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TECHNICAL REPORT

70-20-FL

EFFECTS OF A CONTROLLED ATMOSPHERE SYSTEM ON THE STORAGE LIFE OF LETTUCE

PART II: FIELD TEST

by

Harold Bortlea
Abdul R. Rahman
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October 1969

UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

Food Laboratory
FL-

AD _____

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TECHNICAL REPORT
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EFFECTS OF A CONTROLLED ATMOSPHERE SYSTEM ON THE STORAGE LIFE OF LETTUCE PART II-FIELD TEST

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Project reference
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October 1969

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

FOREWORD

The U. S. Army Natick Laboratories investigated the use of TECTROL controlled atmosphere in laboratory size equipment for reducing spoilage in lettuce. Laboratory findings were very promising and showed feasibility. As a result, the decision was made to determine in a field test whether commercial size TECTROL* controlled atmosphere containers had the capability of improving the quality and reducing the spoilage of lettuce shipped to military organizations overseas.

The work was performed under Production Engineering, 2270.3 Mr. Harold Gorfien was the Official Investigator.

The authors gratefully acknowledge the assistance of personnel within the U.S. Navy and the U.S. Army, particularly Major A. Krome of NLABS and Miss N. Crowley of USARJ. Personnel in various elements of DPSC and DSA are to be commended for their assistance and cooperation in resolving many of the business problems which developed in procurement and transportation. Grateful acknowledgment is accorded Mr. J. Lugg of Transfresh Corp. for assistance and cooperation in overcoming many of the obstacles which developed prior to the field test. Acknowledgment is accorded to Mr. J. Lamp of Transfresh Corp and personnel of Matson Lines for assistance both in the U.S. and Japan.

*TECTROL is a registered trademark of Whirlpool Corp.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Tests were conducted to determine whether TECTROL-controlled atmosphere would lead to an improvement in the quality and storage life of lettuce shipped to military organizations overseas. TECTROL is a proprietory system for shipping fresh fruits and vegetables through the introduction of specially proportioned gases into existing refrigerated containers and rail cars. The tests showed that where controlled atmospheres can be reasonably maintained, improvements in quality and increases in storage life will result. Reduction in the extent of pink rib and decay were found. In these tests lettuce was shipped from the West Coast to Japan requiring five weeks; reductions in lettuce losses were found to range from 5.0% to 16.4% when compared to lettuce shipped conventionally in air. The break even point to defray the additional cost of TECTROL is estimated to be in the range of 2.7% to 5.4% reduction in lettuce loss. This indicates that the cost of TECTROL would be defrayed by reductions in lettuce loss during overseas shipment. Some data are presented to indicate that temperatures in loaded refrigerated containers are frequently somewhat higher than their thermostat settings indicate.

There are engineering problems and shipping precautions associated with the maintenance of controlled atmosphere which remain to be resolved. A failure in maintaining refrigeration for an extended period of time can lead to levels of oxygen less than 1%; thus resulting in the loss of an entire shipment due to anaerobic spoilage.

It is concluded that shipments of lettuce in controlled atmosphere containers to military organizations overseas be initiated on a larger scale. Controlled overseas field test shipments would assist the controlled atmosphere industry and military users in defining and eliminating any engineering flaws which might exist in current commercial scale equipment.

EFFECTS OF A CONTROLLED ATMOSPHERE SYSTEM ON THE STORAGE LIFE OF LETTUCE PART II.-FIELD TEST

Introduction

The supply of good quality fresh fruits and vegetables in quantity to meet the requirements of military personnel overseas has been a concern to the Armed Forces. In view of the extended shipping and storage periods, perishable produce will exhibit a degree of spoilage prior to arrival overseas. Attempts have been made in the last two decades to reduce the spoilage of lettuce by various means including modified packaging. Yet, reports concerning arrival of lettuce overseas with varying degrees of loss due to spoilage have continued.

In 1968 the U. S. Army Natick Laboratories conducted laboratory tests on a commercial controlled atmosphere procedure (TECTROL) for shipping lettuce. The outcome of the laboratory studies indicated that an overseas field test using commercially available TECTROL containers was in order.

Literature Review

Most research on lettuce has been concerned with the market time requirement of one to two weeks from date of picking. In recent years a limited amount of work has involved the longer overseas military requirement of four to eight weeks. Literature on the subject has been adequately covered in a previous report[1]. Data developed by U. S. Army Natick Laboratories in 1968 showed that lettuce stored for five weeks under TECTROL-controlled atmosphere followed by 11 days in air was in better condition than lettuce stored for five weeks in air[1]. Furthermore, use of the TECTROL-controlled atmosphere system resulted in reductions in slime, pink rib, and russet spotting.

Methods and Materials

After discussing the subject with representatives of Defense Personnel Support Center, the decision was made to evaluate a TECTROL-controlled atmosphere container shipment to Japan.

The test plan was designed to determine whether the TECTROL controlled atmosphere container system would result in lettuce with less spoilage than the conventional container system used during military shipping.

The TECTROL system involves the introduction of a properly proportioned blend of gases for specific fruits and vegetables into a refrigerated container as soon after picking as possible. It has been

described in a patent assigned to Whirlpool Corporation[2]. According to the patent, the gas composition consists of 1-5% carbon monoxide, 1-10% oxygen and 1-5% carbon dioxide with the remainder being nitrogen. Carbon dioxide, a product of respiration, is kept at a low level by using carbon dioxide scrubbers. The maintenance of the low oxygen atmosphere depends upon a dynamic relationship between lettuce respiration, which consumes oxygen, and a slow leakage of air into the refrigerated container to replace it.

Iceberg lettuce of the Vanguard seed variety was used in this field test. All the lettuce was picked out of the same field on 28 April 1969. USDA inspectors were in the field and at the vacuum cooler to check the lettuce condition. It was graded No. 1 (45-50% hard heads, 36-41% firm heads, and 13-15% fairly firm heads). After vacuum cooling, crates of lettuce, meeting Federal specification HHH-L-226d, dated 22 March 1963, Lettuce Fresh, were loaded directly into mechanically refrigerated 24-foot length containers as indicated in Table 1.

TABLE 1. KEY TO THE FOUR CONTAINERS

Container Number	Type Container	Preparation	Code
87028	TECTROL	Trimmed and Individually Wrapped* Lettuce	A
81107	Conventional	Trimmed and Individually Wrapped* Lettuce	B
81046	Conventional	Naked Pack Lettuce	C
87042	TECTROL	Naked Pack Lettuce	D

*Wrapped in polyethylene bag. Federal Specification PPP-F-685 . ay 1, 1967, Fresh Fruits and Vegetables, Packaging, Packing, and Ma. king of.

The four test containers described in Table 1 were held for two weeks at the Matson Lines yards in Wilmington, California, since it was desired that the time between picking and arrival overseas be four weeks, the usual shipping time to Vietnam or to Europe. The test containers arrived in Japan four weeks and four days after picking and reached military distribution points during the fifth week. Temperature records were maintained in each container using Ryan recorders. Gas histories were maintained on the two TECTROL containers from the time of picking until just prior to off-loading them in Tokyo. A Beckman automatic oxygen analyzer and an orsat apparatus were used to determine the composition of gas present.

Lettuce from each container was examined by three different procedures:

a. By military personnel using Veterinary Corps Inspection procedures, during the fifth week after picking.

b. During the fifth and sixth week after picking by an NIABs representative using the edible yield procedure[3] and scoring each head of lettuce for (i) general appearance, with wrapper leaves; (ii) general appearance without wrapper leaves; (iii) severity of butt browning; (iv) severity of decay in wrapper leaves; (v) severity of decay in compact portion of head; (vi) severity of russet spotting or spotted wilt; (vii) severity of pink rib; and (viii) severity of other miscellaneous discolorations (Table 2).

c. Following distribution, by a user participant test evaluation method. The user was requested to evaluate the lettuce weekly for a four week period after receipt. Each coded box of lettuce was to be rated for general condition of lettuce, number of heads showing slime or mold, degree of slime or mold, and miscellaneous (Table 3).

Where applicable, the data obtained was statistically evaluated by analysis of variance.

TABLE 2. EVALUATION OF INDIVIDUAL HEADS OF LETTUCE
(NLABS FORM)

Container Van Number _____ Location of Inspection _____
Lettuce Box Code _____ Signature of Inspector _____
Date of Inspection _____
Precision of Scale Used _____

Evaluation of 24 Individual Heads of Lettuce in Each Box	Samples Tested
1. Weight Individual Lettuce Head Before Trimming (to the nearest ounce)	
2. General Appearance Rating of Lettuce Head with Wrapper Leaves*	
3. General Appearance Rating of Lettuce Head without Wrapper Leaves*	
4. Severity of Butt Browning, Rating**	
5. Severity of Decay in Wrapper Leaves, Rating**	
6. Severity of Decay in Compact Portion of Head, Rating**	
7. Severity of Russet Spotting or Spotted Wilt, Rating**	
8. Severity of Pink Rib, Rating**	
9. Severity of other Miscellaneous Discolorations**	
10. Weight Individual Lettuce Head After Trimming (to the nearest ounce)	
11. Percentage Edible Lettuce (10/1 x 100)	

*General appearance Rating Scale from 9 to 1. (9=excellent, no defects; 7=good, minor defects; 5=fair, objectionable defects that can be removed before sale; 3=poor, generally unsalable; 1=inedible)

**Severity of Defects Rating Scale from 0 to 8. (0=none; 2=trace; 4=slight; 6=moderate, 8=severe)

TABLE 3. USER PARTICIPANT EVALUATION FORM

1. General Condition of Lettuce
(Check one for each crate)

Name of ship or installation _____
Date of examination _____

	Code			Code	
	Crate 1	Crate 2		Crate 1	Crate 2
Excellent					
Good					
Fair					
Poor					
Unsatisfactory					

2. There are 24 heads of lettuce in each crate. Please determine and list the number of heads of lettuce in each crate showing slime or mold for each code. Slime may be identified as soft slimy (black or brown) mushy areas which may vary in size from single leaf areas to the entire head of lettuce. _____ _____ _____ _____

3. General degree of slime or mold on heads of lettuce in crate. (Check one for each crate)

Much slime or mold					
Moderate slime or mold					
Slight slime or mold					
No slime or mold					

4. Miscellaneous Comments:

Results

Ryan temperature recorder charts (Figure 1) show that the container temperatures were higher than the thermostat settings for each container throughout the period of shipment. Containers 81107, 81046, and 81042 were originally set at 34°F. Container 87028 was originally set at 36°F. Actual temperatures were near 40°F. most of the time.

Gas analyses (Figure 2) show that TECTROL container 87042 had an oxygen content of 0.4% the day before unloading the containers in Tokyo which is an anaerobic condition. All the lettuce in this container was found unusable. An examination of Ryan temperature recording data (Figure 1) indicated that there had been a refrigeration failure in TECTROL container 87042 during the 10th through the 12th day after picking the lettuce. Temperatures in this TECTROL container were above 50°F and reached a maximum of 57°F. It is believed that the higher temperature in TECTROL container 87042 permitted a lettuce respiration rate high enough to consume the oxygen present. This combined with a low container leak rate caused anaerobic spoilage. The Ryan temperature records (Figure 1) show that the three other test containers did not experience any prolonged refrigeration failure.

The day before unloading the containers in Tokyo, the other TECTROL container 87028 was found to have an oxygen content of 4.2%, a carbon dioxide content of 5.8%, and a carbon monoxide content of 0.2% with the remainder being nitrogen (Figure 2).

Average edible yields, general appearance and severity of defects scores for lettuce from the containers during the 5th and 6th week after picking, are shown in Table 4 and Table 5. Although this crop of lettuce looked good at picking time, its condition on arrival overseas was poorer than anticipated.

In view of the conditions under which the crop was picked and randomized and the 100% lettuce loss experienced in TECTROL container 87042, paired comparison results can be shown only for the field trimmed and wrapped lettuce.

Results on the field trimmed and wrapped lettuce shipped in TECTROL-controlled atmosphere container 87028 and in conventional container 81107 are summarized in Table 4 and Table 5. It is apparent from these results that lettuce from the TECTROL container had a higher edible yield (Table 6), less decay in the compact portion of the head (Table 7), and less pink rib (Table 8) than lettuce from the conventional container. These differences are significant at the 1% level.

The Veterinary Corps Inspectors reported that lettuce from the conventional container looked somewhat better on the outer surface than that from the TECTROL container. However, Veterinary Corps inspection results show that lettuce from the conventional container exhibited

FIGURE I RYAN TEMPERATURE CHARTS FOR EACH CONTAINER - 30 DAY RECORD

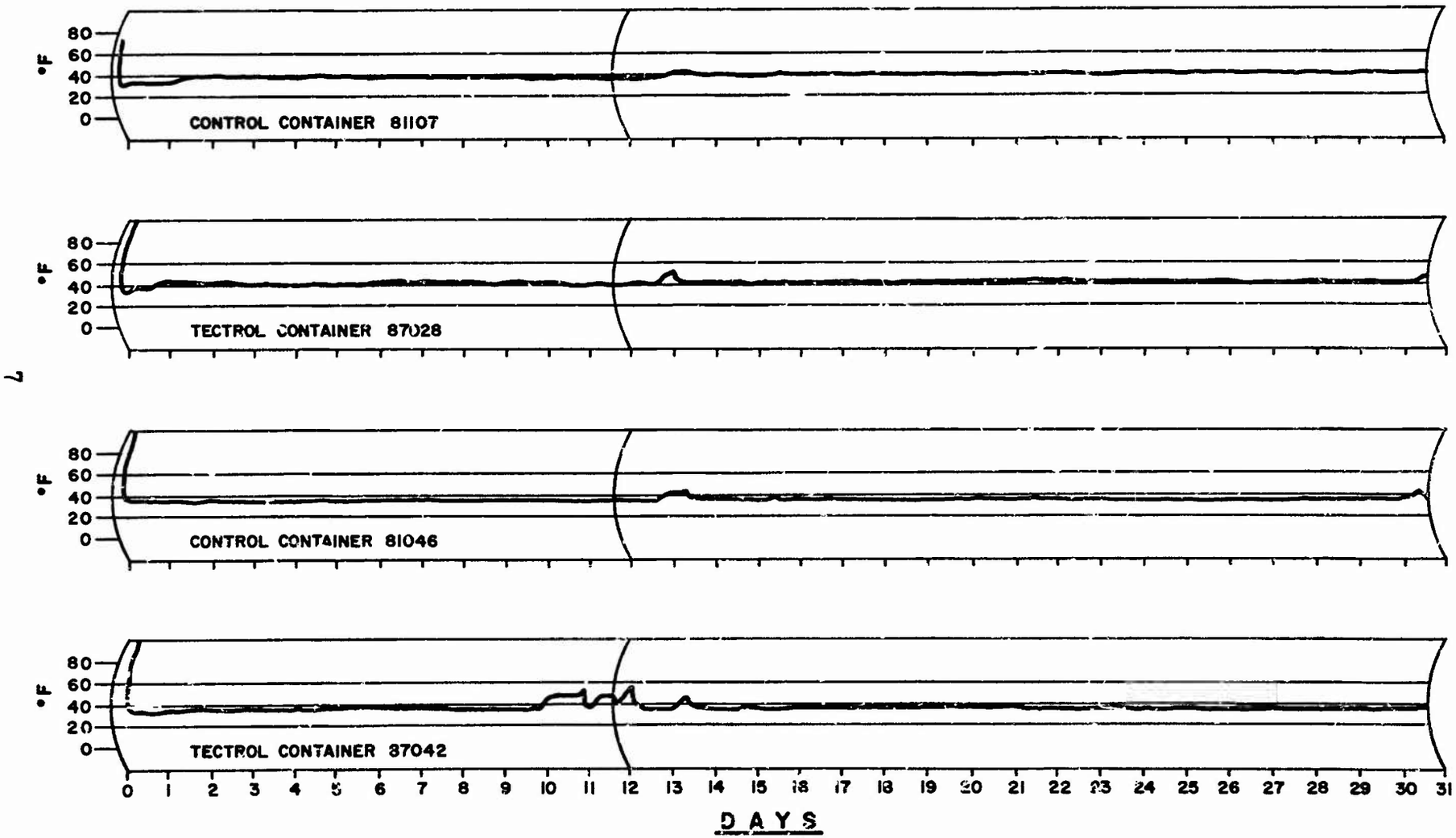

FIGURE 2 - OXYGEN LEVELS IN TECTROL CONTAINERS DURING SHIPMENT

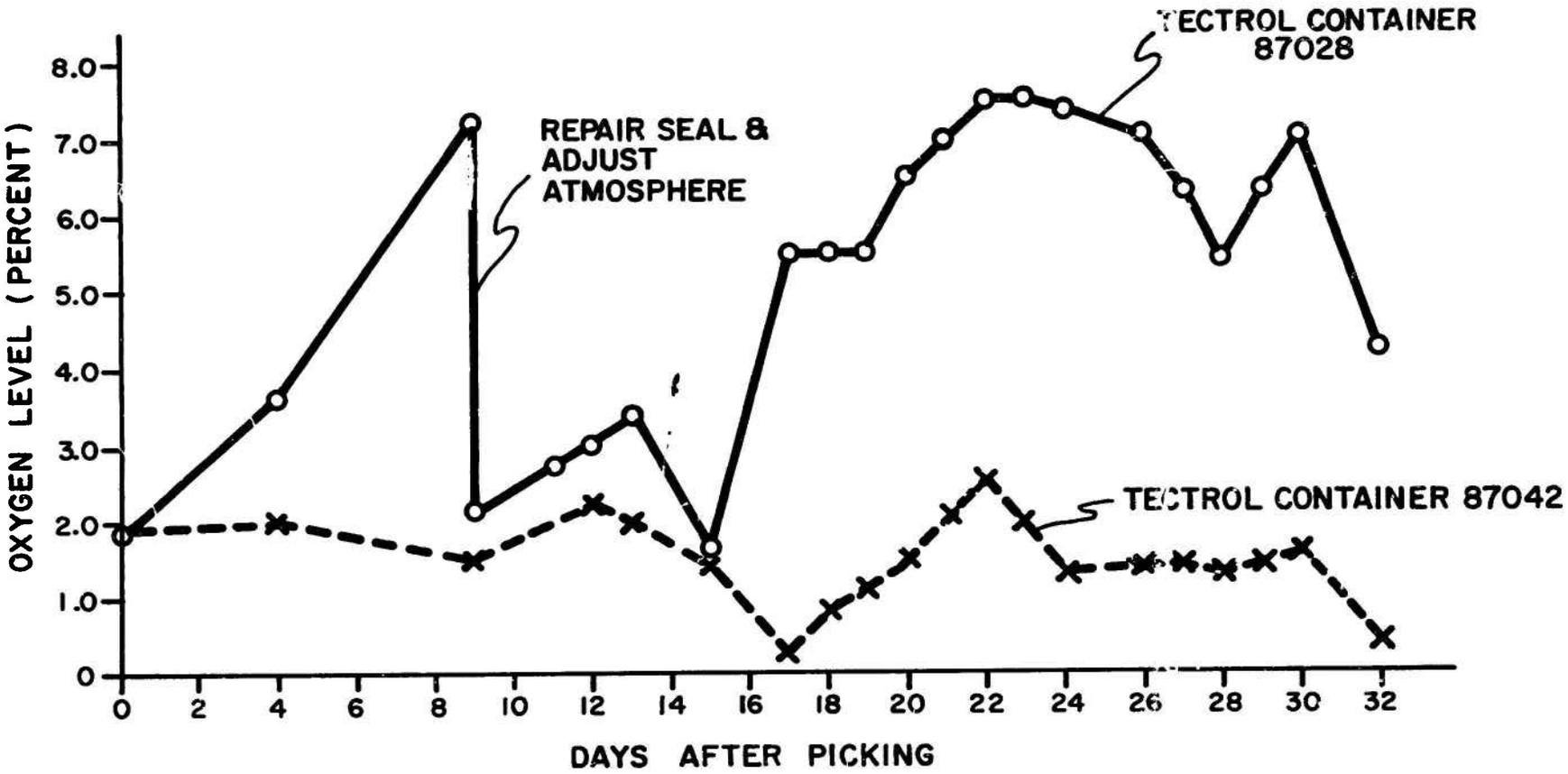

Table 4 LETTUCE AVERAGE YIELDS AND SCORES 5TH WEEK AFTER PICKING

Evaluation Indice	Average Yields and Scores* for Lettuce from Container Number TECTROL 87028	81107	81046	TECTROL 87042
Edible Yield (%)	63.2	51.9	56.0	**
General appearance rating with wrapper leaves (score)	3.5	3.4	3.0	**
General appearance rating without wrapper leaves (score)	6.3	5.8	6.0	**
Severity of butt browning (score)	3.7	4.4	3.5	**
Severity of decay in wrapper leaves (score)	3.5	4.1	3.2	**
Severity of decay in compact portion of head (score)	0.3	1.5	0.0	**
Severity of russet spotting or spotted wilt (score)	2.2	3.3	1.9	**
Severity of pink rib (score)	2.4	4.1	2.3	**
Severity of other miscellaneous defects (score)	1.9	1.4	2.4	**

*General appearance rating scores (9 to 1). The higher the score the better the appearance. Severity rating scores for defects (0 to 8). The lower the score the less severe the defect.

**Discarded after first examination.

TABLE 5. LETTUCE AVERAGE YIELDS AND SCORES 6TH WEEK AFTER PICKING

Evaluation Indice	Average Yields and Scores* for Lettuce from Container Number TECTROL 87028	81107	81046	TECTROL 87042
Edible Yield (%)	56.1	39.7	52.7	**
General appearance rating with wrapper leaves (score)	2.0	2.0	1.9	**
General appearance rating without wrapper leaves (score)	6.5	5.5	6.8	**
Severity of butt browning (score)	5.3	6.3	4.9	**
Severity of decay in wrapper leaves (scores)	4.7	5.7	3.9	**
Severity of decay in compact portion of head (score)	2.1	4.5	0.7	**
Severity of russet spotting or spotted wilt (score)	3.3	3.8	4.1	**
Severity of pink rib (score)	1.5	5.3	3.2	**
Severity of other miscellaneous defects (score)	0.4	0.9	1.0	**

*General appearance rating scores (9 to 1). The higher the score the better the appearance. Severity rating scores for defects (0 to 8). The lower the score the less severe the defect.

**Discarded after first examination.

TABLE 6. FIELD TRIMMED AND WRAPPED LETTUCE - EDIBLE LETTUCE YIELD

Type Container	Edible Lettuce Yield			
	5 Wks. after Picking		6 Wks. after Picking	
	Average* (%)	Range (%)	Average* (%)	Range (%)
Conventional Container 81107	51.9	49.7-55.4	39.7	30.1-44.1
TECTOL Container 87028 (Controlled Atmosphere)	63.2	60.5-66.8	56.1	50.8-61.8

*Statistical Interpretation. $p > 0.01$; Least Significant Difference=9.3 at 0.05 level

TABLE 7. FIELD TRIMMED AND WRAPPED LETTUCE
SEVERITY OF DECAY IN COMPACT PORTION OF HEAD

Type Container	Severity of Decay Scores*			
	5 Wks. after Picking		6 Wks after Picking	
	Average** (score)	Range (score)	Average** (score)	Range (score)
Conventional Container 81107	1.5	0.3-2.6	4.5	3.8-5.9
TECTROL Container 87026 (Controlled Atmosphere)	0.3	0.0-0.8	2.1	1.1-3.0

*The lower the score, the less severe the decay in the compact portion of the head.

**Statistical Interpretation. $p > 0.01$; Least Significant Difference=1.89 at 0.05 level

TABLE 8. FIELD TEST (FIELD TRIMMED AND WRAPPED LETTUCE)
SEVERITY OF PINK RIB

Type Container	Severity of Pink Rib Scores*			
	5 Wks. after Picking		6 Wks. after Picking	
	Average** (score)	Range (score)	Average** (score)	Range (score)
Conventional Container 81107	4.1	3.1-4.7	5.3	4.2-5.8
TECTROL Container (Controlled Atmosphere)	2.4	1.5-3.1	1.5	1.0-1.7

*The lower the score, the less the pink rib defect.

**Statistical Interpretation. $p > 0.01$; Least Significant Difference=1.50 at 0.05 level

severe pink rib, russet spotting, and slime throughout the compact portion of the head. In contrast, the compact portion of the lettuce which had been shipped in the TECTROL van was found to be in good condition after removal of the wrapper leaves.

The Veterinary Corps reported that on the 5th week after picking, field trimmed and wrapped lettuce from the conventional container had an 11.11% loss compared with a 4.75% loss for lettuce from the TECTROL container. They found a 15.36% loss in naked pack lettuce from conventional container 81046 on the 5th week after picking.

Lettuce in TECTROL container 87042 was shipped to the Army. Inspection upon arrival showed 100% loss during transit and no user Army test was possible. For this reason, the user participant test was restricted exclusively to the Navy. Returns from one Navy galley and one Navy commissary did not show any differences in lettuce quality from containers 87028 and 81107. The user participant test was designed to be concerned primarily with external surface appearance because it would have been very difficult to obtain reliable quantitative information in the absence of specially trained personnel. These user participant results interpreted in terms of external surface appearance agree with those obtained by NLABS. However, the user participant results should not be interpreted as defining the condition of the entire lettuce head. Where the outer leaves were removed and the compact portion of the lettuce examined, significant differences were found in quality by both the Veterinary Corps and NLABS.

In addition to an improvement in quality, evidence is presented in Table 6 to show that the edible yield of lettuce from the TECTROL-container six weeks after picking is as good as that from the conventional container five weeks after picking. This shows that for extended shipping time TECTROL (controlled atmosphere) container shipping has the capability of providing at least one more week of shelf life over conventional container shipping, if anaerobic conditions do not result due to equipment breakdown. This additional shelf life occurs after removal from the TECTROL-controlled atmosphere environment. It is of interest that the improvements in quality occurred even though TECTROL container 87028 had a somewhat warmer atmosphere than conventional container 81107 during the shipping period (Figure 1).

Discussion

Reports have been received on a number of occasions concerning losses on shipment of lettuce to military installations overseas. Information has been obtained to show that although the container thermostats had been set at 34°F, actual loaded container temperatures were closer to 40°F. It is possible that had the containers maintained temperatures closer to 34°F, the differences obtained in lettuce quality might even have been greater.

A total of 6 different crops of lettuce have been tested during the years 1965, 1968 and 1969 under controlled atmosphere storage conditions for extended periods of time. These results are presented as evidence to show that where controlled atmospheres can be reasonably maintained improvements in lettuce quality and storage life will result.

A cost analysis estimate of TECTROL shipments is presented in Table 9. The cost data indicates that a reduction in 2.7% to 5.4% lettuce loss is required to defray the additional cost of TECTROL-controlled atmosphere. Reductions in losses of lettuce as expressed in edible yield improvements in both the laboratory tests[1] and the field test (Table 6) were close to or higher than the reduction required to defray the additional cost of the TECTROL-controlled atmosphere.

There are engineering and shipping problems associated with the maintenance of controlled atmosphere in commercial scale equipment that remain to be resolved. During this test an extended refrigeration failure, generated anaerobic conditions in container 87042. In addition, gas analysis records showed that a leak had developed in container 87028 which was repaired 9 days after container loading (May 7, 1969). This leak was reportedly caused by a torn plastic curtain which resulted from the use of wirebound wooden crates for lettuce. The leak was repaired, and the container provided controlled atmosphere again. The TECTROL-controlled atmospheres remained in proper range for the remaining 17 days during shipment to Japan. These problems have now been defined, and precautions can be taken to prevent their reoccurrence on future TECTROL shipments. However, there may be other engineering and shipping problems associated with the maintenance of controlled atmosphere in commercial size equipment which remain to be defined and resolved.

It is concluded that controlled shipments of lettuce in controlled atmosphere containers to military installations overseas should be initiated on a larger scale. Furthermore, it is concluded that box and film variations be included along with the containers in these shipments since all function as a system to contribute to the keeping quality of lettuce. The results of this work should lead to an improvement in the quality and storage life of fresh produce received by the military overseas. Flow of funds from the United States should also be reduced proportional to the reduction in military procurements of fresh fruits and vegetables overseas.

TABLE 9. COST ANALYSIS ESTIMATE

Shipping Unit	Estimated* number lettuce boxes per unit	Point to Point shipping locations	Cost per** shipping unit	Cost lettuce based on $.15/lb. lettuce	Additional*** cost TECTROL per shipment	Minimum Reduction in Lettuce Loss Required to Defray Additional Cost of TECTROL per shipment Based on $.15/lb lettuce (%)	Based on $.13/lb lettuce (%)
24-Foot Container	380	Oakland to Hawaii	$803.00	$1,995.00	$ 93.00	4.66	5.38
24-Foot Container	380	Oakland to Japan	2,?85.00	1,995.00	93.00	4.66	5.38
35-Foot Container	535	Oakland to Republic of Vietnam	2,610.00	2,808.75	115.00	4.09	4.73
Rail Car	1220	West Coast to East Coast	302.00	6,405.00	175.00	2.73	3.15

*Estimated number of lettuce boxes per shipment provided by DPSC, though shipping unit capacity may be slightly higher and number of boxes actually carried may vary somewhat depending on customer order.

**Cost Figures Provided by DPSC.

***Cost Figures Provided by Transfresh Corp.

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13. ABSTRACT

Tests were conducted to determine whether TECTROL controlled atmosphere would lead to an improvement in the quality and storage life of lettuce shipped to military organizations overseas. TECTROL is a proprietory system for shipping fresh fruits and vegetables through the introduction of specially proportioned gases into existing refrigerated containers and rail cars. The tests showed that where controlled atmospheres can be reasonably maintained, improvements in quality & increases in storage life will result. Reduction in the extent of pink rib and decay were found. In these tests, lettuce was shipped from the West Coast to Japan requiring five weeks; reductions in lettuce losses were found to range from 5.0% to 16.4% when compared to lettuce shipped conventionally in air. The break even point to defray the additional cost of TECTROL is estimated to be in the range of 2.7% to 5.4% reduction in lettuce loss. This indicates that the cost of TECTROL would be defrayed by reductions in lettuce loss during overseas shipment. Some data are presented to indicate that temperatures in loaded refrigerated containers are frequently somewhat higher than their thermostat settings indicate.

There are engineering problems and shipping precautions associated with the maintenance of controlled atmosphere which remain to be resolved. A failure in maintaining refrigeration for an extended period of time can lead to levels of oxygen less than 1%; thus resulting in the loss of an entire shipment due to anaerobic spoilage.

It is concluded that shipments of lettuce in controlled atmosphere containers to military organizations overseas be initiated on a larger scale. Controlled overseas field shipments would assist the controlled atmosphere industry and military users in defining and eliminating any engineering flaws which might exist in current commercial scale equipment.

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Lettuce	7		9			
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Protection	7		8			
Military bases			4			