

GASEOUS PRODUCTS OF CUCUMBER PICKLE FERMENTATIONS^{1,2}

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The normal fermentation of cucumber pickles in salt brines is accompanied by the evolution of considerable quantities of gases. At times during the production of gases, a froth may be formed on the surface of the brine to a depth of as much as four or five inches. The presence of carbon dioxide in these gases has been mentioned in the literature, but no systematic study of them has been reported. A study of the gases evolved was undertaken at a temporary field laboratory located at a commercial cucumber pickling plant at Faison, North Carolina. At this plant facilities were provided for the experimental salting of cucumbers using brines of various salt concentrations; 85-bushel vats were used for the purpose.

The evolution of gases from vats has been taken more or less for granted by commercial cucumber salters. It has been used as an index to the rate of fermentation, and when exceptionally large amounts of gas were evolved, the salt concentration of the brine has been increased to decrease the rate of fermentation. When these studies were first undertaken, analyses for carbon dioxide and oxygen were made and it was found that in some cases during active fermentation the carbon dioxide content of the gases was above 99 per cent. It soon became apparent, however, that at times some other gas besides carbon dioxide was being formed because some samples collected during rapid evolution of gases contained less than 50 per cent carbon dioxide and no oxygen. It was then found that the bubbles on the surface of some brines would explode with a distinct pop when touched with a lighted match. Changes were made in the gas-analysis outfit so that combustible gases could be determined. The combustible gas was found to be hydrogen, but it was also found that hydrogen was not produced by all the cucumber-pickle fermentations. The effect of various factors on the production

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of carbon dioxide and hydrogen, and a study of the microorganisms responsible for the production of these gases proved interesting.

ANALYTICAL METHODS

The gases were analyzed in an apparatus similar to the Williams gas analysis outfit, Model B. Carbon dioxide was determined by absorption in a concentrated solution of potassium hydroxide and noting of the decrease in volume. Oxygen was determined by absorption in alkaline pyrogallol solution. Hydrogen was determined by burning with added oxygen in an electric spark explosion burette and noting the decrease in volume. The absence of methane or other combustible hydrocarbon gases was shown by passing the products of combustion through the potassium hydroxide to absorb any carbon dioxide and noting no decrease in volume. Adjustments in the oxygen-sample ratio nearly always resulted in an explosion. Amounts of hydrogen as low as .3 and .2 per cent were determined by this method.

PRELIMINARY EXPERIMENTS

Cucumbers have small bubbles of gas included in their structure which give a rather opaque, white appearance to the sliced fruit. As the cucumbers cure in brine these bubbles disappear and leave the tissues somewhat translucent. These bubbles may be removed by the repeated application of vacuum or by heating. In order to obtain an approximation of the amount and composition of this gas, a flask was filled with cut cucumbers, water was added, and the water boiled slowly. The gases driven off were collected over saturated brine, measured, and analyzed. A kilogram of cucumbers treated in this manner yielded 94 cubic centimeters of gas of which 37.6 cubic centimeters were carbon dioxide and 1.4 cubic centimeters were oxygen. An analysis for hydrogen was not made, but the remainder was undoubtedly nitrogen. This method may be subject to some criticism, but at least it gives an idea of the extent and composition of the gas in fresh cucumbers. These gases, from the interiors of the cucumbers seem to come out at a fairly constant rate during the fermentation: and nitrogen from this source probably accounts for the sum of the carbon dioxide, oxygen, and hydrogen falling short of 100 per cent, especially during slow evolution of gases.

Although no attempt was made to measure the quantity of gas evolved during the fermentations in vats, a laboratory experiment gives some idea as to the amount of gas evolved. A three-liter flask was packed with cucumbers and allowed to ferment in a brine of 15 per cent saturation for four days and then salt was added to bring the salt content to 30 per cent saturation. During the fermentation

4,800 cubic centimeters of gas were collected, of which 4,600 cubic centimeters were carbon dioxide. No analyses for hydrogen were made. In this case the volume of the gas was slightly over one and one-half times the volume of the fermenting brine plus cucumbers. This treatment corresponds roughly to the 20° salometer treatment explained later. It was observed that vat fermentations in 40 and 60 per cent saturated brines gave off considerably larger volumes of gas than fermentations in brines of 20 and 30 per cent saturation; and since there were variations with the same treatment, this can be considered only a very rough estimate.

EXPERIMENTAL PROCEDURE

In general, commercial practices were followed in salting the cucumbers in the experimental vats. The vats were filled with cucumbers, a layer of boards was fastened in place over the cucumbers, and salt brine added to a level about four inches above the layer of boards. Brines of 20, 30, 40, 60, and 80° salometer were used to cover the cucumbers. The degrees salometer of a brine indicates the percentage of saturation of the brine with respect to salt. Thus, a 100° salometer brine would be saturated and contain 26.4 per cent sodium chloride. Additions of salt were made to the vats to maintain the brines at the indicated salometers during the first week, and then salt was added to the 20, 30, and 40° salometer brines so as to raise the concentrations to 70° salometer by the end of the sixth week. The 60° brine was raised to 70° salometer during the sixth week. The 80° salometer brine was maintained at that concentration. The salting procedures will be indicated by the initial brine concentrations. The temperatures of the brines during the fermentations were within a few degrees of 26.7°C. (80°F.). Most of the vats were outside and unsheltered. Three sheltered vats will be indicated. No special starter or inoculation was used. The cucumbers were not washed and undoubtedly an abundance of microorganisms of various types were introduced by the cucumbers and adhering particles of soil. Inverted funnels were placed over cracks in the layer of boards that held the cucumbers immersed in the brine, and samples of the evolving gases collected in the funnels by displacement. The samples were transferred to the gas-analysis outfit for analysis.

A determination for oxygen was made on all samples, but the values are omitted from the tables. The values were too small to be of significance. During the rapid evolution of gases little or no oxygen was detected. The amounts ranged from none to two or three tenths of one per cent. It is believed that the oxygen came largely from the small bubbles in the interiors of the cucumbers.

Larger amounts of oxygen were an indication that something was wrong with the sample, and the oxygen determination served as a check to indicate whether any air had been introduced into the samples.

RESULTS OF GAS ANALYSES

Some of the results of the gas analyses with the 60° salometer brine fermentations are given (Table 1). The gas collected on the second day probably contained a large amount that had been trapped in the vat during filling and also some gas coming from the interiors of the cucumbers, as indicated previously. From the second to the

TABLE 1
*Analyses of Gases Produced by Fermentation of Cucumbers in
60° Salometer Brines*

Age <i>days</i>	Vat 7		Vat 11	
	CO ₂ <i>pct.</i>	H ₂ <i>pct.</i>	CO ₂ <i>pct.</i>	H ₂ <i>pct.</i>
2	45.0	0.0	38.7	0.0
12	33.9	56.2	17.8	35.4
15	60.4	39.1	41.4	35.8
19	52.3	40.4	51.5	40.8
23	65.0	9.1	72.8	20.5
27	87.4	10.0	79.8	15.1
31	88.7	8.8	93.7	3.9
37	90.2	8.5	89.2	7.1
41	78.8	4.1	81.4	12.2
45	68.7	24.4	82.7	9.3
50	70.5	18.0	90.7	4.4

12th day the evolution of gas was so slow that there was an insufficient amount for analysis. On about the 12th day the evolution of gas started and continued until after the 50th day, when the analyses were discontinued. The most important result to be noted is the persistence of a relatively high percentage of hydrogen throughout the fermentations. During the early part of the active fermentation the content of hydrogen ranged around 40 per cent. On about the 21st day the percentage of hydrogen began to decrease.

Some of the analyses of gases from fermentations in 40° salometer brines, with the different treatments indicated (Table 2), show that hydrogen was found in only one vat, No. 14, and it was found as long as the evolution of gases continued from that vat. Even in the case of this vat the percentage of hydrogen was much less than in the cases with 60° salometer brines. The brines in Vats 6 and 10 were circulated for an hour a day with a pump and it was noted that gases were given off over a shorter period of time from these

TABLE 2

*Analyses of Gases Produced by Fermentation of Cucumbers in
40° Salometer Brines*

Age	Vat 1		Vat 14		Vat 2		Vat 5		Vat 6		Vat 10	
	Regular		Regular		Sheltered		Sheltered, stirred		Sheltered, circulated		Circulated	
	CO ₂	H ₂	CO ₂	H ₂	CO ₂	H ₂	CO ₂	H ₂	CO ₂	H ₂	CO ₂	H ₂
<i>days</i>	<i>pct.</i>	<i>pct.</i>	<i>pct.</i>	<i>pct.</i>	<i>pct.</i>	<i>pct.</i>	<i>pct.</i>	<i>pct.</i>	<i>pct.</i>	<i>pct.</i>	<i>pct.</i>	<i>pct.</i>
2	56.3	0	46.9	0.0	49.1	0	43.0	0	39.2	0	44.2	0
7	66.8	0	54.1	21.6	70.7	0	54.8	0	51.1	0	56.4	0
10	53.0	0	60.7	14.0	35.6	0	59.7	0	57.5	0	38.8	0
14	91.0	0	91.0	0.3	61.3	0	43.5	0	52.0	0	91.6	0
20	85.4	0	82.4	1.7	80.7	0	89.9	0	89.0	0	88.2 ¹	0 ¹
24	87.0	0	92.2	1.1	76.2	0	90.7	0

¹ Age 17 days.

