TECHNICAL REPORT

70-58-FL

AD

CONTROLLED ATMOSPHERE SYSTEM LABORATORY STUDIES ON TOMATOES

by

Harold Gorfien

Abdul R. Rahman

George Taylor

Donald E. Westcott

Project reference

PE2270.3

February 1970

UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

U.S. ARMY MATERIEL COMMAND

Food Laboratory

FL-108

This document has been approved for public release and sale; its distribution is unlimited

AD ________________

TECHNICAL REPORT
70-58-FL

CONTROLLED ATMOSPHERE SYSTEM LABORATORY STUDIES ON TOMATOES

by

Harold Gorfien
Abdul R. Rahman
George Taylor
Donald E. Westcott

February 1970

Project reference
PE 2270.3

Series: FL-108

Food Laboratory
U. S. ARMY NATICK LABORATORIES
Natick, Massachusetts 01760

FOREWORD

Previous studies by the US Army Natick Laboratories in the laboratory and overseas indicated that the use of Controlled Atmospheres could improve quality, reduce spoilage and increase the storage life of lettuce shipped to military organizations overseas. In view of these results it was decided to conduct laboratory studies on the effects of low-oxygen atmospheres during transportation of tomatoes to military organizations overseas.

This work was performed under Production Engineering 2270.3; Mr. Harold Gorfien was the Official Investigator.

The authors wish to acknowledge the assistance of the Transfresh Corporation, Salinas, California in providing the test Controlled Atmosphere chests. Assistance of the following personnel of the US Army Natick Laboratories is acknowledged: W. Henning and T. DiNicola for gas analyses and product testing; L. Klarman for writing programs for computer calculations on data; and M. Driver for Color Difference Meter Measurements.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Laboratory tests were conducted to determine the effect of low-oxygen controlled atmosphere (which is carbon dioxide free) on tomatoes. Storage periods approximating the extended overseas distribution time of 3 to 8 weeks as required for military shipments were used. The tests showed that the use of low oxygen controlled atmosphere would lead to significant reductions in spoilage, inhibition of black spot type rot similar to Alternaria rot, improvements in tomato quality, and as much as 2 weeks additional storage life, when compared with tomatoes initially stored in air at the same optimum 50°F. - 55°F. temperatures. These factors became apparent from 1 to 4 weeks after transfer of tomatoes from low oxygen controlled atmospheres to 40°F. air. The break-even point to defray the additional cost of a commercially available controlled atmosphere method of shipping is estimated to be in the range of 1.8% to 3.3% improvement in tomato yield. Data developed in this investigation indicate that improved tomato yields on overseas shipments of tomatoes may be anticipated to be more than enough to defray the additional cost of such a system for shipping fresh produce in refrigerated containers at low levels of oxygen and carbon dioxide.

It is concluded that sufficient information has been developed to warrant a field test on tomatoes shipped in controlled atmosphere containers to military organizations overseas.

CONTROLLED ATMOSPHERE SYSTEM LABORATORY STUDIES ON TOMATOES

Introduction

Availability of good quality fresh fruits and vegetables to meet the requirements of military personnel is of concern to the Armed Forces. Extended shipping and storage periods are required for military shipments overseas compared to those for normal distribution to civilian markets in the continental United States. As a result perishable products will exhibit varying degrees of spoilage before arriving overseas. Fresh tomatoes are among the important food items supplied overseas.

For the 6-month period from July 1969 to December 1969, Defense Personnel Support Center purchased 11,681,726 pounds of tomatoes in the United States. The purchase price and the cost of warehousing, handling and shipping both CONUS and overseas adds up to a considerable sum. Besides these purchases, additional tomato procurements were made from overseas growers in order to help meet the military supply requirements at locations outside the United States.

It used to be difficult to obtain optimum 50°F. - 55°F. temperatures for tomatoes in Navy Reefer ships. As a result tomatoes were generally not shipped from CONUS to overseas military organizations; and when they were shipped, they generally arrived in poor condition. With the advent in the past 2 years of Container vans as a system for transporting cargo, it became possible to ship tomatoes at optimum temperatures. This has led to increased shipments of tomatoes to military units overseas.

Transfresh Corporation had claimed that there were advantages in using their TECTROL* controlled atmosphere system (low-oxygen, low-carbon dioxide environment) for storing tomatoes. Since previous studies at NLABS had shown that there were advantages in using this system on lettuce, it was decided to explore the feasibility of low-oxygen atmosphere (which is carbon dioxide free) as a means of shipping tomatoes overseas.

* TECTROL is a registered trademark of Whirlpool Corporation

Previous related studies

Within the past two decades, research activity involving storage of various crops, including tomatoes, has increased.

Research on fresh produce was initiated by the US Naval Supply Research and Development Facility in 1954 (1). Tests were conducted on New Jersey, California, and Florida grown pink tomatoes rather than mature green tomatoes since optimum storage temperatures were not generally available aboard Navy ships. The use of LSAT cellophane (moderate moisture vapor retention) lined crates for packaging was found to result in firmer tomatoes during a 30-day storage period.

The Quartermaster Food & Container Institute conducted studies in 1956 (2) with tomatoes in different stages of maturity. The results showed that mature green tomatoes stored best when ripened gradually at 55°F. and then stored at 32°F. Where transit storage temperatures around 40°F. were involved, best results were obtained with pink to hard-ripe tomatoes.

Under contract to the Navy the US Department of Agriculture studied tomatoes (3). As a result of these studies conducted aboard a Navy reefer ship, it was recommended that mature green tomatoes be stored at 58°F. until firm ripe and then be transferred to 33°F. - 35°F. storage.

Literature provided by the American Society of Refrigeration Engineers (4) shows that mature-green tomatoes cannot be successfully stored in air at temperatures that greatly delay ripening; tomatoes held in air for 2 weeks or longer at 55°F. may develop an abnormal amount of decay.

In studying the effect of controlled atmosphere on rot pathogens responsible for tomato decay, Lockhart (5) found that most fungal and bacterial rots are retarded by an atmosphere of 3% CO_2 and 3% O_2. However, Alternaria tenius was reported as having been only slightly retarded.

A firm tomato would have less decay because it has less tendency to bruise than a soft tomato. Investigations on Controlled Atmosphere storage by Parsons <u>et al</u> (6) showed that tomatoes stored in 1% oxygen atmospheres for 10 days were firmer - when measured by a USDA mechanical thumb - than those stored in air. No significant effect on flavor was found. Color changes were also inhibited until removal to air. After that, color ripening proceeded.

Color as a factor in tomato ripening was studied by the USDA in a series of 12- to 28-day storage experiments involving hypobaric (less than normal atmospheric pressure) storage (7). In one test series (at 65°F. $\pm$ 3°F.) with pressures ranging from 190 mm to 755 mm of Hg and 21% oxygen levels, red color development was inhibited most where the pressure was lowest. In a second test series where pressures ranged from 755 mm to 180 mm of Hg and oxygen ranged from 5% to 21%, red color development was most inhibited at the 5% oxygen level and 755 mm of Hg. Upon removal to air at 70°F., the red color was found to increase further within a 3-day period. Holding pink or mature-green fruits for over 6 days at 32°F. was found to seriously damage their ability to turn red after removal to 70°F. conditions (8).

In a series of tests with various fruits held at 70°F. for 15 days in modified atmospheres (9), tomato color development was less and tomato respiration rate was lower when storage was at 2% O_2 than when held in air. Exposure of fresh produce to carbon monoxide for periods up to 10 minutes has been found to lower polyphenoloxidase activity (10). Warehouse storage with controlled atmosphere generators to maintain the environment at 1.5% to 3% oxygen and less than 5% carbon dioxide has recently been reported to extend the fresh life of tomatoes for up to 2 months (11). Failure of tomatoes to ripen after exposure to high levels of carbon dioxide has been reported by Smith (12).

Laboratory and field studies conducted at NLABS during 1968 and 1969 (13, 14) have shown that the TECTROL controlled atmosphere system could improve the quality and storage life of lettuce during overseas shipping, distribution and consumption time of 5 to 7 weeks.

Methods and materials.

The test plan was designed to determine the feasibility of a low-oxygen system for shipping and distributing tomatoes to military organizations overseas. This involved holding tomatoes at 50°F. - 55°F. for 3 to 4 weeks and then transferring them to a 40°F. chill box for an additional 1 to 4 weeks.

Four different crops of tomatoes from either California or Florida, as indicated in Table I, were obtained on the local market.

TABLE 1. KEY TO CODING OF FOUR TOMATO CROPS AND THEIR STORAGE PERIODS.

Tomato Crop Code	Source	Picking Time Prior to NLABS Procurement (days)	NLABS Initial Holding Period at 50°F.-55°F. (weeks)	NLABS Additional Holding Period at 40°F.
A	California	10	4	2-4
B	California	10	3	2-4
C	California	10	3	1-3
D	Florida	4	3	1-3

The tomatoes were US No. 1 Grade ranging in color from number 2 "Breakers" to number 3 "Turning" as described in Federal Specification HHH-T-576f, Tomatoes, Fresh. On arrival at NLABS the boxes of tomatoes were randomly distributed among 1) a low-oxygen Chest, 2) a Control air Chest, and 3) a control large chill box. The low-oxygen and Control air chests are 15.6 cubic feet horizontal refrigerated boxes, 36 7/8 inches high, 48 1/2 inches long and 27 7/8 inches deep. These chests are thermostatically controlled and each has a fan for air circulation. The low-oxygen chest has in addition a transparent plastic lid for sealing the chest gas tight. This plastic lid has inlet and outlet ports for gas exchange. The low-oxygen chest and the Control air chest were set to operate at 50°F. to 55°F. The control large chill box operated at 40°F.

Nitrogen was used to produce a low-oxygen level in the low-oxygen chest (primarily nitrogen with low levels of oxygen). Gas analyses were conducted on the low-oxygen chest at 48- to 66-hour intervals throughout the storage period, as required. A Fisher Gas Partitioner Model 25 M was used to determine the percentages of the gases present throughout the 3- to 4-week controlled atmosphere storage period. Air was added to the low-oxygen chest as required at 48- to 66-hour intervals to maintain the oxygen level within a reasonable range. Oxygen ranged from 2% to 4% for most of the storage period, reaching a minimum of 1.8% and a maximum of 5.4%. Nitrogen made up the difference, since carbon dioxide produced by respiration was scrubbed out with hydrated lime for tomato crops coded A, C, and D (Table 1).

In the case of tomato crop B, carbon dioxide produced by respiration increased gradually from 0% to 10% in the course of the 3-week 50°F. - 55°F. initial storage period, since there was no scrubbing.

At the end of the 3- to 4-week storage period the tomatoes were removed from both the low-oxygen control air chests, and held in a large chill room at 52°F. for 24 hours. Then the tomatoes were placed in the control large chill box at 40°F. At periods ranging from 1 to 4 weeks later, quality evaluations were made on the tomatoes. Evaluation of the tomatoes consisted of the following:

(a) Yield of good tomatoes. - Separating good tomatoes from spoiled tomatoes. Determining the weights in each case.

(b) Spoilage. - Describing the nature and extent of the spoilage (black spot type rot, similar to Alternaria rot, fungus rot including mold, filaments, bacterial soft rot).

(c) Color. - Describing tomato color, using the following methods:

(1) Color photos and visual examination of maturity using Tomato Color Classification and designations of the US Department of Agriculture, US Standards for Grades of Fresh Tomatoes as amended October 15, 1961 (1-Green, 2-Breakers, 3-Turning, 4-Pink, 5-Light Red, 6-Red as described in Appendix A).

(2) A Hunter Color-Difference Meter Model D25 Colorimeter (standardized with a Hunter Lab White Standard No. 025-1277, L=93, $a_L = 0.5$, $b_L = 0.4$ and CTC value= -12). Measurements were made on tomato exterior bottom, tomato exterior top with stem cored out and tomato interior centers (tomatoes sliced in half).

(d) Firmness. - Testing tomato firmness by feel using the terms "firm" or "soft".

(e) Flavor. - A flavor panel determining preference by rating paired samples hedonically from 1 to 9 (1 - dislike extremely; 2 - dislike very much; 3 - dislike moderately; 4 - dislike slightly; 5 - neither like nor dislike; 6 - like slightly; 7 - like moderately; 8 - like very much, 9 - like extremely).

Both good tomato yield data, and flavor panel ratings, were statiscally evaluated by the t test for significant difference between low-oxygen and air storage of tomatoes.

Results

Yield of good tomatoes. In three out of the four tomato crops examined, a significant reduction in tomato spoilage was observed with a resulting improvement in yield (Table 2) when low-oxygen (Controlled Atmosphere) was used for storage. The data also indicate that low-oxygen storage had increased the storage life an additional 2 weeks in two of the tomato crops. This has been summarized by the comparisons in footnotes a and b in Table 2 with a $t_{.05}$ level of significance.

Spoilage - degree and type. Controlled Atmosphere appears to have an inhibitory effect not only on the degree of spoilage as evidenced in Table 2 but also on the type of spoilage as evidenced in Table 3. These data indicate that black spot type rot similar to Alternaria rot was inhibited by low-oxygen atmospheres in all four crops. This inhibition in degree and type of spoilage was found from 1 to 4 weeks after removal of the tomatoes from low-oxygen atmospheres to air.

Maturity by Color. None of the tomatoes held at 40°F. for 3 to 4 weeks ripened. When transferred from 40°F. storage to 50°F. - 55°F. or 70°F. storage all the tomatoes spoiled, without ripening, within 1 week.

Tomato ripening in terms of Visual Tomato Color classifications for NLABS holding periods described in Table 1 is shown in Figure 1. Color photographs of these tomatoes are in NLABS files. Crop B low-oxygen stored tomatoes differed from the other 3 crops in final color (Figure 1) and controlled atmosphere storage conditions. Carbon dioxide produced by crop B tomato respiration had not been scrubbed out and gradually increased from 0% to 10% during the 3-week low-oxygen period. This agrees with previous findings in the literature (12) that excessive carbon dioxide may have a damaging effect on color development.

A comparison of Visual Tomato Color Classification scores* with Tomato Color Index (TCI) calculated from Hunter Colorimeter L, a_L and b_L measurements is shown in Table 4. These TCI values and Visual Tomato Color Classification scores show that after the additional 40°F. storage, the Control tomatoes initially stored at 50°F. - 55°F. in air were more uniform and redder in surface color than those initially stored in low oxygen at 50°F. - 55°F.

Color inside tomato. It should be noted that the average Tomato Color Index (TCI) for the cut half of 9.0 percent represented tomatoes initially stored in 40°F. air which were greenish-pink inside; 17.4 percent TCI value represented low-oxygen tomatoes (initially stored at 50°F. - 55°F.) which were pinkish-red inside; and 23.2 percent TCI value represented Control tomatoes (initially stored at 50°F. - 55°F.) which were light red inside.

Firmness. Tomatoes stored initially in low oxygen at 50°F. - 55°F. had a firmer feel (categorized as "firm") after transfer to air storage at 40°F. than tomatoes (categorized as "firm" to "soft") stored initially in air at 50°F. - 55°F. and then transferred to air storage at 40°F.

*See Appendix A

TABLE 2. EFFECT OF LOW-OXYGEN AND AIR (CONTROL) STORAGE ON TOMATO YIELD

Crop Code Table 1	Storage Times: INITIAL* at 50°-55°F (weeks)	(plus)	Storage Times: ADDITIONAL* at 40°F in (Air) (weeks)	Average Yield Good Tomatoes** When INITIAL Storage Was: Low-Oxygen (%)	Average Yield Good Tomatoes** When INITIAL Storage Was: Control (%)	Significance***
A	4 (L)	plus	2	68.3		
	4 (C)	"	2		44.9 (a)	S
	4 (L)	"	4	44.2 (a)		
	4 (C)	"	4		5.2	S
B	3 (L)	"	2	82.3		
	3 (C)	"	2		79.8	NS
	3 (L)	"	4	49.0		
	3 (C)	"	4		31.4	S
C	3 (L)	"	1	85.4		
	3 (C)	"	1		53.8 (b)	S
	3 (L)	"	2	83.7		
	3 (C)	"	2		41.1	S
	3 (L)	"	3	70.5 (b)		
	3 (C)	"	3		23.8	S
D	3 (L)	"	1	65.8		
	3 (C)	"	1		64.6	NS
	3 (L)	"	2	56.4		
	3 (C)	"	2		55.2	NS
	3 (L)	"	3	55.8		
	3 (C)	"	3		49.8	NS
A, B, C, D, Pooled Averages				66.1	45.0	S

* (L) = INITIAL storage period in Low-Oxygen controlled atmosphere.
(C) = INITIAL storage period in air (Control).
ADDITIONAL storage was at 40°F. in air.

** Based on 90 pounds of tomatoes.

*** Statistical analysis, $t_{.05}$ level for significance. S = Significant, NS = Not Significant.
(a) Comparison of 44.2% with 44.9% yield not significant at $t_{.05}$ level.
(b) Comparison of 70.5% with 53.8% yield significant at $t_{.05}$ level.

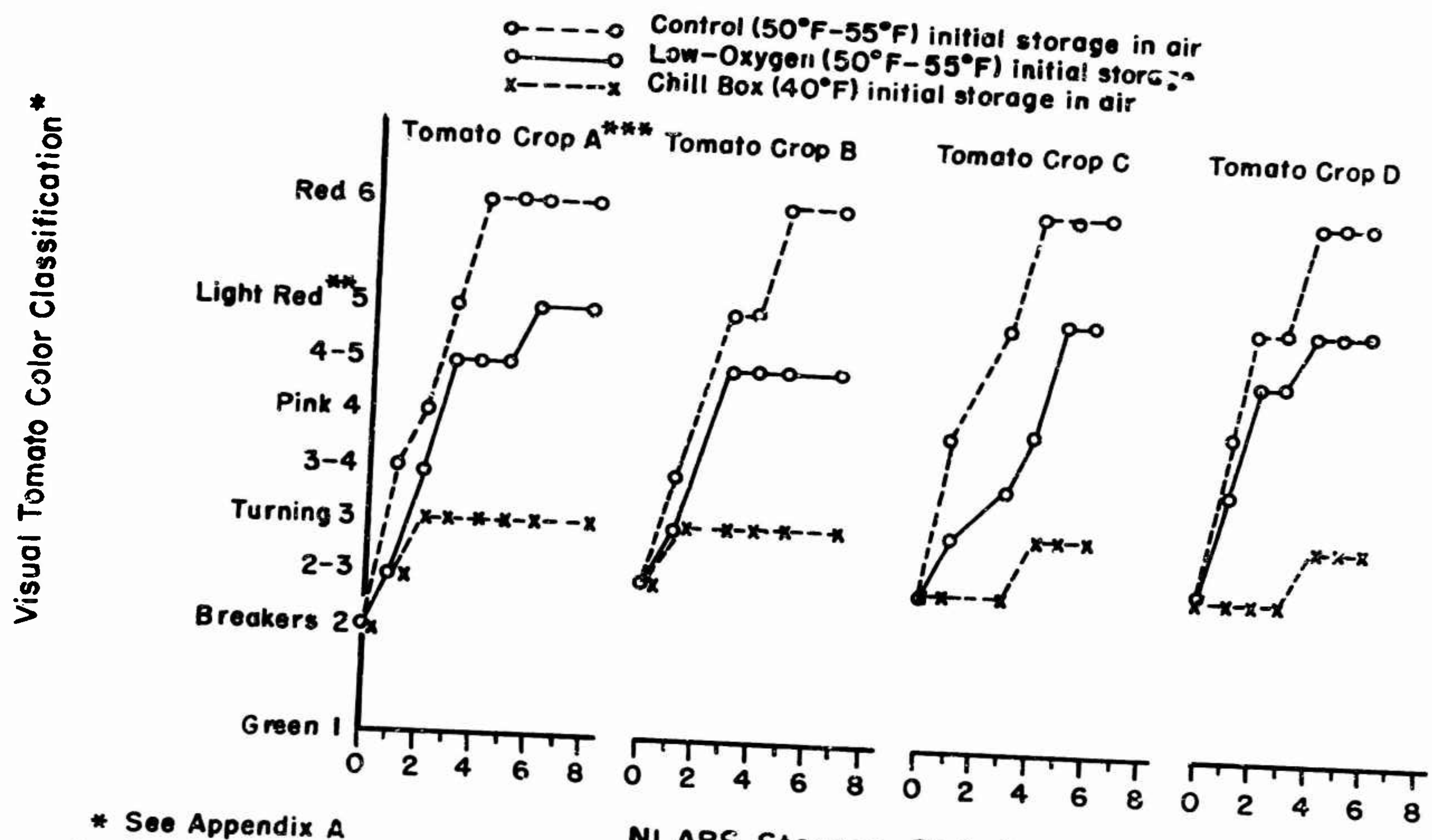
TABLE 3. TYPE OF SPOILAGE OBSERVED AFTER LOW-OXYGEN AND AIR (CONTROL) STORAGE

Crop Code Table 1	Storage Times: INITIAL* at 50°-55°F (weeks)	(plus)	ADDITIONAL* at 40°F (in air) (weeks)	Type of Spoilage** When INITIAL Storage Was: Low-Oxygen	Control
A	4 (L)	plus	2	FB	
	4 (C)	"	2		AFB
	4 (L)	"	4	FB	
	4 (C)	"	4		AFB
B	3 (L)	"	2	FB	
	3 (C)	"	2		AFB
	3 (L)	"	4	FB	
	3 (C)	"	4		AFB
C	3 (L)	"	1	FB	
	3 (C)	"	1		AFB
	3 (L)	"	2	FB	
	3 (C)	"	2		AFB
	3 (L)	"	3	AFB	
	3 (C)	"	3		AFB
D	3 (L)	"	1	FB	
	3 (C)	"	1		AFB
	3 (L)	"	2	AFB	
	3 (C)	"	2		AFB
	3 (L)	"	3	AFB	
	3 (C)	"	3		AFB

* (L) = INITIAL storage period in Low-Oxygen controlled atmosphere
(C) = INITIAL storage period in air (Control)
ADDITIONAL storage was at 40°F in air.

** Type of spoilage (15)
A - Black Spot Type Rot similar to Alternaria Rot
F - Fungus Rot Type (Exclusive of Black Spot Type) including mold filaments
B - Bacterial Soft Rot Type

Figure I. SKIN COLOR OF TOMATOES HELD IN LOW-OXYGEN CONTROLLED ATMOSPHERE AND IN AIR



* See Appendix A
** See Special Note Appendix A
*** See Table 1

TABLE 4. SKIN COLOR OF TOMATOES HELD IN LOW-OXYGEN CONTROLLED ATMOSPHERE AND IN AIR

Type 3-Week INITIAL Storage	Tomato Color Classification *	Tomato Color Index (TCI)**		
		Tomato Exterior Bottom	Tomato Cut in Half	Tomato Exterior Top (Stem end)
		(%)	(%)	(%)
Control (50°-55°F) Air	6 Red	37.8 (34.3-39.8)	23.2 (21.5-24.1)	34.5 (32.1-36.5)
Low-oxygen (50°-55°F)	5 Light Red***	31.6 (29.2-34.8)	17.4 (15.1-19.9)	9.1 (4.3-15.5)
Chill Box (40°F) Air	3 Turning	13.5 (10.4-16.7)	9.0 (3.2-15.7)	5.4 ((-2.8)-7.3)

* By visual examination using the USDA scale. See Appendix A.

** Tomato Color Index (TCI) values calculated from L, a_L and b_L Hunter Colorimeter measurements by the method of McColloch (8). The higher the index, the riper the color. The figure above is the average. The figures in parentheses represent the range.

*** See Appendix A, Special Note on use of "5 Light Red".

Flavor. Flavor panels conducted on good tomatoes out of crops code A and code D 6 weeks after receipt at NLABS indicated the following:

(a) Significant preference at the $t_{.05}$ level was found for crop A good tomatoes stored initially under low oxygen, with an hedonic rating of 6.8 as compared with good tomatoes initially stored in air with an hedonic rating of 4.0. It should be noted that the yield of good tomatoes was significantly higher for the low-oxygen stored tomatoes than air stored tomatoes (Table 2).

(b) For crop D good tomatoes, no significant preference was shown by the flavor panel when low-oxygen (initially) stored tomatoes with an hedonic rating of 5.1 were compared with air (initially) stored tomatoes with an hedonic rating of 4.9. For this crop D, Table 2 indicates no significant difference in yield of low-oxygen stored and air (Control) stored tomatoes.

Discussion

An investigation has been conducted of tomatoes stored for the period (3 to 8 weeks) required by the Department of Defense for overseas shipment, distribution and consumption of fresh produce. The quality characteristics examined in this investigation involve yield, type of spoilage, maturity by color, texture and flavor.

Evidence has been developed which demonstrates that the use of low oxygen controlled atmosphere for initially storing tomatoes (at 50°F. - 55°F.) results in reductions in spoilage, inhibition of black spot type rot similar to Alternaria rot, improvements in quality and increased storage life up to 2 weeks. These factors become significant when comparisons are made with tomatoes which had been stored initially at optimum 50°F. - 55°F. temperatures in air.

The cost analysis estimate (Table 5) indicates that an improvement in tomato yield of 1.8% to 3.3% is required to defray the additional cost of TECTROL controlled atmospheres in refrigerated containers or rail cars used for shipping tomatoes. For overseas shipments, the improvement in tomato yields as indicated by laboratory data (Table 2) is anticipated to be much higher than that required to defray the additional cost of a commercially available system such as TECTROL, for shipping fresh produce in refrigerated containers at low levels of oxygen and carbon dioxide.

It is concluded that there is sufficient laboratory information to warrant a field test on tomatoes shipped to overseas military organizations in controlled atmosphere refrigerated container vans. This test will demonstrate whether the available large commercial controlled atmosphere containers will give the beneficial quality, economic and increased storage-life results that were obtained under relatively (low-oxygen, carbon dioxide free) laboratory conditions. A potential exists for mobile chill storage as a partial replacement for warehouse storage overseas. It is suggested, therefore, that consideration be given to the possibilities for improvement in logistics by using overseas shore-based controlled-atmosphere generators for maintaining controlled atmosphere conditions in combination with controlled atmosphere container shipments and that data on the subject be developed during the field test.

Table 5. Cost Analysis Estimate

Shipping Unit	Tomato boxes per unit* (number)	Point-to-Point shipping locations	Transportation Cost per shipping unit* (dollars)	Cost of tomatoes** (dollars)	Additional cost TECTROL per shipment (dollars)	Tomato Loss Reduction to defray TECTROL cost*** (percent)
24-foot Container	674	West Coast to Hawaii	$803.00	$3,100.40	$93.00	3.00%
20-foot Container	557	West Coast to Subic Bay	1,411.00	2,562.20	85.00	3.31
20-foot Container	557	West Coast to Guam	1,473.00	2,562.20	85.00	3.31
24-foot Container	674	West Coast to Japan	2,285.00	3,100.40	93.00	3.00
35-foot Container	948	West Coast to Republic of Vietnam	2,610.00	4,360.80	115.00	2.90
Rail Car	2163	West Coast to East Coast	302.00	9,949.80	175.00	1.76
40-foot Container	1163	East Coast to Mediterranean (as Naples)	2,590.00	5,350.00	125.00	2.34
40-foot Container	1163	East Coast to Europe (as Rotterdam)	1,886.00	5,350.00	125.00	2.34

* Estimated

** Cost based on $.23/lb tomatoes

*** Minimum reduction in tomato loss required to defray additional cost of TECTROL per shipment; based on $.23/lb tomatoes

References

1. Barton, R. R. and Trauberman, L. 1954. Reduction of Deterioration of Fresh Vegetables, US Naval Supply Research and Development Facility, Bayonne, New Jersey report Project NT002024, Sub-Project CR53-92.

2. Heiligman, F. 1956. Evaluation of Method for Handling and Shipping Fresh Tomatoes. R&D Associates Activities Report 8 (1), 67-70.

3. Parson, C. S. 1959. Extending the Storage Life of Cabbage, Celery, Lettuce and Tomatoes aboard a Navy Supply Ship. USDA Marketing Research Report No. 336.

4. ASHRAE Guide and Data Book, Applications, for 1966 and 1967. Published by the American Society of Heating, Refrigeration and Air-Conditioning Engineers.

5. Lockhart, C. L. 1969. Effect of CA on Storage Rot Pathogens. Proc. National Controlled Atmosphere Res. Conf at Michigan State University 113-131

6. Parsons, C. C., Gates, J. E. and Spalding, D. H. 1964 Quality of Some Fruits and Vegetables After Holding in Nitrogen Atmosphere. American Society for Horticultural Science Proceedings 84, 549-556.

7. Tolle, W. E. 1969. Hypobaric Storage of Mature-Green Tomatoes. USDA Marketing Research Report No. 842.

8. McColloch, L. P. and Yeatman, J. N. 1966. Color Changes and Chilling Injury of Tomatoes Held at Various Temperatures. USDA Marketing Research Report No. 735.

9. Blanpied, G. D. and Hansen, E. 1969. Fruit Ripening Responses to Ethylene in Modified Atmospheres. Proc. National Controlled Atmosphere Research Conference at Michigan State University 141-149.

10. Kaffezakis, J. G., Palmer, S. J. and Kramer, A. 1969. Microbiology of Fresh Apple and Potato Plugs Preserved by Gas Exchange. Food Science 34 (5), 425-429.

11. Oxygen-Starved Tomatoes Stay Fresher. 1969. Chemical and Engineering News 47 (53), 66.

12. Smith, W. H. 1963. The Use of Carbon Dioxide in the Transport and Storage of Fruits and Vegetables. Advances in Food Research 22, 96-146.

13. Gorfien, H., Rahman, A. R., Johnson, K. R. and Anderson, E. E. 1969. Effects of a Controlled Atmosphere System on the Storage Life of Lettuce: Part I-Laboratory Tests. NLABS Technical Report 70-23-FL (FL-99).

14. Gorfien, H., Rahman, A. R. and Westcott, D. E. 1969. Effects of a Controlled Atmosphere System on the Storage Life of Lettuce: Part II-Field Test. NLABS Technical Report 70-26-FL (FL-100).

15. McColloch, L. P., Cook, H. T. and Wright, W. R. 1968. Market Diseases of Tomatoes, Peppers and Eggplants. USDA Agriculture Handbook No. 28.

APPENDIX A. VISUAL TOMATO COLOR CLASSIFICATION SCORE *

Color Classification.

(a) The following terms may be used when specified in connection with the grade statement in describing the color of any lot of tomatoes of a red fleshed variety:

(1) Green. -"Green" means that the surface of the tomato is completely green in color. The shade of green color may vary from light to dark.

(2) Breakers.- "Breakers" means that there is a definite break in color from green to a tannish-yellow, pink or red on not more than 10 percent of the surface.

(3) Turning. - "Turning" means that more than 10 percent but not more than 30 percent of the surface, in the aggregate, shows a definite change in color from green to tannish-yellow, pink, red, or a combination thereof.

(4) Pink. - "Pink" means that more than 30 percent but not more than 60 percent of the surface, in the aggregate, shows pink or red color.

(5) Light Red. Light red" means that more than 60 percent of the surface, in the aggregate shows pinkish-red or red; provided, that not more than 90 percent of the surface is red color.

(6) Red. - "Red" means that more than 90 per cent of the surface in the aggregate, shows red color.

(b) Incident to proper color classification, not more than a total of 10 percent, by count, of the tomatoes in any lot may fail to meet the color specified, including therein not more than 5 percent for tomatoes which are green in color, when any term other than "Green" is specified: Provided, that any lot of tomatoes which does not meet the requirements of any of the above color designations may be designated as "Mixed Color".

SPECIAL NOTE ON USE OF "5 LIGHT RED" IN THIS REPORT

On Table 4 and Figure 1, the "5 Light Red" score for Low-Oxygen tomatoes represents tomatoes with 90 to 100 percent of their surface pinkish-red or red; and not more than 90 percent of their surface is red. This is a more advanced stage of color maturity than defined in the USDA Standards for Grades of Fresh Tomatoes above.

*Color designations of the U.S. Department of Agriculture, U.S. Standards for Grades of Fresh Tomatoes.

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) U. S. Army Natick Laboratories Natick, Massachusetts 01760	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

CONTROLLED ATMOSPHERE SYSTEM LABORATORY STUDIES ON TOMATOES

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)

Harold Gorfien, Abdul R. Rahman, George Taylor, and Donald E. Westcott

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
February 1970	16	15

8a. CONTRACT OR GRANT NO. b. PROJECT NO. PE2270.3 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) 70-58-FL 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) FL-108

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	U.S. Army Natick Laboratories Natick, Massachusetts 01760

13. ABSTRACT

Laboratory tests were conducted to determine the effect of low-oxygen controlled atmosphere (which is carbon dioxide free) on tomatoes. Storage periods approximating the extended overseas distribution time of 3 to 8 weeks as required for military shipments were used. The tests showed that the use of low oxygen controlled atmosphere would lead to significant reductions in spoilage, inhibition of black spot type rot similar to Alternaria rot, improvements in tomato quality, and as much as 2 weeks additional storage life, when compared with tomatoes initially stored in air at the same optimum 50°F.-55°F. temperatures. These factors became apparent from 1 to 4 weeks after transfer of the tomatoes from low oxygen controlled atmospheres to 40°F. air. The break-even point to defray the additional cost of a commercially available controlled atmosphere method of shipping is estimated to be in the range of 1.8% to 3.3% improvement in tomato yield. Data developed in this investigation indicate that improved tomato yields on overseas shipments of tomatoes may be anticipated to be more than enough to defray the additional cost of such a system, for shipping fresh produce in refrigerated containers at low levels of oxygen and carbon dioxide.

It is concluded that sufficient information has been developed to warrant a field test on tomatoes shipped in Controlled Atmosphere containers to military organizations overseas.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

UNCLASSIFIED
Security Classification

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Controlled atmosphere	6		10			
Low-Oxygen system	6		10			
Tomatoes	7		9			
Storage	7		8,4			
Protection	7		8			
Military bases			4			

UNCLASSIFIED

Security Classification