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CALIFORNIA ASPARAGUS

effect of

STABY

Transit Environments

on market quality

Marketing Research Report No. 428

Market Quality Research Division
Agricultural Marketing Service
UNITED STATES DEPARTMENT OF AGRICULTURE

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PREFACE

Fresh asparagus is one of the most perishable of vegetables. Prompt and thorough refrigeration is needed to maintain its quality during marketing. Shipping costs are reduced for heavy loads. These studies were conducted to determine adequacy of refrigeration of heavy loads in both the conventional and in new types of railway cars to take advantage of these reduced costs. This report is part of a broad program of continuing research to improve marketability of farm products and reduce costs.

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CONTENTS

SUMMARY AND CONCLUSIONS

Transit temperatures, relative humidities, and atmosphere compositions were determined in five test cars of California asparagus shipped from Tracy, Calif., to New York City in the spring of 1959. Shipments were made in a conventional ice-bunker refrigerator car, an ice-bunker car equipped with diesel powered fans and thermostat (Cargotemp), and three types of mechanically refrigerated cars. Loads in all the cars were heavy enough to qualify for reduced freight rates.

Temperatures of the asparagus averaged approximately 37° F. after hydrocooling and were maintained between 34° and 39° in transit, which is an acceptable range for asparagus. The mechanical cars held the temperature of the loads near the thermostat setting. Asparagus in the Cargotemp car cooled slightly below the thermostat setting during the first few days in transit, requiring an upward adjustment of the thermostat. However, pulp temperatures were in an acceptable range during the entire transit period. Temperatures were maintained satisfactorily in the conventional ice-bunker car.

Relative humidities were near saturation in all the cars and were within the range considered desirable for asparagus. With these hydrocooled loads there was no appreciable drying out of the asparagus in the mechanical or other cars tested.

Excess accumulations of carbon dioxide and depletion of oxygen were not a problem in the mechanically refrigerated cars when the loads were precooled to 37° F. and transit temperatures were maintained below 40°.

Laboratory tests showed that asparagus spears were not visibly injured by atmospheres of 10 percent carbon dioxide or less combined with 10 percent oxygen or more when held 6 days at 37.5° F. Modification of the atmosphere to this extent was beneficial in reducing the incidence of soft rot and the degree of toughening. These effects were still evident after holding the spears in a normal atmosphere at 59° for 2 days subsequent to the modified atmosphere storage at the lower temperature.

At 50° F., an undesirably high temperature for asparagus, the advantages of atmosphere modification are outweighed by the dangers of injury from excess CO_2 or low O_2. Asparagus respires much faster, produces more carbon dioxide, and uses more oxygen at 50° than at the lower temperature tested and when confined, either in a partially sealed railroad car or package, there is danger of "smothering."

Heavy loads of asparagus carried well in all cars under the conditions of this test. Adequate hydrocooling is particularly important with heavy loads since some railway equipment may lack the refrigeration capacity to precool them.

CALIFORNIA ASPARAGUS: EFFECT OF TRANSIT ENVIRONMENTS ON MARKET QUALITY

I. TEMPERATURE, RELATIVE HUMIDITY, AND ATMOSPHERE COMPOSITION IN RAIL CARS

By W. R. Barger, horticulturist, J. M. Harvey, senior plant pathologist, J. K. Stewart, associate horticulturist, Fresno, Calif., and M. J. Ceponis, associate plant physiologist, New York, N. Y.

II. EFFECT OF ATMOSPHERE COMPOSITION ON QUALITY

By Werner J. Lipton, plant physiologist, Fresno, Calif.

PART I

Asparagus keeps best when held at 32° F. and at a relative humidity above 85 percent (12).[1] However, if temperatures are held between 32° and 40° during transit, little deterioration is likely to develop. Slight modification in the composition of the atmosphere in which asparagus is held has been shown to reduce decay and help maintain quality, but greatly modified atmospheres cause serious damage to the commodity (1, 9, 10).

Mechanically refrigerated railway cars have been used extensively for shipments of fresh asparagus to eastern markets. The tight construction of these cars and the almost sealed load compartment caused concern over the modification of atmosphere that might occur as a result of the high respiratory activity of asparagus. It was also desirable to determine load temperatures in such cars, particularly with heavy loads that reduce shipping costs. Relative humidity in the load compartment is an equally important factor since asparagus readily loses moisture in dry air.

Other developments in refrigerated railway equipment include the "Cargotemp" ice-bunker car, which provides thermostatic control of temperature.[2] The use of heavy loads in this car and in conventional ice-bunker cars required investigation.

Temperatures, atmospheres, and relative humidities were, therefore, determined in three types of mechanically refrigerated cars, the Cargotemp car, and a conventional ice-bunker car. The five cars were accompanied from California to New York City in March and April 1959 to obtain data at intervals in transit.

PROCEDURE

Railway equipment

A standard ice-bunker car, a Cargotemp car, and three mechanically refrigerated railroad cars were loaded with hydrocooled asparagus at Tracy, Calif. The standard car (Car A) was equipped with electric fans, powered by a wheel-driven generator that operated only when the car was in motion. This car served as a check for comparison with the new types of railway equipment included in the test.

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[1] Underscored numbers in parentheses refer to items in Literature Cited, page 26.
[2] Described in section on railway equipment.

The Cargotemp car (Car B) was a modified ice-bunker car equipped with a small diesel engine and generator that provided a constant supply of power to operate the fans. Movement of refrigerated air through the ice bunkers was controlled by thermostatically activated fans and louvers. An additional fan in each end of the car operated continuously to circulate the air within the load compartment.

Three types of mechanically refrigerated cars were tested. Two of these (Cars D and E) had an air-circulating system in which the cooled air from the refrigeration unit was discharged through a plenum (air pressure chamber) above the ceiling which was perforated to permit approximately 20 percent of the air to blow downward over the load while the remainder passed down flues at the sides and opposite end of the car to openings at the floor level. All return air was drawn from under the floor racks back to the cooling coil at one end of the car. The two cars with this type of air circulation differed in length, one being 40 feet long (Car D), and the other 50 feet (Car E). Both were equipped with drains to dispose of water that might collect on the floor of the load compartment. The other mechanically refrigerated car (Car C) lacked ceiling perforations--all the cooled air was circulated through the ceiling and down the wall flues, which opened under the floor racks. In this car, exchange between the air in the load compartment and that in the refrigerated air stream occurred only at the floor racks. This car had a small drain to remove the condensate from the refrigeration coil but no floor drains in the loading space. Descriptions of the various test cars are given in table 1.

Loads

Loads in all the cars were heavy enough to qualify for reduced or "incentive" freight rates (table 2). The crates were set lengthwise in the cars, forming stacks eight crates wide by six crates high. These were secured with car strips on each layer and a center gate at the doorway. The number of stacks in individual cars varied from 19 to 25, depending upon the length of the car.

Test packages

Test packages of asparagus were selected from a single lot to provide uniform material for comparison of the effect of transit conditions in the test cars. A recording thermometer was wrapped in a polyethylene bag and placed in each package, after which a gross weight was obtained. The packages were hydrocooled and placed in the test cars during loading. Two packages were placed in each car at positions that were judged to represent the warmest and coldest positions in the loads. For the ice-bunker cars these positions were the middle layer at the quarterlength, centerline, for the warmest position, and the bottom layer at the bunker, centerline, for the coldest position. For the mechanically refrigerated cars a similar middle-layer position was used for the warmest position, but the bottom layer at the quarterlength adjacent to one side was used for the coldest position.

At destination, test packages were recovered from the cars, reweighed, and the asparagus examined for decay, possible damage from abnormal atmospheres, and other defects. Spears from each test package were held for 2 days at 70° F. and 85-90 percent relative humidity, after which they were rated for the same factors. A sample from each test package was cooked and rated for flavor.

Protective services

The thermostats on the mechanical cars were set at 35° or 37° F., depending upon the shippers' instructions. The thermostat on the Cargotemp car was first set at 37°, but was readjusted in transit (table 2). Both the Cargotemp and conventional ice-bunker car were shipped full bunker Standard Refrigeration with 100 pounds of salt added to the bunkers at shipping point. All the asparagus was hydrocooled to 35°-37° before loading.

Records taken in transit

Measurements of asparagus temperature, relative humidity in the load compartment, and composition of the atmosphere in each car were made during most stops in transit. The stops are shown in table 3.

TABLE 1.--Description of five refrigerator cars used for test shipments of asparagus from Tracy, Calif., to New York market, 1959

Description	Car A Conventional PFE 9290	Car B Cargotemp PFE 8132	Car C 40-foot Mechanical WFEX 7932	Car D 40-foot Mechanical PFE 100009	Car E 50-foot Mechanical PFE 300965
Inside width....	8' 3"	8' 3"	8' 8"	8' 3"	8' 6"
Inside length...	33' 2-3/4"	33' 2-3/4"	34' 2"	35' 4"	44' 6"
Insulation:					
Wall..........	4"	4"	7"	6" & 8"	7" & 8"
Roof..........	4-1/2"	4-1/2"	9"	8"	10-1/2"
Floor.........	4-1/2"	4-1/2"	7"	6"	7"
Refrigeration:					
Type..........	Ice	Ice	Mechanical	Mechanical	Mechanical
Capacity......	11,500 lb.	11,500 lb.	Two 5 hp. compressors	One 7-1/2 hp. compressor	One 10 hp. compressor
Air circulation:					
Type..........	Electric fans	Electric fans[1]	Electric blower[2]	Electric blower[3]	Electric blower[3]
Rated volume..	9,000 c.f.m. at 60 m.p.h.	9,000 c.f.m. from ice bunkers (controlled by thermostat) 3,000 c.f.m. through bypass	4,300 c.f.m.	3,500 c.f.m.	3,500 c.f.m.
Power supply....	Car wheel	5 hp. diesel engine	34 hp. diesel engine	18 hp. diesel engine	36 hp. diesel engine
Thermostatic control.......	No	Yes	Yes	Yes	Yes

[1] One fan in each end of car in continuous operation for circulation of air in load compartment of car. Two fans in each end of car controlled thermostatically to circulate cooled air from ice bunkers.
[2] Semi-envelope design without perforated ceiling; cold air enters load compartment only at bottom of wall flues which open under floor racks.
[3] Semi-envelope design with perforated ceiling in which 20 percent of the cold air blast enters the load compartment through holes in the ceiling chamber and the remainder passes down wall flues and is discharged under the floor racks.

Transit temperatures, taken with 12 electrical resistance thermometers inserted into the crates of asparagus during loading, were obtained in the bottom, middle, and top layers of the loads along the centerline of each car at the bunker, quarterlength, and doorway positions, and also in these three layers adjacent to one side wall at the quarter-length position. These distant-reading thermometers were read from the outside of the cars by members of the test party accompanying the train. In addition, temperatures of the air blast in each car and the air outside the cars were obtained with recording thermometers.

TABLE 2.--Loads and protective services for 5 test cars of asparagus, Tracy, Calif., to New York market, 1959

Test cars[1]	Loads[2]		Protective services		
	Crates[3]	Shipping weights	Rules[4]	Descriptions	Thermostat settings
	Number	*Pounds*			°F
A.	912	36,480	201	Preiced standard refrigeration[5]	--
B.	912	36,480	201	Preiced standard refrigeration[5]	[6] 37
C.	960	38,400	710	Mechanical refrigeration	35
D.	960	38,400	710	Mechanical refrigeration	35
E.	1,200	48,000	710	Mechanical refrigeration	37

1 See table 1 for test-car descriptions.
2 Crates stacked 8 wide and 6 high, 19 to 25 stacks in car, depending on length of loading space.
3 Tapered, nailed wooden crate: 11-1/2 in. wide (bottom) x 11 in. high x 19-3/8 in. long.
4 As specified in Perishable Protective Tariff 17, National Perishable Freight Committee, W. T. Jamison, Agent, Chicago, Ill. 1957, and supplement 22 effective Jan. 24, 1959.
5 100 pounds of salt added after loading was completed, no further salting.
6 Setting changed to 40° F. at Roseville, reset to 37° at Kansas City.

Relative humidity in each car was measured with an electric hygrometer that could also be read from outside the car. Sensing elements of the hygrometers were suspended from the ceilings of the cars and served to measure the relative humidity of the air above the load.

Percentages of carbon dioxide and oxygen in the load compartments of each car were determined by drawing air samples through a copper tube leading from the center of the doorway brace to the outside of the cars and passing these samples through an Orsat-type gas analyzer.

Routing

Test cars were loaded at Tracy, Calif., March 28, 1959, routed over the Southern Pacific, Union Pacific, Wabash, and Pennsylvania railroads and, with the exception of one car, arrived at Greenville, N. J. (in the New York market area) at 6:05 p.m., April 3 (table 3). One car (D) was cut out of the test train at Enola, Pa., for movement to Philadelphia.

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TABLE 3.--Trip log, Tracy, Calif., to New York market, March-April 1959

Date	Station	Miles X to X	Arrive	Depart	Standing time		Outside temperature	
					Hr.	Min.	Time	°F
			P.s.t.	P.s.t.			P.s.t.	
March 29......	Tracy, Calif.....		--	2:30 a.m.			12:15 a.m.	50
	Roseville........	X	8:00 a.m.	3:12 p.m.	7	12	3:12 p.m.	66
		138						
	Sparks, Nev......	X	10:20 p.m.	11:40 p.m.	1	20	10:20 p.m.	43
30......	En route.........		1:00 a.m.	1:30 a.m.	0	30		
	Imlay............	289	3:35 a.m.	3:45 a.m.	0	10		
	Ellison..........		6:00 a.m.	6:35 a.m.	0	35	6:00 a.m.	45
	Carlin...........	X	8:00 a.m.	9:20 a.m.	1	20	8:00 a.m.	46
	En route.........		10:47 a.m.	11:18 a.m.	0	31	10:47 a.m.	45
	Lemay............	249	3:08 p.m.	3:28 p.m.	0	20	3:08 p.m.	45
			M.s.t.	M.s.t.			M.s.t.	
	Ogden, Utah......	X	6:45 p.m.	8:25 p.m.	1	40	6:45 p.m.	44
	Echo.............		9:45 p.m.	10:00 p.m.	0	15		
		176						
	Evanston, Wyo....		11:25 p.m.	11:30 p.m.	0	05		
31......	Green River......	X	1:44 a.m.	2:15 a.m.	0	31		
		134						
	Rawlins..........	X	5:26 a.m.	5:45 a.m.	0	19	5:26 a.m.	31
		116						
	Laramie..........	X	8:20 a.m.	8:28 a.m.	0	08	8:20 a.m.	36
	Cheyenne.........		10:40 a.m.	11:00 a.m.	0	20	10:40 a.m.	38
	Sidney, Nebr.....	282	1:05 p.m.	1:13 p.m.	0	08	1:05 p.m.	42
			C.s.t.	C.s.t.			C.s.t.	
	North Platte.....	X	4:34 p.m.	5:30 p.m.	0	56	4:34 p.m.	50
		136						
	Hastings.........	X	8:27 p.m.	8:34 p.m.	0	07		
		114						
	Marysville, Kan..	X	11:40 p.m.	11:50 p.m.	0	10		
		143						
April..... 1	Kansas City......	X	3:30 a.m.	11:18 a.m.	7	48	11:00 a.m.	54
		130						
	Moberly, Mo......	X	2:00 p.m.	2:25 p.m.	0	25		
		68						
	Hannibal.........	X	4:10 p.m.	4:28 p.m.	0	18	4:10 p.m.	50
		143						
	Decatur, Ill.....	X	8:40 p.m.	11:35 p.m.	2	55	8:40 p.m.	42
		157						
2.......	Logansport, Ind..	X	4:45 a.m.	2:45 p.m.	10	00	6:00 a.m.	38
		197	E.s.t.	E.s.t.			E.s.t.	
	Columbus, O......	X	9:02 p.m.	10:12 p.m.	1	10	9:02 p.m.	44
		406						
3.......	Altoona, Pa......	X	7:45 a.m.	8:12 a.m.	0	27	7:45 a.m.	39
	Huntingdon.......	131	9:12 a.m.	10:05 a.m.	0	53	9:12 a.m.	44
	Enola............	X	12:25 p.m.	1:17 p.m.	0	52		
	Waverly, N. J....	188	5:30 p.m.	5:45 p.m.	0	15		
	Greenville (New York market area)	X	6:05 p.m.					

RESULTS

Temperatures in transit

Commodity temperatures in all cars during transit were adequate for protection of asparagus. Average temperatures for the entire transit period in the various layers and stacks of each load were not over 40° F. (table 4). Variations in temperature from bunker to doorway positions (centerline and wall stacks) were 3 degrees in the conventional car (A) and 2 degrees or less in the other cars. The spread in average temperature between top, middle, and bottom layers of the loads was only slightly greater in the conventional car than in the other cars (3 degrees compared to 2 degrees or less). Differences in layer temperatures were also apparent at various points en route (fig. 1), but were not great enough to be of commercial significance.

Air-blast temperatures averaged 37° F. in the conventional car (A) and 36° to 40° in the cars equipped with thermostats. Average air temperatures in the latter cars were maintained within 3 degrees of the individual thermostat settings.

In the two ice-bunker cars, the advantage of the constant forced air circulation and higher velocity cold air blast in the Cargotemp car (B) over the intermittent air blast occurring in the conventional car (A) with wheel-powered fans was evident especially during the first 12 hours of the trip when train stops were frequent and speed between stops was relatively slow. During this period the temperature of the load was reduced several degrees in the Cargotemp car, whereas little change from the initial temperature occurred in the conventional car (fig. 1).

Relative humidities

Relative humidities in the three mechanical cars (C, D, and E) and the Cargotemp car (B) ranged from 97 to 100 percent during the transit period and were at 100 percent most of the time (table 5). The relative humidity was slightly lower in the conventional car (A) than in the other cars, ranging from 89 to 97 percent and averaging 95 percent. Relative humidities in all the test cars were considered satisfactory for asparagus.

TABLE 4.--Average transit temperatures in specified positions in 5 test cars of asparagus shipped from Tracy, Calif., to New York market, 1959

Test car[1]	Top layer	Middle layer	Bottom layer	Centerline: Bunker stack	Centerline: Quarter-length stack	Centerline: Doorway stack	Wall: Quarter-length stack	Average load[2]	Average air blast
	°F	°F	°F	°F	°F	°F	°F	°F	°F
A...........	36	38	35	37	37	36	34	36	37
B...........	34	34	34	35	34	34	33	34	36
C...........	38	38	36	37	37	38	36	37	37
D...........	36	37	38	37	37	37	35	36	37
E...........	40	39	39	38	39	39	38	39	40

[1] See table 1 for test car descriptions.
[2] Average of 9 centerline positions.

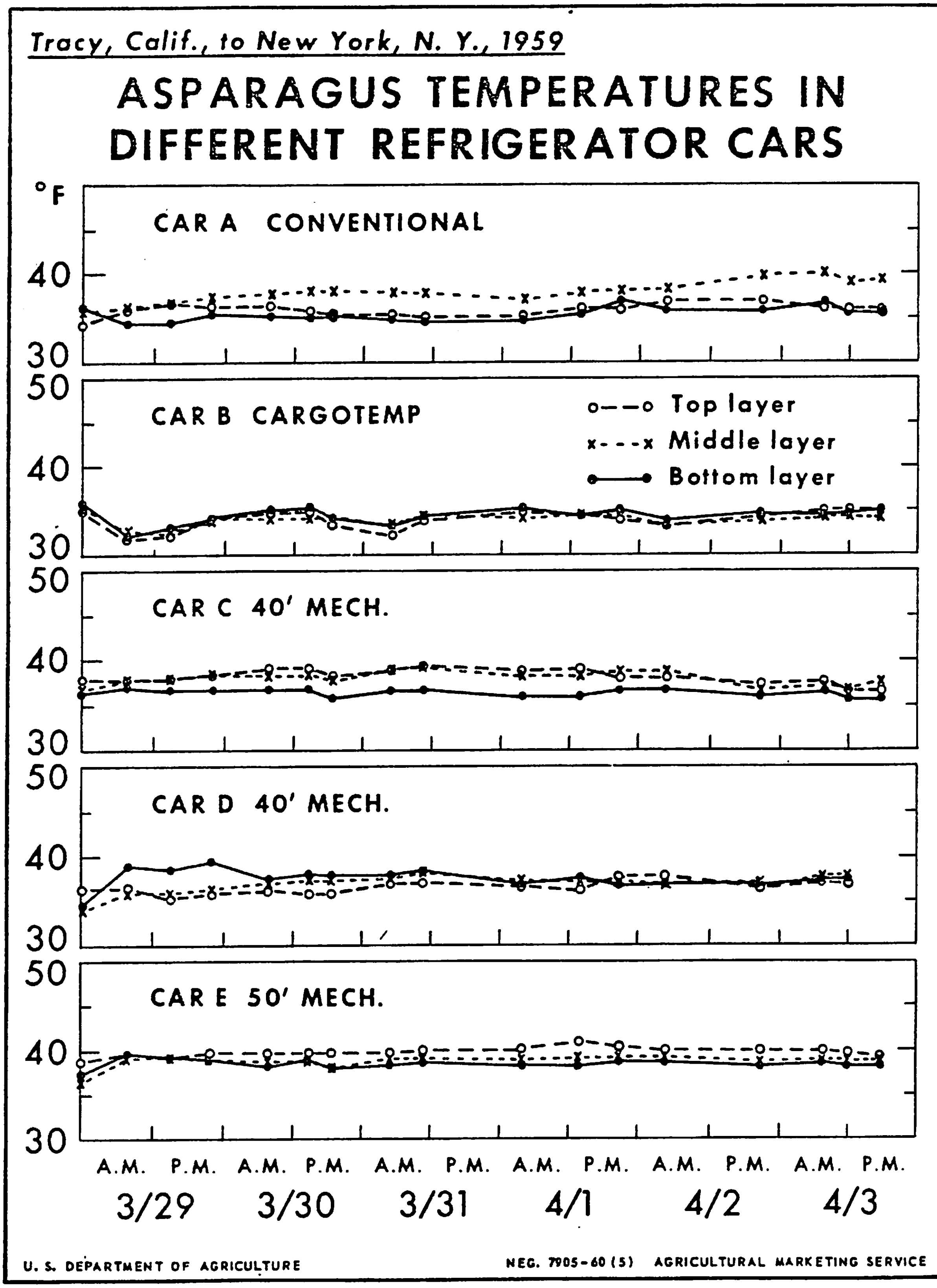
Tracy, Calif., to New York, N. Y., 1959
ASPARAGUS TEMPERATURES IN DIFFERENT REFRIGERATOR CARS
°F
CAR A CONVENTIONAL
CAR B CARGOTEMP
o——o Top layer
x- - -x Middle layer
•——• Bottom layer
CAR C 40' MECH.
CAR D 40' MECH.
CAR E 50' MECH.
30
40
50
A.M. P.M. A.M. P.M. A.M. P.M. A.M. P.M. A.M. P.M. A.M. P.M.
3/29 3/30 3/31 4/1 4/2 4/3
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Figure 1.

TABLE 5.--Relative humidities in 5 test cars of asparagus during transit from Tracy, Calif., to New York market, 1959[1]

Date	Time	Station	Car A	Car B	Car C	Car D	Car E
Mar.	*P.s.t.*		*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
29.....	8:30 a.m.	Roseville, Calif....	94	98	100	97	100
	2:00 p.m.	Roseville...........	89	99	99	100	99
	11:05 p.m.	Sparks, Nevada......	94	100	99	100	100
30.....	9:00 a.m.	Carlin.............	94	100	100	100	100
	M.s.t.						
31.....	11:00 a.m.	Cheyenne, Wyo.......	97	100	100	100	99
Apr.	*C.s.t.*						
1......	6:30 a.m.	Kansas City, Mo.....	97	100	100	100	100
	2:20 p.m.	Moberly.............	93	99	100	100	100
2......	11:45 a.m.	Logansport, Ind.....	97	97	100	100	100
	E.s.t.						
3......	10:00 a.m.	Huntingdon, Pa......	97	100	97	98	99
	6:30 p.m.	Greenville, N. J. (New York market area)............	96	98	97	--	100
5......	12:45 p.m.	Harlem River, N. Y..	--	--	--	--	100
	2:00 p.m.	Jersey City, N. J...	96	--	97	--	--
	3:20 p.m.	Waverly, N. J.......	--	95	--	--	--

[1] See table 1 for test-car descriptions.

Weight loss was not a problem in any of the test packages. A comparison of weights taken before hydrocooling at Tracy and upon arrival at New York showed that the gross weights of the packages increased 1/2 to 1-1/2 pounds. This increase was due to water absorbed by the crates and packing materials during hydrocooling which was not evaporated in transit.

Atmosphere compositions

Practically no modification of the normal atmosphere occurred in the conventional (A) and Cargotemp (B) cars (table 6). Opening the hatches of these cars almost daily to replenish the bunkers with ice apparently provided sufficient ventilation to prevent a build-up of carbon dioxide (CO_2) or a depletion of oxygen (O_2). A slight modification of atmosphere occurred in the 40-foot mechanical cars (C and D), but the percentage of CO_2 did not exceed 1.6 at any time even though the cars were not opened en route. The greatest modification of atmosphere occurred in the 50-foot mechanical car (E). This car

TABLE 6.--Percentages of carbon dioxide and oxygen in 5 test cars of asparagus during transit from Tracy, Calif., to New York market, 1959[1]

Date	Time	Station	Car A		Car B		Car C		Car D		Car E	
			CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2
Mar.	*P.s.t.*		*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
29..	8:30 a.m.	Roseville, Calif....	--	--	--	--	1.2	20.0	0.6	20.4	2.6	18.0
	11:05 p.m.	Sparks, Nev.........	--	--	--	--	0.0	20.3	0.8	20.0	3.3	17.5
30..	9:00 a.m.	Carlin..............	--	--	--	--	1.4	18.0	0.8	19.2	4.8	15.4
	3:15 p.m.	Lemay...............	--	--	--	--	1.0	20.1	0.8	19.5	4.8	16.2
	M.s.t.											
	7:00 p.m.	Ogden, Utah.........	--	--	--	--	--	--	1.2	19.0	--	--
31..	5:30 a.m.	Rawlins, Wyo........	--	--	--	--	1.0	20.4	0.8	19.6	5.8	15.2
	11:00 a.m.	Cheyenne............	--	--	--	--	1.0	20.4	1.2	20.4	4.2	17.4
Apr.	*C.s.t.*											
1...	3:45 a.m.	Kansas City, Kans...	--	--	--	--	0.6	20.4	1.6	20.2	3.6	17.6
	9:15 a.m.	Kansas City, Mo.....	--	--	0.4	--	1.2	20.4	0.6	20.6	2.9	18.5
2...	11:45 a.m.	Logansport, Ind.....	0.6	21.0	--	--	1.4	20.0	0.9	20.5	2.6	18.4
	E.s.t.											
3...	7:45 a.m.	Altoona, Pa.........	--	--	--	--	0.8	20.4	0.4	20.6	3.2	17.6
	12:30 p.m.	Enola...............	--	--	--	--	--	--	0.6	20.2	--	--
	6:30 p.m.	Greenville, N. J. (New York market area)............	0.1	21.2	0.2	21.2	0.5	21.0	--	--	2.9	21.0
5...	12:45 p.m.	Harlem River, N. Y..	--	--	--	--	--	--	--	--	3.1	20.7
	2:20 p.m.	Jersey City, N. J...	1.1	21.4	--	--	--	--	--	--	--	--
	3:20 p.m.	Waverly, N. J.......	--	--	0.1	21.2	--	--	--	--	--	--

[1] See table 1 for test-car descriptions.

contained 25 percent more asparagus, but had the same number and size drains as one of the 40-foot mechanical cars (D). The maximum build-up of 5.8 percent CO_2 in this car was not high enough to cause any damage to the asparagus.

Ice meltage

The amount of ice supplied the two ice-bunker cars (A and B) is shown in table 7. The Cargotemp car (B) consumed 2,700 pounds more ice than the conventional car. This greater ice meltage was accompanied by an average load temperature that was 2 degrees lower in the Cargotemp car than in the conventional car (table 4).

Condition of asparagus at market

At arrival the asparagus from all test packages was firm, crisp, of good color, and free from decay or discoloration. A taste panel judged the asparagus to be of good eating quality with no difference between lots.

After holding asparagus for 2 days at 70° F., 5 percent of it showed decay (table 8). The amount of decay did not differ consistently in relation to the particular test car or position in the load. After holding, bacterial soft rot was the principal type of decay

TABLE 7.--Ice supplied 2 test cars of asparagus at shipping point and in transit, Tracy, Calif. to New York market, 1959[1]

Date	Time	Icing station	Car A	Car B
March	*P.s.t.*		*Pounds*	*Pounds*
28	11:00 a.m.	Tracy, Calif.	11,500	11,500
29	11:45 a.m.	Roseville	700	1,500
	M.s.t.			
30	7:00 p.m.	Ogden, Utah	1,600	900
April	*C.s.t.*			
1	4:00 a.m.	Kansas City, Mo.	600	600
1	9:30 p.m.	Decatur, Ill.	1,500	2,100
	E.s.t.			
3	9:45 a.m.	Huntingdon, Pa.	1,100	2,600
3	6:30 p.m.	Greenville, N. J.	300	800
Total ice supplied			17,300	20,000
Initial supply			11,500	11,500
Total ice melted in transit			5,800	8,500

[1] See table 1 for test-car descriptions. Bunkers filled to "full-bunker" capacity initially and at all reicings.

TABLE 8.--Decay in test packages of California asparagus on arrival and after holding at New York market, 1959

Test car and crate location[1]	Number spears examined on arrival (no decay found)	Examination after 2 days at 70° F.					
		Number spears examined	Decay found				
			Slight	Moderate	Severe	Total	
	Spears	*Spears*	*Spears*	*Spears*	*Spears*	*Spears*	*Percent*
Car A:							
MQ	185	114	8	0	0	8	7.0
BB	217	110	3	0	0	3	2.7
Car B:							
MQ	228	139	1	0	1	2	1.4
BB	127	73	4	2	0	6	8.2
Car C:							
MQ	143	70	2	0	0	2	2.9
BQ	172	90	2	0	0	2	2.2
Car D:							
MQ	253	146	8	2	0	10	6.8
BQ	199	113	7	0	0	7	6.2
Car E:							
MQ	153	74	4	0	0	4	5.4
BQ	128	73	4	2	0	6	8.2
Total or average	1,805	1,002	43	6	1	50	5.0

[1] See table 1 for test-car descriptions. MQ = middle layer, quarterlength stack; BB = bottom layer, bunker stack; BQ = bottom layer, quarterlength stack.

found, although spoilage of a few spears was caused by Fusarium and Penicillium rots. The spears in all lots were fairly firm and crisp at the end of the holding period and their eating quality was fair to good.

The soundness and good quality of the asparagus reflects the thorough precooling and the adequate transit refrigeration that was provided in all loads and cars tested.

PART II

EFFECT OF ATMOSPHERE COMPOSITION ON QUALITY

Modified atmospheres may develop in loads of asparagus when shipped in relatively airtight railroad cars, as indicated in the previous section. Modification of the atmosphere may also occur when asparagus is packaged in certain types of film bags or container liners. Since there is a trend toward both of these practices, there is a need for information on the effect of various degrees of atmosphere modification on the quality of asparagus.

Previous research on the holding of asparagus in modified atmospheres is generally not applicable here, because either the concentrations of carbon dioxide (CO_2) and oxygen (O_2) or the times of exposure were not comparable to those that may occur in shipping asparagus from western growing areas to eastern markets. Moreover, some of the reports give only CO_2 concentrations, making it impossible to determine whether or not the results are ascribable to high CO_2, low O_2 or both. Asparagus held in air slightly enriched in CO_2 and slightly lowered in O_2 has been reported to retain its color more satisfactorily and to show less decay than spears held in normal air (1, 4). Brooks and others (2) noted that flavor was affected adversely by exposure to 25 to 30 percent CO_2 for 48 hours or 40 percent CO_2 for 24 hours with unspecified O_2 concentrations.

Exposing asparagus for one day to O_2 concentrations below 2.8 percent at 68° F. resulted in the collapse of tissue in the zone of elongation (9). Thornton (10) reported injury to asparagus held in 50 percent CO_2 for 3 days, but no injury to spears held in 28 percent CO_2 for the same time at constant temperatures ranging from 32° to 59° F. No data were given for either O_2 concentration or for intermediate CO_2 concentrations.

Modified atmospheres, therefore, may cause serious injury to asparagus or may help retain its quality. The purpose of this study was to determine the quality effects of various modifications in the atmosphere under conditions simulating time and temperature during transit and marketing.

PROCEDURE

Sample preparation

Asparagus for the tests was cut near Porterville, Calif., on May 12 (Test 1) and on May 25 (Test 2), 1959, packed commercially, and hydrocooled to about 40° F. prior to transportation to the laboratory in Fresno. Samples were composited from the commercial lots on the day of harvest for the first test, but the asparagus from the second harvest was held overnight in a room at 37.5° before sample preparation.

After sorting out defective spears, the sound ones were cut to 7-inch lengths and placed in glass respiration jars. Sample size ranged from 2 to 5 kg. of asparagus or about 65 to 190 spears in the first test and from 130 to 300 spears in the second, depending upon the CO_2 and O_2 combination desired, the larger samples being needed for the greater modifications.

Holding conditions

Approximate concentrations of carbon dioxide and oxygen (CO_2/O_2) maintained during the holding period were: 0/21 (normal air), 5/15, 10/10, and 20/2 percent. However, in the second test 15/5 was substituted for 20/2 percent. Table 9 gives the actual concentrations,

TABLE 9.--Concentrations of carbon dioxide and oxygen in atmospheres surrounding asparagus spears during tests 1 and 2, 1959

Holding temperature and number of days from start	Test 1 (harvested May 12, 1959)						Test 2 (harvested May 25, 1959)					
	Desired Concentrations						Desired concentrations					
	5% CO_2-15% O_2		10% CO_2-10% O_2		20% CO_2-2% O_2		5% CO_2-15% O_2		10% CO_2-10% O_2		15% CO_2-5% O_2	
	Measured concentrations						Measured concentrations					
	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2
	Percent		*Percent*		*Percent*		*Percent*		*Percent*		*Percent*	
37.5° F.:												
1....................	5.0	16.0	8.0	11.5	19.0	0.5	3.5	17.0	8.5	8.5	11.0	0.5
2....................	4.0	16.5	9.0	10.0	22.5	0.5	4.5	16.0	10.5	8.5	13.5	3.0
2-1/4................	4.5	16.0	--	--	23.5	0.5	4.5	15.5	--	--	14.5	0.5
3....................	4.5	16.0	10.0	10.0	21.5	2.5	5.5	15.0	10.5	9.5	16.0	1.5
3-1/4................	5.0	15.0	--	--	--	--	--	--	--	--	--	--
4....................	5.5	14.5	9.0	11.0	17.5	3.0	5.0	15.0	11.5	8.0	16.5	3.0
5....................	5.5	15.0	9.0	9.5	19.0	1.5	--	--	--	--	--	--
6....................	5.0	14.5	10.5	7.5	21.0	1.5	5.0	15.0	8.5	12.0	13.5	6.5
6-1/4................	--	--	--	--	--	--	--	--	9.5	11.0	14.0	5.5
7....................	--	--	--	--	--	--	6.0	14.5	11.0	9.0	15.0	3.5
Average[1]..........	5.0	15.3	9.2	10.0	20.2	1.7	4.8	15.4	10.0	9.3	14.3	2.9
50° F.:												
1....................	2.5	18.5	5.0	16.0	13.0	4.0	2.5	17	7.0	12.0	13.0	--
1-1/3................	3.5	17.0	6.5	13.0	15.0	2.5	--	--	--	--	14.5	1.5
2....................	4.0	16.0	8.5	11.5	18.5	1.5	4.0	15.5	9.0	10.5	16.5	2.0
2-1/4................	4.0	16.0	--	--	--	--	4.5	15.0	8.5	10.5	18.0	2.0
3....................	4.5	15.5	7.5	11.5	19.5	1.0	5.0	15.0	10.0	8.5	16.5	3.5
3-1/3................	5.0	15.0	8.5	11.5	--	--	--	--	--	--	--	--
4....................	5.0	14.5	8.5	10.0	17.0	2.5	5.0	14.5	12.0	7.5	15.5	3.5
5....................	5.0	14.5	10.0	9.0	20.0	0.5	--	--	--	--	--	--
6....................	5.5	14.0	11.5	8.5	20.5	2.0	5.5	14.5	7.5	14.5	16.0	3.5
6-1/4................	--	--	--	--	--	--	--	--	8.5	11.0	--	--
7....................	--	--	--	--	--	--	5.5	15.0	11.5	7.5	16.0	3.5
Average[1]..........	4.6	15.3	18.5	10.8	18.3	1.7	4.7	15.1	9.4	10.1	15.8	3.0

[1] Average weighted for number of hours at a given concentration.

measured at intervals with an Orsat-type gas analyzer, except for 0/21. The latter atmosphere was maintained by an air flow sufficiently large to prevent modification. Initial concentrations of these gases were obtained by flushing the jars with the appropriate amounts of CO_2 and nitrogen. During holding, gas concentrations were regulated by adjusting the rate of air flow through the jars, taking advantage of the carbon dioxide produced and the oxygen used by the respiring asparagus.

One-half the samples for each atmosphere combination were held at 37.5° F. and the other half at 50°. These temperatures were chosen because the lower one is representative of acceptable transit temperatures and the higher one lies near the upper limit of temperature that might be encountered in transit.

The asparagus was held at each of the above temperatures for 6 days in test 1 and 7 days in test 2. Part of each lot was held an additional 2 days at 59° F. in normal atmosphere to simulate a wholesale-retail marketing period.

Measurement of quality criteria

Injury attributable to the modified atmospheres was rated on an arbitrary scale ranging from 1 (none, field fresh appearance) to 9 (severe, inedible), each spear being rated individually.

Decay was rated on the same scale as injury. A spear was given a 9 rating when decay had developed on 3/4 inch or more at the butt end or severe decay had developed at the tip.

The tenderness of the spears was determined only at the end of the second holding test and was measured with a fiberometer[3] (11). This instrument (fig. 2) is designed to test the degree of toughness of cooked asparagus by transverse application of a shearing force at points along the longitudinal axis of a spear. The instrument consists of a support with a receptacle to hold the spear and a standardized cutting device which is lowered upon it. The fiberometer used had a cutting wire of 0.79 mm. diameter and the cutting assembly weighed 1,440 grams, which is slightly heavier than the standard model used in industry. The distance between the vertical slots of the support was 13 mm.

Tenderness was measured by setting the weighted wire on the cooked spear, for not more than 5 seconds, in successive slots, starting at the tip end. The first segment not cut was recorded, as the length of the tender portion. While the edible portion was generally longer than the "tender portion" by an undetermined amount, the fiberometer did provide an objective criterion for evaluating tenderness.

Before testing in the fiberometer, spears from the various lots were cooked simultaneously in separate containers in an autoclave to insure uniformity of treatment. The autoclave was preheated and after the pressure had reached 10 p.s.i., it was turned off, reestablishing atmospheric pressure within 5 minutes.

Statistical analyses

The data relating to the incidence of soft rot and to the measurement of toughness were treated according to the statistical method given by Duncan (5).

[3] Loaned by the Western Research Laboratory of the National Canners Association.

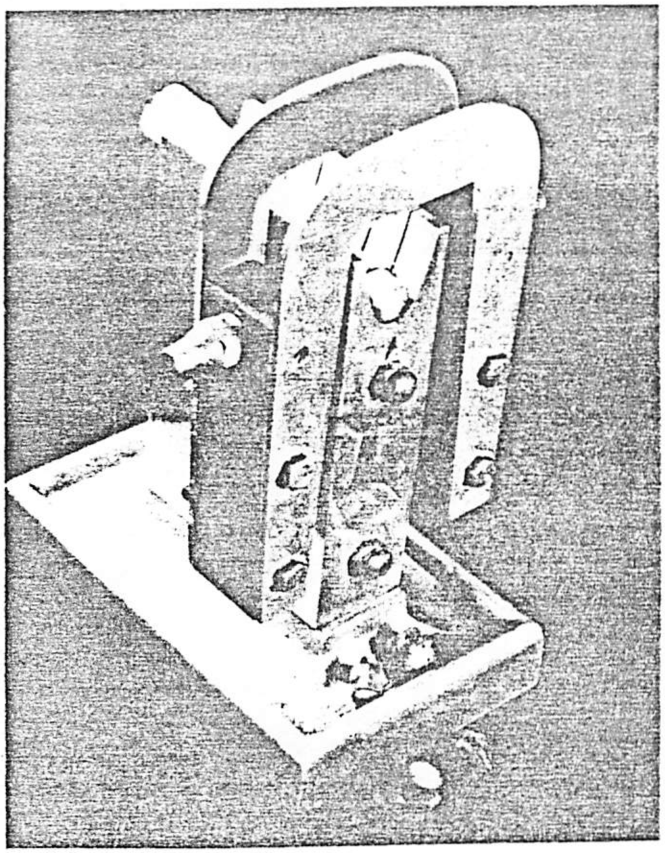

Figure 2.--Asparagus fiberometer. Note the spears supported in the channel of the base and the wire of the U-shaped cutting assembly resting on the spear.

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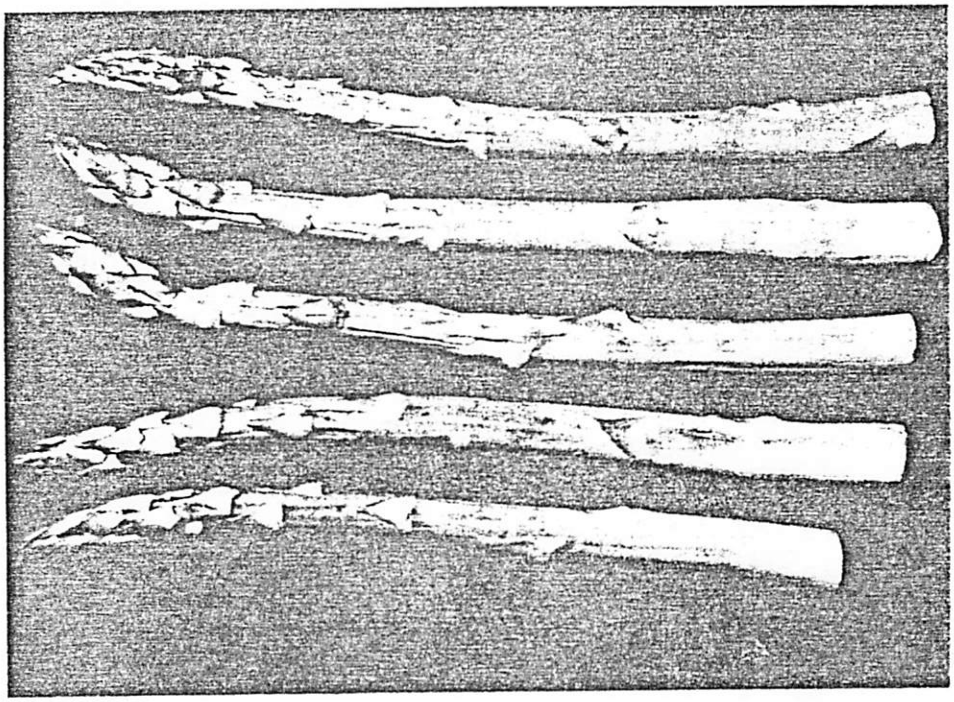

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Figure 3.--Spears injured by holding in an atmosphere of 15 percent CO_2 and 5 percent O_2 for 7 days at 50° F. Normal appearing spear at bottom.

RESULTS

Modified atmospheres in these tests were the result of concurrent increases in the concentrations of CO_2 and decreases in O_2 in respect to normal air. This is the usual type of modification that occurs when plant materials are held in relatively airtight enclosures such as certain refrigerator cars or plastic bags. The effects, therefore, cannot be attributed to either high CO_2 or low O_2, separately.

Injurious effects of modified atmospheres

Spears that were injured by certain of the modified atmospheres (fig. 3) resembled those described by Platenius (9). Longitudinal depressions, up to 2 inches in length, that developed in the central portion of the spears, were the most common type of injury. The spears looked wrinkled, and in severe cases had a crustlike, light brown surface. Other symptoms included small rectangular to circular shallow depressions, that usually were located in the zone of elongation, and pitlike depressions at the bases of some bracts. Softening of the tissue, as observed by Thornton (10) in spears held in 50 to 80 percent CO_2, was absent.

Injury was more prevalent in test 2 than in test 1, particularly at 50° F. This difference may be, at least partially, the result of holding the asparagus 1 day longer in the second test than in the first.

No injuries occurred at concentrations of 5 percent CO_2 and 15 percent O_2 at either 37.5 or 50° F. (table 10). In test 1, 9 percent CO_2 and 10 or 11 percent O_2 resulted in no injury or only traces of injury at either temperature, but in test 2 similar modifications caused traces of injury to a few spears at 37.5° and more serious injury at 50°. Modifications of atmosphere having more than 10 percent CO_2 or less than 10 percent O_2 were decidedly harmful at both temperatures, although a considerable number of individual spears escaped injury even at the most severe modification, 20 percent CO_2 and 2 percent O_2. Where injury did occur, the severity in individual spears and the number of spears affected increased as the degree of atmosphere modification increased.

Holding spears 2 days at 59° F. in normal atmosphere after the initial storage period did not change the appearance of the injury nor did it consistently result in an increase in the number of injured spears.

Effect of modified atmospheres on decay

Bacterial soft rot, one of the most serious market diseases of asparagus, affected fewer spears and was less severe when asparagus was held in modified atmospheres than when it was held in normal atmosphere (table 11).

The reduction in soft rot was not only evident after the holding periods at 37.5° and 50° F., but was still apparent after the additional 2 days at 59° in normal air. However, the occasional large reductions in soft rot obtained at the greatest modifications (20 or 18 percent CO_2 and 2 percent O_2 for test 1, and 14 or 16 percent CO_2 and 3 percent O_2 for test 2) are of no practical value, because the asparagus was injured at these atmospheres. Even at the intermediate modification (about 10 percent CO_2 and 10 percent O_2), advantages from decay reduction can be realized only at the temperatures generally recommended for asparagus, 40° or lower (7), without risking injury from the modifications. While atmosphere modification is not a substitute for low temperature as a means of controlling decay, it may be a promising adjunct. Modified atmospheres would be particularly useful in the shipment of all-green spears since such spears are not only more susceptible to soft rot at the cut ends than spears with tough, white surfaces (8), but any trimming would remove salable and edible portions of the spear.

TABLE 10.--Injury to asparagus spears held in specified temperatures and atmoshperes

Date of harvest, and days held at specified temperatures and atmospheres [1]	Injured spears in lot	Average severity of injured spears	Most severe injury in lot
<u>Test 1, harvested May 12, 1959</u>:			
Held at 37.5° F. 6 days			
Percent CO_2 — O_2	*Percent*	*Rating* [2]	*Rating* [2]
0 — 21	0	1.0	--
5 — 15	0	1.0	--
9 — 10	0	1.0	--
20 — 2	50	4.9	9
Held at 37.5° F. 6 days and at 59° 2 days			
Percent CO_2 — O_2			
0 — 21	0	1.0	--
5 — 15	0	1.0	--
9 — 10	0	1.0	--
20 — 2	51	4.2	9
Held at 50° F. 6 days			
Percent CO_2 — O_2			
0 — 21	0	1.0	--
5 — 15	0	1.0	--
9 — 11	2	3.0	3
18 — 2	16	3.2	5
Held at 50° F. 6 days and at 59° F. 2 days			
Percent CO_2 — O_2			
0 — 21	0	1.0	--
5 — 15	0	1.0	--
9 — 11	4	3.0	4
18 — 2	18	3.2	6
<u>Test 2, harvested May 25, 1959</u>:			
Held at 37.5° F. 7 days			
Percent CO_2 — O_2			
0 — 21	0	1.0	--
5 — 15	0	1.0	--
10 — 9	1	2.0	2
14 — 3	3	2.8	4

See footnotes at end of table.

TABLE 10.--Injury to asparagus spears held in specified temperatures and atmospheres--Continued

Date of harvest, and days held at specified temperatures and atmospheres [1]			Injured spears in lot	Average severity of injured spears	Most severe injury in lot
Test 2, harvested May 25, 1959--Continued					
Held at 37.5° F. 7 days and at 59° F. 2 days					
Percent	CO_2	O_2	*Percent*	*Rating* [2]	*Rating* [2]
	0	21	0	1.0	--
	5	15	0	1.0	--
	10	9	3	3.7	5
	14	3	1	3.0	4
Held at 50° F. 7 days					
Percent	CO_2	O_2			
	0	21	0	1.0	--
	5	15	0	1.0	--
	9	10	14	4.3	7
	16	3	49	6.5	9
Held at 50° F. 7 days and at 59° F. 2 days					
Percent	CO_2	O_2			
	0	21	0	1.0	--
	5	15	0	1.0	--
	9	10	5	4.0	9
	16	3	68	8.2	9

[1] Desired concentrations given; for actual concentrations see table 9.
[2] On a scale of 1 (no injury) to 9 (severe injury).

Soft rot was the only type of decay found in these modified atmosphere tests, but other observers have found that "mould" was reduced during 3 to 4 weeks of storage in atmospheres ranging from 5 percent CO_2 and 5 percent O_2 to 5 percent CO_2 and 15 percent O_2 at both 34 and 41° F. (1). Brooks and others (3) observed a reduction of Rhizopus rot of the tips of spears held in 25 percent CO_2 at 60°.

Effect of modified atmospheres on tenderness

More of the tender portions of asparagus spears remained after 7 days at 37.5° F. when the spears were held under modified atmospheres than when held in normal air (0 percent CO_2, 21 percent O_2). This effect was still apparent, although less uniformly, after an additional 2 days at 59° in normal air. The data at 50° are inconclusive, although significant differences do exist between treatments (fig. 4).

It has been shown previously (7) that some toughening of asparagus occurs even at 32° F. and that the rate and degree of toughening increases with increasing temperatures. If holding asparagus under modified atmospheres should prove to be practical, it could be expected that tenderness would be retained better than in normal air.

TABLE 11.--Effect of indicated modified atmospheres on development of soft rot in asparagus held at specified temperatures, Tests 1 and 2, 1959

Test number, portion of asparagus examined, and concentration of carbon dioxide and oxygen in atmosphere[1]	37.5° F. 6 days		37.5° F. 6 days plus 59° F. 2 days		50° F. 6 days		50° F. 6 days plus 59° F. 2 days	
	Rating[2]	Spears affected[3]	Rating[2]	Spears affected[3]	Rating[2]	Spears affected[3]	Rating[2]	Spears affected[3]
<u>Test 1 (harvested May 12)</u>:								
<u>Butts</u>:		*Percent*		*Percent*		*Percent*		*Percent*
0% CO_2 - 21% O_2	1.5 a	35	2.4 a	34	2.5 a	50	3.5 a	67
5 15	1.3 ab	24	2.0 ab	49	2.1 ab	63	2.2 ab	45
10 10	1.2 bc	21	1.6 bc	35	1.8 bc	[4] 51	1.9 b	[4] 41
20 2	1.0 c	[4] 0	1.3 c	[4] 22	1.4 c	[4] 34	1.4 b	[4] 21
<u>Tips</u>:								
0% CO_2 - 21% O_2	1.0	0	1.1	5	1.0	0	1.6 a	37
5 15	1.0	0	1.1	4	1.0	0	1.3 ab	14
10 10	1.0	0	1.0	2	1.0	[4] 0	1.1 b	[4] 7
20 2	1.0	[4] 0	1.0	[4] 0	1.0	[4] 0	1.0 b	[4] 0
<u>Test 2 (harvested May 25)</u>:	37.5° F. 7 days		37.5° F. 7 days plus 59° F. 2 days		50° F. 7 days		50° F. 7 days plus 59° F. 2 days	
<u>Butts</u>:								
0% CO_2 - 21% O_2	1.6 a	51	2.9 a	47	2.3 a	34	3.4 a	60
5 15	1.2 b	17	2.0 b	32	1.6 bc	23	2.4 b	47
10 10	1.1 bc	9	1.7 bc	25	2.0 ab	[4] 33	2.3 b	[4] 42
15 5	1.0 c	[4] 0	1.1 c	[4] 3	1.4 c	[4] 23	1.9 b	[4] 29
<u>Tips</u>:								
0% CO_2 - 21% O_2	1.1	5	1.4	12	1.5 a	11	4.2 a	63
5 15	1.0	0	1.5	15	1.1 b	4	2.9 bc	54
10 10	1.0	0	1.3	10	1.2 ab	[4] 5	3.6 ab	[4] 52
15 2	1.0	[4] 0	1.2	[4] 5	1.0 b	[4] 0	2.4 c	[4] 22

[1] Desired concentrations given; for actual concentrations see table 9.
[2] Soft rot rating on a scale of 1 (no decay) to 9 (decay on 3/4" or more at butt end or severe decay at tip). Any 2 ratings in a box followed by the same letter are not significantly different; any 2 ratings <u>not</u> followed by the same letter are significantly different at the 5% level. F ratios were not significant for treatments without letters.
[3] Not statistically treated since neither replicates nor subsamples available.
[4] Atmosphere causing injury.

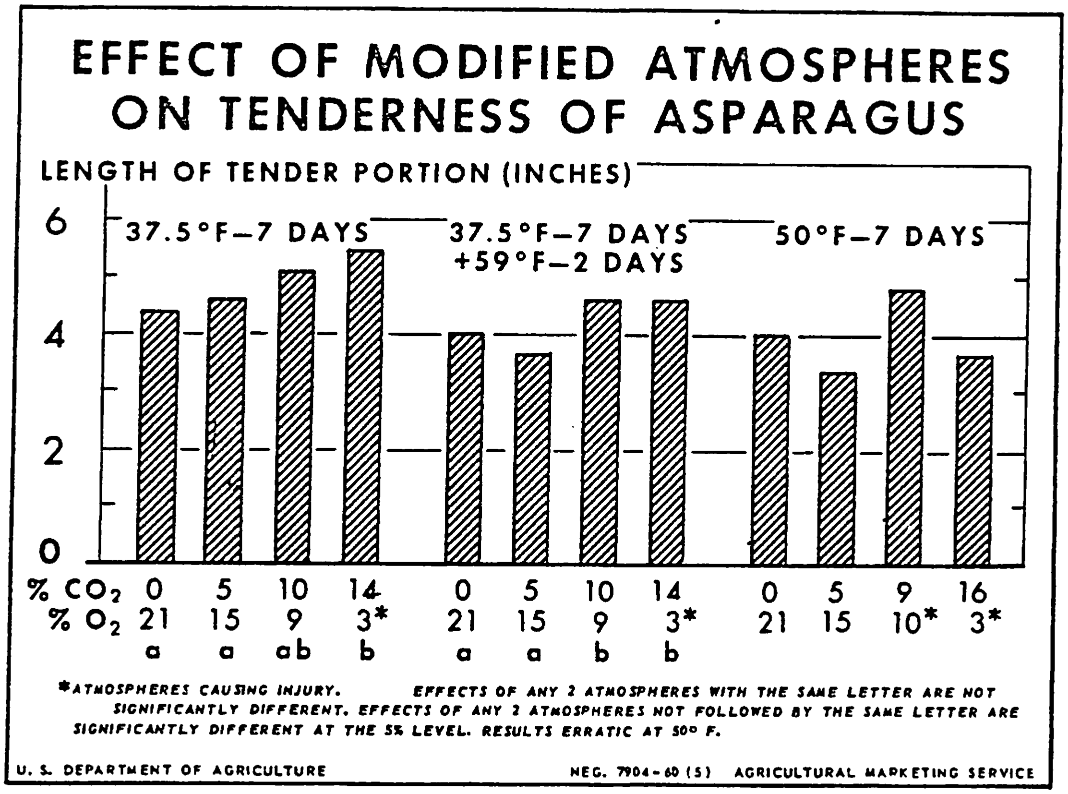

Figure 4.

The reasons for the erratic results at 50° F. are unknown, but it may be related to the unpredictable physiologic responses of asparagus at 50° (6). No data were collected for asparagus held 7 days at 50° and 2 days at 59° because the samples had deteriorated to such an extent that any results would be meaningless.

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