3-1965

The Effect of Ammonia on Frozen Foods

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To the Graduate Council:

I am submitting herewith a thesis written by Abdel-Hamid A. Kassem entitled "The Effect of Ammonia on Frozen Foods." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Science and Technology.

Melvin R. Johnston, Major Professor

We have read this thesis and recommend its acceptance:

Leon E. McCarty, W. W. Overcart

Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

February 25, 1965

To the Graduate Council:

I am submitting herewith a thesis written by Abdel-Hamid A. Kassem entitled "The Effect of Ammonia on Frozen Foods." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Technology.

Mahrim R. Johnston

We have read this thesis
and recommend its acceptance:

Ivon E. McCarty

W W Overcast

Accepted for the Council:

Hilton A. Smith
Dean of the Graduate School

THE EFFECT OF AMMONIA ON FROZEN FOODS

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Abdel-Hamid A. Kassem

March 1965

ACKNOWLEDGMENTS

The author would like to express his sincere appreciation to Dr. Melvin R. Johnston, Head of the Food Technology Department of the University of Tennessee, for his valuable guidance and criticism in the development of this thesis, and to the staff of the Food Technology Department for their encouragement and interest during the preparation of this thesis.

Thanks, too, are due to Dr. Bernadine Meyer, Mrs. Mary Ann Mysinger and Miss Mary Nell Hicks, who conducted the taste panels, and to the kind people who so conscientiously served on the panels.

To all the foregoing, as well as to all the other persons associated with the carrying out of the tests described in this thesis, I should like once more to extend my warm and heartfelt thanks.

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CHAPTER I

INTRODUCTION

On March 3, 1962, a liquid-ammonia line broke in the frozen food storage room at the University of Tennessee Food Technology Department, and exposed the foods in the 0° F storage room to ammonia. Customers of the Department complained that the flavor and odor of the foods had been ruined.

In January 1964, the same type of accident occurred on a commercial scale. A liquid-ammonia line broke in a 0° F storage room at a commercial company in Knoxville, Tennessee. The room was 30 by 60 by 15 feet (approximately 2700 cubic feet), and the amount of ammonia liberated was estimated to be 100 pounds. The break was in the corner of the room next to the door, which appeared to expose the stored food to different concentrations of ammonia. Experiments were made to compare the foods with similar fresh-frozen foods and to measure the effect on the foods' acceptability.

This study was made in an attempt to (1) illustrate the buffer effect of foods, (2) determine the effect of ammonia on the physical characteristics of three different foods: ground beef, strawberries,and green beans, (3) determine the effect of ammonia on the organoleptic qualities of these three foods, (4) compare the permeability of four different package materials to ammonia, and (5) elucidate the rate at which ammonia is able to penetrate into these three foods wrapped in wax paper.

CHAPTER II

REVIEW OF THE LITERATURE

A perusal of the literature reveals an almost complete lack of knowledge of possible changes in certain quality attributes in frozen foods exposed to ammonia. Phillips (16) observed changes in the pH, color, appearance, odor, flavor, and texture of five food products when exposed to two different levels of ammonia in two different wrappers.

Sheets and Lopez (22) developed an apparatus for determining dissolved and dispersed gases in foods. This permitted rapid gasometric determination and quantitative analysis of the total dissolved and dispersed gas content of canned, packaged, or fresh foods. The method was found to be applicable to foods of varying consistency, fluidity, and viscocity. This apparatus was used for studies of internal can corrosion, food discoloration, and flavor changes as related to the gas content of the finished product. The instrument does not appear to be useful in cases where the change in color, odor, or flavor is due to a chemical reaction between the gas and the food product.

Changes in the chlorophyll content in green vegetables has been used as an objective evaluation. Ross, Brekke, and Moore (18) noted that an objective evaluation of green beans for processing was individual color measurements made with a photoelectric filter photometer, such as the Hunter Color and Color Difference Meter. However, Ross, Pauls, and Hard (19) suggested that uniformity of color was another important factor determining quality. If enough individual measurements were made, the bilateral distribution of these values from the main color value should be a measure of degree of uniformity.

The destruction of chlorophyll was found to be the principal factor responsible for color loss in frozen green vegetables, and when cooking green vegetables, Sweeney and Martin (25) noticed that a large portion of the chlorophyll was converted into pheophytin. This conversion was found to be most critical at pH 6 to 7. Previous work attempted to prevent this conversion by adding alkaline materials, such as sodium bicarbonate and hexametaphosphate Gilpin, *et al.* (8), disodium glutamate, sodium hydroxide, and magnesium hydroxide. Malecki (14) and Sweeney and Martin (26) reported that there was a definite relationship between pH and chlorophyll stability and found that spinach and green peas, which were best in chlorophyll retention, also had the highest pH. Conversely, brussel sprouts and green beans, which were lowest in pH when cooked, were also lowest in percent retention of chlorophyll. They demonstrated that adding buffers of pH greater than 7 resulted in little color improvement, but produced a sharp decrease in panel flavor scores.

In the evaluation of strawberries, color was found to be one of the reliable factors. Shah and Worthington (20) used the Hunter Color and Color Difference Meter when measuring the color of strawberries. Color variation was overcome by converting the sample into a homogenous form. Strawberries were blended and deaerated before a color measurement was obtained. They have also used the Photovolt Reflection Meter and the Beckman DU Spectophotometer. Tinsley, Sidwell, and Cain (27) used three methods to measure the color of fresh and frozen strawberries to the Hunter Color and Color Difference Meter: (1) computing the arithmetic means, (2) rotating the sample, and (3) blending. Instrumental color values were compared directly and after conversion to the C. I. E. system with the A. M. S. grades for color.

Sondheimer (23) reported that the anthocyanin pigment of strawberries exists in an equilibrium between a red modification, R, and a colorless form, ROH, and the equilibrium was observed to be pH dependent. Lukton, Chichester, and Mackinney (13) studied the rate of anthocyanin breakdown in nitrogen and oxygen and found that in both cases the breakdown was faster and pH dependent in oxygen, whereas in nitrogen the pH had little effect. They concluded that the rate of oxidation seemed to be directly dependent upon the percentage of pigment existing in the form of the pseudobase.

Karrer, et al. (11) showed that anthocyanins and anthocyanidins isolated from natural sources were readily oxidized by hydrogen peroxide at room temperature to discolored or colorless products. Sondheimer and Kertesz (24) added that there were two mechanisms by which anthocyanin may be decolorized with hydrogen peroxide. One of these reactions is catalyzed by ferrous ions, and the rate of anthocyanin destruction by this reaction was usually much faster than by the non-catalyzed path.

It was noted (1) that maximum protection for frozen strawberries during storage was associated with packaging materials of extremely low gas permeability. The acceptability rating of samples in glass freezer jars is significantly higher for comparable samples stored in other materials.

Again, color was a reliable objective test that indicated deterioration of meat. Changes in acceptability is accompanied by a brownish discoloration:

$$\text{Oxymyoglobin} \longrightarrow \text{Myoglobin} \longrightarrow \text{Metmyoglobin}$$

Townsend and Bratzler (28) pointed out that the two most important factors responsible for the discoloration of meat and the formation of metmyoglobin were light and temperature. Lane and Bratzler (12) added that formation of metmyoglobin in frozen meat was significantly increased by its exposure to fluorescent lights and by the presence of magnesium and ferrous chlorides. Brown and Dolew (5) added, when working on myoglobin solutions, that oxidation was slower at -5°C than at 0°C. At -10°C the solutions were frozen, and the rates of oxidation sharply increased. When the temperature was further decreased, the oxidation rates continued to increase.

Townsend and Bratzler (28) reported that prefreezing conditions affect initial color degradation of packaged meat prior to freezing; repeated freezing and thawing in an oxygen impermeable wrapper had a marked effect on frozen meat color.

Twelve per cent of the packers of frozen fruit and vegetables in the nation use polyethylene bags. In 1960, 31,633,769 pounds of vegetables were wrapped in polyethylene bags, 69 per cent more than in 1959. Strawberries were among the five most important products sold in polyethylene bags. High quality food products must be used in these packs since they experience a severe flavor loss when mishandled. The problems encountered in freezing fruits and vegetables in polyethylene bags are: brittle bags, discoloration, breakage, icing, and opening of seals. Phillips (15) pointed out that there was no single type of film or any combination of films that could meet all the packaging problems. The ultimate packaging decisions rest with the individual product manufacturers. The flexible films commonly used were cellophane, polyethylene, and polyester.

A survey directed by Du Pont Film Department Marketing Research Committee (7) indicated that polyethylene bags tended to increase product consumption. Since American consumers were able to purchase vegetables in polyethylene bags, 18 per cent of them are buying more, because (1) they can use only what they need and can store the remainder, (2) they like to be able to see the product, and (3) they feel that the bags contribute to the economical aspect of the product.

It was reported (1) that in 1961 more frozen fish and sea food were packaged in polyethylene bags than in any other packaging material. The reasons were that polyethylene is completely printable, air tight, easily closed with heat, and less expensive. Porter (17) demonstrated that the two-pound bag was the most popular but that there was an increasing amount of interest in the smaller ones. He also reported that bag designs were becoming more versatile. The majority were printed over a large area with window openings.

Beardsell (3) summarized the conditions that the containers should withstand as follows: (1) substantial changes in temperature, humidity, and vapor pressures, (2) vibration in trucks and railroad cars, (3) low temperatures and high air velocities in blast freezers, (4) condensation from changes in temperature and humidity, and (5) weight of stacking under the foregoing unfavorable conditions.

Sensory methods for the determination of palatability, evaluated by a panel of judges, were essential in most food experiments because they answer the important questions concerning food taste, smell, appearance, and texture. Shallenberger and Mattick (21) assumed that flavor is composed of chemical substances that possess distinct characteristics or the same chemical in different proportions and that there was no instrument that measured precisely "bitterness" and "sweetness." People were more sensitive and could select more minute concentrations of certain flavor chemicals, but they were not very consistent and were easily fatigued. For detection of small differences in the intensity or quality of flavors, three common experimental designs were used: (1) pair tests (Which is the stronger? or, Which is the regular flavor?), (2) duo-trio tests (Which of the two coded aliquots is identical with the third "standard" aliquot?), and (3) triangle tests (Which of the three aliquots is odd?).

A study by Gridgeman (10) suggested that pair tests and triangle tests were normally about equally efficient; these were superior to duo-trio tests. Buch, et al. (6) used an organoleptic evaluation scheme in which the judges were asked to score the sample on a one to ten scale. A sample of the control, arbitrarily given the score of five, was included for the purpose of comparison.

Gordon and Noble (9) reported that the choice of procedure for evaluating flavor requires a decision as to the purpose of the experiment whether (1) the consumer preference, in this case, the opinion of a wide sampling of consumers is ultimately required, or (2) the differences in a specific flavor attribute, in this case, a trained laboratory panel, can give a measure of differences in a flavor attribute without necessarily stating a preference.

Boggs and Hanson (4) suggested that, for high degree of accuracy, experiments should be designed to (1) minimize within sample variation, (2) limit the number of samples and characteristics of each of those judged in one period, (3) submit at one time all the samples for which comparative data are desired, (4) relate experimental samples to control samples, (5) mask all characteristics except the one under consideration, (6) eliminate samples of strong odor or flavor when possible, and (7) judge sufficient replicates to show that trends can be repeated or replicate sufficiently that data can be analyzed statistically.

CHAPTER III

MATERIAL AND METHODS

The frozen foods from a commercial plant in which an ammonia tube broke were sent to the Food Technology Department at the University of Tennessee. They remained in a 0°F room until their frozen and thawed appearances and odors could be examined.

A Beckman Titrometer was used to determine the pH of the samples and to compare it with the pH of the fresh foods. The instrument was standardized and checked periodically with a buffer solution of pH 7.0. To ensure close contact of the electrodes and samples, 50 grams of the samples were homogenized with 150 milliliters of distilled water in an Osterizer for two minutes.

An experiment was designed to determine the buffer capacity of various foods. The products used were as follows:

1. Frozen green beans.
2. Fresh green beans.
3. Frozen potatoes.
4. Fresh potatoes.

5. Frozen green peas.
6. Frozen strawberries.
7. Frozen fish sticks.

Samples of these foods were prepared by osterizing as described above. The 50 gram sample was titrated to pH 9 against 0.1004 N sodium hydroxide and 0.0913 N ammonium hydroxide. The pH was recorded after each milliliter of base was added.

An experiment was designed to study the effect of ammonia on the pH, buffer capacity, color reflectance, appearance, odor, flavor, and texture. Three foods and four wrappers were used (Plate I). The foods were commercially frozen, sliced strawberries, frozen green beans, and frozen ground beef. One package of each product was over-wrapped with (1) regular material, (2) a heat-sealed polyethylene bag, (3) a heat-sealed Cryovac bag, and (4) a heat-sealed wax paper. They were then placed in separate pressure cookers, which were used as treatment chambers to expose the foods to ammonia (Plate II). All packages in batches (2), (3), and (4) were pierced before being over-wrapped to allow the free circulation of the ammonia vapors that penetrated the experimental over-wrappers.

Control Cryovac

Polyethylene Wax

PLATE I

EFFECT OF AMMONIA ON THREE FOODS

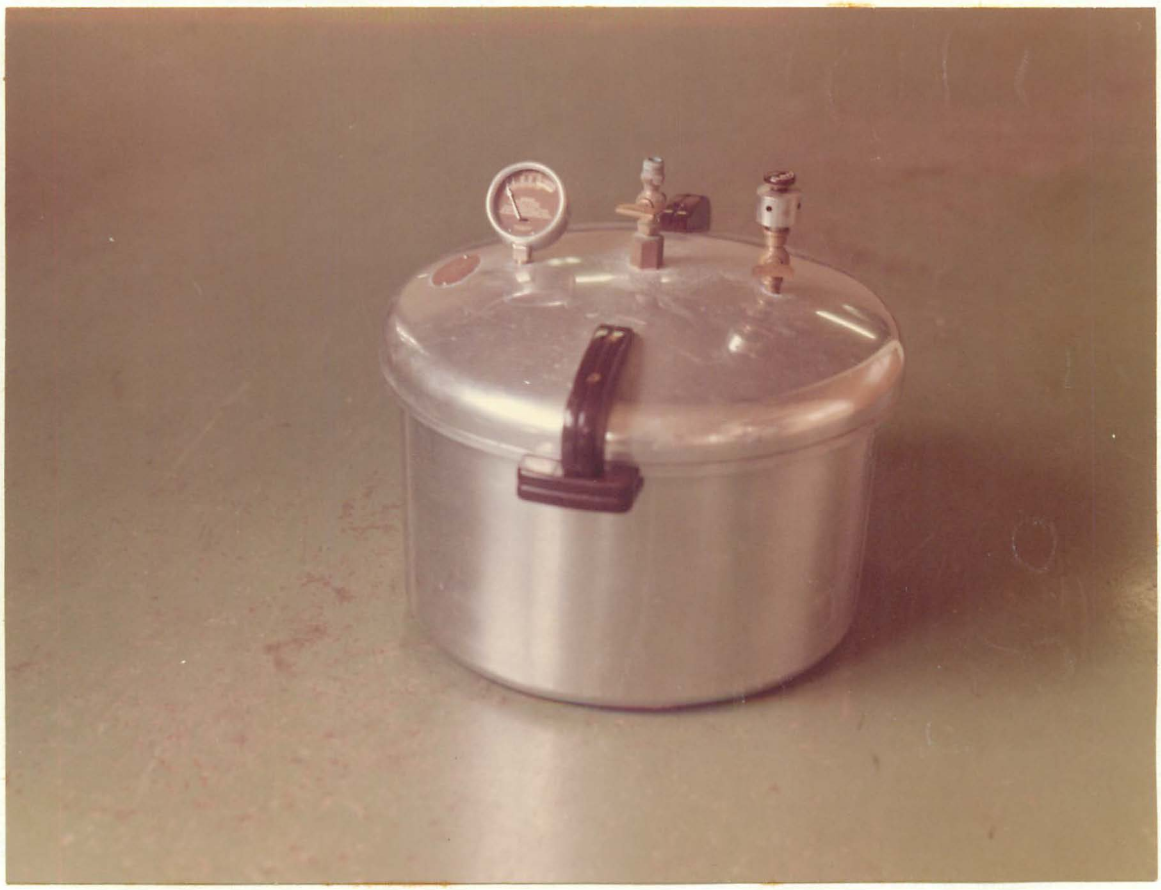


PLATE II

PRESTO PRESSURE COOKER

A cylinder of ammonia was cooled in a -10°F freezer so the ammonia could be drawn off as a liquid. Ten milliliters of liquid ammonia in a glass beaker were placed in each of the treatment chambers. The chambers were sealed and placed in a -10°F storage room. After 60 hours, the chambers were removed and opened, and the samples were taken out and aerated for 30 minutes at room temperature. After aeration, the samples were replaced in the chambers and returned to the storage room for an additional 24 hours before examination. Fifty grams each of strawberries and green beans and 25 grams of ground beef were homogenized with 150 millileters of distilled water in an Osterizer for two minutes. A Zeromatic Beckman pH meter was used to measure the pH of the foods exposed to ammonia and to determine their buffer capacity when titrated against 0.0995 N hydrochloric acid. The pH meter was standardized and checked periodically, using a pH 7 buffer solution (Plate III).

A Hunter Color and Color Difference Meter was used to measure the Hunter values "L", "a", and "b" of each sample (Plate IV). The Color Difference Meter measures the average diffuse, daylight color of a flat, opaque surface. A plastic unit 4 by 4 by 2 inches was used to obtain the color

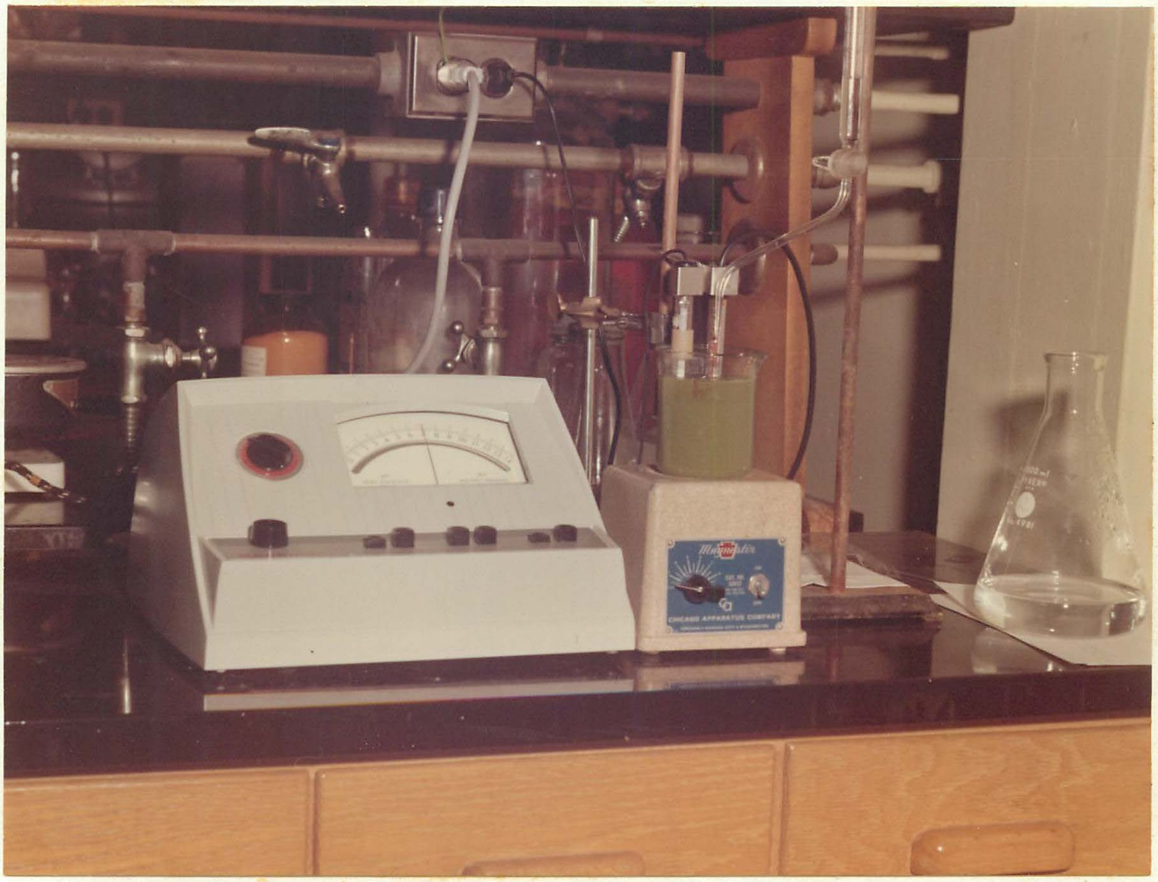


PLATE III

ZEROMATIC BECKMAN pH METER

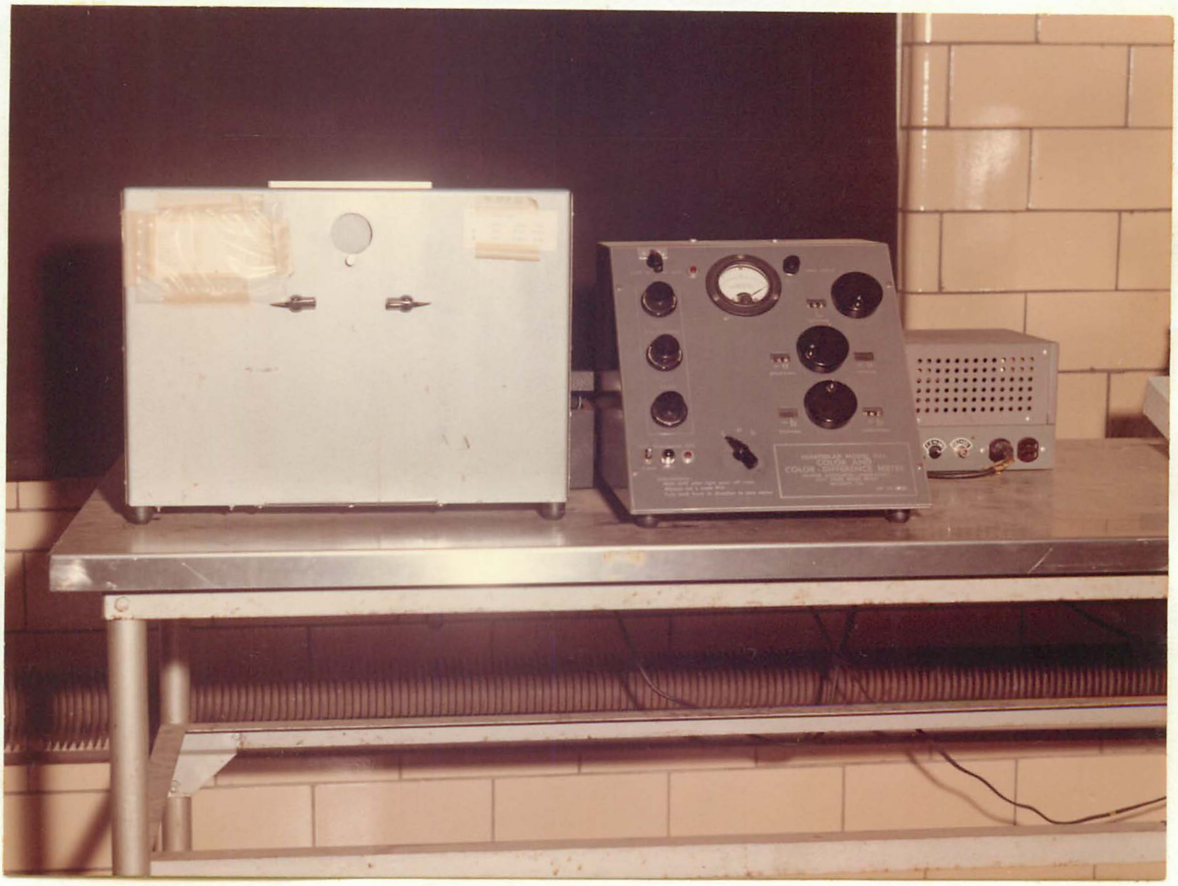


PLATE IV

HUNTER COLOR AND COLOR DIFFERENCE METER

measurements for green beans and strawberries, and the standard circular unit, 1-1/2 inches in diameter, was used for the ground beef samples.

The colorimeter was standardized using plate D25-230. The hitching post technique was employed in determining color values for each of the sample products. Plate D25-232 was used for comparative measurements for strawberries and ground beef. Plate D25-233 was likewise used for green beans.

The foods were prepared for a taste panel evaluation by the Home Economics Laboratory. The green beans were taken from the storage room and placed in boiling water; the water was again brought to a boil, the heat turned to low, and the green beans left to simmer in a covered container for 12 minutes. The strawberries were simply thawed. The ground beef was prepared for the taste panel by making it into patties of 50 grams, 1/2 inch thick. The oven was preheated for 15 minutes on broil, and the patties were broiled for 5 minutes on one side and 4 minutes on the other. Each taster was given half a patty. The samples were judged for flavor, odor, texture, and color by a taste panel of six members. The scale used for evaluation was as follows:

Plus 3 - much better than control

Plus 2 - better than control

Plus 1 - slightly better than control

0 - same as control

Minus 1 - slightly worse than control

Minus 2 - worse than control

Minus 3 - much worse than control

The panel members were instructed to indicate their preference with respect to the control sample for each quality attribute. As previously mentioned, all the treatments within the product were judged at one sitting. A glass of water was provided for each member of the panel. Results of the organolytic tests were obtained by adding the scores of the taste panel algebraically and calculating the means. The panel data was also statistically analyzed, using the analysis of variance and Duncan's multiple range test.

An experiment was run to test the rate at which ammonia is able to penetrate through the foods. Green beans, strawberries, and ground beef were used. They were wrapped in wax paper, heat sealed, and one sample of each was placed in four exposure chambers with 10 milliliters of liquid ammonia and the chambers were placed in the -10°F storage room.

The first chamber was left in the storage room for 6 hours, the second for 24 hours, the third for 48 hours, and the fourth for 72 hours; then they were opened, the food aerated for 30 minutes, replaced in the chambers, and returned to the storage room for 24 hours until examined. Fifty grams of strawberries, 50 grams of green beans, and 25 grams of ground beef were osterized with 150 milliliters of distilled water, then titrated against hydrochloric acid (0.0995 N).

CHAPTER IV

RESULTS AND DISCUSSION

I. TESTING THE FROZEN FOODS FROM THE COMMERCIAL COMPANY

The foods that had been exposed to ammonia at the commercial company were sent to the Food Technology Department at the University of Tennessee. The products, observations and results are shown in Table I.

All products which absorbed ammonia had an ammonia odor, and an off flavor, and a higher pH value than the fresh product. The sliced beef in barbecue sauce had an ammonia odor and an off flavor, but did not show an increase in pH due to the strong acidity of the vinegar and the tomatoes in the sauce. The fish fillet was only affected on the surface due to its compressed form, which did not permit the ammonia vapors to penetrate. The whole chickens in Cryovac and the strawberries in five gallon tanks were not affected at all due to the impermeability of the containers.

TABLE I

RESULTS OF TEST ON FOODS FROM THE COMMERCIAL COMPANY

Product	Package	Observations	pH Evaluation of Samples	
			Ammonia	Fresh
1. Salisbury steak TV dinner	Regular TV dinner package (aluminum tray, covered with foil and placed in a cardboard box)	Strong smell of ammonia before and after thawing. Cooked samples were unedible.		
Meat			7.2	6.0
Peas			8.5	6.5
Potatoes			7.8	6.0
2. Sliced beef and barbecue TV dinner	Ditto	Ditto		
Meat		pH of the meat was not affected due to the acidity of the vinegar and tomatoes in the barbecue sauce	5.6	5.6
Corn			8.3	6.5
Potatoes			8.4	6.0
3. Green beans	Large polyethylene bags and placed in cardboard boxes	Mild odor of ammonia before thawing and unnatural odor after thawing	7.1	6.0

TABLE I (Continued)

Product	Package	Observations	pH Evaluation of Samples	
			Ammonia	Fresh
4. Green beans	Small polyethylene bags	Strong smell of ammonia before and after thawing.	8.7	6.0
5. Halibut steak	Cardboard box	Strong smell of ammonia before and after thawing. Cooked samples were inedible.	7.2	6.5
6. Newburg lobster	Cardboard box	Strong smell of ammonia before and after thawing. Cooked samples had an unnatural objectionable flavor.	7.4	6.0
7. Seabasco downeaster lobster	Cardboard box	Ditto	7.4	6.0
8. Lobster TV dinner	Regular TV dinner package	Strong smell of ammonia, especially in the potatoes and peas. Cooked samples were inedible.		
Lobster			7.8	6.0
Peas			8.9	6.0
Potatoes			8.4	6.5

TABLE I (Continued)

Product	Package	Observations	pH Evaluation of Samples	
			Ammonia	Fresh
9. Shrimp	Cardboard boxes and wrapped in wax paper	Strong smell of ammonia before and after thawing. Cooked samples were inedible.	8.6	6.0
10. Fish filet	Pressed into a large cake in a cardboard box	Slight smell of ammonia on the surface.	7.0	6.5
11. Strawberries	5-gallon cans	Natural odor and flavor	3.5	3.5
12. Hamburgers	Polyethylene bags and placed in cardboard boxes	Light odor of ammonia when frozen. After thawing, natural odor. Cooked samples had a natural flavor and odor.	6.2	6.0
13. Whole chicken	Cryovac bags	Natural odor before and after thawing. Cooked samples had a natural odor and flavor.	6.3	6.2
14. Pieces of breaded chicken	Cardboard box	Strong smell of ammonia before and after thawing. After cooking, strong soapy smell due to the reaction of ammonia with the chicken fat. The samples were inedible.	8.5	6.2

II. BUFFER CAPACITY OF FOODS

The buffer capacity of fresh and frozen potatoes, as shown in Figure 1, indicates that the increase of the pH, after adding alkali, was directly proportional to the added volume of alkali until the pH was 7.5. (A complete listing of the data is to be found in the Appendix.) After reaching pH 7.5, the rate of increase of the pH was not so steep. Although the pH was raised from 6 to 7.5 after the addition of 10 milliliters of alkali, it was only raised from 7.5 to 8.5 after adding 20 milliliters more of the alkali. There was no difference in the buffer capacity of the fresh or the frozen potatoes.

The buffer capacity of frozen and fresh green beans, as shown in Figure 2, indicates that the increase of the pH, after adding alkali, was directly proportional to the added volume of alkali until pH 7.5.

The pH 7.5, or the rate of increase in pH dropping, was noticed more in the fresh green beans than in the frozen product. It was also noticed more in the ammonium hydroxide titration than in the sodium hydroxide titration.

In the fresh product, the pH was raised from 6 to 7.5

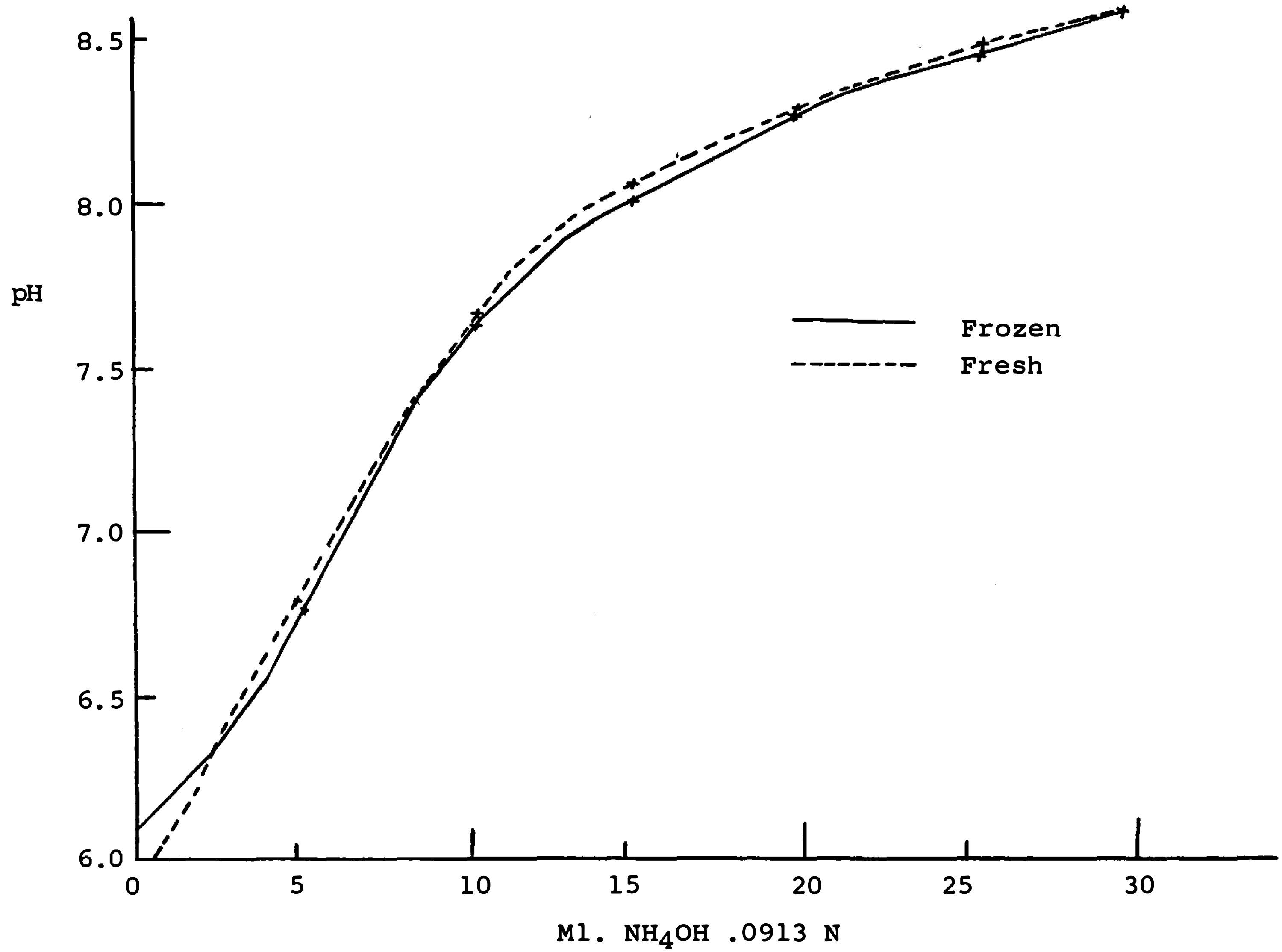


Figure 1. Buffer capacity of potatoes.

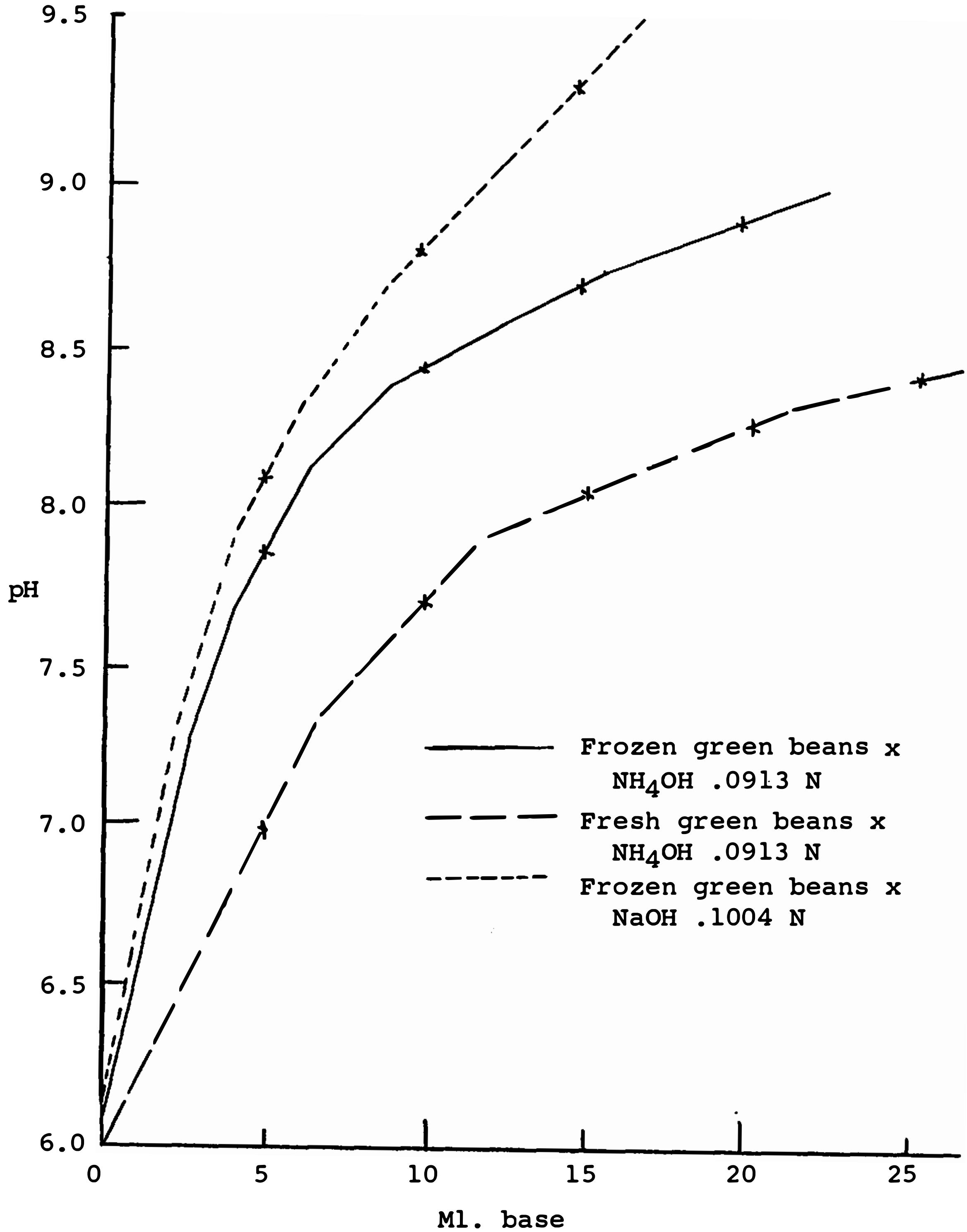


Figure 2. Buffer capacity of green beans.

by the addition of 7 milliliters of alkali, and was raised from 7.5 to 8.5 by the addition of 25 milliliters of alkali.

In the frozen product titrated against ammonium hydroxide, the pH was raised from 6 to 7.5 by the addition of three milliliters of alkali, and from 7.5 to 9 by the addition of 20 milliliters of alkali.

In the frozen product titrated against sodium hydroxide, the pH was raised from 6 to 8 by the addition of 4 milliliters of sodium hydroxide and from 8 to 9.5 by the addition of 13 milliliters of alkali.

It was also observed that in the fresh and frozen product titrated against sodium hydroxide or ammonium hydroxide, the break points at which the product indicated buffer action were similar: approximately 7.5.

The buffer capacity of frozen peas, as shown in Figure 3, indicates that the increase of the pH value after addition of a base was directly proportional to the added volume of base until the pH reached 8, after which the rate of increase in pH dropped. Although the pH increased from 7 to 8 after the addition of 5 milliliters of base, it required 12 milliliters of sodium hydroxide or 25 milliliters of ammonium hydroxide to increase the pH from 8 to 9.

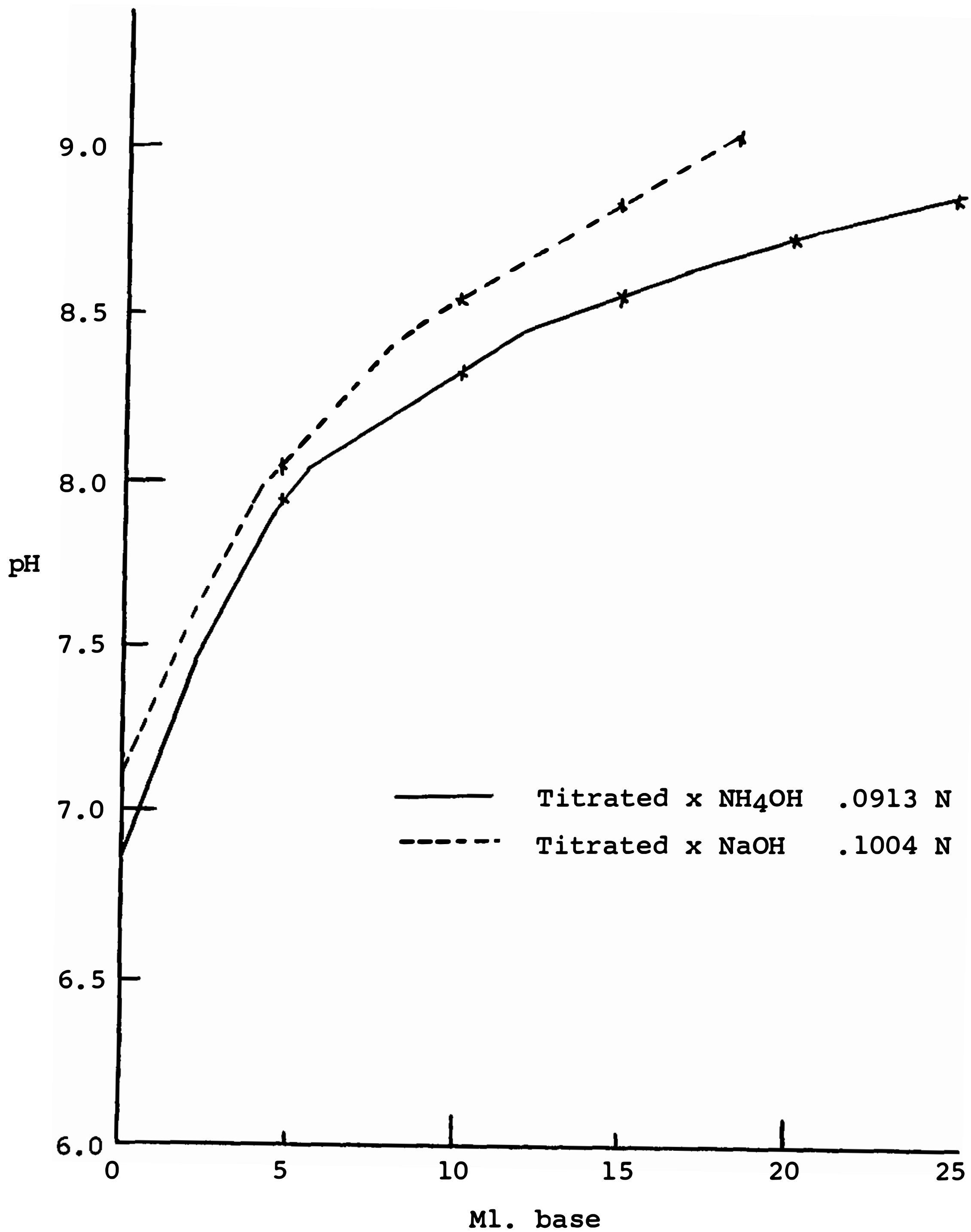


Figure 3. Buffer capacity of peas.

The break point at which frozen peas indicated a buffer action was pH 8.

The buffer capacity of frozen strawberries, as shown in Figure 4, indicates very little effect after the addition of alkali, and, as seen in the figure, the increase in pH was almost directly proportional to the added alkali.

Also, because of the high acidity of the strawberries, a very large amount of alkali was necessary to increase the pH. The strawberries needed 50 milliliters of ammonium hydroxide to increase the pH from 3.7 to 8.2 or 50 milliliters of sodium hydroxide to increase it from 4.8 to 8.2.

The only observation made when titrating a solution of strawberries against either of the two alkalies was that the color of the solution was changed to a dark brown after the alkali was added.

The buffer capacity of frozen fish sticks, as shown in Figure 5, did not indicate a very pronounced buffer capacity after the alkali was added, but the increase in pH was almost directly proportional to the amount of added base. A slight buffer effect beyond pH 8 was noticed.

The buffer capacity of ground beef, as shown in Figure 6, indicates that ground beef, when titrated against alkali,

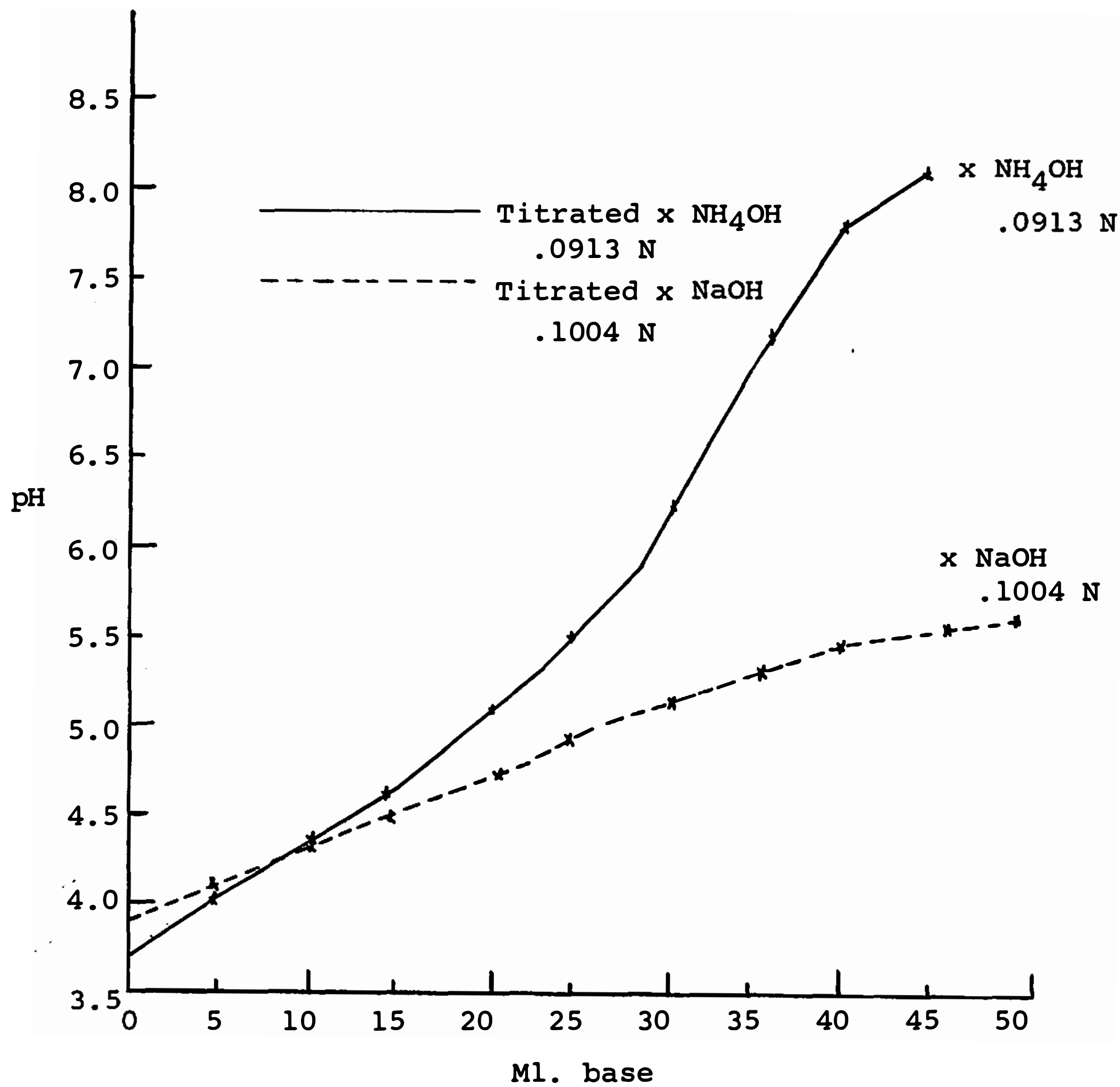


Figure 4. Buffer capacity of strawberries.

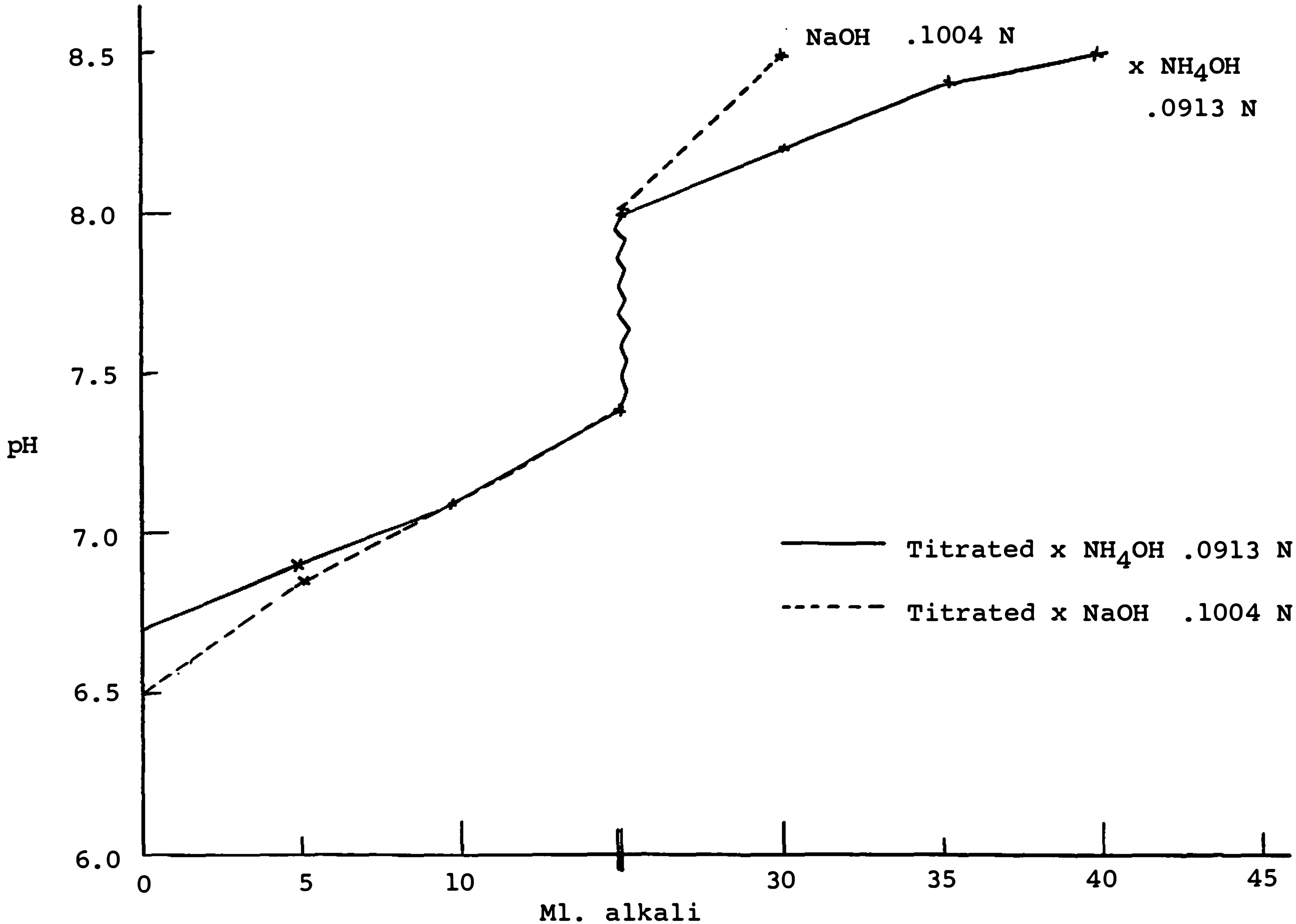


Figure 5. Buffer capacity of frozen fish.

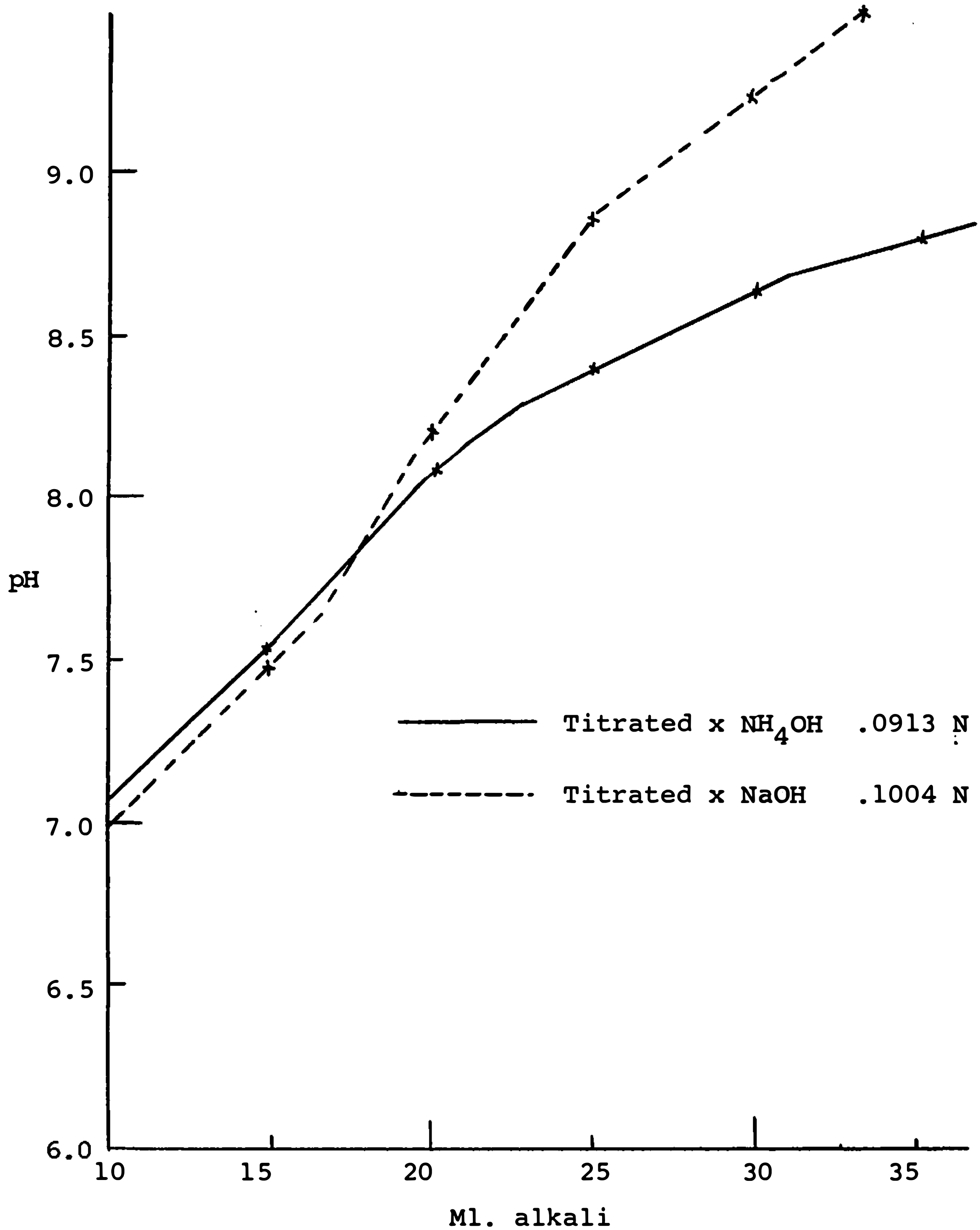


Figure 6. Buffer capacity of ground beef.

indicated a slight buffer effect beyond pH 8. When titrating ground beef against ammonium hydroxide, it required 20 milliliters to increase the pH from 6 to 8, and 20 milliliters to increase it from 8 to 8.9. When titrated against sodium hydroxide, it took 20 milliliters to increase the pH from 6 to 8 and 13 milliliters to increase it from 8 to 9.5.

All these tests were made on commercial samples and, although the samples were of the same brands, they were taken from different lots and they differed in some of their physical and chemical properties. Two samples taken from the same lot indicated slight differences in their pH and buffer capacity. Some of the above experiments were repeated three times, and each time gave different results, although the curves of the products were similar.

III. EFFECT OF AMMONIA ON THREE FOODS USING FOUR WRAPPERS

Green Beans

The green bean samples were removed from storage and examined in the frozen state for appearance, color, and odor. Samples were then thawed and examined for appearance, odor, color reflection, pH, and buffer capacity. All the beans from the four wrappers had a strong smell of ammonia. They had lost their fresh bright green color and had developed yellowish brown spots. The brownish color appeared more pronounced in the samples that were in the regular wrap and the wax paper wrap. Also, the off-color was more intense at the cut ends of the green beans. After thawing, the color remained the same. The samples exposed to ammonia lost their firm texture and were not so brittle as the controls. There was a greater texture change in the samples that were in the regular wrap and the wax paper wrap than those in the polyethylene and Cryovac wraps (Plate V).

The pH of the green beans was higher in the samples treated with ammonia. There was a greater change in the samples in the regular wrap and the wax paper wrap than the other two wrappers, as shown in Table II.

The juice from the green beans was examined, and appeared darker in the samples exposed to the ammonia. The darkest juice was from the sample in the regular wrap, followed by the juice from the wax-wrap sample. The juice from the samples in the polyethylene and Cryovac wraps was the lightest, but still darker than the control sample.

As shown in Figures 7 and 8, the sample in the regular

Control Cryovac

Polyethylene Wax

PLATE V

EFFECT OF AMMONIA ON GREEN BEANS

TABLE II

pH OF FOODS EXPOSED TO AMMONIA

Wrapper	pH of Foods Exposed to Ammonia		
	Green Beans	Strawberries	Ground Beef
Cryovac	7.25	4.00	7.00
Polyethylene	7.65	4.00	6.70
Wax	9.10	4.10	9.40
Regular	9.80	4.30	8.90
Control	6.40	3.20	6.00

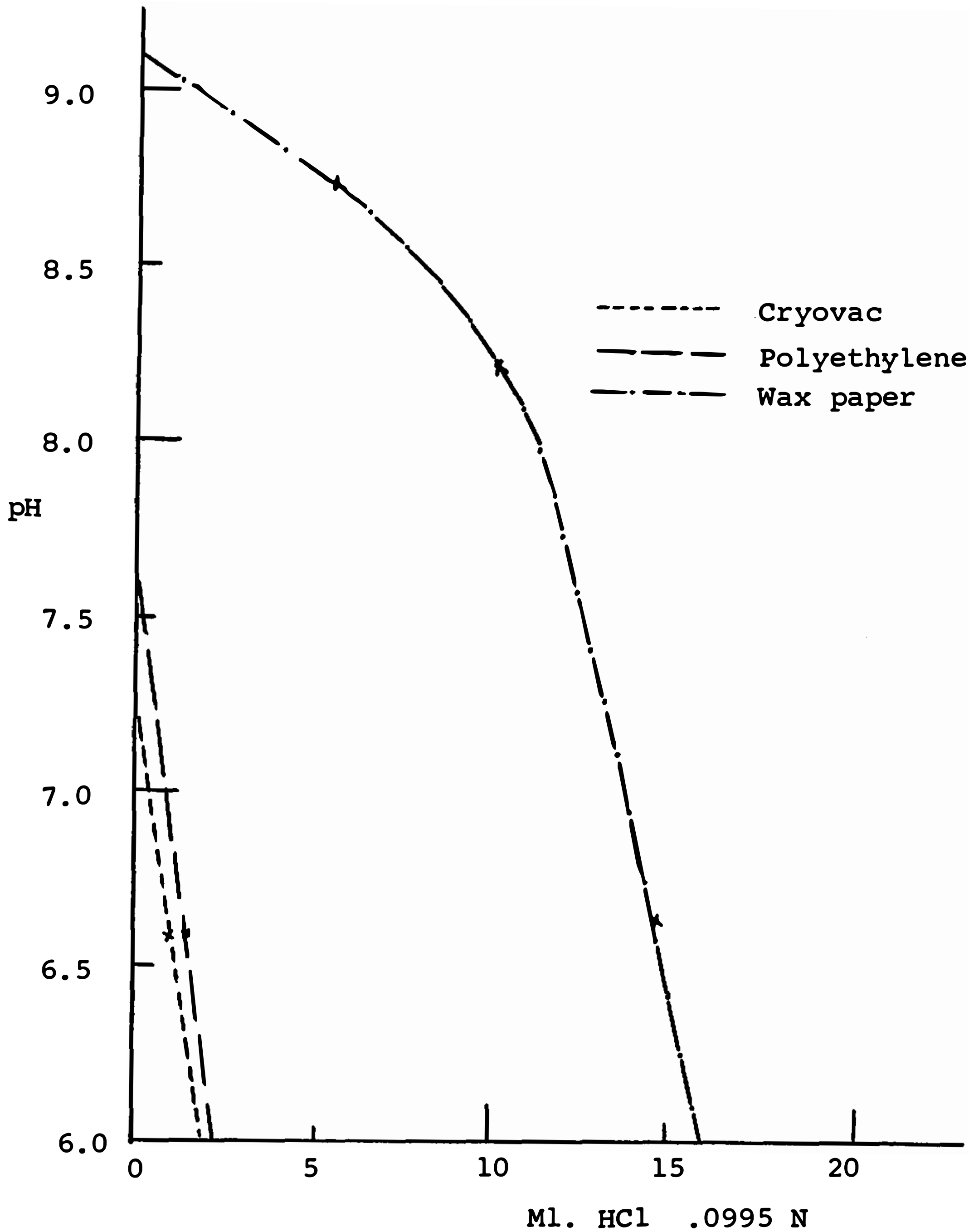


Figure 7. Neutralizing NH_3 absorbed by green beans.

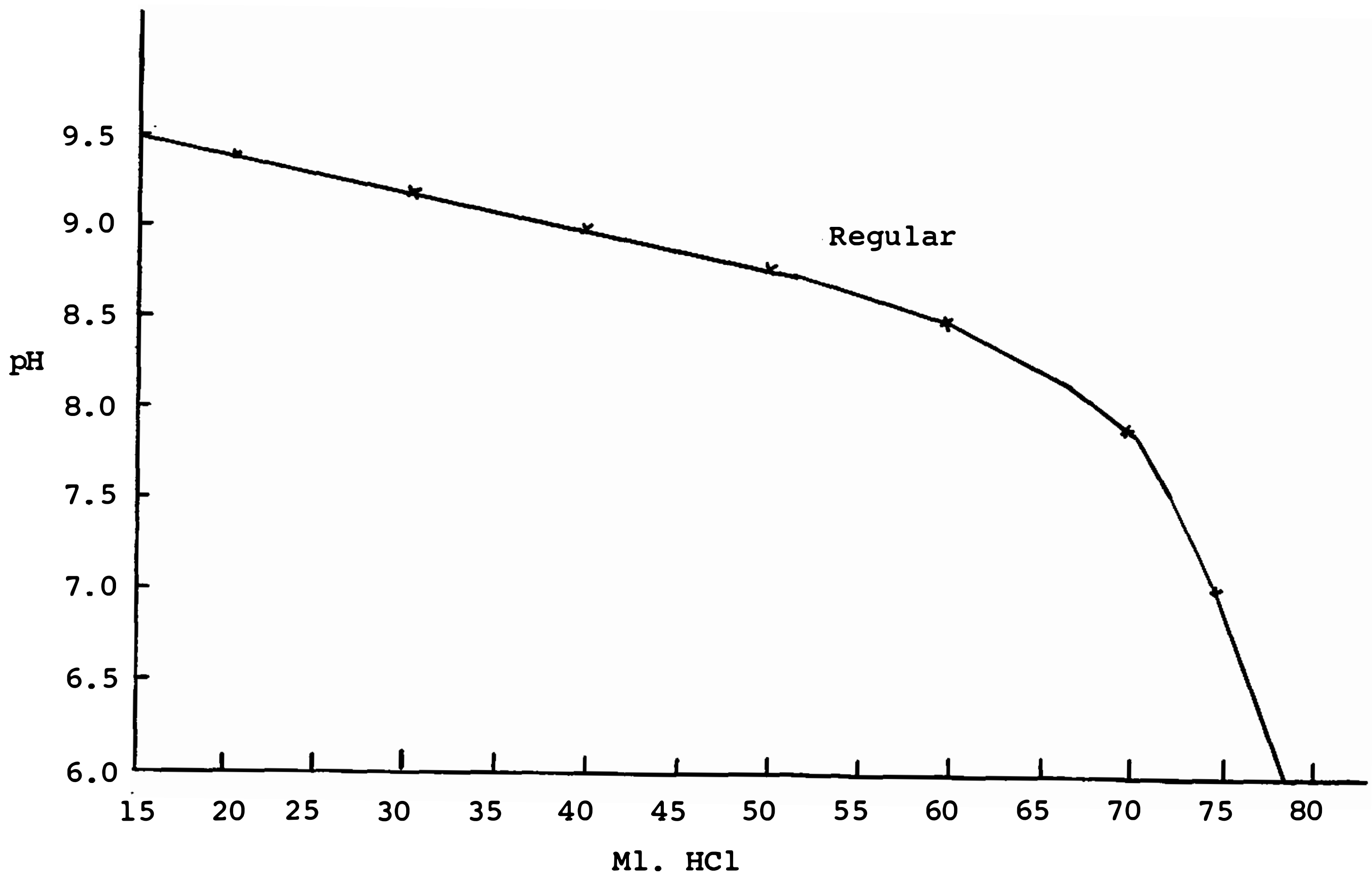


Figure 8. Neutralizing NH_3 absorbed by green beans.

wrap had the highest pH (9.8), and required 76 milliliters of 0.0995 N hydrochloric acid to bring it to its normal pH of 6. The sample in the wax wrap had a pH of 9.1 and required 16 milliliters of hydrochloric acid to bring it to pH 6. The two samples in the polyethylene and Cryovac had a pH of 8.5 and 7.25, respectively, and needed only 2.5 milliliters of acid to reduce the pH to normal.

This indicates that the pH value is not an accurate indication of the amount of ammonia absorbed by the foods; rather, this is a result of the buffer capacity of these foods, which has been shown in greater detail earlier.

The effect of various packages on the organoleptic evaluation of the flavor of green beans, as shown in Table III, indicates that the sample in the regular wrap was the most objectionable, its mean being -2.33, followed by the sample in the wax wrap, with a mean of -1.83, followed by the sample in the Cryovac wrap, with a mean of -0.83. The sample in the polyethylene wrap had a mean of 0, and therefore was judged similar to the control sample.

Statistically, at 0.05 level all packages gave a lower mean than the control. There was no significant difference between the control, the polyethylene- and the Cryovac-

TABLE III

EFFECT OF VARIOUS PACKAGES ON THE ORGANOLEPTIC EVALUATION OF THE FLAVOR OF GREEN BEANS

Individual	Control	Polyethylene	Cryovac	Wax	Regular
1	0	+1	+1	-2	-2
2	0	0	-1	-1	-3
3	0	-1	-1	-3	-3
4	0	0	-3	-3	-3
5	0	0	0	-2	-3
6	0	0	-1	0	0
Total	0	0	-5	-11	-14
Mean	0	0	-.83	-1.83	-2.33
Statistical significance at 0.05 level	———	———	———		
			———	———	
				———	———

Analysis of variance of the organoleptic evaluation of the flavor of green beans:

Source	d.f.	M.S.	F. ratio
Treatments	3	6.5	7.8**
Tasters	5	2.6	3.0
Residuals	15	.8333	
	23		

wrapped samples, and there was no significant difference between the Cryovac- and the wax-wrapped samples. Also, there was no significant difference between the wax-wrapped sample and the regular-wrapped sample. Analysis of variance shows that the treatments gave a significant difference at 0.01 level, but tasters did not show a significant difference within the panel scores.

The effect of the various packages on the organoleptic evaluation of the odor of green beans, as shown in Table IV, indicates that the samples in the regular wrap and in the wax wrap were the most objectionable, the sample in the polyethylene wrap was less objectionable, and the sample in the Cryovac wrap was similar to the control.

Statistically, at 0.05 level, although the polyethylene-wrapped sample gave a lower mean, there was no significant difference between the control, the Cryovac- and the polyethylene-wrapped samples at the 0.05 level. There was a significant difference between the control and the wax- and regular-wrapped samples. Analysis of variance shows that the treatment differences were significant at the 0.01 level, but the tasters did not show a significant difference within the taste panel scores.

TABLE IV

EFFECT OF THE VARIOUS PACKAGES ON THE ORGANOLEPTIC EVALUATION OF THE ODOR OF GREEN BEANS

Individual	Control	Cryovac	Polyethylene	Regular	Wax
1	0	0	0	-2	-2
2	0	0	0	-3	-2
3	0	0	-1	-3	-2
4	0	0	0	0	-3
5	0	0	-1	-2	-2
6	0	0	+1	-2	-1
Total	0	0	-1	-12	-12
Mean	0	0	-.16	-2	-2
Statistical significance at 0.05 level	———	———	———		
			———	———	———

Analysis of variance of the organoleptic evaluation of the odor of green beans:

Source	d.f.	M.S.	F. ratio
Treatments	3	7.3750	13.62**
Tasters	5	.5416	1.00
Residuals	15		
	23		

The effect of various packages on the organoleptic evaluation of the texture of green beans, as shown in Table V, indicates that the four samples had an inferior texture compared with the control. The wax-wrapped sample had a mean of -1.0, the Cryovac-wrapped sample had a mean of -0.83, the regular wrapped sample had a mean of -0.66, and the polyethylene-wrapped sample had a mean of -0.33.

Statistically, there were no significant differences between the control sample and the four treated samples. Analysis of variance shows that neither treatments nor tasters show any significant differences by the taste panel scores.

The effect of various packages on the organoleptic evaluation of the color of green beans, as shown in Table VI, indicates that the color of the treated samples was judged superior to the control sample. This is because of the bluish color of the ammonia-treated foods.

Statistically, the means of the exposed samples were higher than the means of the control; there was no significant difference between the control, the regular-, the wax-, and the Cryovac-wrapped samples. There was also no significant difference between the wax-, the Cryovac-, and the

TABLE V

EFFECT OF VARIOUS PACKAGES ON THE ORGANOLEPTIC EVALUATION OF THE TEXTURE OF GREEN BEANS

Individual	Control	Polyethylene	Regular	Cryovac	Wax
1	0	-1	-1	-1	-1
2	0	0	0	0	0
3	0	-1	-3	-1	-3
4	0	0	0	0	-1
5	0	0	0	0	0
6	0	0	0	-3	-1
Total	0	-2	-4	-5	-6
Mean	0	-.33	-.66	-.83	-1
Statistical significance at 0.05 level					

Analysis of variance of the organoleptic evaluation of the texture of green beans:

Source	d.f.	M.S.	F. ratio
Treatments	3	3.8194	2.69
Tasters	5	1.6416	1.16
Residuals	15	1.4194	
	23		

TABLE VI

EFFECT OF VARIOUS PACKAGES ON THE ORGANOLEPTIC EVALUATION OF THE COLOR OF GREEN BEANS

Individual	Polyethylene	Cryovac	Wax	Regular	Control
1	+2	+1	+1	+1	0
2	+3	+3	+3	+3	0
3	+1	0	-1	-1	0
4	+1	+1	+1	-1	0
5	+1	+1	+1	+1	0
6	0	-2	-1	-3	0
Total	+8	+4	+4	0	0
Mean	+1.33	+.66	+.66	0	0
Statistical significance at 0.05 level	———	———	———		
		———	———	———	———

Analysis of variance of the organoleptic evaluation of the color of green beans:

Source	d.f.	M.S.	F. ratio
Treatments	3	1.7777	4.32*
Tasters	5	9.1666	22.30**
Residuals	15	.4111	
	23		

polyethylene wrapped samples. Analysis of variance shows that treatment differences were significant at 0.05 level, and tasters gave significant differences at 0.01 level on the taste panel scores.

Hunter color values, shown in Table VII, illustrate that the "L" values of the green beans exposed to ammonia were lower than the control sample. The "a" values were also lower. The thawed, uncooked samples were not as green as the control and had a brownish shade to them. The "b" values differed very little from the control.

Strawberries

The strawberries were removed from storage and examined for appearance and odor. They were thawed and re-examined for appearance, odor, pH, buffer effect, and percentage of color reflectance (Plate VI).

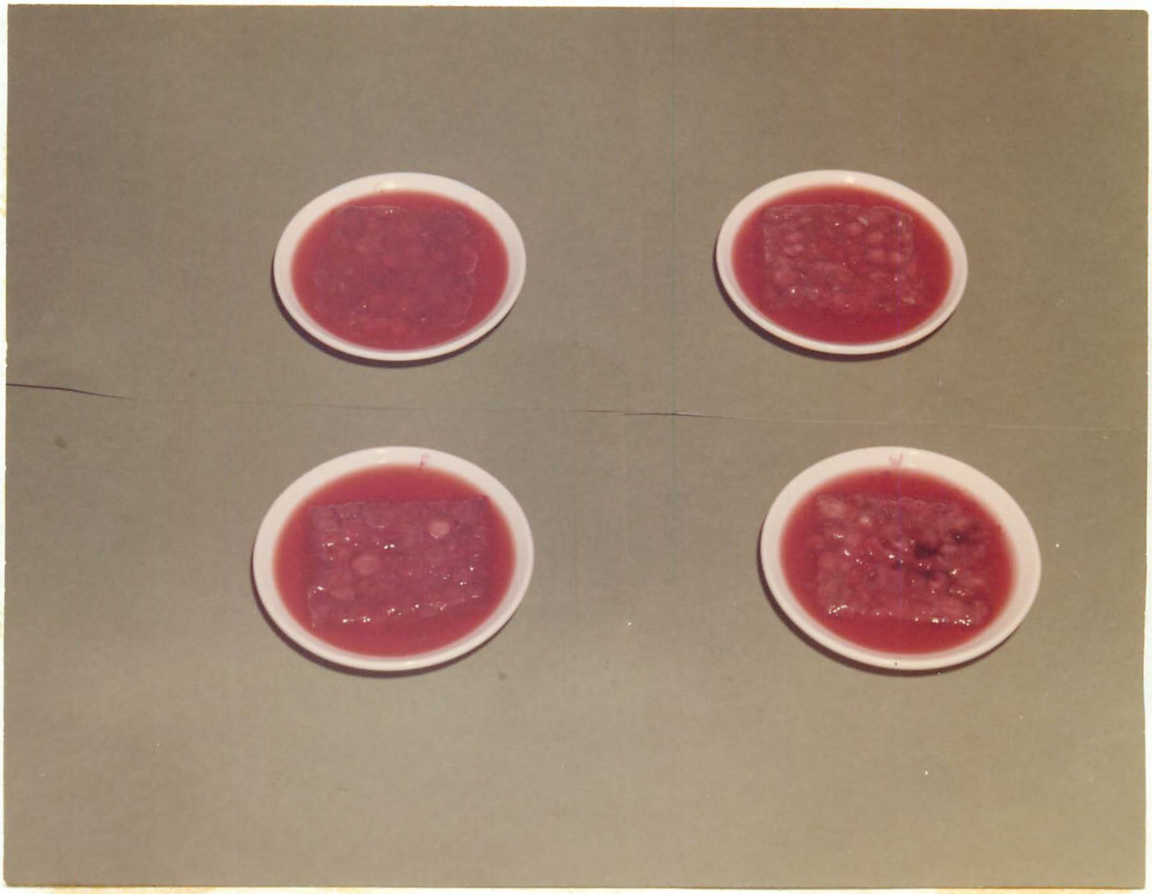
Ammonia odor was strong in all samples. Black patches were scattered on the surface of the frozen cube, especially at the places where the original package had been pierced and the ammonia had penetrated.

The regular wrap and the wax paper wrap had the bigger patches on them. The black patches on the regular

TABLE VII

HUNTER "L", "a" AND "b" VALUES

	Control	Regular	Wax	Polyethylene	Cryovac
Straw-berries					
L	18.9	20.5	16.7	19.5	20.7
a	+17.3	+17.0	+7.3	+18.1	+19.1
b	8.3	+8.8	+4.6	+9.5	+9.7
Green beans					
L	28.8	26.7	26.2	25.0	28.1
a	-11.6	-8.0	-8.0	-8.5	-11.7
b	+12.5	+12.7	+13.5	+12.5	+12.9
Ground beef					
L	30.9	26.2	24.8	25.6	26.2
a	10.0	+4.1	+4.9	+4.9	+2.1
b	8.5	+4.6	+4.3	+4.6	+4.0



Control Cryovac

Polyethylene Wax

PLATE VI

EFFECT OF AMMONIA ON STRAWBERRIES

wrapped sample were not only on the surface of the frozen product, but the color had penetrated the sample.

The polyethylene-wrapped sample had a few smaller patches, while the Cryovac-wrapped sample had the least. The control sample had a uniform pink color.

After thawing, the black patches remained the same, but the syrup became much darker, almost black, in the regular- and wax-wrapped samples. Samples retained their ammonia odor. The pH was higher in all the treated samples, especially in the wax- and regular-wrapped samples, as shown in Table II, page 38. Figure 9 shows that Cryovac wrap and polyethylene wrap samples absorbed less ammonia (pH 4) than the wax- and regular-wrapped samples (pH 4.3 and pH 4.1, respectively). The amount of acid needed to neutralize the ammonia absorbed was almost directly proportional to the pH. This is because strawberries show a buffer capacity at a higher pH.

The effect of various packages on the organoleptic evaluation of the flavor of strawberries, as shown in Table VIII, indicates that the polyethylene- and Cryovac-wrapped samples gave a lower mean, although Duncan's Multiple Range Test showed no significant difference with the control. The

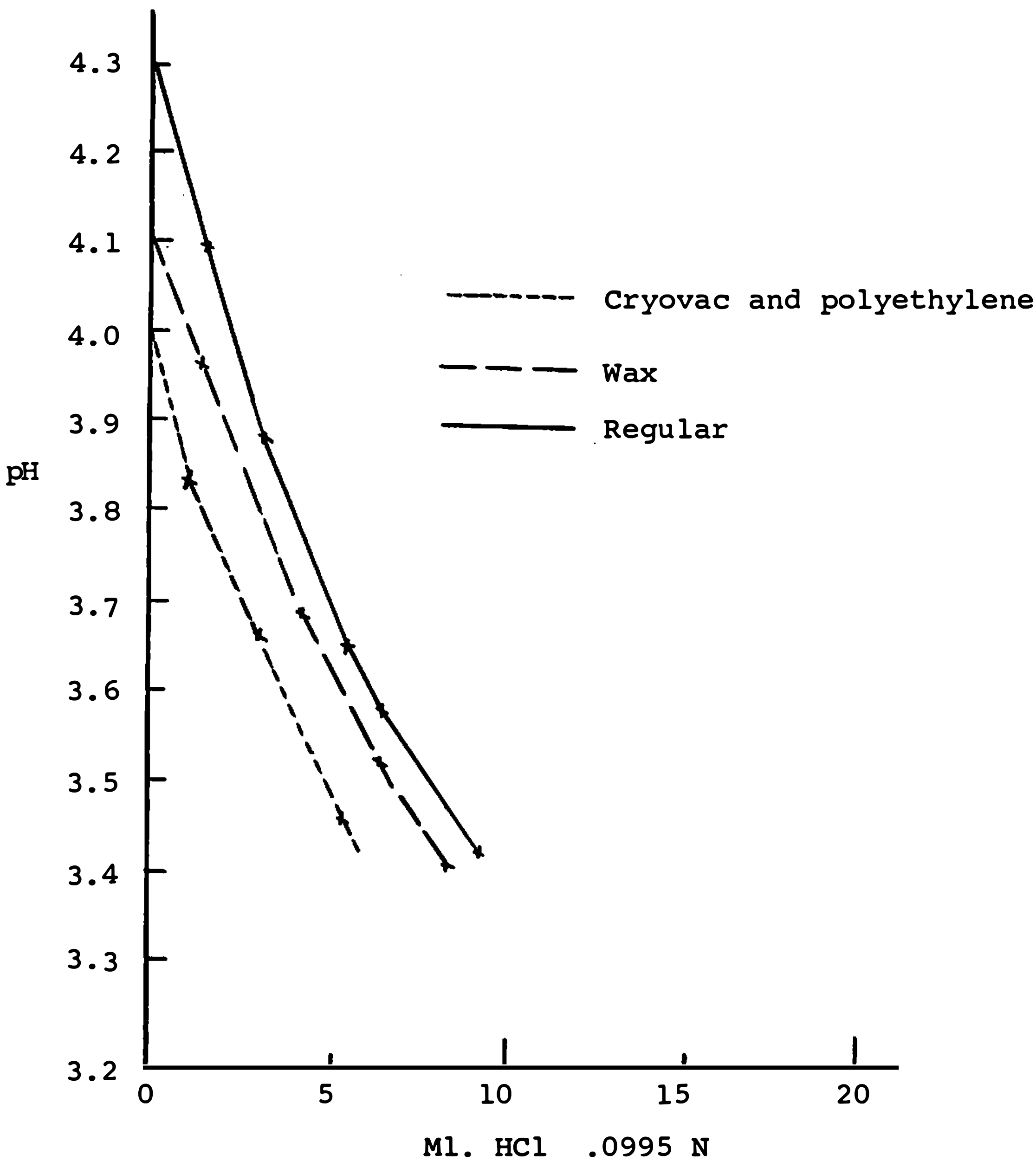


Figure 9. Neutralizing NH_3 absorbed by strawberries.

TABLE VIII

EFFECT OF VARIOUS PACKAGES ON THE ORGANOLEPTIC EVALUATION OF THE FLAVOR OF STRAWBERRIES

Individual	Regular	Control	Polyethylene	Cryovac	Wax
1	0	0	0	0	0
2	+2	0	-1	- 2	-3
3	-1	0	0	- 1	-2
4	0	0	0	+ 1	-2
5	-1	0	0	- 1	-2
6	+2	0	-1	+ 1	-2
Total	+2	0	-2	-2	-11
Mean	+.33	0	-.33	-.33	-1.83
Statistical significance at 0.05 level	———	———	———	———	

Analysis of variance of the organoleptic evaluation of the flavor of strawberries:

Source	d.f.	M.S.	F. ratio
Treatments	3	6.2683	4.48*
Tasters	5	.3750	0.27
Residuals	15	1.3972	
	23		

wax-wrapped sample gave a lower mean, with a significant difference at 0.05 level. The regular-wrapped sample showed a higher mean, but it showed no significant difference with the control, the polyethylene- or the Cryovac-wrapped samples. Analysis of variance shows that the treatment differences were significant at the 0.05 level, but the tasters show no significant difference within the taste panel scores.

The effect of various packages on the organoleptic evaluation of the odor of strawberries, as shown in Table IX, indicates that there was very little difference in the odor of strawberries between the control sample and the exposed sample. Although the wax-wrapped sample gave a lower mean, it showed no significant differences between the control sample and the exposed samples. Analysis of variance shows that neither the different treatments nor the tasters show a significant difference.

Hunter color values shown in Table VII illustrate that the differences between the "L" values of the exposed samples and the control were insignificant. The "a" values show that the regular and the wax paper wrapped samples were less red than the control, and that the polyethylene and the Cryovac-wrapped samples did not differ from the control.

TABLE IX

EFFECT OF VARIOUS PACKAGES ON THE ORGANOLEPTIC EVALUATION OF THE ODOR OF STRAWBERRIES

Individual	Control	Polyethylene	Cryovac	Regular	Wax
1	0	0	0	0	0
2	0	+1	0	0	+1
3	0	0	0	0	0
4	0	-1	-1	0	-3
5	0	0	+1	0	-1
6	0	0	0	0	0
Total	0	0	0	0	-3
Mean	0	0	0	0	.5
Statistical significance at 0.05 level	—	—	—	—	—

Analysis of variance of the organoleptic evaluation of the odor of strawberries:

Source	d.f.	M.S.	F. ratio
Treatments	3	.3750	0.85
Tasters	5	1.3750	3.1132
Residuals	15		
	23		

The "b" values did not differ except for the wax-wrapped sample which gave a lower reading.

The same results are obtained from Table X on the organoleptic evaluation of the texture of strawberries. Although the polyethylene- and wax-wrapped samples show a lower mean than the control, there was no significant difference between the control sample and the exposed samples. The analysis of variance also shows that neither treatments nor tasters show a significant difference.

The effect of the various packages on the organoleptic evaluation of the color of strawberries, as shown in Table XI, indicates that the exposed samples have a color inferior to that of the control sample, and only the wax-wrapped sample showed a significant difference. The analysis of variance shows that treatment differences had a significant effect on the panel scores at 0.05 level, although the tasters showed no significant differences.

Ground Beef

The ground beef was removed from storage and examined for appearance and odor; it was left to thaw and re-examined for odor, color, pH, and color reflectance. All samples had

TABLE X

EFFECT OF VARIOUS PACKAGES ON THE ORGANOLEPTIC EVALUATION OF THE TEXTURE OF STRAWBERRIES

Individual	Control	Regular	Cryovac	Polyethylene	Wax
1	0	0	0	0	0
2	0	+1	0	0	+1
3	0	+1	+1	-1	-1
4	0	-1	-2	0	-3
5	0	-2	+1	0	-2
6	0	+1	0	-1	-2
Total	0	0	0	-2	-7
Mean	0	0	0	-.33	-1.16
Statistical significance at 0.05 level	—	—	—	—	—

Analysis of variance of the organoleptic evaluation of the texture of strawberries.

Source	d.f.	M.S.	F. ratio
Treatments	3	1.8194	1.68
Tasters	5	1.9750	1.82
Residuals	15	1.0861	
	23		

TABLE XI

EFFECT OF VARIOUS PACKAGES ON THE ORGANOLEPTIC EVALUATION OF THE COLOR OF STRAWBERRIES

Individual	Control	Cryovac	Polyethylene	Regular	Wax
1	0	0	0	0	-1
2	0	-1	-2	-1	-1
3	0	+1	-1	0	-2
4	0	-2	0	0	-3
5	0	-1	0	-2	-2
6	0	0	-1	-1	-3
Total	0	-3	-4	-4	-12
Mean	0	-.5	-.6	-.6	-2
Statistical significance at 0.05 level					

Analysis of variance of the organoleptic evaluation of the color of strawberries:

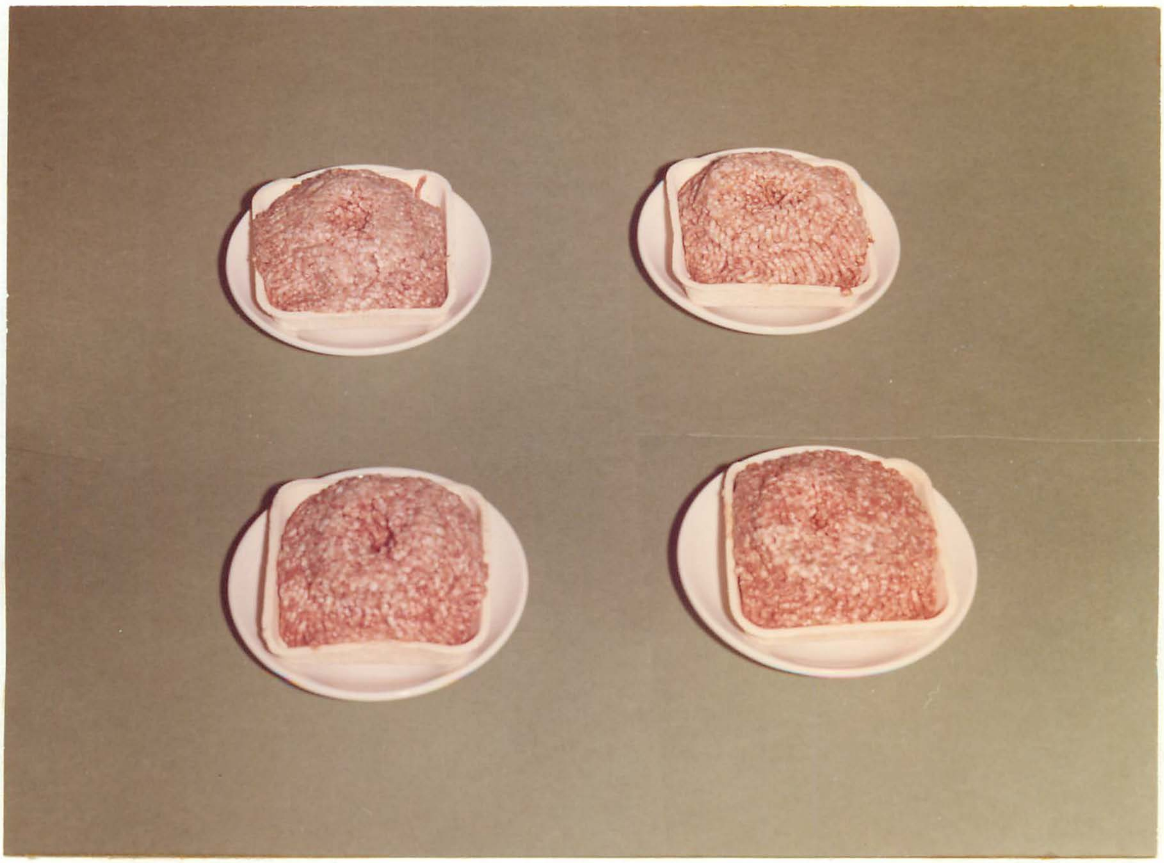
Source	d.f.	M.S.	F. ratio
Treatments	3	2.9305	3.68*
Tasters	5	.8416	1.06
Residuals	15		
	23		

a strong smell of ammonia. The meat had a grayish color, which was more pronounced in the regular- and wax-wrapped samples. This was noticed to be only a surface phenomena, because when the meat was cut, it had a regular buff color like that of the control sample. After thawing, the meat retained the same characteristics as in the samples before thawing (Plate VII).

The treated samples were difficult to make into patties, as the meat would not hold together as it did in the control sample. This could be due to the replacement of the sodium-calcium ion by the ammonia ion.

Figure 10 shows the pH and the buffer effect of the four samples in different wrappers. The wax-wrapped sample had a pH of 9.4 and required 49 milliliters of acid to reduce it to the normal pH of 6. The regular-wrapped sample had a pH of 8.9 and required 31 milliliters of acid to reduce it to pH 6. The polyethylene- and Cryovac-wrapped samples had a pH of 6.7 and 7.0 and required 9 milliliters of acid to reduce them to pH 6.

Again, it is obvious that the amount of acid needed to neutralize the ammonia absorbed by the product is a better way to evaluate the amount of ammonia absorbed than the pH



Control Cryovac

Polyethylene Wax

PLATE VII

EFFECT OF AMMONIA ON GROUND BEEF

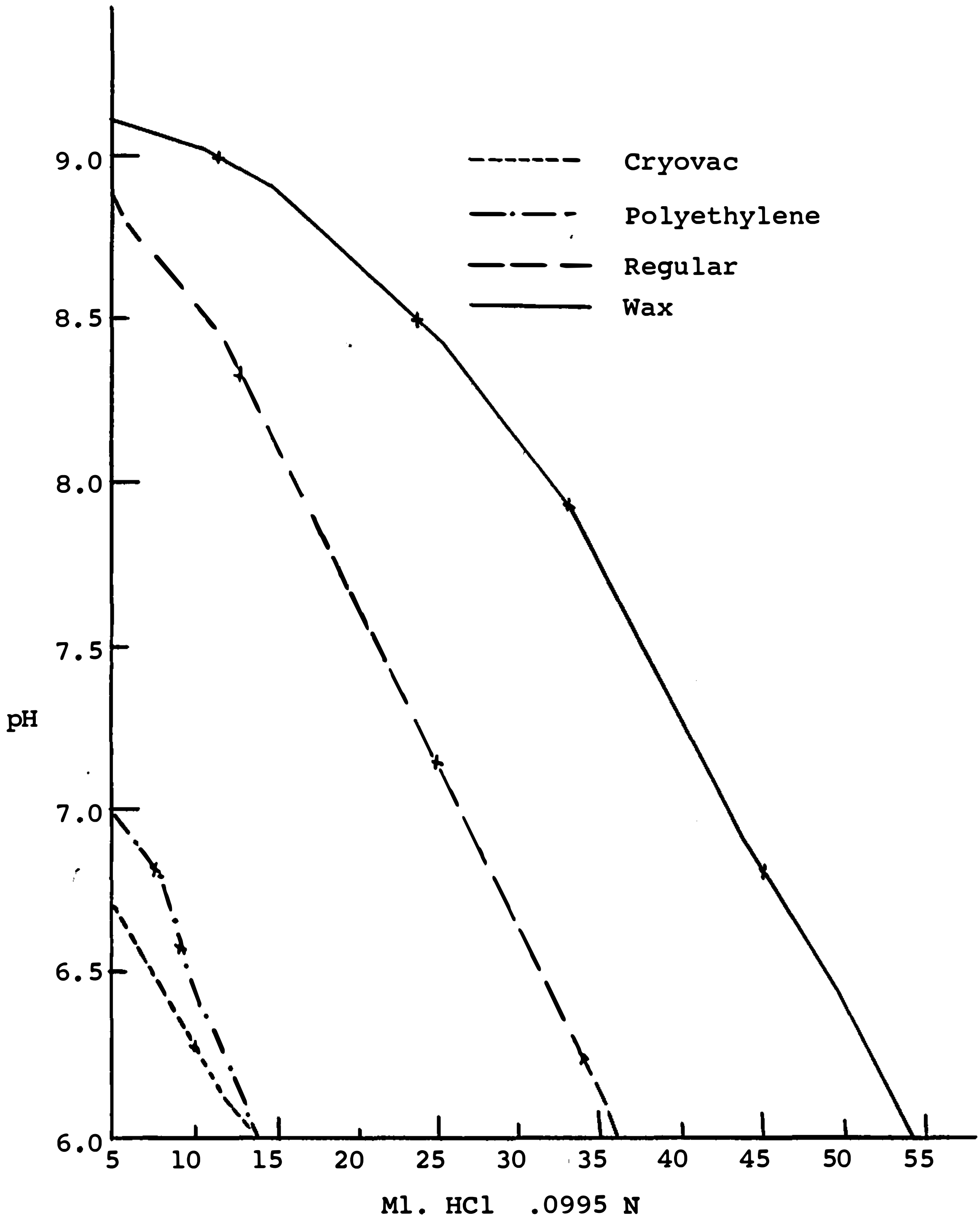


Figure 10. Neutralizing NH_3 absorbed by ground beef.

value. This is due to the high buffer capacity of the ground beef.

The organoleptic tests were analyzed like the green beans and strawberries, by adding the taste panel scores algebraically and calculating the means.

The effect of various packages on the organoleptic evaluation of the texture of ground beef hamburger patties, as shown in Table XII, indicates that the texture of the samples exposed to ammonia was superior to that of the control, probably "less chewy." There was no significant difference between the control and the exposed samples. An analysis of variance shows that neither treatment nor tasters indicate a significant difference by the taste panel scores.

The effect of various packages on the organoleptic evaluation of the odor of ground beef hamburger patties, as shown in Table XIII, indicates that the odor was found to be inferior to the odor of the control sample. It was most objectionable in the wax-wrapped sample, and least objectionable in the polyethylene-wrapped sample.

There was no significant difference between the control, polyethylene-, regular-, and Cryovac-wrapped samples. Also, there was no significant difference between the wax-,

TABLE XII

EFFECT OF VARIOUS PACKAGES ON THE ORGANOLEPTIC EVALUATION OF THE TEXTURE OF GROUND BEEF HAMBURGER PATTIES

Individual	Wax	Cryovac	Polyethylene	Regular	Control
1	0	+2	0	0	0
2	0	0	0	0	0
3	+1	0	+1	0	0
4	0	0	0	0	0
5	+1	0	0	0	0
6	0	0	0	0	0
Total	+2	+2	+1	0	0
Mean	+.33	+.33	+.16	0	0
Statistical significance at 0.05 level	—	—	—	—	—

Analysis of variance of the organoleptic evaluation of the texture of ground beef hamburger patties:

Source	d.f.	M.S.	F. ratio
Treatments	3	.1527	.53
Tasters	5	.2416	.84
Residuals	15	.2861	
	23		

TABLE XIII

EFFECT OF VARIOUS PACKAGES ON THE ORGANOLEPTIC EVALUATION OF THE ODOR OF GROUND BEEF HAMBURGER PATTIES

Individual	Control	Polyethylene	Regular	Cryovac	Wax
1	0	0	0	0	0
2	0	0	0	-2	-1
3	0	-1	0	0	-2
4	0	0	0	0	0
5	0	-1	-3	-2	-3
6	0	0	-1	-1	-3
Total	0	-2	-4	-5	-9
Mean	0	-.33	-.66	-.83	-1.5
Statistical significance at 0.05 level					

Analysis of variance of the organoleptic evaluation of the odor of ground beef hamburger patties:

Source	d.f.	M.S.	F. ratio
Treatments	3	1.4444	2.50
Tasters	5	2.8666	4.96*
Residuals	15	.5777	
	23		

Cryovac-, and the regular-wrapped samples. The only significant difference was between the wax-wrapped sample, polyethylene-wrapped, and regular samples. Analysis of variance shows a significant effect at the 0.05 level by the scores of the taste panel, but the treatments did not.

The effect of various packages on the organoleptic evaluation of the flavor of ground beef hamburger patties, as shown in Table XIV, indicates that the samples exposed to ammonia had an inferior flavor. The flavor was most objectionable in the wax-wrapped sample, followed by the regular-wrapped sample and the polyethylene-wrapped sample, respectively, with the Cryovac-wrapped sample being least objectionable.

There were no significant differences between the control and the four treated samples. Analysis of variance shows that neither treatment nor tasters indicated significant differences within the taste panel scores.

The effect of various packages on the organoleptic evaluation of the color of ground beef hamburger patties, as shown in Table XV, indicates that the color of the regular-wrapped sample was superior to the control, and that the polyethylene-, Cryovac-, and wax-wrapped samples were

TABLE XIV

EFFECT OF VARIOUS PACKAGES ON THE ORGANOLEPTIC EVALUATION OF THE FLAVOR OF GROUND BEEF HAMBURGER PATTIES

Individual	Control	Cryovac	Polyethylene	Regular	Wax
1	0	+1	0	0	0
2	0	-1	+1	-1	-2
3	0	-3	-3	0	-1
4	0	+1	0	-1	-1
5	0	-1	-2	-1	+1
6	0	0	0	-2	-3
Total	0	-3	-4	-5	-6
Mean	0	-.5	-.66	-.83	-1
Statistical significance at 0.05 level					

Analysis of variance of the organoleptic evaluation of the flavor of ground beef hamburger patties:

Source	d.f.	M.S.	F. ratio
Treatments	3	.2777	.16
Tasters	5	2.0000	1.17
Residuals	15	1.7111	
	23		

TABLE XV

EFFECT OF VARIOUS PACKAGES ON THE ORGANOLEPTIC EVALUATION OF THE COLOR OF GROUND BEEF HAMBURGER PATTIES

Individual	Regular	Control	Polyethylene	Cryovac	Wax
1	0	0	0	0	0
2	0	0	0	-1	0
3	0	0	-1	-1	-2
4	0	0	0	-2	-2
5	+1	0	-1	0	+1
6	0	0	0	0	-1
Total	+1	0	-2	-4	-4
Mean	+.16	0	-.33	-.66	-.66
Statistical significance at 0.05 level					

Analysis of variance of the organoleptic evaluation of the color of ground beef hamburger patties:

Source	d.f.	M.S.	F. ratio
Treatments	3	.9305	1.87
Tasters	5	1.0750	2.16
Residuals	15	.4972	
	23		

inferior to the control.

There were no significant differences between the control and the four treated samples. Analysis of variance shows that neither treatment nor tasters indicated significant differences by the taste panel scores.

Hunter color values shown in Table VII, page 49, illustrate that the "L" values of the treated samples were lower than the control, due to the grayish color of the meat exposed to ammonia. The "a" values were also lower than the control, and little difference was noticed between the four treated samples. The "b" values also gave lower readings than the control.

IV. RATE OF PENETRATION OF AMMONIA IN FOODS

Strawberries

The odor of ammonia was present in all four samples. Physical defects and darkening of color also showed on the four samples, although it was lighter in the 6-hour sample. In the 24-hour sample, the dark color appeared in the syrup after thawing. There was no difference in the appearance of the 48-hour and the 72-hour samples. Both had large patches of black on them, and the syrup after thawing was much darker than the control.

When titrated against HCl (Figure 11), the 6-hour samples showed a pH of 3.8, lower than the three other samples and needed 16 milliliters of acid to neutralize the ammonia and to reduce the pH to 3. The other samples had a higher pH, 4.3 for the 24- and 72-hour samples, requiring 28 milliliters and 25 milliliters of acid, respectively, to reduce the pH to 3. The 48-hour sample had the highest pH and required 46 milliliters of acid to neutralize it.

It can be concluded that food absorbs its maximum quantity of ammonia over a 24-hour exposure period. The differences noticed in the graphs are probably due to differences in commercial packaging or differences due to different lots of food.

Green Beans

The green beans exposed for six hours showed no physical defects except for a strong odor of ammonia. When titrated against HCl, the pH of the green beans was 9.4 and required 26 milliliters of acid to neutralize it. The samples exposed to ammonia for 48 and 72 hours showed yellowish brown spots and had lost their brittle texture. Their pH

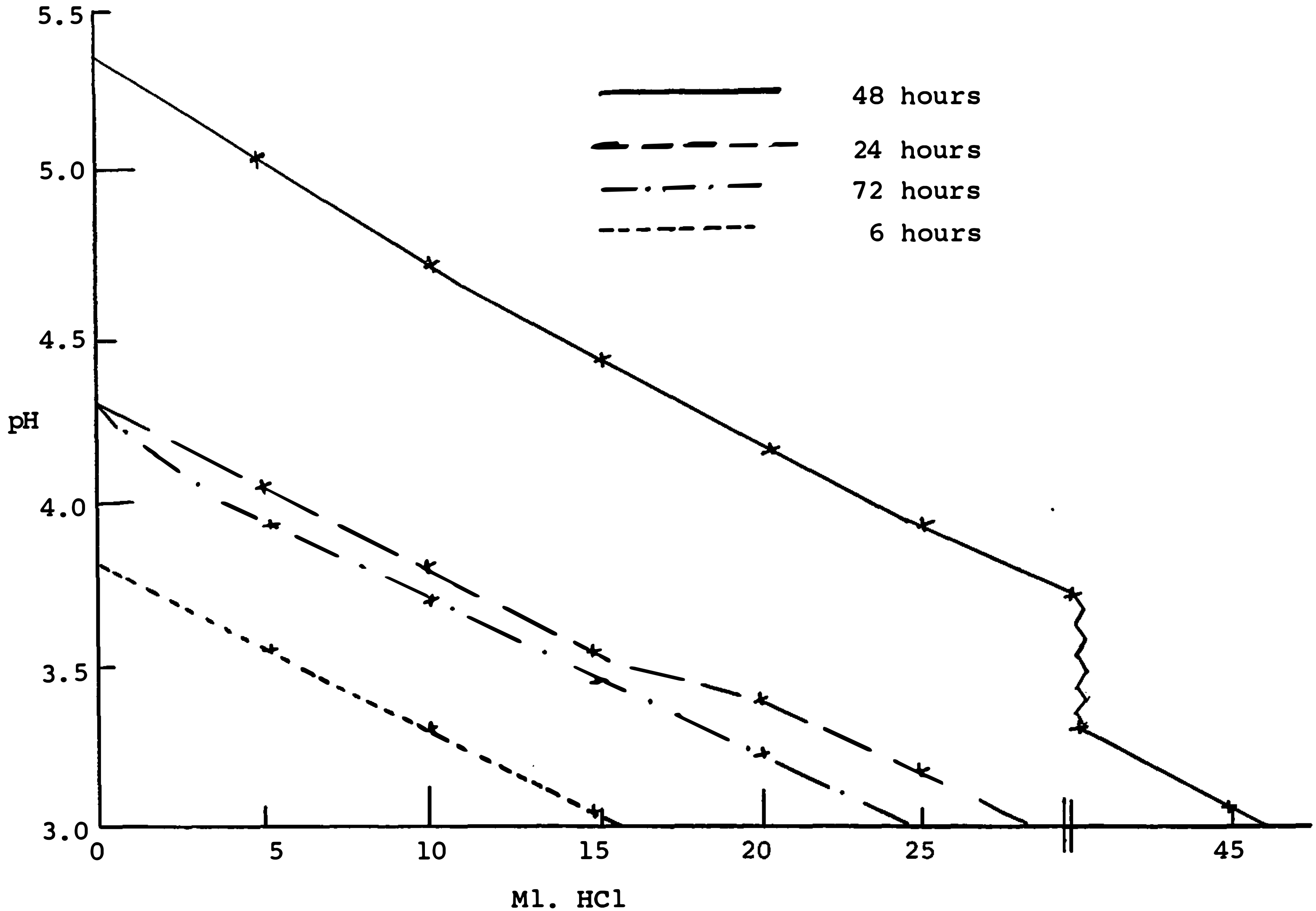


Figure 11. Titrating strawberries exposed to NH_3 for 6-24-48-72 hours.

had increased to 10 (Figure 12), and required more than 100 milliliters of HCl for neutralization. This indicates that exposing green beans to ammonia for six hours is enough to ruin their organoleptic acceptance but when exposed for 24 hours or more, the green beans absorbed much larger quantities of ammonia.

Ground Beef

Ammonia odor was present in all samples. Physical defects showed only on the samples exposed for 48 hours or more. When titrated against acid, the 6-hour samples had a pH of 7.1 and required 10 milliliters of acid to reduce it to 6. The 24-, 48-, and 72-hour samples had a higher pH and needed more acid to neutralize it (Figure 13).

The results obtained were most inconsistent, probably due to commercial packaging.

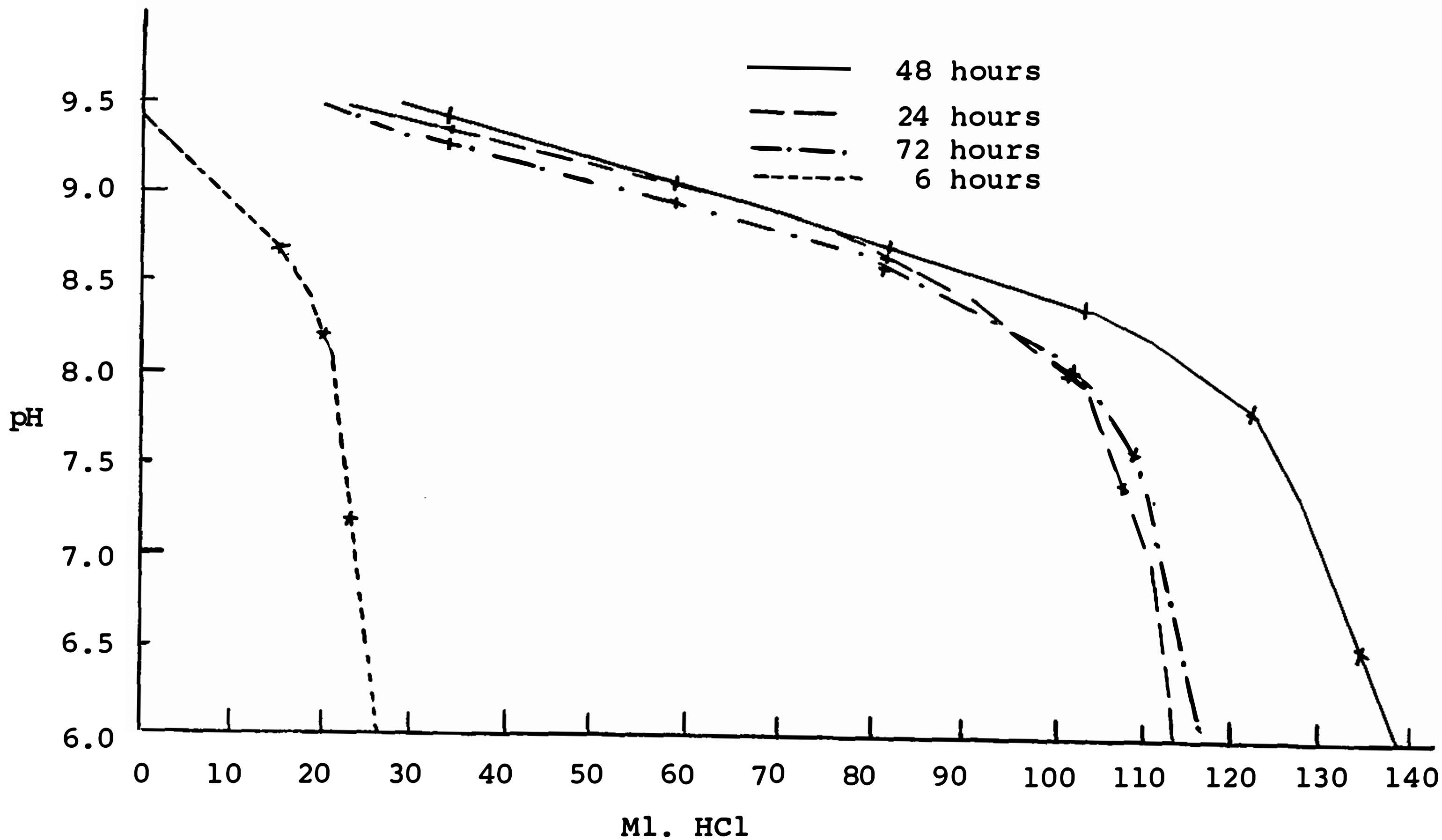


Figure 12. Titrating green beans exposed to NH_3 for 6-24-48-72 hours.

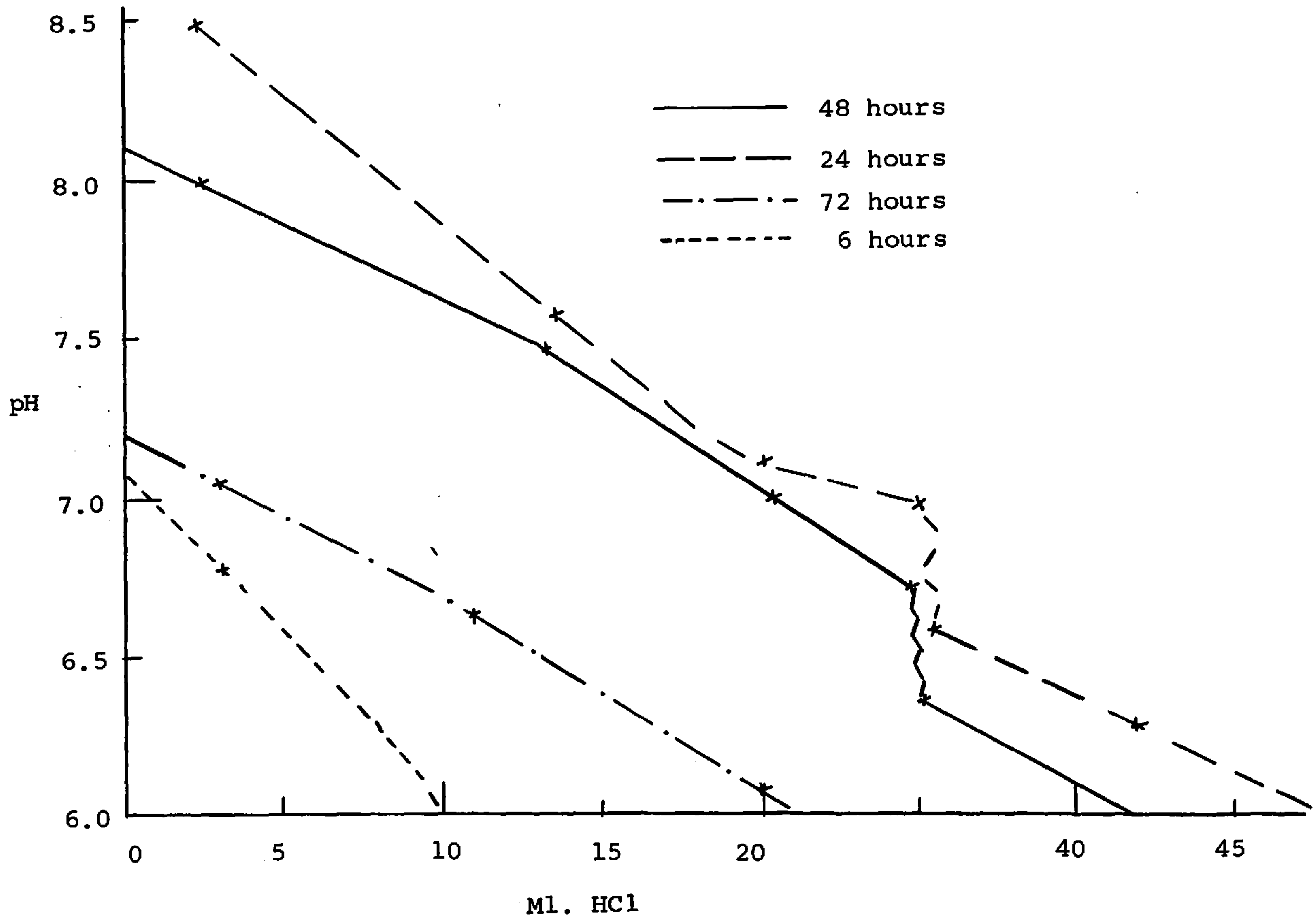


Figure 13. Titrating ground beef exposed to NH_3 for 6-24-48-72 hours.

CHAPTER V

SUMMARY

A study has been made to illustrate the buffer effect of foods, to determine the effect of ammonia on the physical characteristics of ground beef, strawberries, and green beans, to determine the effect of ammonia on the organoleptic qualities of these foods, and to compare the permeability and rate of penetration of ammonia through different wrappers.

Under conditions of the experiments reported in this paper it was found that:

1. All foods show a buffer effect when titrated against an alkaline solution, and their pH values were not directly proportional to the amount added.

2. The physical properties of the foods were adversely affected by the ammonia.

3. The organoleptic qualities of the foods exposed to ammonia were downgraded by the taste panel, except for the color of the green beans, which was upgraded.

4. The most permeable wrapper to ammonia was wax paper, and the least permeable was Cryovac.

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APPENDIX

TABLE XVI

BUFFER CAPACITY OF FROZEN FRENCH FRIED POTATOES AND FRESH POTATOES WHEN TITRATED AGAINST A SOLUTION OF NH_4OH (.0913 N) AND A SOLUTION OF NaOH (.1004 N)

Ml. of Base	NH_4OH	
	pH Frozen Pot.	pH Fresh Pot.
0	6.1	5.95
1	6.2	6.1
2	6.3	6.3
3	6.4	6.45
4	6.6	6.6
5	6.8	6.85
6	7.0	7.0
7	7.2	7.15
8	7.3	7.35
9	7.5	7.5
10	7.6	7.6
11	7.7	7.75
12	7.8	7.85
13	7.9	7.9
14	7.95	8.0
15	8.0	8.0
16	8.05	8.1
17	8.1	8.1
18	8.15	8.2
19	8.2	8.2
20	8.22	8.25
21	8.29	8.3
22	8.32	8.32
23	8.35	8.4
24	8.4	8.4
25	8.42	8.42
26	8.45	8.45
27	8.5	8.5
28	8.5	8.5
29	8.52	8.52
30	8.55	8.55

TABLE XVII

BUFFER CAPACITY OF FROZEN AND FRESH GREEN BEANS WHEN TITRATED AGAINST A SOLUTION OF NH_4OH (.0913 N) AND A SOLUTION OF NaOH (.1004 N)

Ml. of Base	NH_4OH pH Frozen Green Beans	NH_4OH pH Fresh Green Beans	NaOH pH Frozen Green Beans
0	6.0	6.0	6.1
1	6.5	6.3	6.6
2	7.0	6.5	7.2
3	7.5	6.6	7.6
4	7.7	6.8	7.9
5	7.9	7.0	8.1
6	8.1	7.2	8.3
7	8.2	7.4	8.45
8	8.3	7.5	8.6
9	8.4	7.6	8.7
10	8.45	7.7	8.8
11	8.5	7.8	8.9
12	8.55	7.9	9.0
13	8.6	7.9	9.1
14	8.65	8.0	9.25
15	8.7	8.02	9.35
16	8.75	8.1	9.45
17	8.8	8.15	9.55
18	8.82	8.2	9.65
19	8.85	8.2	9.7
20	8.87	8.25	9.8
21	8.9	8.3	9.95
22	9.0	8.3	
23		8.3	
24		8.35	
25		8.4	
26		8.4	
27		8.45	
28		8.5	
29		8.5	
30		8.5	

TABLE XVIII

BUFFER CAPACITY OF FROZEN PEAS WHEN TITRATED AGAINST A SOLUTION OF NH_4OH (.0913 N) AND NaOH (.1004 N)

Ml. of Base	NH_4OH pH Frozen Peas	NaOH pH Frozen Peas
0	6.9	7.1
1	7.2	7.35
2	7.45	7.57
3	7.6	7.75
4	7.8	7.95
5	8.0	8.05
6	8.05	8.2
7	8.1	8.3
8	8.2	8.4
9	8.3	8.45
10	8.35	8.52
11	3.4	8.6
12	8.45	8.66
13	8.5	8.72
14	8.52	8.77
15	8.58	8.8
16	8.6	8.9
17	8.62	8.95
18	8.68	9.0
19	8.7	
20	8.71	
22	8.75	
24	8.8	
26	8.88	
28	8.9	
30	9.0	

TABLE XIX

BUFFER CAPACITY OF FROZEN STRAWBERRIES WHEN TITRATED AGAINST A SOLUTION OF NH_4OH (.0913) AND NaOH (.1004 N)

Ml. of Base	NH_4OH	NaOH
	pH Frozen Strawberry	pH Frozen Strawberry
0	3.7	3.9
1	3.75	3.95
2	3.8	4.0
3	3.9	4.02
4	4.0	4.02
5	4.05	4.08
6	4.1	4.12
7	4.15	4.16
8	4.25	4.2
9	4.3	4.25
10	4.35	4.3
11	4.4	4.35
12	4.5	4.45
13	4.55	4.5
14	4.6	4.5
15	4.65	4.52
16	4.75	4.55
17	4.8	4.6
18	4.9	4.62
19	5.0	4.66
20	5.05	4.7
21	5.1	4.75
22	5.2	4.8
23	5.3	4.9
24	5.4	4.92
25	5.5	4.95
26	5.6	5.0
27	5.7	5.02
28	5.8	5.07
29	5.9	5.12
30	6.05	5.12

TABLE XIX (Continued)

Ml. of Base	NH_4OH pH Frozen Strawberry	NaOH pH Frozen Strawberry
31	6.2	5.17
32	6.3	5.2
33	6.5	5.23
34	6.7	5.3
35	7.0	5.32
36	7.2	5.36
37	7.4	5.4
38	7.6	5.4
39	7.7	5.45
40	7.8	5.45
41	7.9	5.45
42	7.9	5.48
43	8.0	5.48
44	8.02	5.5
45	8.1	5.55
46	8.12	5.58
47	8.18	5.6
48	8.2	5.6
49	8.22	5.6
50	8.25	5.6

TABLE XX

BUFFER CAPACITY OF FROZEN BREADED FISH STICKS (THE BREADED LAYER WAS REMOVED) WHEN TITRATED AGAINST A SOLUTION OF NH_4OH (.0913 N) AND NaOH (.1004 N)

Ml. of Base	NH_4OH	NaOH
	pH Frozen Fish	pH Frozen Fish
0	6.7	6.5
1	6.7	6.65
2	6.8	6.7
3	6.8	6.8
4	6.85	6.8
5	6.9	6.85
6	6.95	6.9
7	7.0	6.97
8	7.02	7.0
9	7.1	7.05
10	7.08	7.1
11	7.15	7.15
12	7.22	7.2
13	7.3	7.25
14	7.35	7.3
15	7.4	7.37
16	7.48	7.4
17	7.52	7.45
18	7.6	7.5
19	7.65	7.6
20	7.7	7.65
21	7.78	7.7
22	7.85	7.75
23	7.9	7.85
24	7.95	7.95
25	8.0	8.02
26	8.05	8.15
27	8.1	8.25
28	8.18	8.3
29	8.22	8.4
30	8.18	8.5
31	8.3	8.6

TABLE XX (Continued)

Ml. of Base	NH_4OH pH Frozen Fish	NaOH pH Frozen Fish
32	8.33	8.65
33	8.38	8.7
34	8.4	8.78
35	8.42	8.8
36	8.47	8.85
37	8.5	8.9
38	8.5	8.95
39	8.51	9.0
40	8.51	9.0
45	8.58	
50	8.62	

TABLE XXI

BUFFER CAPACITY OF GROUND BEEF WHEN TITRATED AGAINST A SOLUTION OF NH_4OH (.0913 N) AND NaOH (.1004 N)

Ml. of Base	NH_4OH pH Ground Beef	NaOH pH Ground Beef
0	6.0	6.0
1	6.15	6.1
2	6.28	6.2
3	6.4	6.23
4	6.5	6.42
5	6.58	6.5
6	6.68	6.6
7	6.78	6.68
8	6.88	6.78
9	6.95	6.85
10	7.05	6.97
11	7.12	7.02
12	7.22	7.12
13	7.33	7.22
14	7.42	7.35
15	7.55	7.48
16	7.65	7.6
17	7.78	7.72
18	7.9	7.9
19	8.0	8.08
20	8.1	8.23
21	8.18	8.38
22	8.23	8.5
23	8.3	8.63
24	8.35	8.75
25	8.42	8.88
26	8.48	8.97
27	8.5	9.1
28	8.55	9.25
29	8.6	9.25
30	8.62	9.25
31	8.67	9.32
32	8.7	9.4

TABLE XXI (Continued)

Ml. of Base	NH4OH	NaOH
	pH Ground Beef	pH Ground Beef
33	8.7	9.48
34	8.78	9.58
35	8.8	9.6
36	8.82	9.65
37	8.85	9.7
38	8.88	9.7
39	8.9	9.72
40	9.0	9.7

TABLE XXII

GREEN BEANS TITRATED AGAINST HCl (.0995 N) 50 Gm. GREEN BEANS AND 150 Ml. H_2O

Ml. HCl	Wax	Regular	Polyethylene	Cryovac
0	9.1	9.8	7.65	7.25
1	9.05	9.8	6.9	6.5
2	8.95	9.75	6.25	5.95
3	8.9	9.7	5.75	5.55
4	8.85	9.7		
5	8.75	9.7		
6	8.7	9.65		
7	8.6	9.65		
8	8.5	9.6		
9	8.4	9.6		
10	8.25	9.6		
11	8.1	9.55		
12	7.8	9.55		
13	7.45	9.5		
14	6.85	9.5		
15	6.5	9.5		
16	6.1	9.45		
17	5.8	9.45		
18		9.4		
20		9.4		
25		9.3		
30		9.2		
35		9.1		
40		9.0		
45		8.9		
50		8.8		
55		8.65		
60		8.5		
65		8.25		
70		7.9		
75		6.9		
79		6.0		

TABLE XXIII

TITRATING NH_3 ABSORBED BY STRAWBERRIES WRAPPED IN DIFFERENT OVERWRAPS USING HCl (.0995)

Ml. HCl	Wax	Regular	Polyethylene	Cryovac
0	4.3	4.1	4.0	4.0
1	4.2	4.0	3.85	3.85
2	4.05	3.9	3.8	3.75
3	3.9	3.8	3.7	3.7
4	3.8	3.7	3.6	3.65
5	3.75	3.65	3.5	3.5
6	3.6	3.55	3.4	3.4
7	3.55	3.5		
8	3.45	3.4		
9	3.4			
10				

TABLE XXIV

GROUND BEEF TITRATED AGAINST HCl (.0995 N)
25 Gm. AND 150 Ml. H_2O

Ml. HCl	Wax	Regular	Polyethylene	Cryovac
0	9.1	8.9	7.0	6.7
1	9.1	8.8	6.95	6.65
2	9.1	8.75	6.9	6.55
3	9.05	8.7	6.8	6.4
4	9.0	8.6	6.6	6.35
5	9.0	8.55	6.45	6.25
6	9.0	8.5	6.3	6.15
7	9.0	8.4	6.2	6.1
8	9.0	8.3	6.1	5.85
9	8.95	8.2	6.0	
10	8.9	8.1	5.9	
11	8.8	8.0		
12	8.8	7.9		
13	8.85	7.8		
14	8.7	7.7		
15	8.65	7.6		
16	8.6	7.45		
17	8.6	7.3		
18	8.55	7.25		
19	8.5	7.1		
20	8.45	7.05		
22	8.35	6.9		
24	8.2	6.75		
26	8.05	6.55		
28	7.9	6.15		
30	7.7	6.0		
31	7.6			
35	7.25			
40	6.8			
45	6.4			
49	6.0			

TABLE XXV

TITRATING STRAWBERRIES EXPOSED TO NH_3 FOR 6-24-48-72 HOURS AGAINST HCl (.0995 N), 50 Gm. STRAWBERRIES AND 150 Ml. OF H_2O

Ml. HCl	6 Hours	24 Hours	48 Hours	72 Hours
0	3.8	4.3	5.35	4.3
1	3.7	4.25	5.3	4.2
2	3.7	4.2	5.25	4.1
3	3.6	4.15	5.2	4.1
4	3.6	4.1	5.1	4.0
5	3.5	4.1	5.05	4.0
6	3.5	4.05	5.0	3.9
7	3.45	4.0	4.9	3.9
8	3.4	3.9	4.85	3.8
9	3.3	3.8	4.8	3.8
10	3.3	3.8	4.7	3.7
11	3.25	3.7	4.7	3.7
12	3.2	3.7	4.6	3.6
13	3.2	3.65	4.55	3.6
14	3.1	3.6	4.5	3.5
15	3.05	3.6	4.5	3.5
16	3.0	3.5	4.4	3.4
17		3.5	4.4	3.4
18		3.45	4.3	3.35
19		3.4	4.25	3.3
20		3.35	4.2	3.2
22		3.25	4.1	3.15
24		3.2	4.0	4.03
26		3.1	3.9	2.95
28		3.0	3.8	
30			3.7	
35			3.5	
40			3.4	
45			3.3	
50			2.8	

TABLE XXVI

TITRATING GREEN BEANS EXPOSED TO NH_3 FOR 6-24-48-72 HOURS AGAINST HCl (.0995 N), 50 Gm. GREEN BEANS AND 150 Ml. of H_2O

Ml. HCl	6 Hours	24 Hours	48 Hours	72 Hours
0	9.4	10.0	10.1	10.0
1	9.4	10.0	10.1	9.9
5	9.2	9.9	9.95	9.8
10	9.0	9.8	9.8	9.7
15	8.7	9.7	9.7	9.6
20	8.2	9.6	9.65	9.5
25	6.7	9.5	9.55	9.45
27	6.0	9.45	9.55	9.4
30		9.4	9.5	9.4
35		9.3	9.4	9.3
40		9.25	9.4	9.25
45		9.2	9.3	9.2
50		9.1	9.25	9.1
55		9.2	9.15	9.0
60		9.1	9.05	9.0
65		9.0	9.0	8.9
70		8.9	8.9	8.8
75		8.8	8.85	8.75
80		8.75	8.8	8.7
85		8.6	8.7	8.5
90		8.5	8.65	8.8
95		8.4	8.6	8.3
100		8.2	8.5	8.2
105		8.0	8.6	8.0
110		7.6	8.3	7.6
115		6.0	8.15	6.6
117			8.1	6.0
120			7.95	
125			7.7	
130			7.0	
133			6.1	

TABLE XXVII

TITRATING GROUND BEEF EXPOSED TO NH_3 FOR 6-24-48-72 HOURS AGAINST HCl (.0995 N), 25 Gm. GROUND BEEF AND 150 Ml. of H_2O

Ml. HCl	6 Hours	24 Hours	48 Hours	72 Hours
0	7.1	8.5	8.1	7.2
1	7.0	8.5	8.1	7.2
2	6.9	8.5	8.1	7.1
3	6.8	8.45	8.0	7.1
4	6.7	8.4	8.0	7.0
5	6.6	8.4	7.9	7.0
6	6.5	8.3	7.8	6.9
7	6.4	8.3	7.8	6.85
8	6.3	8.1	7.75	6.8
9	6.15	8.0	7.7	6.7
10	6.05	7.9	7.6	6.7
11	5.9	7.8	7.6	6.6
12		7.7	7.55	6.6
13		7.5	7.5	6.5
14		7.5	7.4	6.4
15		7.4	7.3	6.3
16		7.3	7.25	6.3
17		7.2	7.2	6.2
18		7.2	7.1	6.2
19		7.15	7.05	6.1
20		7.1	7.0	6.1
21		7.1	7.0	6.0
22		7.1	6.9	5.9
25		7.1	6.8	
30		6.8	6.6	
35		6.6	6.4	
40		6.35	6.15	
45		6.15	5.9	
50		6.0		

VITA

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