And few foods offer the outstanding nutrient profile; milk's nutrients are necessary for all age groups. But today's technology and increased use of various chemicals in the environment may occasionally lead to contamination of milk. Such accidental contamination is rare and potential danger to the public is minimal due to federal regulations. Nevertheless these dangers have been exaggerated through rumors and reports in the mass media.

PBB's: Polybrominated Biphenyls

PBB's are primarily used as a component of fire retardants. In 1973 there was a mix-up in Michigan and a batch of fire retardant was mistakenly added to animal food. The result was the condemnation and destruction of thousands of agricultural animals along with tons of milk, butter and cheese.

While no adverse effects could be detected in the general population, isolated cases of ill-effects were noted primarily by farmers who used the PBB contaminated animal food and chemical plant workers who were exposed to PBB's via non-dietary sources. Recent studies in Michigan have shown that PBB's are not readily taken up by plants or leached from the soil into water, thus contamination of animals and animal by-products via soil contamination appear unlikely.

Food and Drug Administration permits 0.3 parts per million (PPM), fat basis, PBB's in dairy foods, which provides a 100 fold margin of safety. While most consumers have heard of PBB's, only one percent of those surveyed in Michigan reported decreased milk purchases and consumption because of concern over milk contaminated with PBB's.

The PBB contamination in Michigan was the worst chemical accident in agricultural history. Although financial losses were great, there was no hazard to the consumer, thanks to strict regulation and observation.

PCB's: Polychlorinated Biphenyls

PCB's have a number of industrial applications as insulated agents in electrical equipment, in paints for silos and other metal structures, as lubricants in paper container manufacture, and as an ingredient in pesticides. Over the years, PCB's have been found as contaminants in various agricultural commodities, including dairy foods.

In 1970, the U.S. Department of Agriculture banned PCB's in pesticides. Voluntary action by industry has been effective in decreasing the use of PCB's even more. Such action has led to steadily declining levels of contamination in foods—far below FDA permitted levels. Ironically, since contamination has been proved avoidable, FDA has proposed lowering permitted levels of PCB contamination in dairy foods from 2.5 ppm to 1.5 ppm (fat basis). Today, game fish are the primary source of PCB's in the diet.

PCP's: Pentachlorophenol

PCP is an industrial chemical primarily used by the wood preserving industry and as an insecticide against termites in the south. During the production of PCP the final product is often contaminated with another class of chemical compounds—dioxins—which are a highly toxic class of chemicals. Present data indicated that the quantities of the dioxins present in PCP production do not constitute a danger to man or the environment.

Contamination of milk with PCP can be oral (ingestion by dairy cows) or tactile (absorption through the skin of dairy cows). While exposure to PCP is minimal when good manufacturing practices are followed and manufacturers directions are followed when used in preserving wood, the American Wood Preserving Institute recommends that PCP's not be used in closed environments or on wood used for animal food storage or feeding.

Recently six Michigan dairy herds were quarantined due to suspected contamination of these animals with PCP or dioxins. Food and Drug Administration examination of milk from these herds proved negative. Clearly PCP's and its co-contaminant dioxins may have toxic effects. However, if used properly potential contamination of dairy herds and milk products are negligible.

REFERENCES