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TECHNICAL REPORT
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QUALITY OF LETTUCE AS AFFECTED BY
REFRIGERATION AND CONTROLLED ATMOSPHERE
SYSTEMS DURING TRANSPORTATION

by
Abdul R. Rahman
D. E. Westcott

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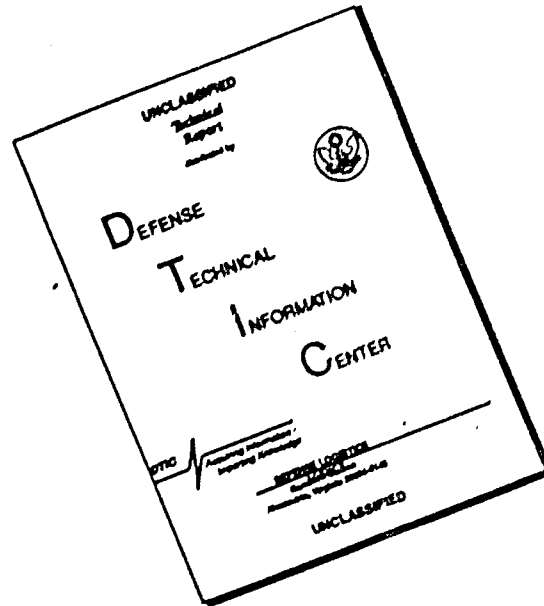


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TECHNICAL REPORT
71-10-FL

QUALITY OF LETTUCE AS AFFECTED BY REFRIGERATION AND
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by

Abdul R. Rahman
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FOREWORD

Laboratory investigations were conducted at the U.S. Army Natick Laboratories on the effect of a low oxygen controlled atmosphere system on the shelf life of lettuce. Results showed an advantage in favor of the controlled atmosphere system. Therefore, it was decided to conduct a field test using commercially available, controlled atmosphere shipping vans (Oxytrol*) to determine their effectiveness in reducing spoilage of lettuce shipped to military installations overseas.

In addition, a Cooltainer** van was also included in this field test in order to determine the effectiveness of a new refrigeration system on the shelf life of lettuce.

This work was performed under Production Engineering Project 2270.3. Dr. Rahman was the principal investigator.

The authors wish to acknowledge the assistance of personnel within DOD, the U.S. Army and U.S. Navy who assisted during the course of this field test, especially LTC D. A. Christophenson at Yokosuka Naval Base and Major W.K. Kerr at Yokohama, U.S. Army Veterinary Station for their cooperation and personal involvement in the detailed coordination of the test. Personnel in various departments of DPSC and DSA are to be commended for their valuable assistance in implementing this test especially Col. Richard Smith and Major Alan Krome. Special thanks are extended to the Oxytrol and Frigitemp Corporations for their full cooperation throughout the field test. Acknowledgement is accorded to Messrs. J. K. Stewart, R. T. Hinsch and J. Anthony, U.S.D.A. representatives, for their valuable assistance and active participation, especially in the loading and installation of thermocouples in the vans. Thanks are also accorded to personnel of the President Lines and Bud Antle Corp. for their corporation.

* Oxytrol is a registered trademark of Occidental Petroleum Corporation
** Cooltainer is a registered trademark of Frigitemp Corporation

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ABSTRACT

A shipping test from Oakland, California to Japan was conducted to determine the effect of a low oxygen controlled atmosphere system (Oxytrol) as well as a new refrigeration system (Cooltainer) on the shelf life of lettuce shipped to military organizations overseas. The Oxytrol system is a complete, self-contained atmosphere control system designed to be used as an adjunct to normal refrigeration equipment in conventional transport vehicles.

Results indicated that lettuce shipped under the low oxygen controlled atmosphere system (oxygen level ranged from 2.2 to 4 percent) gave significantly higher edible yields than lettuce shipped in conventional or Cooltainer vans regardless of the packaging (wrapping versus no wrapping) and packing (wire-bound wooden boxes versus cardboard wax impregnated boxes).

All wrapped lettuce exhibited significantly higher edible yields than unwrapped lettuce regardless of packing and shipping vans. However, no significant difference was shown between lettuce packed in wirebound wooden boxes and that packed in cardboard wax impregnated boxes regardless of the shipping vans. The ambient temperature in the vans as indicated by the Ryan recorders as well as the heart (compact portion) temperature of the lettuce as indicated by thermocouples fluctuated widely. Although the controls in all vans except Cooltainer were set at 34° F., temperatures as high as 45° F. were recorded. Chill damage to the lettuce occurred in the Cooltainer van in which temperatures as low as 29° F. to 31° F. were recorded for several thermocouples upon arrival to Japan. It is concluded that shipping lettuce in controlled atmosphere vans under the conditions presented in this field test was advantageous. However, further shipping tests to various overseas destinations are recommended in order to obtain sufficient factual data on the effect of various atmosphere systems and refrigeration systems on the quality of lettuce and other fresh produce.

Introduction

The procurement and supply of fresh produce to the Military Services overseas represents a sizable investment particularly when one considers not only the acquisition cost but also the cost of inspection, transportation, cold storage and distribution to the customer. The supply of high quality produce to the overseas customer is essential both for morale purposes and for good nutrition. However, reports continue to be received of spoilage of produce, particularly lettuce, at overseas supply points.

Spoilage of lettuce is a problem which has existed for many years. Although significant improvements have been made in packaging, refrigeration, and controlled atmosphere shipping, spoilage losses are still encountered in lettuce shipped overseas.

In 1969 the U.S. Army Natick Laboratories conducted laboratory tests on the shelf life of lettuce as affected by controlled atmosphere systems using Tectrol (3) and Oxytrol (1) systems.

Rahman, et al. (1) reported on previous collaborated research conducted by NLABS, USDA and academic institutions on the effects of refrigeration temperatures, packaging, packing, chemical additives, and controlled atmosphere on the shelf life of lettuce. It was also indicated that lettuce stored under controlled atmosphere system at oxygen levels ranging from 3 to 5.8 percent and temperatures from 34 to 36° F. for 2 to 7 weeks gave significantly higher edible yield and showed higher mean scores for overall quality than lettuce stored under normal atmosphere at similar temperatures. As a result an overseas field test using commercially available controlled atmosphere vans was conducted.

Experimental Procedures

A Factorial Design experiment was developed to determine whether a controlled atmosphere system (Oxytrol*) as well as a new refrigeration system (Cooltainer**) would increase the shelf life of lettuce as compared with the conventional van system during military overseas shipment.

The Oxytrol system is a complete, self-contained atmosphere control system designed to be used as an adjunct to normal refrigeration equipment in conventional transport vehicles. Liquid nitrogen supplied from a portable container is used to reduce the oxygen level. The van is insulated and equipped with a refrigeration unit to control temperatures. Automatic operation of the

* Oxytrol is a registered trademark of Occidental Petroleum Corporation.

** Cooltainer is a registered trademark of Frigitemp Corporation.

No flow is provided by special controls in the system. Carbon dioxide released during respiration is maintained at a low level by means of hydrated lime (scrubber). The Cooltainer van was equipped with dual compressors, dual condensers and other system components for in-transit back up and reserve capacity. The van uses pressurized air circulation - high volume, positive, center-of-load distribution featuring under-the-floor air flow.

Iceberg lettuce of the Vaganari seed variety was used in the field test. All was No. 1 grade lettuce in accordance with Federal Specification HHH-L-2261 Lettuce. Fresh and picked from the same field on 22 May 1970 at Salinas, California. The lettuce was packed in the field and immediately vacuum cooled to the desired heart temperature as measured by a USDA inspector.

The cases of lettuce were loaded into mechanically refrigerated vans in accordance with Table 1. The loading pattern which allows maximum air circulation throughout the van, was performed under the supervision of USDA representatives in accordance with Transportation Bulletin No. 9 (Headquarters, Defense Personnel Support Center). The time schedule for the field test is shown in Table 2.

USDA representatives inserted 24 thermocouples at random in individual heads of lettuce throughout each controlled atmosphere van as well as the Cooltainer van. However, only ten thermocouples were used in each of the conventional vans. These thermocouples were used to check the heart temperature of the lettuce during the field test.

The five vans were held for two weeks at the President Line pier in San Francisco, California, since it was desired that the time between picking and arrival overseas be not less than 4 weeks. During this period, daily temperature readings were recorded. The vans were loaded aboard the President McKinley ship on June 15, 1970. The ship anchored at Yokohama Japan on 25 June 1970 with the lettuce 5 weeks after picking. The five vans were off-loaded and arrival temperatures recorded as well as a Fyrite test for percent O_2 and CO_2 . Two vans, a controlled atmosphere and a conventional, were delivered to Yokosuka Naval base and the rest remained at Yokohama. Temperature records were maintained in each van using Ryan recorders. Oxygen levels were measured in the controlled atmosphere van using an O_2 Meter. In addition O_2 and CO_2 were measured periodically using the Fyrite analyzer. The O_2 level during the field test is presented in Figure 1. The CO_2 Fyrite readings were below 1 percent throughout the field test. The temperatures recorded during the field test are shown in Table 3.

Test samples representing approximately 10 percent of the total load were withdrawn and held in cold storage at 40°F. Additional samples were taken by military personnel to be evaluated in accordance with Veterinary Corp Inspection Procedures.

Examination of lettuce was made immediately upon arrival (5 weeks after picking) and continued until the lettuce was 7 weeks old after picking, using the following procedure:

1. Overall appearance - using a 9-point scale (9 = field fresh, 1 = inedible, Figure 2)
2. Defects, such as decay, pink rib, russet spotting, mold etc. using a 9-point scale (9 = defects absent; 1 = severe defects, Figure 2).
3. Edible yield; determined by removing the butts as well as the defective parts of the lettuce head and weighing the remainder as the edible portion. This was divided by the original weight to obtain percent edible yield.

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

Results and Discussion

Edible yield

Average percent edible yields of lettuce during the 5th, 6th, and 7th week after picking are shown in Tables 4 and 5 and Figures 3 and 4. Lettuce shipped under controlled atmosphere conditions in which oxygen level ranged from 2.2 to 4 percent gave significantly higher edible yield than lettuce shipped in conventional or Cooltainer vans regardless of packaging (wrapping vs. no wrapping) and packing (wirebound wooden boxes vs. cardboard wax impregnated boxes). A higher percentage of edible yield of trimmed wrapped lettuce (5.8 to 17.0%) and of untrimmed naked lettuce (7.5 to 19.3%) was obtained from controlled atmosphere vans in comparison with conventional vans. A higher percentage of edible yield ranging from 5.1 to 21.0 for trimmed wrapped lettuce and 5.5 to 32.0 for untrimmed naked lettuce was obtained from controlled atmosphere vans in comparison with the Cooltainer van (Table 6).

All trimmed wrapped lettuce exhibited significantly higher edible yield than unwrapped lettuce regardless of packing and shipping vans. However, no significant difference was shown between lettuce packed in wooden wirebound boxes and that packed in cardboard wax impregnated boxes regardless of the shipping vans. Although edible yield lettuce from the conventional as well as the Cooltainer vans was significantly lower than that of the controlled atmosphere, the difference in edible yield between the unwrapped lettuce of the Cooltainer van and that of the conventional vans was also significant.

Edible yield of unwrapped lettuce packed in wax impregnated boxes 5 weeks after picking obtained from the Cooltainer vans was significantly higher than that obtained from the conventional van. However, at the end of 6 and 7 weeks after picking, significantly higher edible yield of similar lettuce was obtained from the conventional vans than the Cooltainer van. Such differences were not significant between the wrapped lettuce.

Temperature Control

From the temperature records (Table 3), it is evident that fluctuations of several degrees in temperature took place in all the vans. For four consecutive days the temperature was above 40° F. in 3 of the vans (565195, 565178 and 565198), whereas in the Cooltainer van as well as van No. 565207 the temperatures ranged from 32 to 40° F. The lettuce temperature in the conventional van 565178 with lettuce packed in wirebound wooden boxes was higher than the other conventional van No. 565207 where the lettuce was packed in cardboard wax impregnated boxes. However, these differences did not influence the quality of the lettuce since no significant difference was obtained between lettuce packed in wooden boxes and that packed in wax impregnated boxes.

The ambient temperature as well as the heart temperature of the lettuce in the Cooltainer van was relatively lower than the other vans and chill damage was evident upon arrival to Japan. Five thermocouple readings ranging from 29 to 31°F. were recorded upon arrival to Japan. No such low reading was recorded during the stationary period. This suggests that the temperature may have dropped to a freezing level aboard ship during the 11 days sea voyage. The chill damage occurred at higher frequency and intensity in the unwrapped lettuce than the trimmed and wrapped lettuce. This could explain the low edible yield obtained with the unwrapped Cooltainer lettuce.

There are obvious engineering problems associated with the maintenance of temperature in shipping vans within the desired range of 32° - 34°. Therefore, the use of a controlled atmosphere system as a safeguard to combat temperature fluctuations is justified for extended shipping periods.

Gas analyses (Figure 1) show that the O₂ content in the controlled atmosphere was fluctuated slightly during the field test ranging from 2.2 to 4 percent. The CO₂ content was maintained below 1 percent since it was scrubbed by the hydrated lime.

Overall Appearance and Defects

Pink rib ranging from moderate to severe was evident in lettuce shipped in the conventional and Cooltainer vans whereas it was absent or slight in lettuce shipped in the controlled atmosphere vans. Similar observations were made relative to the occurrence of slime and decay. Russet spotting was very slight in all the lettuce.

Higher average scores for appearance and absence of defects were obtained in lettuce shipped in controlled atmosphere vans than that shipped in conventional or Cooltainer vans (Tables 7 and 8).

The Veterinary Corps Inspectors reported 3, 10 and 14 percent losses in lettuce packed in wax impregnated boxes and shipped in controlled atmosphere conventional and Cooltainer vans respectively 5 weeks after picking, compared to 3.5 and 6.2 percent loss for lettuce packed in wirebound wooden boxes and shipped in controlled atmosphere and conventional vans, respectively. These results were not based on complete examinations (internal and external) of each lettuce head.

A cost analysis estimate of controlled atmosphere is presented in Table 9. It indicates that a reduction in approximately 9 percent lettuce loss is required to defray the additional cost of controlled atmosphere. Reduction in losses of edible yield lettuce obtained in this field test are often higher than the reduction required to defray the additional cost of the controlled atmosphere system (table 6).

It is concluded that shipping lettuce in controlled atmosphere vans under the conditions present in this field test was advantageous. However, further field tests or regular shipments that can provide adequate data on the quality of lettuce are recommended to various destinations in Southeast Asia and Europe in order to obtain sufficient factual data on the effect of the various controlled atmosphere systems, as well as refrigeration systems on the quality of fresh produce.

The use of wrapped lettuce is recommended in place of unwrapped due to the higher edible yield of wrapped lettuce shipped in all the vans. Since no difference was exhibited between lettuce packed in wirebound wooden boxes and that packed in fiberboard wax impregnated boxes, it is recommended that lettuce be shipped in the latter containers due to their lower cost (?) and better configuration which leads to better stacking and handling.

References

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2. Brugh, J.F., Evaluation of Impregnated Fiberboard Boxes for Chill Provisions. Report No. 68-A13-R2 - Naval Supply Systems Command, Naval Logistics Engineering Group, Cheatham Annex, Williamsburg, Virginia 1970.
3. Gorfien, H., A.R. Rahman, K.R. Johnson, and E.E. Anderson. Effect of a Controlled Atmosphere System on the Storage Life of Lettuce. Technical Report 70-23-FL, Food Laboratory FL-99, U.S. Army Natick Laboratories, Natick, Massachusetts, 1969.

Table 1. Loading Variables of the Lettuce

Packaging and Packing	Type of Vans					
	Controlled Atmosphere 20 ft Vans		Cooltainer 40 ft Vans		Conventional 20 ft Vans	
	Van No.	No. of Cases	Van No.	No. of Cases	Van No.	No. of Cases
Naked, packed in wax impregnated cardboard boxes* (24 heads/box)	565195	129	CCLJ0002	170	565178	149
Trimmed and individually wrapped in polystyrene film**packed in wax impregnated cardboard boxes (24 heads/box)	565195	129	CCLJ0002	169	565178	173
Naked, packed in wirebound wooden boxes*(24 heads/box)	565198	126	CCLJ0002	176	565207	126
Trimmed and individually wrapped in polystyrene film-packed in wirebound wooden boxes (24 heads/box)	565198	126	CCLJ0002	124	565207	126

* Boxes per Federal Specification HHH-L-226d (They contained 3 slots of 3/4 x 3" on each side and one similar slot plus a hand hole on each end).

** Federal Specification PPP-F-635B Fresh Fruits and Vegetables, Packaging, Packing and Marking Of.

Table 2. Time Schedule of the Lettuce Field Test

Date	Days after picking	Operation
22 May 70	0	Harvest and loading into the vans
15 June	23	Loading the vans aboard ship in San Francisco
25 June	33	Unloading the vans at Yokohama, Japan
26 June - 10 July	50	Product evaluation

Table 3. Temperature Ranges of Lettuce Heart as Measured by Thermocouples and of Air in Front and Back Vans as Measured by Ryan Recorders

		Type of Van						
Days	565155 Controlled atmosphere (wax impreg- nated boxes)	565178 Conven- tional (wooden boxes)		565198 Controlled atmosphere (wooden boxes)		565207 Conven- tional (wax im- pregnated boxes)		CCU002 Cool- tainer
		Temper- ature range of 24 thermo- couples	Temper- ature range of 24 thermo- couples	Temper- ature range of 10 thermo- couples	Temper- ature range of 10 thermo- couples	Temper- ature range of 10 thermo- couples	Temper- ature range of 24 thermo- couples	
1-3		Front: 34-39 Back: 40-44	Front: 40-42 Back: 43-44	Front: 34-39 Back: 40-42	Front: 39-40 Back: 44-45	Front: 33-36 Back: 35-36	Front: 32-34 Back: 37-40	
4-7		34-39 40-45	40-42 42-38	34-42 40-45	33-35 37-39	35-36 35-36	32-37 33-40	
7-18		35 38	35-37 41-42	32-38 35-36	34-35 38-39	35 35	32-38 32-34	35-40
Date of Arrival		- -	- -	35-36	- -	34-36	29-36	- -

Table 4. Percent Edible Yield of Lettuce Packed in Wirebound Wooden Boxes as Affected by a Controlled Atmosphere System and Temperature During Transportation

TIME IN WEEKS	Controlled Atmosphere*		Cooltainer*		Conventional*	
	Wirebound Wooden Boxes		Wirebound Wooden Boxes		Wirebound Wooden Boxes	
	Wrapped	Unwrapped	Wrapped	Unwrapped	Wrapped	Unwrapped
5	78.7	69.7	66.4	51.7	67.7	52.3
	78.8	73.3	74.4	54.9	72.4	65.8
	68.0	64.5	69.6	30.1	68.2	53.8
	AV.	75.2	70.1	45.6	69.4	57.3
6	50.4	67.2	61.2	38.0	62.2	60.3
	58.4	63.6	53.2	57.1	58.0	52.0
	73.4	64.1	66.6	35.7	69.3	53.4
	AV.	70.7	65.0	60.3	43.6	63.2
7	70.7	61.9	61.4	24.4	66.9	49.0
	72.5	66.0	55.9	28.2	62.1	39.5
	73.9	59.4	52.7	38.7	44.2	40.7
	AV.	72.4	62.4	56.6	30.4	57.7

* Significant at the 1 percent level
 Least significant difference at 5 weeks = 6.73
 Least significant difference at 6 weeks = 6.39
 Least significant difference at 7 weeks = 4.63

Table 5. Percent Edible Yield of Lettuce Packed in Wax Impregnated Boxes as Affected by a Controlled Atmosphere System and Temperature During Transportation.

TIME IN WEEKS	Controlled Atmosphere		Cooltainer		Conventional	
	Cardboard Wax Impregnated Boxes		Cardboard Wax Impregnated Boxes		Cardboard Wax Impregnated Boxes	
	Wrapped	Unwrapped	Wrapped	Unwrapped	Wrapped	Unwrapped
5	80.3	75.7	66.9	61.0	58.2	45.7
	71.6	74.8	67.6	63.8	71.6	63.9
	79.7	57.1	69.6	66.2	60.7	60.8
AV.	77.2	69.2	68.0	63.7	63.5	56.8
6	77.8	69.0	54.5	60.7	67.0	52.0
	65.7	55.9	65.1	51.0	56.8	59.6
	76.5	56.8	68.3	38.4	53.3	57.7
AV.	73.3	63.9	62.6	50.0	59.0	56.4
7	72.6	57.6	51.2	26.4	54.8	44.3
	78.1	56.1	60.5	23.2	59.3	44.6
	75.4	64.3	51.5	35.4	61.1	50.2
AV.	75.4	52.3	54.4	28.3	58.4	46.4

Significant at the 1 percent level
 Least significant difference at 5 weeks = 6.73
 Least significant difference at 6 weeks = 6.34
 Least significant difference at 7 weeks = 4.63

Table 6. Additional Edible Yield Resulted from the Use of Controlled Atmosphere System Over Conventional or Cooltainer Systems

Time in Weeks	Over Cooltainer System				Over Conventional System			
	Cardboard wax-impregnated box		Wirebound wooden box		Cardboard wax-impregnated box		Wirebound wooden box	
	Wrapped	Unwrapped	Wrapped	Unwrapped	Wrapped	Unwrapped	Wrapped	Unwrapped
5	9.2	5.5	5.1	23.6	13.7	12.4	5.8	11.9
6	10.7	13.9	10.4	21.4	14.3	7.5	7.5	9.8
7	21.0	31.0	15.8	32.0	17.0	12.9	14.7	19.3

Table 7. Mean Scores* for Overall Appearance of Lettuce as Affected by Slime and Decay Formation

TIME IN WEEKS	Controlled Atmosphere				Cooltainer				Conventional			
	Cardboard Wax- Impregnated Box		Wirebound Wooden Box		Cardboard Wax- Impregnated Box		Wirebound Wooden Box		Cardboard Wax- Impregnated Box		Wirebound Wooden Box	
	Wrapped	Unwrapped	Wrapped	Unwrapped	Wrapped	Unwrapped	Wrapped	Unwrapped	Wrapped	Unwrapped	Wrapped	Unwrapped
5	8.0	8.6	8.0	6.5	7.5	5.5	6.7	6.3	5.5	4.7	6.0	7.3
	6.8	8.5	7.4	8.1	7.1	7.0	6.9	6.6	7.2	7.6	7.6	7.9
	7.5	6.8	6.8	6.8	6.9	6.7	7.0	7.1	5.9	7.1	4.6	5.0
	7.4	7.9	7.4	7.2	7.2	6.4	6.9	3.7	6.2	6.5	6.1	6.7
6	8.2	8.7	7.8	6.6	7.6	7.5	2.7	5.7	7.1	4.7	7.2	4.7
	7.1	7.6	5.9	6.7	7.6	1.2	5.5	7.3	6.6	7.0	6.5	4.3
	6.7	6.3	7.3	6.8	7.0	2.0	5.5	3.0	6.2	6.0	5.3	5.2
	7.3	7.5	7.0	6.7	7.4	3.6	4.6	5.3	6.6	5.9	6.3	4.7
7	7.5	7.5	7.0	6.5	7.0	3.0	7.0	3.0	6.0	6.2	4.2	4.7
	7.6	7.0	7.0	6.0	4.0	8.0	5.0	5.0	5.0	5.2	6.3	5.0
	6.5	7.0	6.0	5.5	5.0	7.0	4.8	5.0	4.0	4.4	6.0	2.0
	7.0	7.2	6.7	6.0	5.3	6.0	5.6	4.3	5.0	5.3	5.5	3.9

* Mean Score for Appearance: 9 = field fresh, 1 = inedible

Table 8. Mean Scores for Defects* of Lettuce as Affected by Defects Such as Pink Rib and Russet Spotting

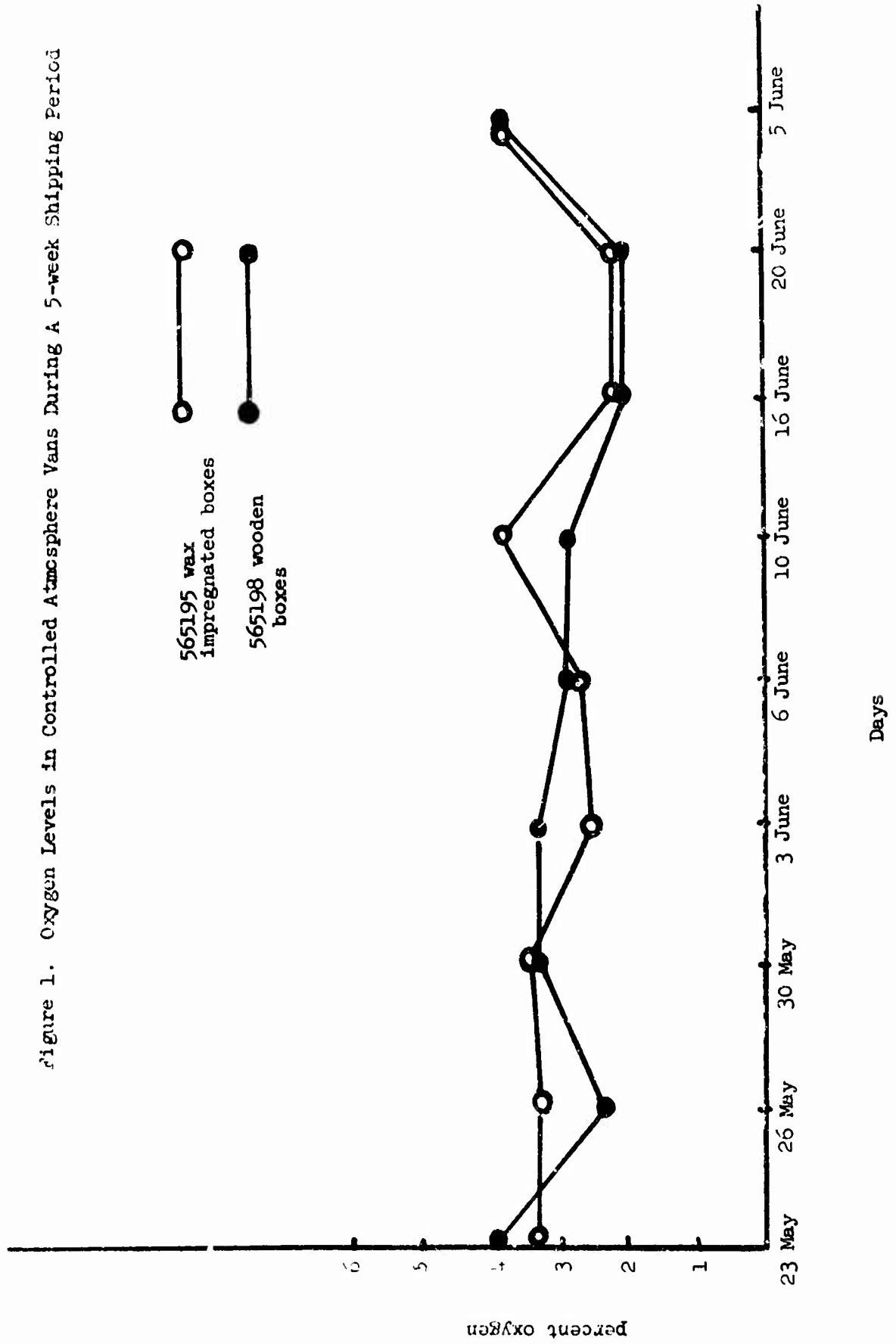
TIME IN WEEKS	Controlled Atmosphere						Cooltainer						Conventional					
	Cardboard Wax-Impregnated Box			Wirebound Wooden Box			Cardboard Wax-Impregnated Box			Wirebound Wooden Box			Cardboard Wax-Impregnated Box			Wirebound Wooden Box		
	Wrapped	Unwrapped	Average	Wrapped	Unwrapped	Average	Wrapped	Unwrapped	Average	Wrapped	Unwrapped	Average	Wrapped	Unwrapped	Average	Wrapped	Unwrapped	Average
5	8.5	8.7	8.6	8.3	6.9	7.6	8.0	3.2	7.4	7.4	7.4	6.4	5.6	4.5	7.0	7.0	7.8	7.8
	7.1	8.8	7.95	8.0	8.3	8.15	7.6	7.1	7.4	7.4	6.7	7.2	7.8	7.3	8.3	8.3	8.4	8.4
	8.4	6.9	7.65	7.5	7.0	7.25	6.9	6.8	4.5	4.5	7.2	6.4	6.4	7.3	5.7	5.7	5.2	5.2
6	8.0	8.1	8.05	7.9	7.4	7.65	7.5	5.7	6.4	6.4	6.8	6.4	6.5	6.5	7.0	7.0	7.1	7.1
	8.0	8.6	8.3	8.5	7.0	7.75	8.0	8.0	1.7	1.7	5.8	5.8	4.9	7.8	7.8	7.8	5.6	5.6
	7.9	7.4	7.65	6.3	6.9	6.6	7.8	1.0	6.0	6.0	7.4	6.1	6.0	6.0	6.9	6.9	4.0	4.0
7	7.5	6.5	7.0	7.1	7.1	7.1	5.0	2.0	5.8	5.8	3.0	3.0	6.0	6.0	5.6	5.6	4.6	4.6
	7.8	7.5	7.65	7.3	7.0	7.15	6.9	3.7	4.5	4.5	5.4	6.6	5.6	6.8	6.8	4.7	4.7	
	8.0	8.0	8.0	7.0	6.8	6.9	7.0	3.0	7.0	7.0	3.0	6.1	6.0	4.2	4.2	4.0	4.0	
AV	6.7	7.0	6.85	6.9	8.0	7.45	4.0	7.0	4.0	4.0	1.0	6.0	5.7	4.8	5.0	5.0	3.0	3.0
	7.2	7.3	7.25	7.0	6.9	6.95	4.3	5.3	5.0	5.0	2.0	5.7	5.5	5.3	5.3	2.7	2.7	

* Mean Scores for Defects: 9 = defects absent, 1 = severe defects

Table 9. Cost Analyses of Lettuce Field Test Shipped in 20 ft Controlled Atmosphere Vans.

No. of cases per van	Packaging	Cost per shipping van from Oakland to Japan*	Cost lettuce **	Additional cost of Controlled Atmosphere Vans	Minimum reduction loss required to defray additional Controlled Atmosphere cost per van
256 wirebound wooden boxes	128 trimmed, wrapped in polystyrene film 128 untrimmed, unwrapped	\$1858.00	\$766.00	\$235.00	9.0
252 wax impregnated fiberboard boxes	126 trimmed, wrapped in polystyrene film 126 untrimmed, unwrapped	\$1858.00	\$781.00	\$235.00	8.9

Figure 1. Oxygen Levels in Controlled Atmosphere Vans During A 5-week Shipping Period



**LETTUCE EVALUATION
TEST #**

	O.A. (W.W.L.) = Overall Appearance - With Wrapper Leaves	Date _____
	O.A. (Trimmed) = Overall Appearance - Trimmed	Duration _____
*Field Fresh 5	Good-Minor Defects 6 7 8	Treatment _____
	Fair-Removable Defects 5	Carton # _____
	Poor-Generally Unsalable Defects 4 3 2	Chamber # _____
	In-edible 1	
SCORING CRITERIA	Decay - Pink Rib - Russet Spotting	Name _____
	Defects Absent 9	
	Trace 8	
	6 7	
	Slight 5	
	Moderate 4 3	
	Severe 2 1	

	Top Layer												Bottom Layer											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
DEFECTS																								
O.A. (W.W.L.)																								
O.A. (Trimmed)																								
Decay (Slime, mold, etc.)																								
Pink Rib																								
Russet Spotting																								

* The following are considered defects: Discoloration such as browning, darkening, black, pink, red spotting or the presence of any color not typical of the fresh product; physical damage such as bruises and skin breakage; diseases such as mold, slime and soft rot; wrinkled surface; wilt; tip burn; spotting; dehydration and any other sign not typical of the fresh product.

Other Comments _____

FIGURE 2. TECHNOLOGICAL EVALUATION SHEET

Figure 3. Percent Edible Yield of Wrapped and Unwrapped Lettuce Packed in Wirebound Wooden Boxes as Affected by Temperature and Atmosphere Conditions of Shipping Vans

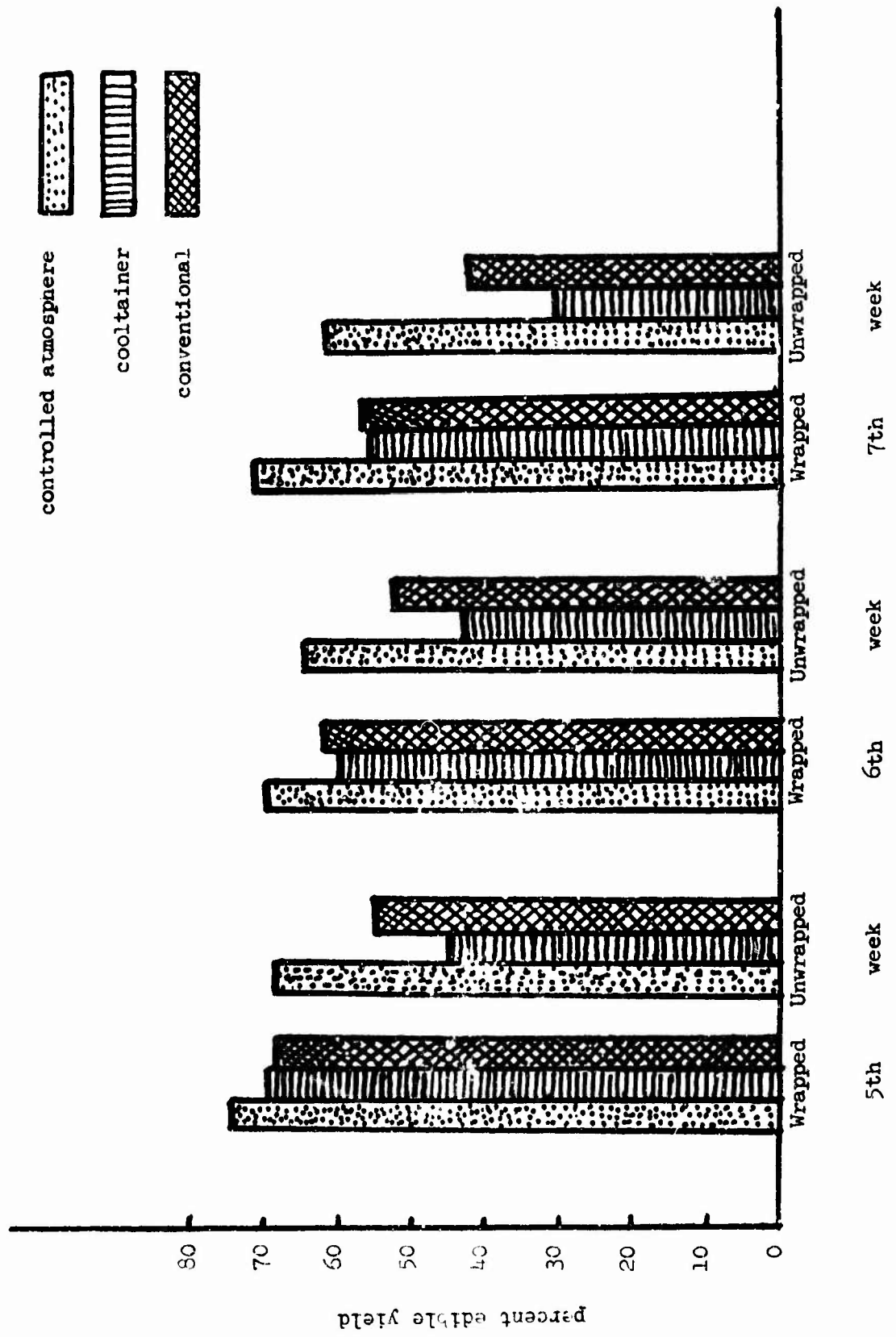
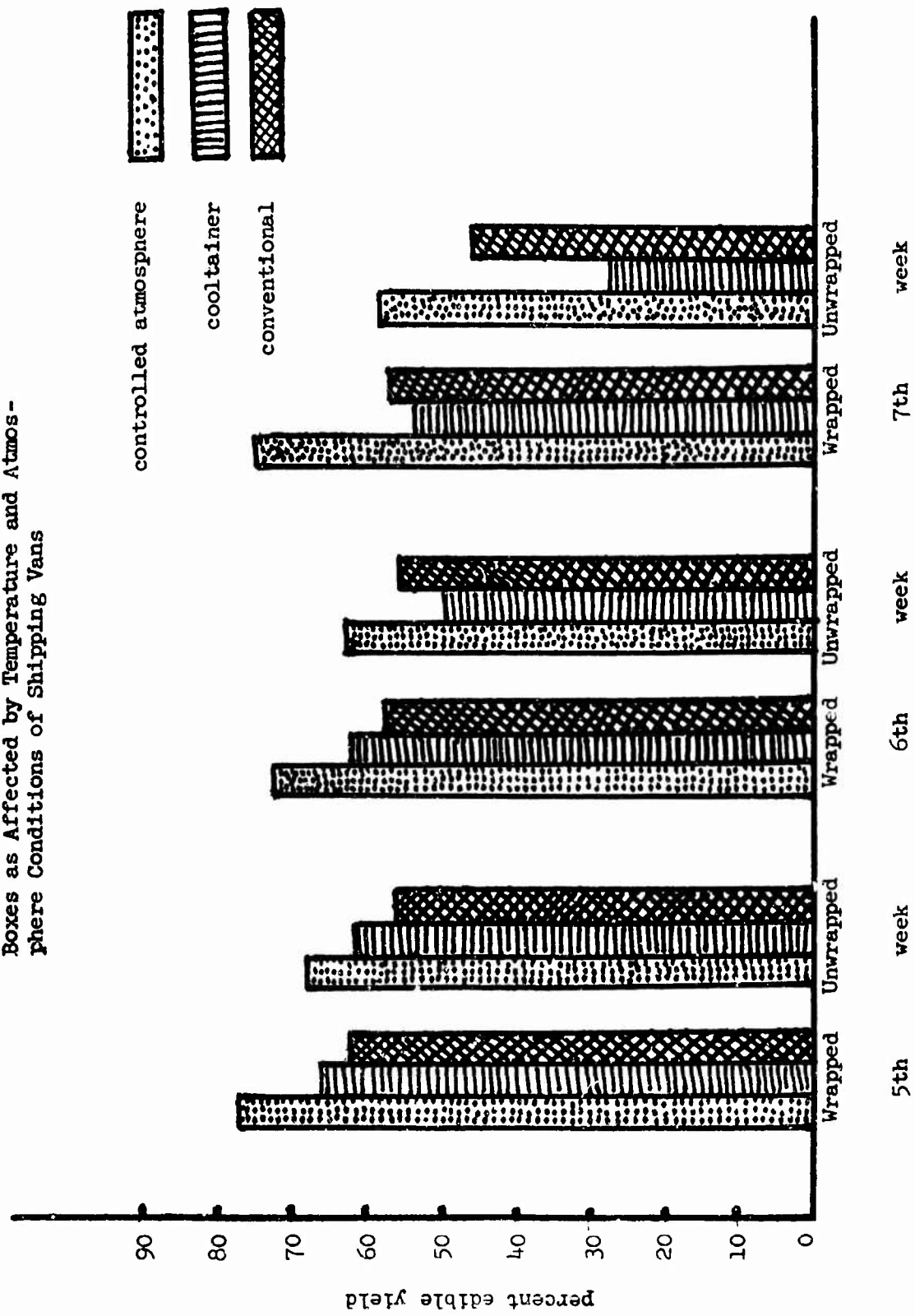


Figure 4. Percent Edible Yield of Wrapped and Unwrapped Lettuce Packed in Cardboard Wax Impregnated Boxes as Affected by Temperature and Atmosphere Conditions of Shipping Vans



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13. ABSTRACT A shipping test from Oakland, California to Japan was conducted to determine the effect of a low oxygen controlled atmosphere system (Oxytrol) as well as a new refrigeration system (Cooltainer) on the shelf life of lettuce shipped to military organizations overseas. The Oxytrol system is a complete, self-contained atmosphere control system designed to be used as an adjunct to normal refrigeration equipment in conventional transport vehicles. Results indicated that lettuce shipped under the low oxygen controlled atmosphere system (oxygen level ranged from 2.2 to 4 percent) gave significantly higher edible yields than lettuce shipped in conventional or Cooltainer vans regardless of the packaging (wrapping versus no wrapping) and packing (wirebound wooden boxes versus cardboard wax impregnated boxes). All wrapped lettuce exhibited significantly higher edible yields than unwrapped lettuce regardless of packing and shipping vans. However, no significant difference was shown between lettuce packed in wirebound wooden boxes and that packed in cardboard wax impregnated boxes regardless of the shipping vans. The ambient temperature in the vans as indicated by the Ryan recorders as well as the heart (compact portion) temperature of the lettuce as indicated by thermocouples fluctuated widely. Although the controls in all vans except Cooltainer were set at 34°F., temperatures as high as 45°F. were recorded. Chill damage to the lettuce occurred in the Cooltainer van in which temperatures as low as 29°F. to 31°F. were recorded for several thermocouples upon arrival to Japan. It is concluded that shipping lettuce in controlled atmosphere vans under the conditions presented in this field test was advantageous. However, further shipping tests to various overseas destinations are recommended in order to obtain sufficient factual data on the effect of various atmosphere systems and refrigeration systems on the quality of lettuce and other fresh produce.		

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Cold storage	8		7			
Controlled atmosphere	8		6			
Oxytrol system	10		6			
Cooltainer system	10		6			
Lettuce	9		7			
Cargo transportation	10,4		7,4			
Military bases	4		4			