It seems, therefore, that darkening of petals in 'Baccara' roses is due to 2 processes: a) accumulation of tannins, probably by enzymatic oxidation of polyphenols, b) increase in the content of anthocyanin in pigments. The former occurs exclusively in outdoor roses and is presumably stimulated by wounds inflicted on the tissue as a result of wind, rain and extreme temperature variations. The latter is related to the drop in temperature during the winter, and may occur both in protected and unprotected flowers.

LITERATURE CITED

1. ARISUMI, K. 1967. Studies on the flower colors in Rosa, with special reference to the biological and genetic analysis and to the application of those results to practical breeding. III. *Bul. Fac. Agr. Yamagutti Univ.* 18:1077–1089.
2. HALEVY, A. H. 1962. Anthocyanins in petals of tulip var. President Eisenhower. *Biochem. J.* 83:637–639.
3. HARBORNE, J. B. 1958. The chromatographic identification of anthocyanin pigments. *J. Chromat.* 1:473–488.
4. ————. 1961. The anthocyanins of roses, occurrence of peonin. *Experientia* 17:72.
5. ————. 1965. Flavanoids: Distribution and contribution to plant color. *In:* Chemistry and Biochemistry of Plant Pigments, Goodwin, T. W., ed. Academic Press, N.Y. p. 247–278.
6. HOROWITZ, W. (Ed.) 1965. Official methods of analysis—A.O.A.C., 10th Edition, Washington, D.C.:219.
7. RATSEK, J. C. 1944. The effect of temperature on bloom color of roses. *Proc. Amer. Soc. Hort. Sci.* 44:549–551.
8. SHISA, M., and T. TAKANO. 1964. Effect of temperature and light on the coloration of rose flowers. *J. Japan Soc. Hort. Sci.* 33:140–146.
9. SMITH, L., and E. STOLZ. 1955. *In:* Methods in Enzymology Collowick, S. P. and N. O. Kaplan, ed. Academic Press, N. Y., Vol. 2:740.
10. YASUDA, H. 1967. Studies on the expression of color tone in rose petals. V. *Bot. Mag. (Tokyo)* 80:357–362.

Results of Using Sodium Dehydroacetate Applications to Reduce Discoloration of Snapbeans Damaged by Machine Harvesting[1]

F. M. Isenberg and Roger F. Sandsted
Cornell University, Ithaca, New York

Abstract. Sodium dehydroacetate solutions in concentrations up to 0.8% were found to be effective in reducing discoloration of cut and bruised surfaces of mechanically harvested snapbeans and in reducing some mold and bacterial damage. Techniques for objectively measuring color differences using the Hunterlab Meter D 25 are described.

INTRODUCTION

SNAPBEANS, *Phaseolus vulgaris* L., are affected with a number of market and transit diseases that are constant problems for both the fresh market and processing grower. Zaumeyer and Thomas (7) list 11 fungus diseases, 2 bacterial and 2 non-parasitic diseases under this category. It appears that, with the increased use of machine harvesting and bulk handling techniques, more problems of this nature can be expected since these operations damage the pods considerably more than hand picking. Furthermore, the present and prospective labor situation is such that hand harvesting of snapbeans has little future.

Damage and discoloration of pods caused by machine picking takes various forms, some probably due to enzymatic browning of cut or bruised tissue, similar to the russet described by Zaumeyer and Thomas (7). Only preliminary testing was undertaken in 1965 to see if chemical treatments might reduce the discoloration during the normal time required to market the fresh produce. Beans intended for processing also were similarly effected the following year.

Because preliminary tests indicated that one chemical, sodium dehydroacetate (NaDHA), greatly reduced discoloration and prolonged the storage life of bean pods, this work concerns the use of NaDHA.

NaDHA is not a new chemical. Thomas (5) in 1952 showed that NaDHA was a good preservative for fresh strawberries, raspberries and peaches. Francis and Jimenz (1) in 1961 indicated its usefulness in preserving prepeeled squash.

[1]Paper No. 581. Department of Vegetable Crops.

MATERIALS AND METHODS

In the preliminary tests in 1965 both hand picked and machine picked beans in one-lb. lots were dipped in solutions of the following chemicals, NaDHA @ 8 g/1., ascorbic acid @ 10 g/1., sorbic acid @ 25 g/1., Shell Chemical SD 4901 @ 0.1 g/1., Botran WP @ 0.9 g/1 and 1.8 g/1., and tap water. They were held in unsealed plastic bags at 41°F for 11 days, then compared to a dry control similarly stored. Evaluation was subjective using a 1 to 5 scoring system. From this procedure all but NaDHA were discarded.

In 1966, both machine picked and hand picked green and yellow beans were tested. Concentrations of the dipping solutions were 0.0, 0.2, 0.4, 0.8% by weight and the beans were held in solution for 1 minute.

Color change was measured by wrapping bunches of beans around the center with electrician's tape, then cutting the bundle at right angles and measuring the color of the cut surfaces on a D 25 Hunterlab Color Difference Meter using the 2 inch oriface. After an initial color measurement was made bean discs were placed in unsealed polyethylene bags and stored at 40, 60 or 75–80°F. Color readings were made daily for this test.

In January of 1967, both green and yellow beans received in the local supermarkets appeared to be of inferior quality to beans observed in other years due to an increased number of mechanically damaged pods. It was the opinion of the trade that the beans had been mechanically picked and that no hand picked beans were available as in other years. Two crates of beans of a recent shipment were obtained directly from a warehouse, made into discs and treated with the same NaDHA concen-

Table 1. Hunterlab Color Meter readings at 7 day intervals of yellow snapbeans treated with NaDHA, January 1967.

Concentration (%)	Zero days	7 days	14 days	Δ 0–14 days	Mean
L values:[a]					
0.0	65.20	56.30	38.30	26.90	53.26
0.2	61.05	59.25	48.55	12.50	56.28
0.4	64.85	16.70	49.65	15.20	58.78
0.8	61.50	59.40	54.15	5.25	58.35
Mean	63.15	59.16	47.66		
a values:[b]					
0.0	−0.60	+4.70	+11.15	+11.75	+5.08
0.2	−0.50	+2.00	+6.95	+7.45	+2.46
0.4	−1.15	−2.40	+6.60	+7.75	+2.28
0.8	+1.00	+0.60	+4.00	+3.00	+1.87
Mean	−0.31	+1.92	+7.17		
b values:					
0.0	26.95	22.90	15.65	11.30	21.83
0.2	25.75	22.30	20.00	5.75	22.68
0.4	27.10	23.40	20.55	6.55	24.28
0.8	25.55	22.35	22.75	2.80	23.55
Mean	26.33	22.74	19.74		

[a]L Highest mean best, lowest Δ best.
[b](−) more green, (+) more red.

trations as in 1966 and stored in polyethylene bags at 40°F for 14 days. Colorimetric readings were taken at cutting, 7 and 14 days.

In the summer of 1967 locally grown green and yellow snapbeans were again tested using the bean disc technique for color measurement. Applications of treatment were delayed for periods of 0, 2, 4 and 6 hr. The manufacturer of NaDHA had indicated that quite possibly a sticker material would be incorporated in the commercial product, probably Methocel, Type MC Premium by Dow Chemical or CMC 7 HF Cellulose Gum by Hercules. Three series of solutions of 0.0, 0.2, 0.4 and 0.8% NaDHA were tested, one NaDHA alone, one containing Methocel at 0.4% and CMC at 0.3%. All treated beans were placed in plastic bags, held at 40°F and inspected at 7 and 14 days after treatment. Each experiment was performed twice using two or more samples for each treatment.

Several observation trials were conducted in late August and early September 1968 with pods taken directly from machine harvesters or from sacks of hand picked beans in the field. Lots of approximately one bushel each were dipped for one minute in a 0.5% NaDHA solution,

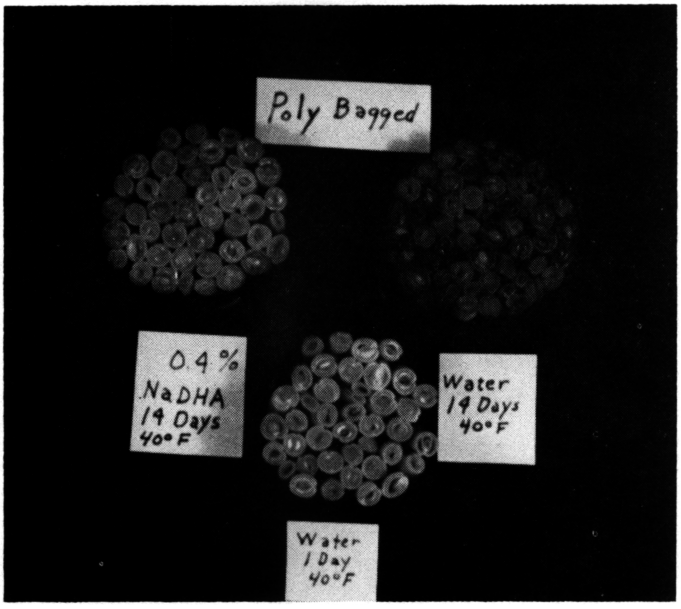

Fig. 1. Discoloration of yellow beans stored 14 days at 40° F in polyethylene bags. Upper left, 1 minute dip in 0.4% NaDHA. Upper right, 1 minute in water. Lower center, one day water only.

Table 2. Analyses of variance of color changes of yellow snapbeans treated with NaDHA in January 1967.

"L" values	DF	F	0.1% significance
Inspections	2	144.92	6.9
Conc NaDHA	3	10.53	5.95
Conc & Insp.	6	9.99	4.82
Error	12		
Total	23		
"a" values	DF	F	0.1% significance
Inspections	2	196.52	6.93
Conc NaDHA	3	63.68	5.95
Conc & Insp.	6	15.72	4.82
Error	12		
Total	23		
"b" values	DF	F	0.1% significance
Inspections	2	130.79	6.93
Conc NaDHA	3	10.65	5.95
Conc & Insp.	6	8.54	4.82
Error	12		
Total	23		

drained and then divided into 2-lb. samples for storage in perforated polyethylene bags at 40°, 50° and 70°F. Comparable samples of pods were dipped in water only and stored at the same temperatures. No objective ratings were made other than to observe gross changes in storability of treated and untreated pods every few days and to record differences with photographs.

Tasting of treated and non-treated bean pods in 1968 seemed to indicate that treated beans were somewhat sweeter. To check this possibility, a sugar test was performed. Harvester variety beans were treated with 0.5% NaDHA solutions and held at 40°, 50° or 70°F for 3 days then analyzed for sugar equivalents by the method of McCready et al. (3) as modified by Sadik and Ozbun (4).

Results and Discussion

The results of the 1966 Hunterlab Color Meter readings on bean discs indicated that at 40°F storage in polyethylene bags, little change occurred in yellow beans until 9 days when the check become somewhat brown. After 14 days the differences were quite marked as shown in Fig. 1.

With green beans, stored at 7 days at 40°, 60°, and 75–80° (air temperature) the temperature seemed to have greater effect than concentration of NaDHA on reducing discoloration. Those in air were worthless in a few days due to browning and fungus. Of the other 2 temperatures, only the 0.4% and 0.8% concentrations in the 40°F tem-

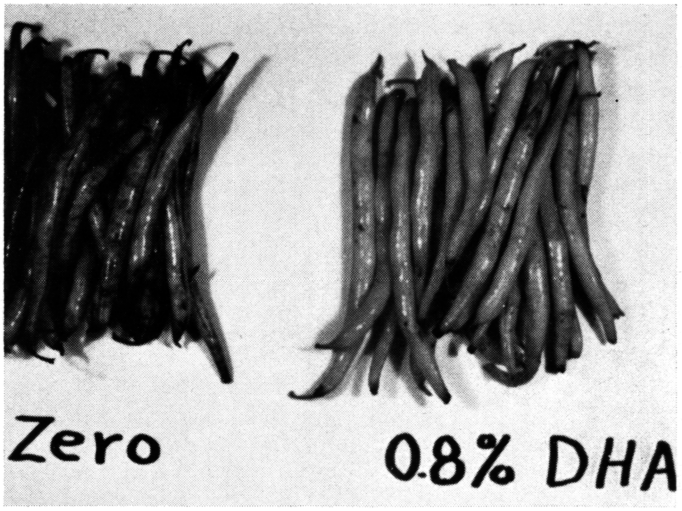

Fig. 2. The effects of NaDHA on beans held at 40° F for 26 days. Left—40° F. Right—Polybagged—26 Days.

Table 3. Representative examples of viscosities in cps of solutions of NaDHA and methylcellulose materials as measured by a Brookfield viscometer, 1967.

Surfactant	NaDHA	Av 3 trials
Djstilled H_2O		3.5
None	0.2%	3.23
None	0.4%	3.47
None	0.8%	3.67
Methocel 0.4	0.0%	13.50
Methocel 0.4	0.2%	6.20
Methocel 0.4	0.4%	20.17
Methocel 0.4	0.8%	8.43
CMC 0.3	0.0%	97.96
CMC 0.3	0.2%	60.67
CMC 0.3	0.4%	33.30
CMC 0.3	0.8%	36.13

Table 4. Combined analysis of variance of L value data (lightness) of yellow beans over two week periods, summer 1967.

Variable	DF	F	0.1	0.5
Surfactants	2	37.42	4.70	3.03
Inspections	2	440.68	4.70	3.03
Concentrations	3	37.70	3.87	2.64
Delay	2	3.04	4.70	3.03
Conc. & Inspection	6	12.49	2.89	2.13
Error	272			
Total	287			

perature were acceptable after 7 days. Fig. 2 shows the long time effect of NaDHA on beans treated and held at 40° for 26 days. The results of the January 1967 tests on yellow snapbeans shipped from out of the state are given in Tables 1 and 2. Table 1 indicates the degree of color change as measured on the Hunterlab Color Difference Meter D 25 at two intervals, 7 and 14 days treatment. The changes in luminescence or brightness as represented by the "L" scale values were greatest for the zero concentration and least for the 0.8% NaDHA treatment. These changes are in the direction of less brightness and are readily apparent visually.

Mature yellow beans have very little green color in the fresh state and the Hunterlab Meter "a" values indicate this by the very low initial values of the "a" scale. The shift in hue in every case was toward more redness but the amount was small and at that point on the "a" scale the color saturation for redness is low. The change in the "b" values are all representative of a loss of yellowness. The effect is a decrease in saturation of purity of yellowness. The change was greatest for the zero treatment and least for the 0.8% concentration. The visual effects were similar to those shown in Fig. 1.

Table 2 shows the statistical significance of the changes in the 3-scale values of the Hunterlab Meter. The F values for all 3 scales indicate that the greatest change in color can be partitioned to the time interval alone. However, concentrations of NaDHA solution also had significant effects but of less magnitude. The interaction of concentration and time are also significant for all scale changes and shown very well by the △ 0–14 day column in Table 1. The authors have chosen to treat the 3 scale values of the Hunterlab instrument as independent variables for the purpose of indicating the statistical significance of the changes since the meter locates a point in color solid by the intersection of 3 coordinates. By so doing the changes can be mentally evaluated by anyone familiar with this instrument. These particular data however are correlated with an r_{xy} for a × b of −.85, for L × a of −.92 and L × b of +.95, so there is no particular combination of any one pair whose tangent angle has any more validity than any other pair. To combine these data into one statistic using the formula

$$\triangle E = \sqrt[1/2]{(\triangle L)^2 \times (\triangle a)^2 \times (\triangle b)^2}$$

would give the spatial relationship of the change from the initial to final point in the color solid in Hunterlab Meter Scale units, but it would be a ± value that would not indicate the direction of the change. Analysis of these data indicated that the degree of significance or order of magnitude would not be changed by the combination treatment from any of the scale values analyzed independently so the authors discarded this concept.

In the case of green beans treated in January, no treatment was found to be much better than the check treatment, hence these data are omitted.

In the 1967 snapbean tests, considerable difficulty was experienced in preparing the NaDHA solutions containing the sticker materials Methocel and CMC. When in solution, the stickers reacted with the NaDHA to produce solutions of widely different viscosities. They followed no particular pattern that could be related to the concentration of either component of the system. The pH adjustment was found not to be satisfactory so that one concentration of each sticker was ultimately used. Representative examples of these solutions are listed in Table 3.

In the summer of 1967 russeting or discoloration of field grown snapbeans was not especially bad. There were very few complaints from the industry. Considerable difficulty was experienced in producing the discoloration

Table 5. Interaction of NaDHA concentration and inspection date effects on L value (lightness) of yellow snapbeans, summer 1967.[a]

Concentration (%)	initial insp.	2nd insp.	3rd insp.	△ initial-3rd
0.0	63.85	61.94	55.03	8.82
0.2	63.88	63.39	58.28	5.60
0.4	64.30	63.44	58.68	5.62
0.8	64.47	63.54	60.49	3.98
$\bar{X}$	64.12	62.82	58.12	

[a]Highest mean best, lowest △ best.

Table 6. Combined analysis of variance of "a" value data (change toward redness) of yellow beans over two week periods, summer 1967.

Variable	DF	F	0.1	0.5
Surfactants	2	6.30	4.68	3.03
Inspection	2	595.29	4.68	3.03
Concentration	3	18.14	3.86	2.64
Delay	2	33.07	4.68	3.03
Conc. & Insp.	6	8.32	2.88	2.13
Error	272			
Total	287			

Table 7. Interaction of NaDHA concentration and inspection date effects on "a" values (color change) of yellow snapbeans, summer 1967.

Concentration (%)	1st insp.	2nd insp.	3rd insp.	△ 1st–3rd insp.
0.0	−2.04	−0.15	+3.23	+5.27
0.2	−2.23	−1.05	+1.92	+4.15
0.4	−1.93	−0.89	+1.88	+3.81
0.8	−2.11	−0.75	+0.95	+3.06

[a](−) values more greenish, (+) values more reddish.

Table 8. Combined analysis of variance of L value data (lightness) of green beans over two week period, summer 1967.

Variable	DF	F	0.1
Surfactants	2	8.01	4.69
Inspections	2	75.09	4.69
Concentrations	3	4.71	3.86
Delay	3	6.76	3.86
Conc. & Inspection	6	4.00	2.88
Error	271		
Total	287		

Table 9. Interaction of NaDHA concentration and inspection date effects on L values (lightness) of green snapbeans, summer 1967.

Concentration (%)	initial	1st insp.	2nd insp.	Δ initial–2nd insp.
0.0	45.35	45.55	40.93	4.42
0.2	45.63	46.69	42.73	2.90
0.4	44.50	47.25	43.34	1.16
0.8	44.48	47.13	43.93	0.55

Highest mean best, lowest Δ best.

Table 10. Combined analysis of variance of "a" values (change from greenness) of green snapbeans over a 2-week period, summer 1967.

Variable	DF	F	0.1
Surfactants	2	13.22	4.69
Inspections	2	143.80	4.69
Concentration	3	5.52	3.86
Delay	3	13.62	3.86
Conc. & Insp.	6	54.09	2.88
Error	271		
Total	287		

Table 11. Interaction of NaDHA concentration and inspection date effects on "a" values (color change) of green snapbeans, summer 1967.

Concentration (%)	initial	1st insp.	2nd insp.	Δ initial–2nd insp.
0.0	−11.33	− 9.11	−3.43	+7.90
0.2	−11.31	−10.04	−5.27	+6.04
0.4	−11.08	− 9.93	−6.58	+4.05
0.8	−11.06	−10.34	−7.08	+3.98

(−) values more green, (+) more brown.

Table 12. Effect of NaDHA on ethanol—soluble sugar in bean pods, held at various temperatures.

Temperature	Glucose equivalents per gram fresh weight	
	Control	NaDHA dipped
F	mg	mg
40°	25.58	23.82
50°	26.17	25.90
70°	22.80	24.20

condition in the laboratory. The results of numerous experiments for the season are combined into single analyses of variance for the Hunterlab L and a values. The b values were determined but were of little statistical or practical significance. Most of the differences were small from a practical point of view and statistically significant only because of the number and precision of the tests. The data do show that the NaDHA material works but is only dramatic in effect when the discoloration is severe.

The results of Hunterlab Meter "L" values for yellow beans are given in Table 4 and the "a" values in Table 6. The direct effects of surfactants, NaDHA concentration and delay of application made only slight differences in lightness and color change. The greatest change in lightness and color change was due to length of time in storage as indicated by the magnitude of the F values for inspection. The concentration of NaDHA did retard the rate of change of these two values and the magnitude of these effects is shown in Tables 5 and 7.

The results of the Hunterlab Meter "L" values are given in Table 8 and the "a" values in Table 10 for green beans. Again the direct effects of surfactants, concentration of NaDHA and delay of application made only slight differences in lightness change. Time in storage made the greatest effect, as indicated by the magnitude of the F value for inspections. In "a" values or color change surfactants and concentration had very little direct effect. Delay of application had some effect on color change, but time in storage had the greatest effect. The concentration of NaDHA did retard the rate of discoloration as shown by the interaction of concentration and inspection data in Tables 9 and 11.

On the basis of these results, surfactants are not recommended for inclusion with NaDHA treatments. Delay of application for several hours is not detrimental if discoloration has not already occurred.

The results of the 1968 field trials indicated that at 70°F storage temperature a dip in a 0.5% solution of NaDHA for one minute always delayed discoloration of broken, bruised, scratched or cut pod surfaces for 24 to 36 hrs. when compared with pods dipped in water only. Differences in discoloration of abrasions became less apparent after 2 or 3 days. After this length of time molds often developed rapidly in untreated pods when compared with NaDHA treated pods. After 4 or 5 days molds usually developed at a slow rate in the treated pods. The amount of mold was always greater on machine picked than on hand picked pods, probably because of the bruising and scraping of machine drum fingers which open pathways for disease organisms into the pods.

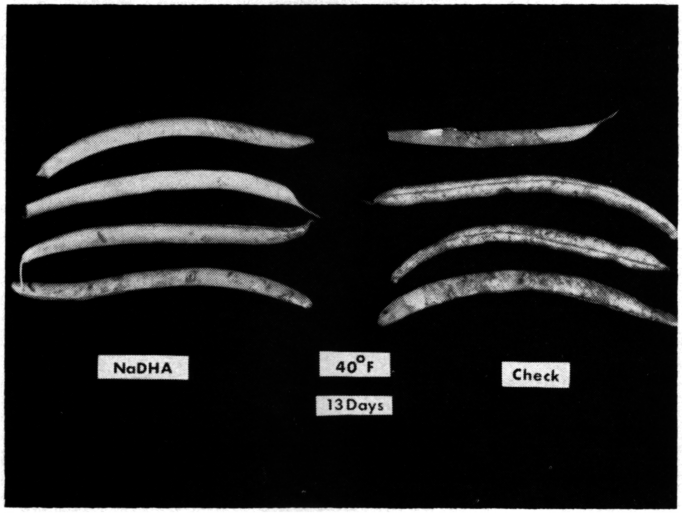

Fig. 3. The suppression of russeting of snapbeans treated with 0.5% NaDHA in field and held in polyethylene bags at 40° F for 13 days.

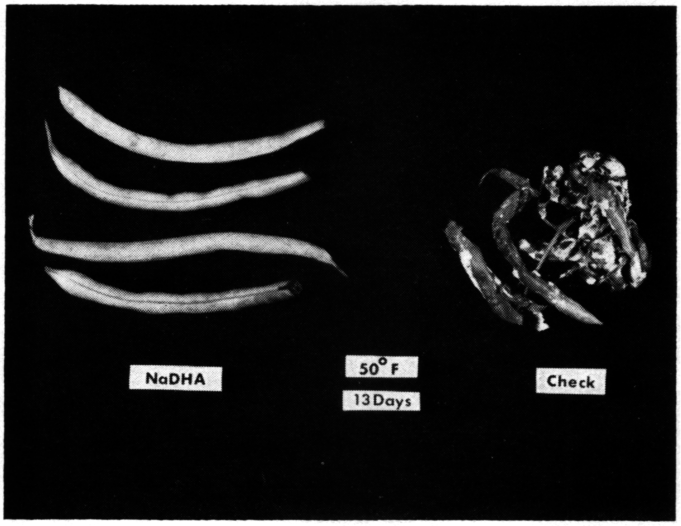

Fig. 4. The bacterial and fungicidal action of NaDHA on beans treated with 0.5% solutions in the field, and held 13 days in polyethylene bags at 50° F.

NaDHA treated pods and pods dipped in water only and stored at 50°F kept in good condition for a week or more at which time the untreated pods began to mold or rot rapidly (Fig. 4). Results in the 40°F were similar to those in the 50° room except that the development of rots and molds were at a slower rate (Fig. 3). If treated and untreated samples were left at 40° or 50° for a month or more the untreated pods were always completely disintegrated and mushy while the NaDHA treated lots held their original shape.

Although there was detectable sweetness in beans treated with NaDHA solution, the differences between treated and non-treated beans in ethanol soluble sugars was not sufficient to account for the taste differences. Since the beans were tasted in the raw state, the taste sensation may be due to the NaDHA itself. Table 12 shows the results of the sugar test.

In summation, snapbeans treated with NaDHA solution discolor less rapidly than non-treated beans. This material has not been approved for use on beans by the Federal Government to date. Residue tests are in process and will be reported in a separate paper.

Literature Cited

1. Francis, F. J., and M. A. Jimenz. 1961. Dehydroacetic acid treatments for prepeeled, cubed squash. *Food Tech.* 15:322–327.
2. Ma, R. M., and M. P. Morris. 1965. Dehydroacetic acid. Food Additives Analytical Manual, U. S. Dept. Health, Education and Welfare, Food and Drug Administration, Washington, D. C.
3. McCready, R. M., J. Guggolz, V. Silviera, and H. S. Owens. Determination of starch and amylase in vegetables. *Anal. Chem.* 22:1156–1158.
4. Sadik, S., and J. L. Ozbun. 1968. The association of carbohydrate changes in the shoot tip of cauliflower with flowering. *Plant Physiol.* (In press).
5. Thomas, F. B. 1952. Delaying decay of fruits after harvest. *Pa. Agr. Exp. Sta. Prog. Rept.* 70.
6. Woods, L. A., F. E. Shideman, M. H. Seevers, J. R. Weeks, and W. T. Kruse. 1950. Dehydroacetic acid (DHA). III Estimation, absorption and distribution. *J. Pharmacol. Therapeutics* 99:84–97.
7. Zaumeyer, W. J., and H. R. Thomas. 1957. A monographic study of bean diseases and methods of their control. *U. S. Dept. Agr. Tech. Bul.* 868.

Rate of Ripening of Initiated Bananas as Influenced by Oxygen and Ethylene[1,2]

C. W. Hesselman and H. T. Freebairn,
University of Houston, Houston, Texas

Abstract. The ability of initiated bananas to ripen at rates close to those considered normal was found to be ethylene dependent in low oxygen concentrations. Fruit denied ethylene by low oxygen treatments, which reduced the fruit's ability to produce ethylene, ripened far slower than similarly treated fruit receiving exogenous ethylene. A sequence of ripening changes was proposed to account for the present knowledge of ripening.

Introduction

The storage and ripening of banana fruit has been studied by a number of investigators in relation to O_2 and CO_2 influences (4, 5, 6, 12). Some confusion has resulted because of inadequate control of ethylene (C_2H_4) concentrations in relation to O_2 and CO_2 levels as well as the state of initiation of the fruit. Mapson and Robinson (8) and Quazi (9) reported that lowered O_2 concentrations reduced the rate of C_2H_4 synthesis in uninitiated banana fruit and suggested that the primary reason low O_2 could delay ripening was because of the reduced C_2H_4 synthesis. It was also found that C_2H_4 could overcome some of the retarding influences of low O_2 concentrations on the ripening of un-initiated fruit. Stewart (12) reported that C_2H_4 synthesis could be separated from its action, that there are 2 separate C_2H_4 synthesis mechanisms, and hypothesized that C_2H_4 may be necessary for ripening after initiation.

The work of Quazi (9) and Stewart (12) was concerned primarily with changes before and during initiation of ripening while the present investigation was carried out to extend the studies to the influence of O_2, CO_2 and C_2H_4 on processes occurring after initiation.

[1]Received for publication February 25, 1969.

[2]This work was supported by a grant from Banana Control, Incorporated. The assistance of Mrs. Addette Stowe is gratefully acknowledged.

Materials and Methods

'Valery' variety bananas, *Musa sapientum* L., from Honduras and Panama were obtained the morning after arrival at the port of Galveston. Fruits were marked with a hand number and a group number. The fruit was then distributed into experimental groups of 6–8 fingers so that each hand contributed to each group. The markings thus allowed the detection of differences in a response of single hands to our treatments.

A "vacuum addition" process was used to insure the introduction of the desired gases inside the fruit. This vacuum-addition process consisted of placing 6 to 8 fingers of fruit in a 250 mm I.D. desiccator and removing the gases with a vacuum of less than 10 mm pressure of mercury. A known gas mixture was then introduced to replace the removed gases and the procedure was then repeated. The effectiveness of this treatment has been previously reported and also found to be noninjurious to tissue cultures (12) and our work has shown it noninjurious to intact bananas. Initiation was accomplished by adding 100 ppm C_2H_4 in air as a replacement gas and as a flow of gas for the following 12–16 hr. Immediately after the initiation period, all groups were again treated by vacuum-addition with whatever gas they were to receive. They were then connected to a flow system which flushed the desired gas through containers at a rate of 0.236 liters per minute. The mixtures of gases were pre-