Effects of High Temperature Storage on the Quality of Fresh Cucumber Pickles *

by ***R. C. Nicholas and I. J. Pflug*** AGRICULTURAL ENGINEERING DEPARTMENT, MICHIGAN STATE UNIVERSITY

DURING the summer of 1957 the authors made a temperature survey of the warehouse of a Michigan pickle manufacturer. Some of the temperatures, particularly near the ceiling, were over 100°F. How long, we wondered, will these high temperatures prevail in a warehouse, and what effect will they have on the quality of the products stored there? A preliminary test, conducted the following winter (1957) indicated that such high temperatures have an adverse effect on pickles. A more extensive study was therefore made to characterize the deterioration observed at these high temperatures, discover how rapidly this deterioration takes place at different temperatures, determine the cooling rate of the product stored in the warehouse, and make recommendations regarding satisfactory storage temperature.

The Test

Five 12-jar cases each containing three fresh cucumber pickle products (predominantly variety SR-6) which had been packed on August 8, 1958, were brought to East Lansing, Michigan. On August 15, one case of each product was placed in each of five temperature controlled rooms: 40, 72, 86, 90, and 100°F. The probable temperature of the products before the test was in the range of 85-90°F. The products remained in the paperboard cases and were not exposed to light, except when being evaluated.

In this study, quart jars of fresh-whole dill pickles, the most common fresh cucumber product, were used. These are manufactured by placing fresh cucumbers in jars, then adding brine containing salt, acetic acid, and spices. Only the cucumber skin is exposed to view.

A second product studied was a fresh cucumber dill strip, in which the cucumber is cut length-wise, packed vertically with the cut side next to the glass, exposing the inner surface of the cucumber. They were covered with a brine similar to that of the whole dill pickle.

The third product was a fresh cucumber strip also packed with the cut surface exposed to view, but covered with a sweet liquor containing sugar in addition to salt and acid.

Evaluation

Although there are many criteria by which to evaluate fresh cucumber products—such as acid, salt, sugar, drained weight, and height of fill—it was felt that these were secondary to those of appearance, flavor, and texture which are the determining factors for consumer acceptance. In spite of the difficulties inherent in making these evaluations, as well as the lack of agreement as to what constitutes a good pickle, we nevertheless conducted periodic tests on this basis.

The ideal fresh cucumber pickle has a bright, opaque appearance, the skin being similar to that of the fresh cucumber; it also differs from a processed pickle, which looks translucent.

The inside surface of the cut, fresh cucumber is bright, white, and opaque but under adverse conditions loses its brightness, becomes darker, and appears translucent. The property described here as translucent can also be called a cured look. If the covering liquor contains sugar, deterioration is accompanied by a marked darkening of the product.

The ideal pickle is crisp; it parts with a distinct snap when bitten, and chewing is accompanied by a definite crunching. The texture of whole pickles can be measured by the Magness-Taylor fruit pressure tester. In this study whole dill pickles were tested in this manner using the 5/16″ head. The results of fruit pressure tests are reported here as pounds pressure by convention.

Loss of crispness is generally evidenced first in the seed cavity which loses body texture altogether; the flesh fails to crunch upon chewing; and in the final stages of texture loss, the skin will tear with very little applied force.

Flavor is more difficult to discuss other than to say that it is "off," that it is not the same as the flavor of a good pickle, nor is it desirable. In addition to the above properties, a cloudiness of brine was observed in the most advanced stages of deterioration.

The general appearance of these products was given a rating based on a five-point scale. The highest rating, 5, is that of the product just after pasteurization, and the lowest rating, 1, is based on the appearance of thoroughly deteriorated pickles, examples of which were available from a 1957 pack that had been stored under adverse conditions for one year. In general, a product rated as 3 can be described as edible and no doubt salable, but one which has definitely suffered storage deterioration and which, on the shelf, would look inferior to a product that had had better treatment.

Three jars of each type of product, one rating 5, one rating 3, and one rating 1, were selected from samples in various stages of quality deterioration available from the 1957 and spring, 1958, trials; these were kept at 40°F during the tests and were used as standards.

Color photographs of the products were taken periodically. These are available in department files.

RESULTS

Appearance

Storage at 40°F. All three products stored at this tem-

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perature remained in excellent condition in all respects throughout the test period (388 days). Afterwards, they were rated at 4½ in overall appearance, since they compared favorably with similar products from the 1959 pack. The reason for the down-grading was the presence of small, opaque areas on the cut surface of both strip products and on the skin of the whole dills.

Storage at 72°F. All products held up very well in all respects at this temperature, at least through January 27, 1959. At that time they could not easily be distinguished from the same product stored at 40°F. By the June 4, 1959, evaluation, a cured appearance (translucent) had developed to some extent in both the strip products, and the brine in the whole dill jars had become somewhat cloudy.

At the end of the test period, the dill strips were rated at 3½ (acceptable), sweet strips at 3, and whole dills at 3½. Both strip products were rated down largely on the basis of obvious translucent areas; the whole dills were rated down on the basis of the cloudy brine.

Storage at 86°F and 90°F. These two storage temperatures will be discussed together because the same remarks apply to both. By October 7, 1958, after only about 50 days in storage, all three products began to show a change in appearance; they were graded down on the basis of a loss of brightness (the appearance of translucent regions) compared to products stored at lower temperatures.

By December 1, 1958, the strip products had reached a score of about 4 on appearance but by January 27, 1959, both strip products had dropped to a score of 3 for the 86°F storage and 2 or less for the 90°F storage. A score of 2 is unacceptable.

By June, 1959, after about 9 months in storage, the two strip products had deteriorated about as far as they could go, although they were easily distinguished from the products stored at 100°F. At the end of the test, the rating was determined as 2 (little obvious change from the previous determination), but at this time the brine was noticeably cloudy.

Perhaps the only reason these were not rated at 1 was that the products stored at 100°F looked even worse. Changes in appearance in the whole dill pickles were not as rapid, or as obvious. By January there was definite loss of brightness, and, by June, the brine was distinctly cloudy; at the end of the test the skin was definitely opaque and the brine, very cloudy. A rating of 2 or less was assigned.

Storage at 100°F. On September 23, 1958, after about five weeks in storage (six weeks after processing) the two strip products showed signs of deterioration and were marked down because of the translucent areas. By the end of December the strip products scored 3 or less and by the end of January, 2 or less. At the end of the test they were rated at 1; the brine was quite cloudy.

The whole dill pickles did not show deterioration as readily as the strip products. By January 1959, all the whole pickles stored at 72°F, and higher, were less bright than those stored at 40°F, but there was no obvious distinction among them. By June, 1959, the whole dills stored at 100°F had noticeably more cloudy brine than those at lower temperatures, and because of the translucent appearance, were hardly distinguishable from processed dill pickles. The product stored at 100°F showed a definite drop in the brine level.

General remarks on outward appearance. The dill strips began to show deterioration somewhat earlier than the sweet strips; however, the darkening of the sweet product was greater at the end of the test. When the jars were put on the examining table at random, it was simple to rearrange them according to their increasing storage temperatures. Deterioration occurred at all storage temperatures used in this study.

Texture

Table I gives the average pressure (as a function of time and storage temperature) of at least 10 cucumbers from a single jar of the whole dill pickles. High pressure readings are indicative of firm, crisp pickles. The test jars were cooled or warmed as required to about 72°F before determining the pressure with the Magness-Taylor fruit pressure tester. In only one instance was a second jar examined at the same time and temperature. These pressure data must be regarded as suggestive rather than conclusive, because they do not provide enough information for a statistical analysis. Since this was a commercial pack, the initial pressure of the cucumbers before processing is not known, but was probably about 15 lbs. Pickles testing 10 lbs. or more can be regarded as satisfactory to excellent; those testing 5-10 lbs. should be suspected of deterioration; and pickles testing 5 lbs. or less are soft, and, therefore, unsatisfactory. In interpreting Table 1, bear in mind that the variation in pressure from jar to jar at a particular time and storage temperature is probably in the range of 2-3 lbs.

The fruit pressure tester cannot be used to test strip products. By the end of the test, the strip products stored at 86°F, and above, were softened, as measured subjectively by biting or feeling. Those stored at 100°F were appreciably worse than those at 86°F and 90°F. The pattern of texture loss with time for the strip product probably follows that of the whole dills.

Table 1

Average pressure, lb., (10 or more pickles) in jars of whole fresh cucumber dill pickles

Storage Temperature, °F	Days in Storage 104	125	161	289	338
40	12.6	8.5[1] 11.4[1]	10.8	8.8	13.6
72	9.5	9.8	10.3	8.8	12.2
86	9.0	9.0	9.2	9.8	10.9
90	9.2	8.1	9.1	7.2	8.3
100	9.1	7.4	8.0	4.5	< 3.4

[1] Two jars tested.

Flavor

The emphasis in this study was on appearance of the products in the jars. Flavor is not only difficult to characterize, but it also involves wide differences of opinion. Suffice it to say that the authors judge the flavor of all products stored at 86°F and above to have marked off-odor and taste at the end of the test period.

Warehouse Temperatures

Some of the results of a study made of products in a warehouse are shown in Figure 1. The figure shows product temperatures at several locations as a function of time. These results are presented here to show how product

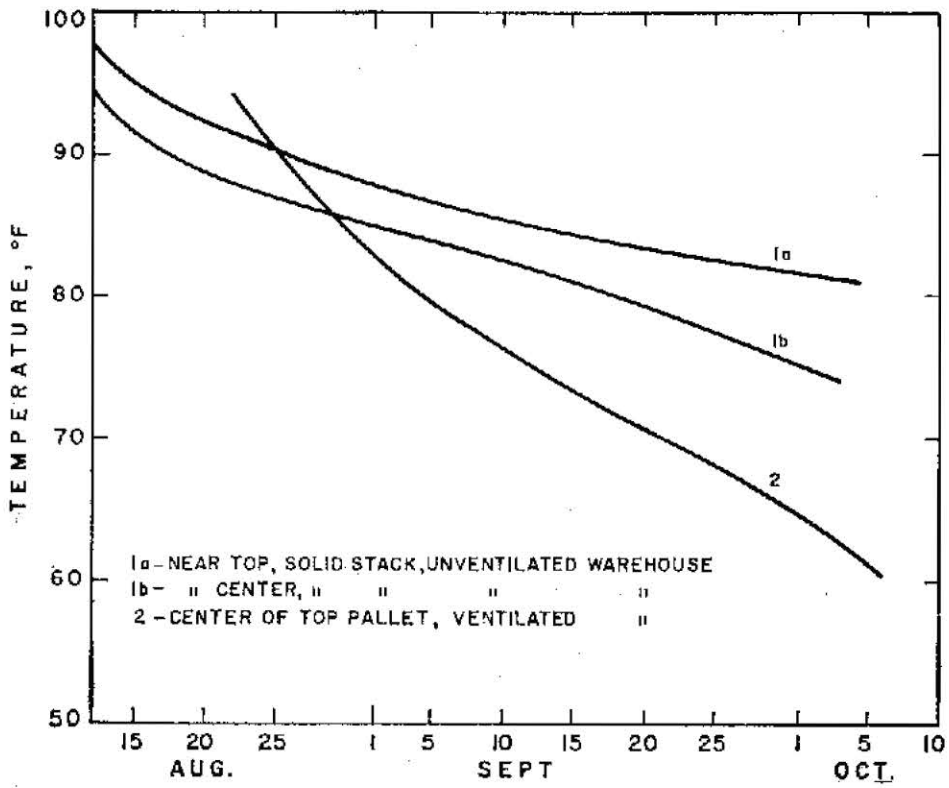

Fig. 1. Product temperatures in two warehouses.

cooling proceeds in a particular warehouse at a particular location. Some of the factors which affect the rate of product cooling are discussed below.

In general, the rate of cooling varies as the square of the minimum dimension of the stack or pallet and directly as the temperature difference between the air in the warehouse and the product that is being cooled.

RECOMMENDATIONS

First, the product should be cooled as quickly as possible, and second, an average effective temperature of 72°F or less should be maintained for the entire storage period.

It should be understood that there is no simple breaking point above which storage deterioration is certain, and below which no deterioration will occur. This study indicates that the same amount of deterioration will result from certain combinations of storage time and temperature, according to a pattern such as 100°F—1 day; 82°F—2 days; 58°F—5 days; 40°F—10 days. That is, a product stored 1 day at 100°F will show the same deterioration as the same product stored for 10 days at 40°F (or 2 days at 82°F or 5 days at 58°F).

For example, the products in this study stored at 100°F showed just perceptible change at about 6 weeks; those stored at 40°F showed a similar slight change at approximately 13 months, or about 10 times as long a storage period.

Another important feature of storage deterioration is the additivity of the adverse storage effects. For comparison purposes a reference temperature of 40°F is chosen, and one day of storage at 40°F is assigned the value of one storage-day-temperature (DT) unit. To get the storage DT units accumulated at other temperatures, a factor is needed to convert the days of storage at that temperature to equivalent days of storage at 40°F, or storage DT units. Equivalent days factors for several temperatures are listed in Table 2.

Table 2
Conversion Factors for Various Storage Temperatures

Storage Temperature, °F	Equivalent Days Factor
100	10.0
90	6.8
86	5.8
82	5.0
72	3.4
58	2.0
40	1.0

Table 3 gives the storage DT units corresponding to a quality classification based on the results of this study.

Table 3
Fresh Cucumber Pickle Quality

Quality Rating	Storage DT Units
Excellent-to-good	Less than 400
Good-to-fair (still salable)	400 - 1400
Fair-to-poor	1400 and over

Storage DT units at a particular temperature are obtained by multiplying the number of days of storage at that temperature by the equivalent days factor for that temperature. These factors are based on a Q_{10} of 2,[1] which appeared to fit the data.

To illustrate the use of Tables 2 and 3, the following example is cited. Table 4 gives a representative storage history of a fresh cucumber product and the corresponding storage DT units for each time-temperature combination.

The storage DT units accumulated during the 30 days of storage at 72°F is obtained by multiplying 30 days times 3.4, the equivalent days factor (from Table 2) corresponding to 72°F.

[1] Temperature coefficient. Here the rate of deterioration doubles for every 10°C increase in storage temperature.

Table 4
Storage History

Storage Temp., °F.	Days	Storage DT units
100	1	10
90	5	34
72	30	102
58	75	150
Total	111	296

This product has a total of 296 storage DT units at the end of the 111 days of storage and is, therefore, still classified as excellent-to-good quality (Table 3). This particular product will have 104 days (400-296) of 40°F. equivalent storage left (from Table 2) before the quality drops below the good-to-excellent classification. If, at the end of the 111 days of storage, the product moves into marketing channels where the temperature is 82°F., then there will be 21 days of storage life remaining (104 ÷ 5); if the temperature in the marketing channels is 72°F., there will be 30 days of storage life left (104 ÷ 3.4).

It must be understood that the above example is worked out for good-to-excellent appearance at the time of purchase, since the homemaker cannot be expected to pick a poor product off the shelf. The best guess that can be made based on the data in this study for the equivalent days' storage for a product that is just acceptable is 1400 equivalent (to 40°F.) storage DT units. The products stored at 72°F. in this study were kept for 388 days and were judged to be acceptable; this length of storage corresponds to 1290 storage DT units.

The procedure for a manufacturer to follow is primarily one of learning what his warehouse conditions are during the storage period. Temperature should be measured regularly in the stacks of goods at several points, particularly at suspected trouble spots such as points near the ceiling, points exposed to direct sunlight, and points near heaters, boiler rooms, or processing plant entrance.

Some of the factors that will influence the time spent at high temperatures are the initial temperature of the product leaving the processing line, the method of stacking (whether solid or on pallets), position in the stack, location of the stack in the warehouse with respect to trouble spots, general design of the warehouse with respect to artificial or natural ventilation, and the outdoor temperature.

It will be necessary for the manufacturer to know his warehouse and the condition of the product in it before he can decide whether his warehousing procedures need revision.

SUMMARY

Deterioration during storage of fresh cucumber pickles was found to be a function of temperature, the rate of degradation being faster at higher temperatures. The basic recommendation for quality retention is to cool the product quickly and keep it cool. A method is described for predicting quality as a function of storage conditions.

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