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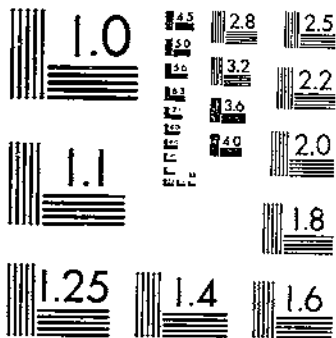
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BODY ICING IN TRANSIT REFRIGERATION OF VEGETABLES

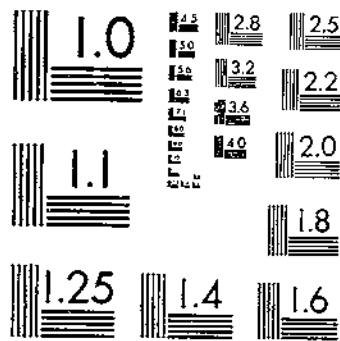
MALLISON, E. D. RENTZER, H. J.

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UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

BODY ICING IN TRANSIT REFRIGERATION
OF VEGETABLES

By E. D. MALLISON, *associate horticulturist*, and W. T. PENTZER, *physiologist*,
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INTRODUCTION

The refrigeration of certain vegetables in transit by body icing, that is, by placing ice in the car in direct contact with the lading, is a practice that has been followed for many years. Information as to who originated the practice or when it originated is lacking as little has been published on the subject. One of the earliest uses of body icing was apparently in the shipment of barreled beer. Fish has been shipped for many years with ice in the package or on top of the lading. This method has been used for a long time in the shipment of

¹Submitted for publication February 7, 1936.
²The experimental work prior to 1930 was under the direct supervision of Lon A. Hawkins, thereafter under the direction of D. F. Fisher. Other staff members who assisted in these tests were W. S. Graham, R. L. Newton, C. W. Mann, R. C. Wright, G. B. Ramsey, C. O. Bratley, J. S. Want, P. L. Harding, and C. E. Asbury, of the Division of Fruit and Vegetable Crops and Diseases, and W. V. Hukill, of the Bureau of Agricultural Engineering. Delbert Garman, of the Interstate Commerce Commission, accompanied each of the tests made prior to 1935 as an observer. A. F. Wahlstrom and E. A. Gorman made the drawings. The writers are indebted to R. C. Wright for the data on rate of cooling and sugar content of green corn. The generous cooperation of the Pacific Fruit Express Co., Santa Fe Refrigerator Department, Northern Pacific Refrigerator Department, Fruit Growers Express Co., American Refrigerator Transit Co., and the Atlantic Coast Line, the Chicago, Burlington & Quincy, the Denver & Rio Grande, the Erie, the Missouri Pacific, the Northern Pacific, the Pennsylvania, the Richmond, Fredericksburg & Potomac, the Seaboard Air Line, and the Wabash railroads, and the connecting lines over which the transportation tests were routed is acknowledged; also the cooperation of shippers at the various shipping points in forwarding shipments under various experimental methods of refrigeration. Special acknowledgment is made to the representatives of the railroads and refrigerator car lines who participated in these tests and rendered material assistance in the handling of the test cars en route. Without the cooperation and assistance of the agencies mentioned the investigation could not have been made.

DEPOSITORY

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spinach, particularly from certain regions where it was shipped in box-cars. The value of body icing in shipping spinach from Texas in refrigerator cars was made the subject of an investigation by the Department of Agriculture in 1921.³ In recent years the use of body ice has become quite common in shipping green peas, cabbage, green corn, bunch carrots, bunch beets, celery, cauliflower, radishes, lettuce, spinach, and other leafy vegetables that are not injured by being shipped wet. This method is employed in the western and southern parts of the United States, but it is not used to any considerable extent in the Middle Western or Northeastern States except when a long rail haul is necessary.

The refrigerator car is designed primarily to refrigerate commodities by means of ice in the bunkers or special compartments, which are provided with drains for eliminating water from the melting ice. Until after this investigation there was no provision made for removing the water from ice placed with the lading in the body of the car, or for waterproofing the floors. Since the completion of certain phases of the investigations in 1927 nearly all refrigerator cars have been equipped with waterproofed floors and an outlet has been provided for the water from the melted body ice.

The use of body icing brings up the question of the effect of the water from the melting ice on the insulation and floor of the car, as this occasionally amounts to several tons. Most insulation in common use, or available for use in refrigerator cars, will absorb water, but with such absorption its efficiency in retarding the flow of heat is greatly lowered. The effect on the wooden floor of the car is important, it being well known that wood when wet and exposed to the air will rot unless treated with some fungicidal material, and that it will deteriorate much more rapidly if kept moist than if kept dry.

At the instance of both shippers and carriers, a cooperative investigation by the Department of Agriculture and the Interstate Commerce Commission was undertaken in 1924 to determine (1), whether produce commonly shipped under body icing can be transported to market in good condition without body icing, or whether some form of body icing is necessary; (2), the effect of the water from melting body ice on the car; and (3), how damage to cars, if found resulting from body icing, can be prevented economically and effectively. No attempt was made to determine the value of body icing for all the commodities with which it is employed, the tests being limited to the more important ones. The work reported in this bulletin is confined to that on lettuce, cauliflower, and green corn.

A complete and detailed report⁴ was mimeographed and released at the close of certain phases of the investigation in 1927, but copies of this report are no longer available. The results relative to the effects of body icing on car structure were immediately transmitted to the carriers which instituted and have since largely completed necessary modifications in methods of insulating and waterproofing the car floors to permit body icing to be used satisfactorily. Details regarding these studies therefore are omitted from this bulletin as having served their purpose, but information relative to the use of body icing in the refrigeration of different vegetables in transit is still in demand. This

³ RIDLEY, V. W. HANDLING SPINACH FOR LONG-DISTANCE SHIPMENT. U. S. Dept. Agr. Farmers' Bul. 1189: 6. 1921. Out of print, but may be consulted in libraries.

⁴ HAWKINS, LON A., TAYLOR, G. F., MALLISON, E. D. INVESTIGATION ON THE BODY ICING OF VEGETABLES. U. S. Dept. Agr. p. 243, illus. 1927. [Mimeographed.]

portion of the report therefore is being placed in permanent form, together with results of certain other work along the same line done at a later date.

DEFINITION OF TERMS

Definitions of several technical terms, as used in this bulletin, follow:

"Package ice" is the ice placed in the package with produce; "top ice" is the ice placed over the top of the load; "body ice" is any ice placed with the load in the body of the car; "pigeonhole ice" is chunk ice placed in spaces left between packages in the load; "bunker ice" is the ice (usually in chunk form) placed in the bunkers of the car.

"Standard refrigeration" is the filling of the bunkers to capacity, generally prior to loading, and then refilling at all regular icing stations. These stations are generally spaced so that the cars are reiced at least once each 24 hours. "Initial icing" is filling the bunkers to capacity at shipping point and not reicing them in transit.

A "layer" is a horizontal section of the load, one package in height, and is numbered from the bottom of the car; a "row" is a vertical section of the load, running lengthwise of the car, one package in width, and is numbered from a side wall; a "stack" is a vertical section of the load, crosswise of the car, one package in length, and is numbered from a bulkhead. As used in this report the "bunker position" is in the stack next to either bunker bulkhead; the "quarter-length position" is in the stack midway between a bulkhead and the doorway, while the "doorway position" is in the stack between the doors. A "through load" is one in which the packages are continuous between the bulkheads, while a "divided load" has an open space between the doors and is braced with wooden timbers to prevent shifting of the packages.

EXPERIMENTAL PROCEDURE

The experimental work consisted of making observations on shipments of vegetables under various methods of refrigeration. In any particular test the shipments came from the same or nearby shipping points and all usually had the same destination. The time of loading and unloading was approximately the same for all cars. Two types of tests were made and are referred to as transportation tests and shipping tests. Transportation tests were those in which observers accompanied the cars and obtained a complete record of conditions in transit; shipping tests were those in which one or more cars were shipped from the same locality but were not accompanied by observers. In some of the latter, temperature records were obtained with thermographs placed in various parts of the load, generally within packages. In these tests no observations were made on ice melage or outside temperatures in transit.

The lading of test cars was carefully inspected for quality and condition at time of loading. When package ice was used in lettuce tests, the ice for 12 crates was weighed and the packages were loaded in the first, fourth, and eighth stacks, center row, one in each of the four layers. These crates were opened at destination and the unmelted ice was removed and weighed to determine the melage in transit. All other body ice was either weighed or carefully estimated when placed in the cars, and the unmelted portion was weighed when

the cars were unloaded at destination. In the transportation tests, the ice placed in the bunkers at each re-icing station was weighed by the observers and the amount of ice left in the bunkers at time of unloading was estimated, after first piking down the ice and measuring the distance between the top of the ice and the top of the bunker.

In the transportation tests, electrical resistance thermometers were used to obtain commodity and air temperatures within the car. The sensitive part or bulb of the instrument was inserted into a vegetable or hung in the air at desired locations in the car. Leads from these bulbs were connected to a master cable, which was carried out of the car through a thin door plate placed at the top of the doorway and thence to the running board on top of the car (fig. 1). Readings were made by connecting the end of the master cable to an indicator or reading box equipped with a suitable selector switch by which the electrical resistance of each of the 12 bulbs can be determined. The indicator box is a modified Wheatstone bridge utilizing a sensitive galvanometer. Changes in the temperature of the bulb produce a corresponding change in the resistance of the coil in the bulb, which the indicator shows directly in degrees Fahrenheit. By using this equipment temperature readings were obtained at a number of places within the car without opening the doors. In the tests under discussion, readings were obtained at intervals of 4 to 6 hours. Outside air temperatures were obtained at the same time with a mercury thermometer.

An effort was made to have comparable cars in each test, with the exception of two tests in which new cars were intentionally tested against old ones. Generally the cars used were 1 to 4 years old and had $1\frac{1}{2}$ to 2 inches of insulation in the ends and side walls, and 2 to $2\frac{1}{2}$ inches in the floor and roof. The old cars were 7 to 8 years old and had about the same thickness and kind of insulation.

The average temperatures of the various layers as given in this bulletin are averages of the three commodity temperatures in each layer for each time the readings were taken. There was very little temperature variation between the different positions in each layer.

LETTUCE

Lettuce is the most important of the vegetables shipped under body icing, in respect to tonnage, and is grown commercially in 24 or more of the States. The New York variety grown in the Western States, where body icing of vegetables is most common, is also known as Mountain Iceberg, Los Angeles, and Los Angeles Market, but is most commonly called "Iceberg." Lettuce is shipped throughout the year from the Pacific Coast or the Rocky Mountain States. Table 1 shows the average number of carlot shipments of lettuce by months, 1927-36, from each of the four most important lettuce-producing States where body icing is utilized.

PACKAGE

Head lettuce from the Western States is generally packed in crates, of which two sizes were in common use at the time of this investigation; one is 13 by 18 by $21\frac{1}{2}$ inches inside dimensions, and the other is 13 by 18 by $23\frac{1}{2}$ inches inside dimensions. Besides these there are a number of other crates having slightly different dimensions.

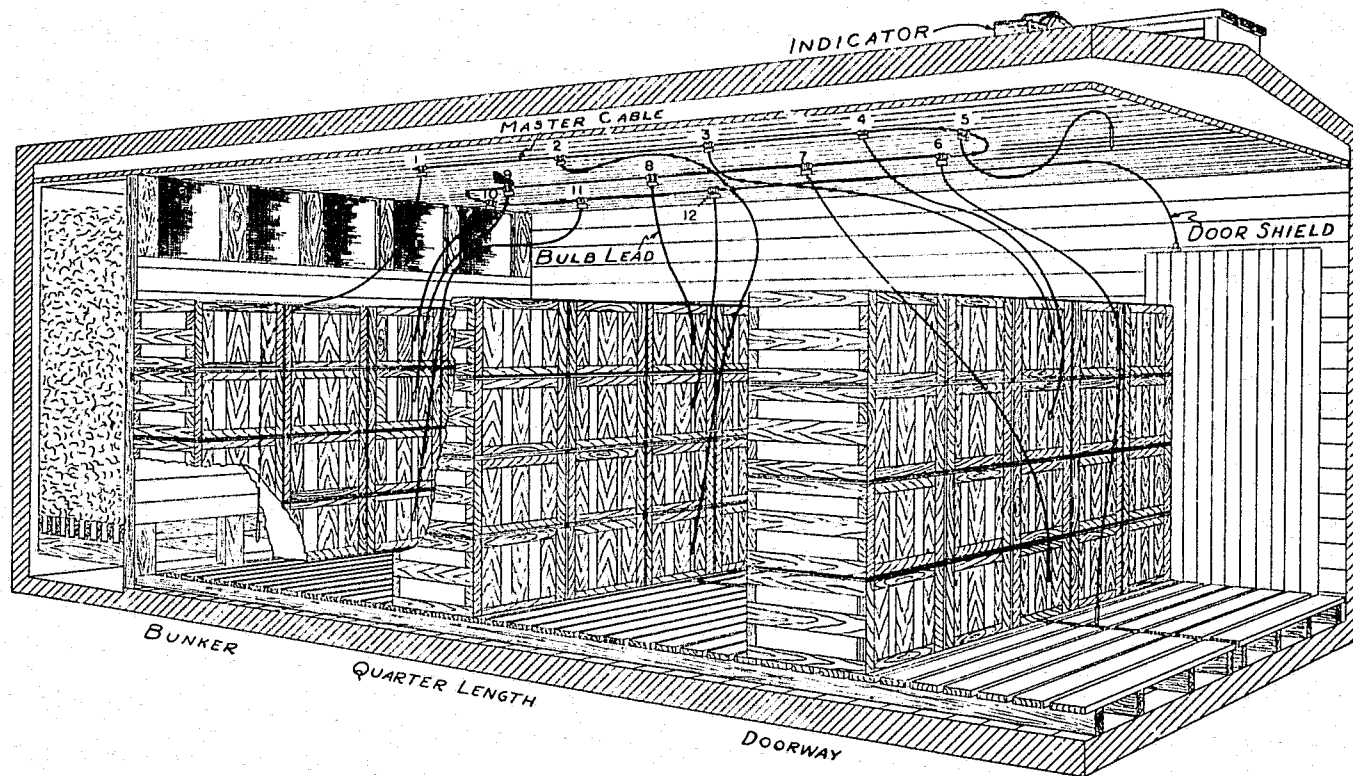


FIGURE 1.—Sketch showing electrical resistance thermometers installed in a refrigerator car loaded with lettuce.

TABLE 1.—Average number of carlot shipments of lettuce by months (1927-36) from each of the 4 principal western lettuce-shipping States

State	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Arizona.....	1,278	363	2,062	2,463	7						132	2,354
California.....	3,163	4,185	2,455	2,586	4,213	1,869	2,260	2,207	2,430	3,282	3,272	1,528
Colorado.....						60	105	576	440	44		
Washington.....					142	537	420	132	24	42	64	4

In packing, the crates are first lined with heavy waterproofed paper, and the heads of lettuce with the butts up are then packed in layers (fig. 2, *B*). Crushed ice is placed between the first and second and

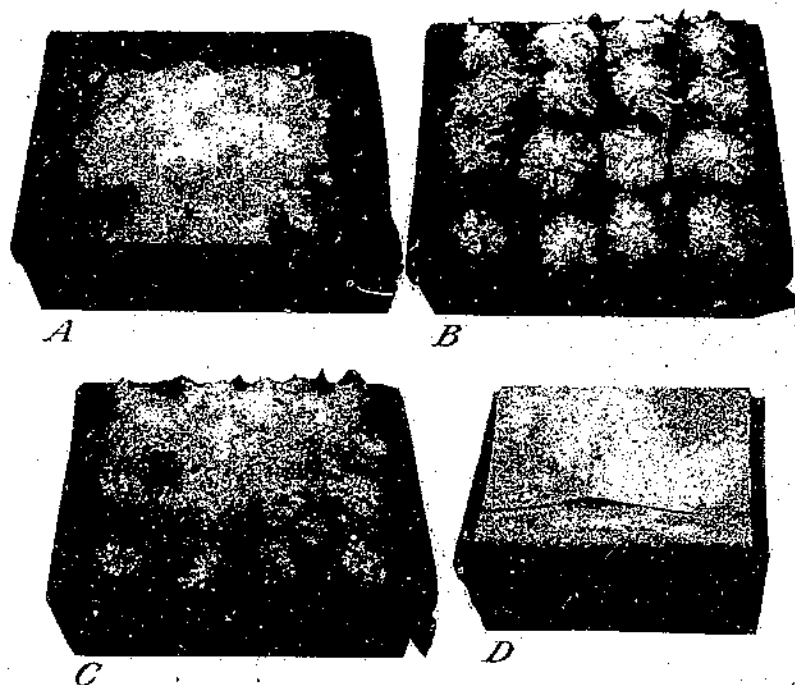


FIGURE 2.—Method of packing lettuce: *A*, Middle layer covered with ice; *B*, top layer before icing; *C*, top layer covered with ice; *D*, packing completed, paper liner folded over and ready for lidding.

between the second and third layers (fig. 2, *A*), and generally a few pounds of ice are placed on the top layer (fig. 2, *C*) before the paper liner is folded over the top of the lettuce (fig. 2, *D*). In either case, when properly applied, all the lettuce is in contact with ice. This method of packing is used almost exclusively for head lettuce from the producing districts of California, Oregon, Washington, Colorado, Idaho, Arizona, New Mexico, and Texas.

LOAD

The packages are ordinarily loaded in a through load 4 layers high, 5 rows wide, and 16 stacks long, except in cars that are not long enough to accommodate 16 stacks, or when irregular sized crates are used, or when they are loaded only 4 rows wide in the 2 stacks between the doors in order to leave room for additional ice.

The ice for top icing may be either crushed or in chunk form. In the latter case the ice is placed on top of the load during the loading of the car. If crushed ice is used it is blown over the top of the load by mechanical means after loading is completed. The amount of top ice used is generally between 5,000 and 15,000 pounds, varying largely with the season of the year and the producing area. The method of loading and icing shown in figure 3, *A*, was used in the tests from 1924-27, and was common commercial practice at that time. In the 1935 and 1936 tests the three bottom layers of crates were loaded on their sides (fig. 3, *B*) and the top layer was placed with the bulge up, and crushed ice was blown over the top of the load according to the present commercial practice. The high bulge of this type of package (fig. 4) requires that the bottom-layer crates be loaded on their sides.

PRECOOLING

The effects of precooling were studied in some of the tests. The lettuce loaded in two of the test cars from Sumner, Wash., was pre-cooled by placing the heads in a cold-storage room for a few hours prior to packing, until the temperature of the lettuce was between 40° and 45° F. The heads were then removed and packed.

A different type of precooling was studied in the 1936 tests from Salinas, Calif. The precooling equipment used consisted of fans set in frames fitted with plates, which covered the top bunker opening. The fans were eight-bladed, 18 inches in diameter, and each was connected directly to a small electric motor. One fan was installed in each end of the car before loading and was removed at the end of the precooling period of 4½ to 7 hours. This type of equipment cools the commodity by circulating cold air from the top bunker opening through the load, returning the air to the bunkers through the bottom bunker opening. The ice in the bunker removes the heat which the air has taken from the commodity. Salt was added to the ice to give a low-temperature ice-salt mixture, which will more quickly cool the air passing through the bunker, thus increasing the rate of cooling the load.

REFRIGERATION

Most of the shipments made during the winter, late fall, and spring months have top ice, in addition to the package ice. During the remainder of the year initial icing or standard refrigeration is used in addition to the body icing. Since about 1932 crushed ice blown over the top of the load has largely superseded chunk ice for top icing.

LOCATION OF THERMOMETERS

Electrical resistance thermometers, previously described, were placed in the first-, third-, and fourth-layer crates in the center row in the first, fourth, and eighth stacks, or at the bunker, doorway, and quarter-length positions, as shown in figure 1. Air temperatures were obtained at the bottom bulkhead opening, at the doorway near the floor, and about 6 inches below the ceiling.

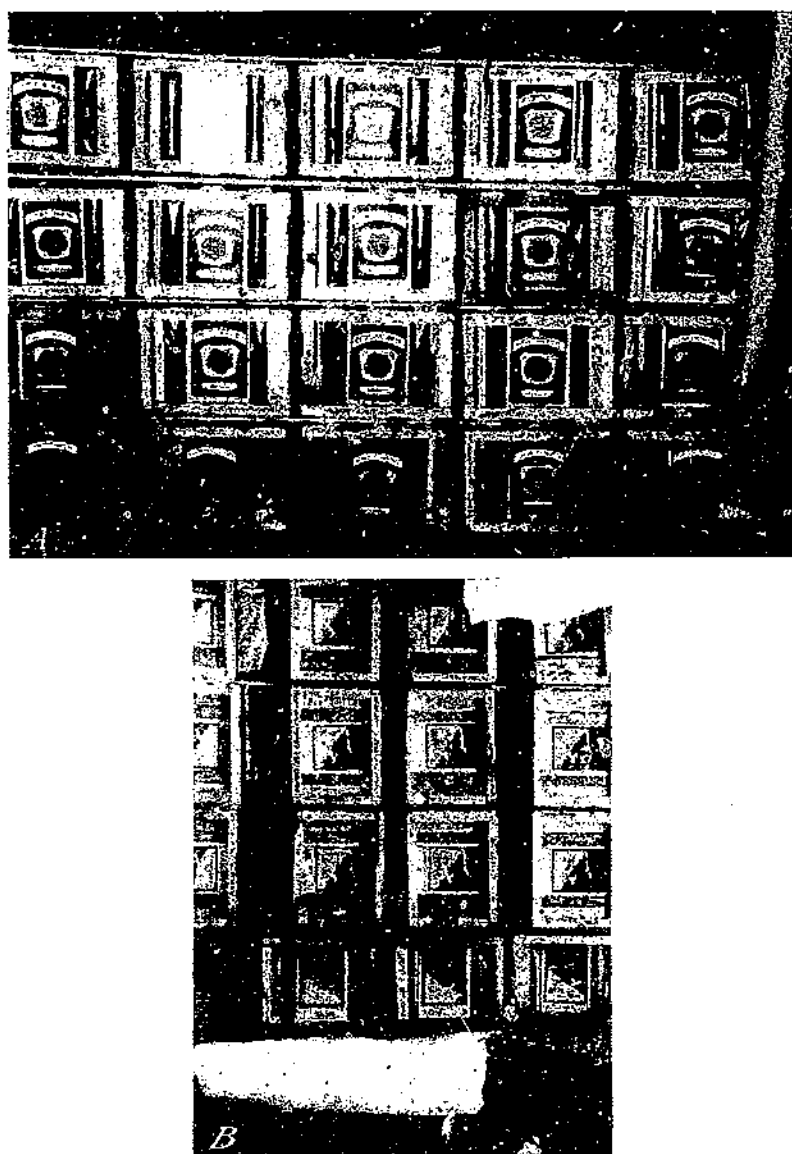


FIGURE 3.—Cross section of two carloads of lettuce, showing arrangement of commercial load: *A*, Method used during the time of the 1924-27 tests; *B*, method used during the 1935-36 tests. This car was shipped in June and shows the crushed ice remaining at time of unloading.

EXPERIMENTAL WORK AND RESULTS

The experimental work with lettuce comprised observations on 9 transportation tests with a total of 34 cars, and 15 shipping tests with a total of 30 cars. The shipping tests consisted of paired cars, one with top ice and the other without. The transportation tests also contained comparable cars shipped with and without top ice. In

[Correction for Technical Bulletin 627, U. S. Department of Agriculture]

The following illustration should be substituted for that shown as figure 3, on page 8.

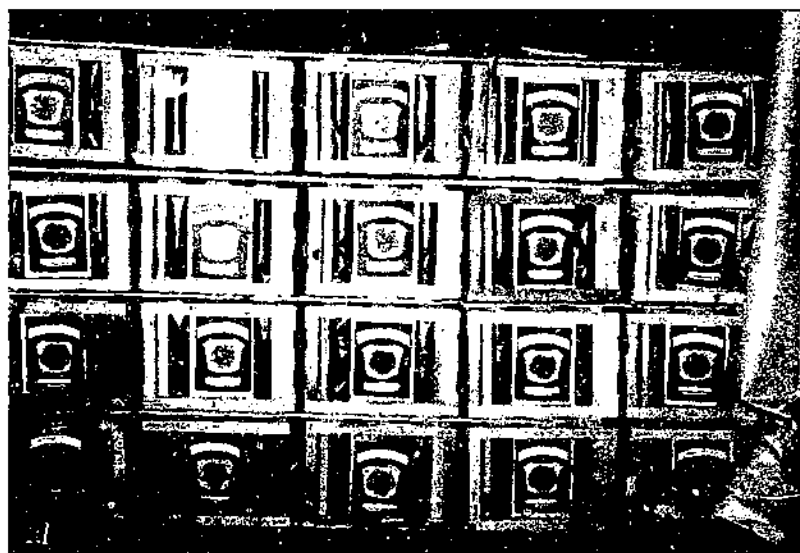


FIGURE 3. Cross section of two carloads of lettuce showing arrangement of commercial load: *A*, Method used during the time of the 1924-27 tests; *B*, method used during the 1935-36 tests. This car was shipped in June and shows the crushed ice remaining at time of unloading.

addition, cars were included to determine (1) whether lettuce could be safely shipped without body ice under standard refrigeration, (2) the effect of age of refrigerator cars on their efficiency, (3) the temperatures in transit of cars shipped with crushed top ice versus chunk top ice, and (4) information on the precooling of lettuce after loading, and its effect on subsequent transit temperatures and ice meltage.

The tests were all from Western States, 42 cars being from various parts of California, 3 from Washington, 13 from Arizona, and 6 from Colorado. Most of these test cars were unloaded in New York City,

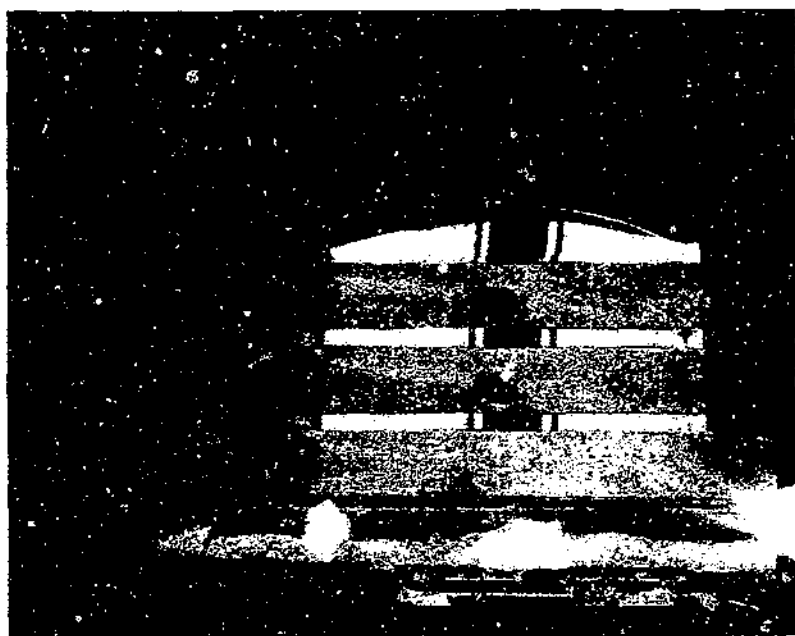


FIGURE 4.--Crate of lettuce showing a 3 $\frac{3}{4}$ -inch bulge at time of unloading in Washington, D. C., May 1937.

Philadelphia, Pittsburgh, and Chicago. The lettuce was in the cars from 8 to 15 days, mostly 10 to 11 days. As the season is the most important factor in determining the amount of refrigeration necessary for the safe carriage of lettuce the tests from the Western States will be considered in three sections; namely, those made during the winter months (December, January, and February), those in the summer (June, July, and August), and those during the fall and spring when temperatures are moderate.

TESTS DURING WINTER MONTHS

Two transportation tests consisting of five cars each were made from Phoenix, Ariz., and Brawley, Calif., to New York City, during January and February 1926. Each test consisted of shipments with and without top ice in 8-year-old and 1-year-old refrigerator cars. Included with each test was one extra car that did not receive body ice but was shipped under standard refrigeration.

INSPECTION OF LETTUCE

A record of the condition of the lettuce at time of loading is given in table 2, as is also the average percentage of heads that showed decay at destination after being in transit 10 or 11 days under various methods of refrigeration. The data indicate that when package ice is used it is immaterial whether top ice or bunker ice is used for additional refrigeration. In each of the two tests one car was shipped under standard refrigeration without body ice. One of these cars arrived in good condition while the other showed much decay, mostly slimy soft rot (bacterial soft rot), which is believed to have been due to the higher outside temperature that prevailed during this test.

TABLE 2.—Record of inspections of lettuce shipped in test cars during January and February 1928 from Arizona and California to New York City, and percentage of decay after 10 or 11 days in refrigerator cars under various methods of refrigeration

PACKAGE ICE—TOP ICE

Test		Condition ¹ of lettuce heads at time of loading			Heads showing decay at destination	Test		Condition ¹ of lettuce heads at time of loading			Heads showing decay at destination
No.	Car	Average temperature when packed	Solid to firm	Soft		No.	Car	Average temperature when packed	Solid to firm	Soft	
		° F.	Percent	Percent	Percent			° F.	Percent	Percent	Percent
6	J	45.6	96	4	0	7	JJ	53.6	93	2 10	0.5
	J-1	43.1	95	5	0		J	54.3	90	2 10	.6

PACKAGE ICE—INITIAL ICING

6	H	48.1	90	10	0	7	HH	41.3	90	2 10	0
	H-1	52.1	95	4	0		H	53.7	90	2 10	.5

STANDARD REFRIGERATION ONLY

6	E	52.3	95	5	0	7	E	63.0	91	2 10	(4)
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¹ No lettuce showed tipburn or decay.

² Includes 4 percent burst heads.

³ No paper in crates; all others lined with waterproofed paper.

⁴ Much decay.

RATE OF COOLING

The rate of cooling in cars shipped with (1) package ice and top ice, (2) standard refrigeration (no body ice), and (3) package ice with initial icing is shown in table 3. It is evident that the top layers cooled more rapidly in the top-iced cars than in those without top ice, while the rate of cooling in the bottom layers of these cars was about the same. There was not much difference in the average temperature of the load resulting from the two methods of supplemental icing. On the other hand, standard refrigeration without package ice resulted in much slower cooling and higher average temperatures than where body ice was used. In the cars under

standard refrigeration which had no body ice, the slow cooling of all the lettuce except that near the bottom bunker opening indicates the need of having the ice in direct contact with the commodity. This is also shown in figure 5, which presents the average temperatures in transit of lettuce in cars under the three methods of refrigeration, in test 7 from Brawley to New York City. In this figure average temperatures are shown because all the temperatures obtained in each layer were nearly the same. Similar results were also obtained in a duplicate test from Phoenix to New York City. The rate of cooling in the car without body ice was more rapid in the end of the car where the load was four rows wide than in the opposite end where it was five rows wide.

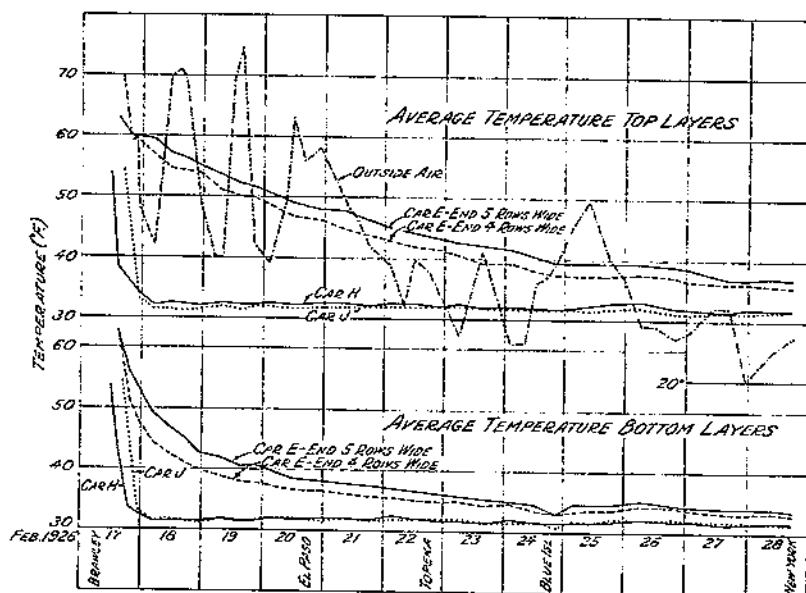


FIGURE 5.—Outside air temperature and average temperature of top and bottom layers of lettuce in transit under the following conditions: Car H, package ice and bunker ice; car J, package ice and top ice; and car E, standard refrigeration (one end four rows wide and the opposite end five rows wide).

INFLUENCE OF OUTSIDE TEMPERATURES

The influence of fluctuating outside temperatures on lettuce temperatures shipped with top ice was very slight. A 25° to 30° F. rise in outside temperature generally caused a rise of 5° in the temperature of the air in the car near the ceiling at the doorway, but practically no change in the air temperature at the bottom doorway or in the commodity temperature in any part of the load. However, when the outside temperature dropped to a minimum of 5° F. on two nights during the test from Arizona in January 1926, there was freezing in all of the test cars. Because of the rapid cooling obtained by the use of body icing the temperature of the lettuce in these cars was already comparatively low, and these shipments, therefore,

suffered greater damage from freezing than those shipped without body ice. Freezing in cars without body ice was largely confined to the bottom layer with some slight freezing along the sides of the load. However, freezing in the body-iced cars was found in both the top and bottom layers, also along the sides of the load and next the bunker bulkheads. In the bottom layer of such cars entire crates of lettuce were found frozen solid, while in the top layer the freezing damage was slight and confined to the outer leaves. It appears therefore that during severe cold weather the presence of ice in the body of the car increases the hazard of freezing.

TABLE 3.—Time necessary for lettuce to reach 40° and 32° F. after loading; maximum, minimum, and average outside temperatures and lettuce temperatures in the top and bottom layers of cars shipped from Arizona and California to New York City under various methods of refrigeration during January and February 1926

PACKAGE ICE—TOP ICE

Test	Car	Time required for lettuce to reach—				Temperatures								
		40° F.		32° F.		Outside			Top layer			Bottom layer		
No.		Top layer	Bottom layer	Top layer	Bottom layer	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
		Hours	Hours	Hours	Hours	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
6	J	2.0	0.5	12	4	55	5	30.1	46	31	31.5	46	31	31.7
	J-1	.5	.5	16	24	55	5	30.1	48	31	31.9	43	31	32.1
7	JJ	3.0	2.0	24	18	75	20	41.2	53	31	32.5	53	31	32.0
	J	2.5	2.0	12	12	75	20	41.2	54	31	32.0	54	31	32.2

PACKAGE ICE—INITIAL ICING

		Hours	Hours	Hours	Hours	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
6	II	2.0	1.0	20	11	55	5	30.1	48	32	32.5	48	31	32.4
	II-1	2.0	2.0	24	23	55	5	30.1	53	32	32.2	53	31	31.8
7	III	3.5	3.0	(1)	15	75	20	41.2	45	32	33.1	45	31	32.2
	II	3.0	3.0	18	12	75	20	41.2	53	31	32.7	53	31.5	32.1

STANDARD REFRIGERATION ONLY

		Hours	Hours	Hours	Hours	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
6	E	106.0	31.0	(1)	110	55	5	30.1	63	31	40.0	53	30.5	34.4
7	E	167.0	56.0	(1)	(1)	75	20	41.2	63	37	45.2	63	33	35.6

¹ Lettuce did not cool to 32° F. during trip.

ICE MELTAGE

There was not a great deal of difference in the total ice meltage in the body-iced cars (table 4), the meltage being only slightly greater in the cars without top ice despite the fact that an average of 5,227 pounds more ice was placed in them than in those with top ice. The results indicated that lettuce with package ice can be shipped without ice on top of the load during the winter months if initial bunker icing is provided. However, they also indicated that the combination of package ice and top ice is more economical than package ice and initial icing because of the saving of an average of over 5,000 pounds of ice per car.

TABLE 4.—Record of ice supplied and melted in cars of lettuce shipped from Arizona and California to New York City during January and February 1926 under various methods of refrigeration

PACKAGE ICE—TOP ICE

Test		Package (average) ¹			Top			Bunker			Total		
No.	Car	Supplied	Melted		Supplied	Melted		Supplied	Melted		Supplied	Melted	
		Lb.	Lb.	Pct.	Lb.	Lb.	Pct.	Lb.	Lb.	Pct.	Lb.	Lb.	Pct.
6.	J.	30	10.5	35.0	4,848	785	16.19	0	0	0	14,448	4,115	28.09
6.	J-1	30	11.2	37.3	4,848	1,061	21.89	0	0	0	14,448	4,645	32.15
7.	JJ	30	15.8	52.0	6,000	2,075	34.58	0	0	0	15,600	7,131	45.71
7.	J	30	17.9	59.6	6,096	1,662	27.26	0	0	0	16,696	7,390	47.08
Average		30	13.85	46.2	5,448	1,396	25.62	0	0	0	15,048	5,828	38.73

PACKAGE ICE—INITIALLY ICED, NOT RE-ICED

No.	Car	Supplied	Melted		Supplied	Melted		Supplied	Melted		Supplied	Melted	
		Lb.	Lb.	Pct.	Lb.	Lb.	Pct.	Lb.	Lb.	Pct.	Lb.	Lb.	Pct.
6.	II.	30	10.8	36.0	0	0	0	11,000	2,750	25.0	20,000	6,206	30.13
6.	II-1	30	11.0	36.6	0	0	0	10,500	1,312	12.5	20,100	4,832	24.04
7.	III	30	20.1	67.0	0	0	0	10,600	400	3.8	20,200	6,832	33.82
7.	II	30	21.6	72.0	0	0	0	10,800	400	3.8	20,200	7,312	36.20
Average		30	15.9	53.0	0	0	0	10,675	1,215	11.38	20,275	6,295	31.05

STANDARD REFRIGERATION ONLY

No.	Car	Supplied	Melted		Supplied	Melted		Supplied	Melted		Supplied	Melted	
		Lb.	Lb.	Pct.	Lb.	Lb.	Pct.	Lb.	Lb.	Pct.	Lb.	Lb.	Pct.
6.	E.	0	0	0	0	0	0	14,235	3,735	26.25	14,235	3,735	26.25
7.	E	0	0	0	0	0	0	15,898	5,298	33.32	15,898	5,298	33.32
Average		0	0	0	0	0	0	15,068	4,515	29.98	15,068	4,518	29.98

¹ The cars contained 320 crates per car, except car E which had 288 crates.

The average amount of ice placed in the two cars shipped under standard refrigeration was about the same as that placed in the top-iced cars, but the meltage in the former was materially less and the average lettuce temperatures maintained were correspondingly higher (fig. 5).

TESTS DURING SUMMER MONTHS

Two transportation tests were made from Sumner, Wash., and Minturn, Colo., to Chicago, Ill., during July and August 1925, and one test from Salinas, Calif., to Chicago, Ill., Philadelphia, Pa., and New York City in August 1926. A total of seven shipping tests was made during September 1926 and July 1927, from the Watsonville and Salinas, Calif., districts to New York City, Philadelphia, Pa., and Chicago, Ill. These tests comprised a total of 27 cars.

INSPECTION OF LETTUCE

A record of the condition of the lettuce at time of loading and upon unloading at destination 8 to 15 days later is shown in table 5. In general this lettuce did not have the same quality and condition as that used in the winter tests, it being more affected with tipburn at the time of shipment; in several cars it also showed early stages of slimy soft rot. In each test the lettuce was comparable at time of shipment. The inspection data show that the use of top ice had a noticeable effect on the amount of decay found at destination, the

TABLE 5.—Record of inspections of lettuce shipped in test cars during July, August, and September from California, Colorado, and Washington to eastern markets, showing number of days lettuce was in cars and percentage of decay in cars with and without top ice ¹

PACKAGE ICE—BUNKER ICE—NO TOP ICE								
Test		Condition of lettuce at time of loading				Time in car	Heads showing decay at destination	
No.	Car	Temperature when packed	Heads					
			Solid to firm	Soft	Showing tipburn	Showing decay		
		° F.	Percent	Percent	Percent	Percent ?	Days	Percent
2	A	68.8	60	40	8	0	9	3.2
2	B	40.5	85	15	7	0	8	3.0
3	A	59.0	100	0	2	0	8	3.9
17	A	75	25	2	2	3	12	2.9
18	A	90	10	2	2	0	12	8.2
19	A	65.4	90	10	4	0	12	3.5
20	A	60.0	96	4	4	1	13	2.1
21	A	65.0	90	10	8	4	13	3.2
22	A	61.0	95	5	25	2	13	10.5
23	A	61.0	95	5	20	T	10	2.9

PACKAGE ICE BUNKER ICE—TOP ICE								
2	C	45.2	83	17	3	0	8	.0
3	D	64.0	100	0	2	0	9	1.7
17	B	75	25	2	2	3	12	2.9
18	B	90	10	2	2	0	13	4.8
19	B	66.0	90	10	8	T	12	1.1
20	B	59.0	96	4	4	T	15	1.3
21	B	65.0	95	5	4	T	14	2.3
22	B	61.0	95	5	25	2	13	3.7
23	B	61.0	95	5	20	T	10	1.0

¹ In addition to the tests listed, there was 1 in 1936 consisting of cars with pre-cooled and nonpre-cooled loads, and nonpre-cooled loads with and without bunker ice. In general, the condition of the lettuce on arrival, aside from bruising, was about the same as when shipped. Decay, tipburn, and slimy soft rot were negligible.

² T=trace.

decay being generally heaviest where no top ice was used. An examination of the lettuce shipped in the 1936 test showed no difference between that which had been pre-cooled and that which had not, nor between the nonpre-cooled loads shipped with and those shipped without bunker ice.

RATE OF COOLING

Top-iced cars maintained lower temperatures in the top layer in transit than comparable cars that were not top-iced, while in the bottom layers the temperatures were about the same (table 6 and fig. 6). From these records on summer shipments it is clearly indicated that top ice must be used in addition to package ice and standard refrigeration if top-layer temperatures are to be kept uniformly low during the transit period.

In general, the results of the summer tests showed that the 30 pounds of package ice and standard refrigeration, even with salt added to the bunker ice, cannot be depended upon under all conditions to maintain the low temperatures necessary for long-distance shipment of head lettuce. The addition of top ice to the lading during these months is essential. The effectiveness of the top ice was demonstrated

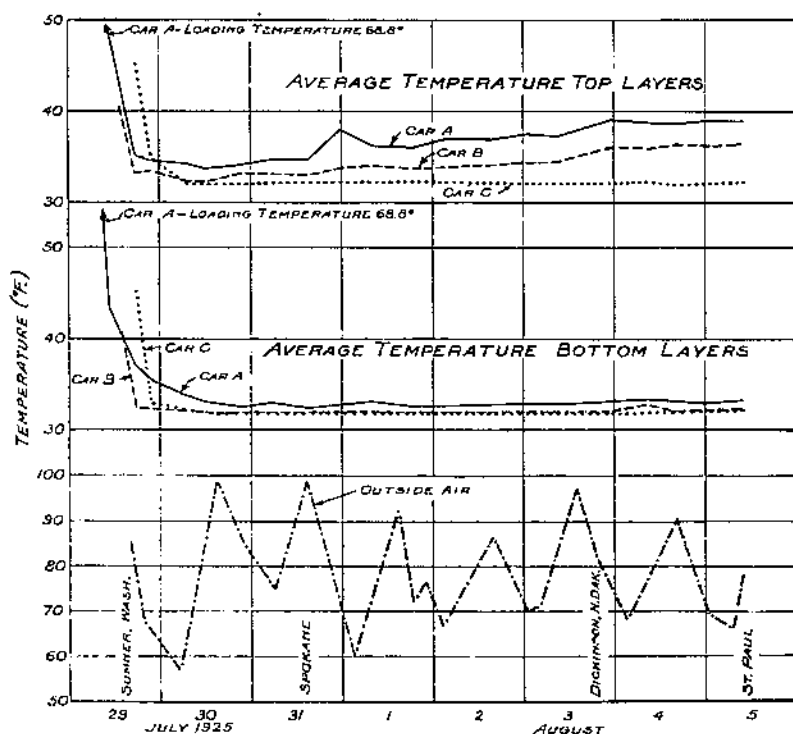


FIGURE 6.—Outside air temperature and average temperature of top and bottom layers of lettuce in transit under the following conditions: Car A, standard refrigeration, package ice; car B, standard refrigeration, package ice, lettuce precooled; car C, standard refrigeration, package ice, top ice, lettuce precooled.

TABLE 6.—Time necessary for lettuce to reach 40° and 32° F. after loading; maximum, minimum, and average outside temperatures and lettuce temperatures in top and bottom layers of cars shipped from Washington and Colorado to eastern markets with and without top ice during July, August, and September 1925

PACKAGE ICE—STANDARD REFRIGERATION

Test	No.	Car	Time required for lettuce to reach				Temperatures								
			40° F.		32° F.		Outside			Top layer			Bottom layer		
			Top layer	Bottom layer	Top layer	Bottom layer	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
			Hours	Hours	Hours	Hours	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
2		A	4	3.0	0	0	98	57	76.0	68	34	37.3	68	33	33.7
3		B	1	.5	1	8	98	57	75.0	41	34	34.3	41	32	32.2
3		A	6	5.0	1	1	103	55	75.5	50	34	37.1	59	33	34.4

PACKAGE ICE—STANDARD REFRIGERATION—TOP ICE

Test	No.	Car	Top layer	Bottom layer	Top layer	Bottom layer	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
2		C	2	1.5	0	7	98	57	76.0	45	32	32.3	45	32	32.3
3		D	3	3.0	33	32	103	55	75.5	64	32	32.9	64	32	32.9

¹ Lettuce temperature did not reach 32° F. during test.

² Lettuce precooled prior to loading.

in the August 1936 test in which lettuce with package ice was shipped without bunker ice but with 15,000 pounds of crushed top ice. This lettuce arrived at distance destination in as good condition as that shipped with bunker ice in addition and the transit temperatures in the two loads were about the same.

PRECOOLING

The lettuce loaded in two of the cars in the transportation test from Sumner, Wash., was precooled to an average temperature before loading of 41° F. in one car and 45° in the other. It is shown in figure 6 that the temperature of the lettuce in the top layer of the precooled loads was lower throughout the trip than in the nonprecooled loads. Of the two cars with no top ice only the one loaded with precooled lettuce reached a temperature of 32° in transit. The lowest temperatures in transit were obtained in the car loaded with precooled lettuce and top ice.

In the 1936 test from Salinas, Calif., the lettuce was precooled after loading with portable electrically driven fans placed at the top bunker opening. Package ice was used with both the precooled and nonprecooled loads. During the precooling period faster cooling was obtained in the precooled cars than in the nonprecooled loads without the use of fans; however, at no time was there more than 5° difference between the average temperature of the precooled and nonprecooled lettuce. Within 15 to 17 hours after precooling was stopped there was practically no difference in the temperature of the precooled and nonprecooled loads, and this condition continued during the remainder of the transit period.

These data show that precooling lettuce having package ice is not necessary, since the ice in contact with the lettuce gives the rapid cooling desired.

TEMPERATURES OF LETTUCE IN MIDDLE AND BOTTOM LAYERS OF CRATE

In this study it was found that the rate of cooling was slower in the bottom layer than in the layer directly above it. At the time of loading the heads in the middle layer of the crate were as much as 17° cooler than those in the bottom layer. Temperatures in transit were also slightly lower in the middle layer of heads. This was due to a difference in the application of the ice in the crates. The lettuce in the bottom layer had ice above it only, while that in the upper layers had ice both above and beneath each layer.

TEMPERATURES OF LETTUCE LOADED WITH THE BOTTOM AND BULGE OF CRATE NEXT TO THE WALL

In these studies the lettuce was loaded with either the bottom or the bulge of the crate next to the side wall of the car. When the bulge is next to the side wall there is a protective layer of package ice between the top layer and wall, while with the bottom next to the wall there is not. The only difference in temperature resulting from these two methods of loading was that the lettuce cooled faster when the bulge was next to the side wall of the car. It took about 8 hours

longer to cool the lettuce to the same temperature when the bottom of the crate was next to the side wall.

INFLUENCE OF OUTSIDE TEMPERATURE

High outside temperatures prevailed during these summer tests, but they exerted less influence on the temperatures inside the car when top ice was used with the test shipments. A rise and fall in outside temperatures of 30° to 40° F. caused a corresponding rise and fall of about 5° in the air temperature near the ceiling at the doorway, and a 2° variation at the bottom doorway.

In the loads without top ice there was a gradual increase during transit in the temperature of the lettuce in the top layer in some cases amounting to as much as 5°, but in the top-iced cars at corresponding positions there was practically no change. In the car loaded with precooled lettuce which was shipped with package ice and under standard refrigeration in these summer tests there was a gradual increase of 3° to 3½° in the temperature of the lettuce in the top layer, but no change was noted in the other layers. The gradual rise in temperature of the lettuce was no doubt caused by the outside temperatures.

ICE MELTAGE

Two transportation tests were conducted during July and August when ordinarily the maximum outside temperatures would prevail and when the greatest ice meltage would be expected. The total ice meltage in the top-iced cars and those without top ice was approximately the same, as shown in table 7, although the top-iced cars received an average of about 4,000 pounds more ice. These data show that the average meltage of bunker ice was 8,535 pounds in the cars not top iced and 4,921 pounds in the top-iced cars. This difference of 3,614 pounds nearly equals the 4,000 pounds of additional ice supplied the top-iced cars. The icing records for these tests showed that the top-iced cars generally received from 400 to 900 pounds of ice at each icing station, whereas the car without top ice received 900 to 1,200 pounds. The ice meltage in the car loaded with precooled lettuce was also noticeably less than that in the cars loaded with warm lettuce.

Tests 15 to 23, inclusive (table 7), were shipping tests, hence the icing records of those cars shipped under standard refrigeration are incomplete. These tests were made during September when the weather is ordinarily cooler than during July and August. However, the amount of package ice melted was about the same.

TESTS DURING SPRING AND AUTUMN MONTHS

The experimental work conducted during the fall and spring months consisted of two transportation tests from Brawley and Vega, Calif., during March and October, respectively, to New York City and Pittsburgh, Pa. Six shipping tests of two cars each were also made from the Imperial Valley, Calif., and Phoenix, Ariz., to New York City and Baltimore, Md., during the latter part of March and April 1926.

TABLE 7.—Record of ice supplied and melted in cars of lettuce shipped from Washington, Colorado, and California to eastern markets during July, August, and September 1925-27, with and without top ice

PACKAGE ICE—BUNKER ICE

Test		Package (average)			Top			Bunker			Total		
No.	Car	Supplied	Melted	Supplied	Melted	Supplied	Melted	Supplied	Melted	Supplied	Melted	Supplied	Melted
		Lb.	Lb.	Pct.	Lb.	Lb.	Pct.	Lb.	Lb.	Pct.	Lb.	Lb.	Pct.
2	A	35	29.1	83.14	0	0	0	19,967	10,317	51.82	31,865	20,241	63.52
3	B	35	18.3	52.29	0	0	0	17,888	8,772	49.04	29,088	14,994	50.34
15	A	35	21.2	60.14	0	0	0	14,422	9,422	65.33	25,622	17,009	66.38
16	A	30	21.2	70.67	0	0	0	0	0	0	0	0	0
17	A	30	25.0	83.33	0	0	0	0	0	0	0	0	0
18	A	30	22.2	74.00	0	0	0	0	0	0	0	0	0
19	A	30	26.7	89.00	0	0	0	0	0	0	0	0	0
20	A	30	25.3	84.33	0	0	0	10,600	5,600	52.83	20,200	13,696	67.80
21	A	30	23.3	77.67	0	0	0	0	0	0	0	0	0
22	A	30	24.6	82.00	0	0	0	0	0	0	0	0	0
23	A	30	21.8	72.67	0	0	0	0	0	0	0	0	0
Average		31.25	23.75	76.00	0	0	0	15,719	8,535	54.3	26,519	16,500	62.12

PACKAGE ICE—TOP ICE—BUNKER ICE

		Supplied	Melted	Pct.	Supplied	Melted	Pct.	Supplied	Melted	Pct.	Supplied	Melted	Pct.
2	C	35	15.8	45.14	8,000	6,217	77.71	16,026	6,550	40.87	35,226	18,130	50.49
3	D	30	19.9	66.33	6,517	4,113	63.11	13,063	5,563	42.59	29,180	15,964	54.70
15	B	30	19.7	65.67	5,797	4,127	71.10	0	0	0	0	0	0
16	B	30	10.5	35.00	0,000	4,900	68.00	0	0	0	0	0	0
17	B	30	25.0	83.33	7,500	1,750	23.33	0	0	0	0	0	0
18	B	30	16.5	55.00	7,500	4,395	58.60	0	0	0	0	0	0
19	B	30	18.2	60.67	7,500	4,327	57.69	0	0	0	0	0	0
20	B	30	25.0	83.33	7,500	4,365	58.20	10,600	2,650	25.00	27,700	15,615	56.37
21	B	30	18.9	63.00	9,150	8,658	94.63	0	0	0	0	0	0
22	B	30	22.0	73.33	9,600	7,656	79.76	0	0	0	0	0	0
23	B	30	15.2	50.67	9,200	5,936	64.52	0	0	0	0	0	0
Average		30.4	19.8	63.13	7,660	4,995	65.21	13,230	4,921	37.2	30,702	16,573	53.98

¹ Lettuce precooled.² Shipped initially iced, not re-iced; all others shipped under standard refrigeration.³ Average of three cars receiving bunker ice.

INSPECTION OF LETTUCE

The lettuce shipped in the spring was in about the same condition as that shipped during the winter, being generally free from injuries and decay; that shipped in the fall was in poorer condition, being affected with slimy soft rot at time of loading. Most of the lettuce shipped in the experimental cars during the fall months showed from 1 to 6 percent of tipburn. At destination there was slightly less decay in the cars with top ice than in those without it. Detailed data regarding the condition of the lettuce at time of loading, the number of days the lettuce was in the cars, and the percentage of decay at time of unloading are shown in table 8.

Lettuce, from a car (car B, fig. 7) shipped without body ice under standard refrigeration and 5 percent of salt, was in poor condition at the time of unloading; the outer leaves showed decay and wilting so that heavy trimming was required to make the load salable. This was due to high transit temperatures, as shown in figure 7. A few crates of lettuce from near the bottom bunker opening were in good condition, due to the low temperature obtained at these two locations.

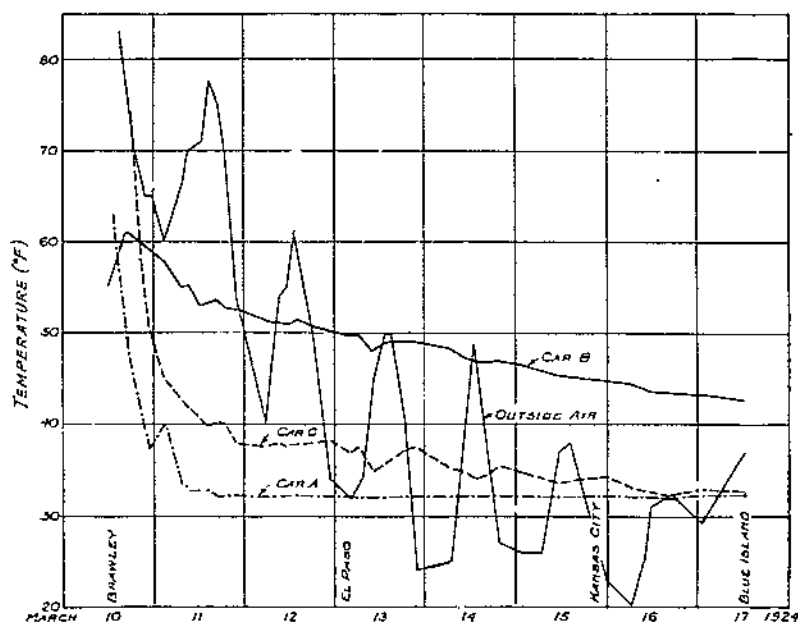


FIGURE 7.—Outside air temperature and average temperature of lettuce while in transit under the following conditions: Car A, top ice and package ice; car B, standard refrigeration, 5 percent salt, no body ice; car C, standard refrigeration and package ice.

TABLE 8.—Record of inspections of lettuce shipped in test cars during October, March, and April, from Arizona and California 1925-26, to New York City, Pittsburgh, Pa., and Baltimore, Md.; and percentage of decay after 10 to 13 days in transit with and without top ice

PACKAGE ICE—STANDARD REFRIGERATION

Test		Condition of lettuce at time of loading						Heads showing decay at destination
No.	Car	Temperature	Heads				Time in car	
			Solid to firm	Soft	Showing tip-burn	Showing decay		
		° F.	Percent	Percent	Percent	Percent	Days	Percent
4	A	58.5	98	2	2	T	10	0.2
	A-1	58.2	97	3	3	3	12	4.7
9	A	61.5	98	2	2	0	12	2.4
10	A	64.2	50	50	2	0	12	2.2
11	A	71.4	80	20	1	0	11	1.8
12	A	64.9	95	5	1	0	10	5.7
13	A	59.4	75	25	6	T	12	2.3
14	A	63.5	85	15	5	0	10	15.8

PACKAGE ICE—TOP ICE

		° F.	Percent	Percent	Percent	Percent ¹	Days	Percent
4	D-1	59.5	98	2	2	T	12	1.6
	D-14	58.9	97	3	3	3	13	12.8
9	B	65.3	98	2	0	0	12	4.3
10	B	68.0	50	50	2	0	12	3.7
11	B	71.4	80	20	1	0	11	1.8
12	B	57.5	95	5	1	0	10	2.5
13	B	67.4	75	25	6	T	10	.0
14	B	60.7	85	15	5	0	10	.2

¹ T=trace.

² Shipped standard refrigeration.

³ Shipped initially iced; not re-iced.

RATE OF COOLING

The rate of cooling of the lettuce to a temperature of 40° F. in the top-iced cars and in those without it was about the same (table 9), but between 40° and 32° the cooling was much faster in the top layer of the top-iced cars. The average length of time required to cool the lettuce in the bottom layers of the cars shipped with and without top ice was about the same, indicating that most of the cooling in this layer was done by the package ice. It is evident from this table that there was practically no difference in the average transit temperatures of the different cars. A rise and fall of 20° to 30° in the outside temperature caused a corresponding rise and fall of only approximately 5° in the air near the ceiling, with no noticeable influence on the temperature of the lettuce in any part of the load. This was, no doubt, due to the short duration of the high outside temperatures.

The beneficial effect of ice in direct contact with the lettuce is shown in figure 7 comparing top-layer temperatures in three cars; one (car A) shipped with top ice and package ice, the second (car B) without body ice under standard refrigeration and 5 percent of salt (530 pounds) on the first re-icing, and the third (car C) with package ice and standard refrigeration. It will be noted that the package ice and standard refrigeration were more effective than standard refrigeration with salt.

TABLE 9.—Time required for lettuce to reach 40° and 32° F. after loading; maximum, minimum, and average outside temperatures, and lettuce temperatures in top and bottom layers of cars shipped from California to New York City with and without top ice, October 16-29, 1925

PACKAGE ICE—STANDARD REFRIGERATION														
Test		Time required for lettuce to reach—				Temperature								
No.	Car	40° F.		32° F.		Outside			Top layer			Bottom layer		
		Top layer	Bottom layer	Top layer	Bottom layer	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
		Hours	Hours	Hours	Hours	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
4	A	6	4	(1)	72	68	35	48.6	58	32.5	33.4	58	32	32.6
	A-1	2	2	45	20	65	35	48.0	58	32.0	32.9	58	32	32.4
PACKAGE ICE—TOP ICE—STANDARD REFRIGERATION														
4	D	4	3	34	52	68	35	48.6	59	32.0	32.7	59	32	32.8
	D-1	1	5	17	48	68	35	48.0	57	32.0	32.7	57	32	32.8

¹ Temperature did not reach 32° F. during trip.

ICE MELTAGE

The average total ice meltage for the top-iced cars and those without top ice was about the same, the difference being 407 pounds (table 10). The highest percentage of ice meltage in any of the test cars was with the package ice and the least with the bunker ice. Since the average bunker-ice meltage for the top-iced cars was only 1,575 pounds, and for those without top ice 2,372 pounds, or 13.9 percent and 18.4 per-

cent, respectively, of the total ice furnished, it is apparent that bunker ice was not utilized to any great extent in the refrigeration of the commodity. As ice must be melted before it can furnish refrigeration, the small meltage of the bunker ice indicates that top ice and package ice would be sufficient for the successful shipment of lettuce from the Western States to the far eastern markets during these (spring and fall) months.

TABLE 10.—Record of ice supplied and melted in cars of lettuce shipped from California and Arizona to New York City, Pittsburgh, Pa., and Baltimore, Md., during October, March, and April 1925-26, with and without top ice

PACKAGE ICE—STANDARD REFRIGERATION

Test No.	Car	Package (average)			Top			Bunker			Total		
		Supplied	Melted		Supplied	Melted		Supplied	Melted		Supplied	Melted	
		Lb.	Lb.	Pct.	Lb.	Lb.	Pct.	Lb.	Lb.	Pct.	Lb.	Lb.	Pct.
4.....	A	35	22.4	64.0	0	0	0	12,919	2,419	18.72	24,119	9,567	39.75
4.....	A-1	35	23.8	68.0	0	0	0	12,826	2,326	18.14	24,026	9,942	41.38
9.....	A	30	23.6	79.3	0	0	0	0	0	0	0	0	0
10.....	A	30	24.7	82.3	0	0	0	0	0	0	0	0	0
11.....	A	30	23.8	79.3	0	0	0	0	0	0	0	0	0
12.....	A	30	20.3	67.7	0	0	0	0	0	0	0	0	0
13.....	A	30	18.0	60.0	0	0	0	0	0	0	0	0	0
14.....	A	30	15.0	60.0	0	0	0	0	0	0	0	0	0
Average.....		31.25	21.85	69.9	0	0	0	12,872	2,372	18.43	24,072	9,704	40.59

PACKAGE ICE—TOP ICE—BUNKER ICE

Test No.	Car	Supplied	Melted	Pct.	Supplied	Melted	Pct.	Supplied	Melted	Pct.	Supplied	Melted	Pct.
4.....	D	30	16.7	55.7	7,101	2,276	32.0	12,394	1,894	15.28	29,095	9,614	33.70
4.....	D-1	30	19.4	64.7	7,151	2,068	28.9	12,521	1,921	15.34	29,272	10,197	34.84
9.....	B	30	21.3	71.0	7,590	2,585	34.2	0	0	0	17,150	9,742	56.80
10.....	B	30	23.0	76.7	7,590	4,253	56.7	0	0	0	17,190	11,613	67.91
11.....	B	30	20.5	68.3	4,800	2,691	56.0	10,600	1,375	12.97	25,000	10,626	42.50
12.....	B	30	15.5	51.7	4,800	1,743	36.3	0	0	0	25,000	9,403	37.61
13.....	B	30	18.2	60.7	4,800	2,266	47.2	10,600	1,313	12.29	25,000	10,104	38.59
14.....	B	30	15.7	52.3	6,000	3,705	61.8	10,600	1,375	12.97	26,200	10,104	38.59
Average.....		30	18.8	62.7	6,213	2,698	43.43	11,343	1,575	13.89	24,117	10,171	42.17

¹ Cars shipped under standard refrigeration.

² Cars shipped under initial icing.

³ Average of five cars receiving bunker ice.

TESTS WITH OLD AND NEW REFRIGERATOR CARS

Two transportation tests were made to determine the comparative efficiency of refrigerator cars of different ages in the transportation of lettuce. The first test was from Vega, Calif., to New York City in October 1925, and the second from Phoenix, Ariz., to New York City in January 1926. The new cars were about 1 year old and the older ones between 7 and 8 years old. The dimensions of the old and new cars were the same, but there were slight differences in the thickness of the insulation and insulating materials, as shown in table 11.

A comparison of the ice meltage in the various test cars, presented in table 12, shows very little difference between comparable shipments of lettuce in cars that had been in service for about 7 years and for only 1 year. The maximum, minimum, and average temperatures of the lettuce in the top and bottom layers are given in the same table, showing very little difference between the temperatures in the various cars.

TABLE 11.—*Thickness and type of insulation in old and new refrigerator cars used in tests conducted from California and Arizona to New York City during October 1925 and January 1926*

Item	Insulation used in October 1925 test				Insulation used in January 1926 test			
	Old car ¹		New car ²		Old car ¹		New car ²	
	Material	Thick-ness	Material	Thick-ness	Material	Thick-ness	Material	Thick-ness
Floor	Hairsteel	1 1/2	Cork	2	Flaxinum	2 1/2	Cork	2
Roof	do	2	Hairsteel	2	Hairsteel	2 1/2	Hairsteel	2 1/2
Sides and ends	do	1 1/2	Flaxinum	1 1/2	Fibroselt	2	Flaxinum	2

¹ Built in 1917.² Built in 1921.TABLE 12.—*Maximum, minimum, and average temperatures in transit of lettuce in top and bottom layers of refrigerator cars 7 years and 1 year old, shipped from California and Arizona to New York City in October 1925 and January 1926; and total ice meltage*

CARS 7 YEARS OLD

Test	Lettuce temperatures in transit							Total ice		
	Top layer			Bottom layer			Supplied	Melted		
	No.	Car	Maximum	Minimum	Average	Maximum	Minimum			
			°F.	°F.	°F.	°F.	°F.	°F.	Pounds	Percent
4		A	58	32	32.9	58	32	32.4	24,026	9,942
		D	57	32	32.7	57	32	32.8	29,272	10,197
6		H-1	53	32	32.2	53	31	31.8	20,100	4,832
		J-1	43	31	31.9	43	31	32.1	14,448	4,645

CARS 1 YEAR OLD

4		B	58	32 1/2	33.4	58	32	32.8	24,119	9,587	39.75
		C	50	32	32.7	50	32	32.8	29,095	9,514	32.70
6		H	45	32	32.5	45	31	32.4	20,680	6,206	30.13
		J	46	32	31.5	46	31	31.7	14,448	4,145	28.69

Under the conditions of these tests there was no noticeable difference in temperature that could be ascribed to the difference in age of the refrigerator cars.

DECAY IN TRANSIT

In each test car, as previously mentioned, test crates were placed in each layer at the doorway, quarter-length, and bunker positions and were inspected at destination. The data shown in table 13 indicate that there was no significant difference in the amount of decay found in different layers. It is evident that the decay was least in the winter and greatest in the summer. This was no doubt because of two conditions: (1) Less favorable weather during the summer, fall, and spring months, and (2) the much better condition of the lettuce during the winter than during the other seasons of the year. Undoubtedly, the latter had more effect than the weather.

TABLE 13.—Percentage of decay (mostly slimy soft rot) found in the various layers of loads of lettuce shipped with bunker ice, package ice, and with and without top ice; summary of results of all tests, 1925-27

Season	Test cars	Heads inspected	Heads showing decay in various layers				Average decay
			Bottom	Second	Third	Top	
	Number	Number	Percent	Percent	Percent	Percent	Percent
Winter	8	5,068	0.039	0.01	0.79	0.0	0.22
Fall and spring	10	9,771	1.2	.75	.93	1.12	3.98
Summer	21	12,997	1.17	.88	1.02	1.57	4.68

COMPARATIVE EFFICIENCY OF CHUNK AND CRUSHED TOP ICE

Chunk top ice was used almost exclusively with body-iced shipments of lettuce up to about 1931 or 1932. Since that time there has been a rapid change, especially with shipments originating along the Pacific coast, and crushed or snow top ice has supplanted chunk ice for this

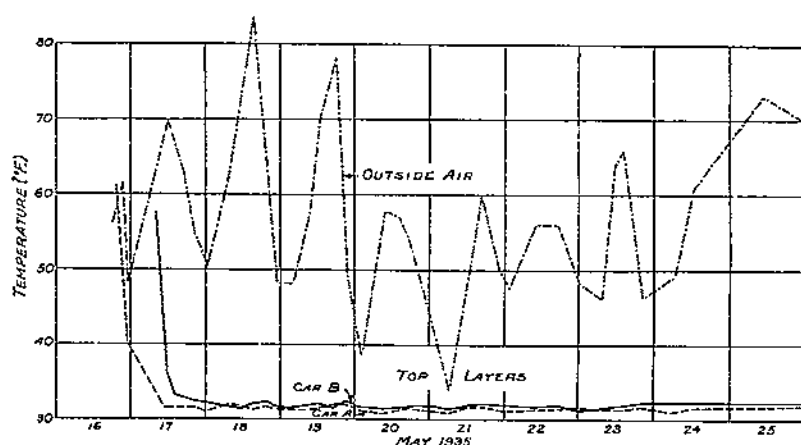


FIGURE 8.—Outside air temperature and average temperature of top-layer lettuce in transit from the Watsonville-Salinas district to Chicago, Ill., under the following conditions: Car A, crushed top ice; car B, chunk top ice.

purpose in many vegetable-producing districts. The snow top ice, as it is commonly called, is mechanically crushed and blown over the load after loading has been completed, while the chunk top ice is placed on each stack as loading progresses.

Data were obtained in January 1926 on one car of lettuce with finely chopped ice thrown back over the load with a shovel during loading. However, since the change to snow top ice took place after the earlier phases of this body-icing investigation were completed in 1927, a test was made in May 1935 to determine whether any material difference in transit temperatures and ice meltage is obtainable with these two methods of top icing.

TEMPERATURES IN TRANSIT

A comparison of the average temperatures in transit of the top layer, as given in figure 8, shows that there was no appreciable differ-

ence between the results obtained by the two methods of top icing. Individual temperatures as obtained at the various positions in the load are not given, as there was practically no difference in the temperatures at the doorway, quarter-length, and bunker positions of the various layers. This condition would be expected because of the uniform distribution of the package ice and top ice.

These results confirmed those obtained with shipments in January 1926 when chunk and finely chopped top ice were used. The results of both of these tests show that there was no appreciable difference in the rate of cooling or in the temperatures in transit due to the difference in method of top icing the shipments. It would not be expected that there would be a great deal of difference in the rate of cooling of loads covered with either crushed or chunk top ice, as most of the cooling of the lettuce is done by the package ice. The top ice prevents the warm air above the load from coming in contact with the packages and is largely responsible for maintaining the temperature of the load while in transit. The chief advantages of snow ice are that of being more easily placed in the car, and that it is less likely to damage the top-layer crates.

ICE MELTAGE

The total ice supplied and melted in each of the cars shipped with crushed and chunk top ice in May 1935 is given in table 14. These data indicate that about 1,200 pounds more ice was placed in the car with chunk top ice and about 1,200 pounds more ice melted in this car than in the one with crushed top ice. During the test in January 1926 about 4,800 pounds of ice was used in each of the two test cars. On arrival at destination it was found that 785 pounds of chunk top ice had melted, as compared with 1,061 pounds of chopped top ice. The average meltage of package ice was about the same for the two cars. These data indicate that there is no great difference in the meltage of body ice when crushed or finely chopped ice and chunk ice are used for top icing the loads.

INSPECTION OF LETTUCE

The lettuce in the cars iced with crushed and chunk top ice of both tests arrived in good condition, there being no discernible difference between them. This could have been expected because the lettuce was in good condition at time of loading, and the ice meltage and temperatures in transit were about the same for all the cars.

TABLE 14.—*Total ice furnished and melted in cars shipped with crushed and chunk top ice from the Salinas-Watsonville district to New York City during May 1935*

Ice	Car A (crushed top ice)			Car B (chunk top ice)		
	Supplied	Melted		Supplied	Melted	
		Pounds	Percent		Pounds	Percent
Package ice.....	10,920	4,493	41.1	12,480	6,365	51.0
Top ice.....	9,600	5,803	60.4	9,600	5,371	55.9
Ice at doorway ¹	1,800	421	23.4	1,500	179	11.9
Total.....	22,320	10,717	48.0	23,580	11,915	50.5

¹ Two 300-pound cakes of ice were placed on end next to the doors on each side of car with a 300-pound chunk of ice placed on top of the upright cakes.

INFLUENCE OF LOW-TEMPERATURE BODY ICE ON THE FREEZING OF LETTUCE IN TRANSIT

The temperature of ice, as of other inert, nonliving substances, follows rather closely that of the surrounding air. In fact, ice responds more readily to a change in temperature of the surrounding air than many other substances because of its low specific heat. If ice that has been stored at a low temperature is quickly placed in close contact with lettuce or other commodities ordinarily shipped with body ice, it is likely to cause freezing injury to the lettuce. Although in many cases the temperature of the ice might not be sufficient to cause freezing injury, it does cause the commodity with which it comes in contact to freeze more quickly and severely when subsequently exposed to low temperatures. It is well known that the lower the temperature of a commodity the quicker it will freeze when subjected to a temperature below its freezing point; thus it would be expected that the greatest amount of freezing injury to lettuce in transit would occur during the colder months of the year.

The average freezing point of lettuce is $31.2^{\circ}\text{F}.$ ⁵, which is nearly 3° higher than for most fruits and only 0.8° below the freezing point of pure water. It is apparent that the contact of head lettuce with low-temperature ice would soon cause freezing of the outer leaves. Records have been obtained showing that many commercial companies furnishing ice to the shippers of body-iced vegetables ordinarily store their ice at temperatures ranging from 23° to 28° .

The freezing of lettuce in transit is due either to cold weather, the ice in the car, or a combination of the two. During the summer and most of the fall and spring months weather conditions need not be considered, leaving the body ice as the direct cause of freezing injury.

The location in the load of the lettuce showing freezing injury will under most conditions give a clue as to the cause of the damage. When such lettuce is confined to the crates next to the bottom bulkhead opening it is apparent that too low temperature from the bunkers is the cause. If the freezing damage is largely confined to the bottom-layer crates and to those next to the side walls of the car, the cause without doubt is weather conditions. However, in many instances where freezing is found in the bottom layer and up the sides of the load it is also found in the upper part of the top-layer crates and is caused either by cold weather, low-temperature top ice, or by both conditions combined. Freezing injury caused by low-temperature package ice when scattered through the load may be mistaken for field freezing. When the freezing injury is confined to the upper part of the top-layer crates in the load then the top ice is without doubt the main cause, although cold weather may have had an influence.

A few tests were made at Arlington Experimental Farm, Va., in 1935 to determine whether lettuce could be frozen in the crate by contact with low-temperature ice. The ice was finely crushed and placed in rooms ranging in temperature from 17° to $32^{\circ}\text{F}.$, and was held there until the temperature of the ice approximated that of the room. The test crates of lettuce were packed with this low-temperature ice. Each crate was then placed in a large box in a room held at 32° to $33^{\circ}\text{F}.$ (approximate average transit temperature for lettuce),

⁵ WRIGHT, R. C. THE FREEZING TEMPERATURES OF SOME FRUITS, VEGETABLES, AND FLORISTS' STOCKS. U. S. Dept. Agr. Cir. 447, 11 pp. 1937.

and the crate was then surrounded with crushed ice of the desired temperature. The results of these tests are given in table 15 and show that freezing of the outer leaves occurred with ice having a temperature of 25° or below, and that the lower the temperature of the ice the greater the extent of the injury. The time required to produce freezing injury with ice at this temperature could not be determined definitely under the conditions of this test. The data obtained with crates 3 and 4 indicate that the length of the exposure of the lettuce to the ice made a difference as to the extent of the freezing injury. Most cars of western-grown lettuce are in transit for 5 to 9 days, so that had this test been continued for the same length of time greater injury might have been obtained than was noted after 20 to 48 hours.

TABLE 15.—*Extent of freezing injury obtained with lettuce in contact with ice of varying temperatures*

Crate No.	Length of test	Temperature of—			Extent of freezing injury
		Lettuce ¹	Packing ice	Top ice	
	Hours	° F.	° F.	° F.	
1.....	24	58	32	25	No freezing.
2.....	24	58	25	25	Slight freezing of outer leaves of few heads.
3.....	24	58	22	22	Outer leaves of most heads frozen.
4.....	48	58	22	22	Outer leaves of all heads frozen, few heads frozen 2 to 3 layers deep.
5.....	20	32	32	17	Severe freezing on outer 2 to 4 leaves of all heads.
6.....	20	32	17	17	Severe freezing on outer 3 to 6 leaves of all heads.

¹ Temperature of lettuce at time crates were repacked with ice.

Through the cooperation of the Bureau of Agricultural Economics records were obtained on 92 cars of lettuce shipped from the Pacific coast during 1935 in which freezing injury was found; however, it occurred almost entirely in the outer layer of heads in the upper part of the top-layer crates. This distribution is considered reasonable evidence that the freezing injury found in them was because the lettuce had been in contact with low-temperature ice. These cars were unloaded at destination during all months except April and July. No effort was made to obtain a complete list and no doubt there were other cars showing freezing injury from low-temperature ice on which records were not obtained.

Of the 92 cars on which records were obtained, 50 were unloaded during November 1935. As most of these cars were loaded in the central district of California (of the 3,523 cars of lettuce shipped from California during November of that year, 3,267 were shipped from this district) the natural route to eastern markets would be via Ogden, Utah; Chicago, Ill.; and thence east. Records obtained by the United States Weather Bureau at its various stations along this route show that the mean temperature for November ranged between 33° and 48° F. A study of the daily temperatures shows that there were a few nights of low temperatures, but that during the daytime the temperatures were moderately high, indicating that the periods of low temperature to which these cars were subjected were of short duration. Weather conditions were such that transit freezing probably would not have occurred had the lettuce not been in contact with

low-temperature ice. There were many other cars originating from the same district and unloaded at destination at the same time that arrived without freezing injury.

The results just discussed indicate that low-temperature ice does cause freezing of the outer leaves of head lettuce while in transit. Other body-iced commodities, such as carrots, are also frozen by contact with low-temperature ice. This type of transit freezing injury can be easily prevented by permitting the cakes of ice to stand in the packing house until they start to melt when the ice will be at a safe temperature.

DISCUSSION

Studies were conducted from 1924 to 1927, inclusive, from western producing districts to determine if body ice is necessary for the safe carriage of lettuce to eastern markets. Additional work was done in 1935 and 1936 on other phases of lettuce transportation. A total of 66 test cars were shipped during the six seasons.

The data obtained during this investigation showed that lettuce could be safely shipped under standard refrigeration without body ice only during cold weather, and that lettuce shipped by the same method during mild weather in the winter months arrived in poor condition. The results indicated that the hazards of shipping without body ice are too great for general commercial practice.

It was also evident that top ice, in addition to other means of refrigeration, is necessary for lettuce shipments during a period of approximately 6 months beginning about April 1. The quantity of top ice melted varied with the outside temperatures. It was found that for shipments moving during the hottest weather in July and August from 7,000 to 9,000 pounds of top ice was melted; whereas for shipments moving during the other summer months the meltage of ice was from 4,000 to 6,000 pounds. During winter months the meltage of top ice for the most part was between 1,000 and 2,000 pounds, while during the balance of the year it was from 2,000 to 4,000 pounds.

Although the above amounts represent the approximate quantity of top ice actually melted to provide necessary refrigeration in transit, additional ice should be supplied as a factor of safety and to allow the receiver some leeway in the disposal of the load after arrival at destination.

Package ice is necessary with shipment of lettuce from western producing districts. The amount of additional refrigeration required will vary with the season. Either top ice or bunker ice is needed in addition to the package icing. Top icing is preferable to bunker icing because it provides quicker and more uniform cooling of the lettuce and better protection against the penetration of outside heat. The one test in which salt was added to the bunker ice indicated no material benefits from its use.

Thirty to thirty-five pounds of finely crushed ice in the package was found sufficient to provide the necessary quick cooling and the moisture needed to keep lettuce fresh and crisp. This quantity is small enough to induce no undue slackness of the pack when it has melted. A source of moisture inside the crate is required because the waxed paper liner (fig. 2) prevents the entrance of water from the melting top ice.

The results show that crushed top ice gives practically the same results as to temperatures in transit and arrival condition of the lettuce as chunk top ice. The crushed as compared with the chunk top ice is more easily placed over the load and saves time in loading. It is also reasonable to expect that there should be less breakage of the top-layer crates in shipments under crushed top ice than where chunks of ice are thrown over the load.

The contact of the package ice with the heads gives sufficiently rapid cooling of the lettuce to make precooling by mechanical means unnecessary. Moreover, no significant saving in ice can be expected because of precooling since the ice meltage in transit of precooled and nonprecooled cars was practically the same.

During cold weather the presence of body ice in the car increases the hazards of freezing injury, because it maintains the lettuce at a temperature only slightly above its freezing point. Therefore, when body ice is used the lettuce is more quickly reduced below the freezing point under the influence of colder outside temperatures, so that during cold weather freezing of the lettuce in the load is more likely to occur.

The results discussed on pages 27 and 28 also indicate that low-temperature ice sometimes causes freezing of lettuce while in transit, even during the summer months. The extent of the injury is determined by the temperature of the ice and of the lettuce at time of packing. This freezing injury is easily prevented by permitting the cakes of ice to stand in the packing house until they start to melt.

The most satisfactory temperature for carrying lettuce was found to be between 35° and 32° F., and was obtained by the use of package icing and by one of the two other available methods of supplemental refrigeration, namely, ice over the top of the load or ice in the bunkers of the car.

It is evident that temperatures in transit and the condition of the lettuce at time of shipment are the chief determining factors in its successful transportation to market. In these tests lettuce reached the market in good condition when it was cooled quickly, as by the use of body ice. When the lettuce cooled slowly, as in the shipments without body ice, its condition was generally poor on arrival at destination. Lettuce that was in good sound condition when shipped under body ice arrived in good condition; that affected with decay, tipburn, or burst heads often arrived showing excessive decay regardless of the amount of refrigeration furnished in transit.

Marked changes in the methods of packing and loading lettuce came into use between the 1924-27 tests and the 1935-36 tests. The package ice used in the later tests was finely crushed by a machine; in the 1924-27 tests it was shaved by hand and contained many comparatively large chunks that were capable of causing more bruising injury than the crushed ice now used. During the early tests the lettuce was packed so that there was little or no bulge, thus permitting the crates to be loaded right side up one above the other. There was no excessive bruising or injury of the outer leaves noted during these tests, although an occasional head would be indented by contact with a large chunk of package ice. In more recent times the crates have been packed with such a high bulge (fig. 4) that it is necessary to load the crates in the three bottom layers on their sides (fig. 3). This, even with the finely crushed package ice, causes excessive bruising of the outer leaves.

Bruising of the heads not only seriously detracts from the appearance of the lettuce but necessitates heavy trimming. After the bruised ribs and leaves of an originally well-formed head have been trimmed off on the market only a small misshapen head is left. Such a head not only gives a poor appearance but wilts and discolors quickly, so that further trimming is needed before it can be used. During these tests it was found that permitting the heavy protective wrapper leaves to remain on the head at time of packing reduced the extent of the injury but did not prevent it. It is evident that the excessive bruising injury in transit is due to excessively heavy packing of the crates and can be avoided by use of a lighter pack. The excessively heavy packing of lettuce is therefore undesirable. It has grown up in the industry as a result of buying by the package and selling by head. This practice is not confined to the packing of lettuce but is on the increase with other vegetables and fruits as well. However, any practice that gives the consumer an inferior product and requires the payment of freight and refrigeration charges on waste is highly undesirable.

CAULIFLOWER

Cauliflower is grown and shipped commercially in the States located chiefly along the Pacific coast and in the Great Lakes region. The average yearly shipment for the United States is between 7,000 and 8,000 cars, of which more than three-fourths are shipped from States in which body icing is commonly used in the transit refrigeration of this commodity. Cauliflower is shipped during the year from the principal producing regions, as shown in table 16.

The long-season late-maturing cauliflower is sometimes referred to commercially as "broccoli." This plant requires the entire season to mature and makes its heads in the spring. It is the cauliflower shipped chiefly from Oregon, is very similar to the winter cauliflower grown in California, and is handled in much the same way. The "broccoli" shipments from Oregon are included in this report as cauliflower.

TABLE 16.—Average number of carlot shipments of cauliflower by months (1927 to 1936, inclusive) from five principal western cauliflower-shipping States

State	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Arizona	74	8									5	28
California	1,255	1,219	1,151	679	338	27	4	2	4	44	493	1035
Colorado							22	263	385	188	8	
Oregon		11	74	29			3	7	15	216	271	23
Washington							32	41	9	5	7	

PACKAGE

Cauliflower is generally packed in the field in flats or pony crates for shipment. The crates used in California have an inside measurement of 8½ by 18 by 21½ inches; those in Oregon are 8 by 16½ by 23½ inches. The untrimmed heads are first set erect in the crates (fig. 9)



FIGURE 9.—A method of packing cauliflower in the field: *A*, Sorting of heads and placing in crates butts down; *B*, trimming off leaves with large knife; *C*, packed crate ready for cover.

with the leaves of the jacket sticking above the sides of the crate, and the leaves are then trimmed (fig. 9, *B* and *C*) so that the lid may be nailed to the crate.

LOAD

The test cars contained 500 to 512 crates, loaded according to the common commercial practice at that time. The packages were loaded bottom side up to prevent water from collecting in the heads. Because cauliflower is packed only one layer to the crate, package icing is impractical. In body-icing this commodity, the ice was placed either on top of the load (fig. 10, *A*) or on top of the load and in

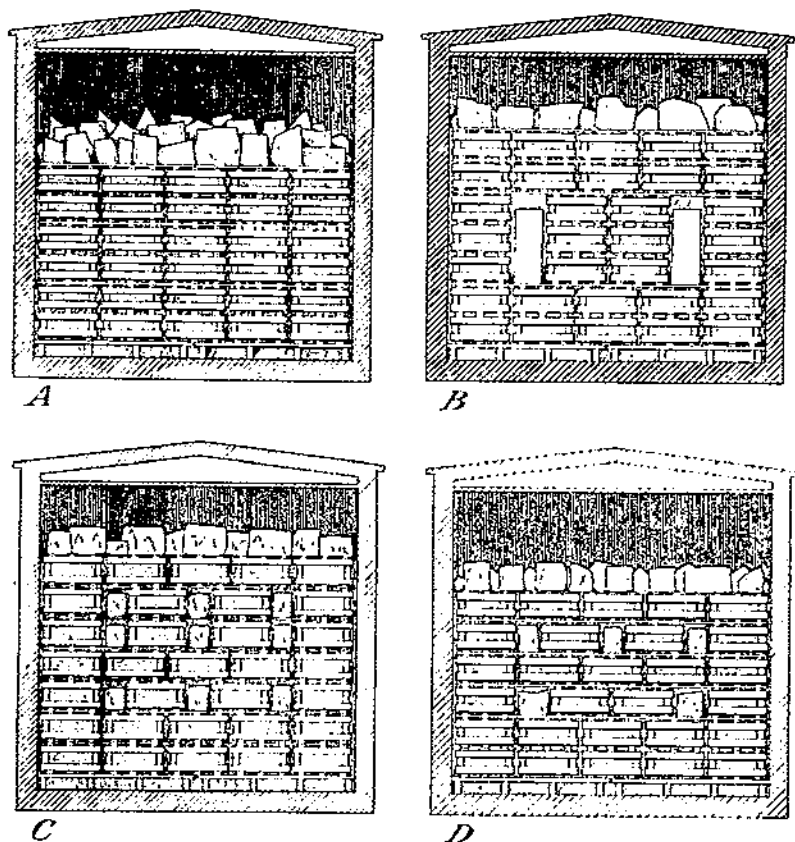


FIGURE 10.—Methods of loading cars with cauliflower: *A*, Top icing only; *B*, *C*, and *D*, top icing with pigeonhole icing.

pigeonholes; that is, in open spaces left in the load. There were several different methods of placing these pigeonholes, the more common ones being shown in figure 10, *B*, *C*, and *D*.

REFRIGERATION

The test shipments were made during the winter and early spring months from California and Oregon, with and without body icing,

and under either standard refrigeration or initial icing. The body ice was placed on or in the load in chunks.⁶ Two of the shipping tests made in April were under standard refrigeration plus 3 percent of salt. The customary method of shipping cauliflower is with body icing and bunker icing without salt.

LOCATION OF THERMOMETERS

Electrical resistance thermometers, previously described, were placed along the center line of the car in the first, fourth, and top layers of the first, fourth, and eighth stacks; that is, at the bunker, quarter-length, and doorway positions, each of the nine thermometers being buried in a head of cauliflower. Air temperatures were obtained at the bottom bunker opening, at the doorway near the floor, and at the top of the car about 6 inches below the ceiling.

EXPERIMENTAL WORK AND RESULTS

The experimental work with cauliflower consisted of two transportation tests from Compton, Calif., to New York City and Chicago, Ill., during December 1925 and 1926; four shipping tests from the vicinity of Los Angeles, Calif., to New York City and Philadelphia, Pa., during January 1927; two shipping tests from Roseburg, Oreg., to New York City in March 1927; and two tests from Guadalupe, Calif., to New York City and Philadelphia in April 1927.

Each shipping test consisted of a pair of cars, one with body ice and the other without, and both under bunker refrigeration. Most of the test shipments were initially iced, not re-iced, and a few were shipped under standard refrigeration. Most of the non-body-iced shipments received standard refrigeration, but a few were initially iced and not re-iced.

The tests conducted with cauliflower were made during the winter and spring months to determine the need for ice in the body of the car in order to deliver the cauliflower to the market in good condition, the quantity of ice required, and the most desirable location for it.

INSPECTION OF CAULIFLOWER

The cauliflower loaded in the test cars was in good condition, with no decay, heads generally compact, with little fuzziness, riciness, or spreading. Riciness is caused by the elongation of the stems of the flower clusters giving an uneven or rough surface, sometimes with a granular appearance; fuzziness is the elongation of floral bracts of the individual flowers giving a velvety hairy appearance to the heads; spreading is caused by the separation of the clusters giving the head a loose open texture in the more advanced stages. These conditions are not generally serious but are an indication of overmaturity.

Inspection at destination (table 17) indicated that body icing had little, if any effect on the amount of decay, fuzziness, riciness, or spreading of the curds found at time of unloading. These conditions were as prevalent in body-iced cars as in cars without body ice.

⁶ Crushed ice is now being used extensively with cauliflower shipments and has largely superseded chunk ice.

However, the body ice did have a decided effect in preventing the yellowing of the jacket leaves. No wilting and very little browning of the jacket leaves were found in the body-iced cars, whereas in the cars without body ice four arrived with little wilting, two cars with the top layer wilted, and four with practically all of the heads wilted. The shipments made in December and January arrived with the least wilting and discoloration, whereas those in March and April were the poorest.

TABLE 17.—Record of inspections of cauliflower shipped in test cars during December, January, March, and April, 1925-27, from California and Oregon to New York City, Philadelphia, Pa., and Chicago, Ill.; showing percentage of decay under various methods of refrigeration

BUNKER ICE—NO BODY ICE											
Condition of cauliflower at time of											
Test		Loading					Unloading ¹				
No.	Car	Temperature	Compact	Spreading	Riley	Fuzzy	Good condition	Spreading	Riley	Fuzzy	Decay
		° F.	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
1	E	86	37.0	3.0	5.0	5.0	81.3	5.2	2.6	7.1	3.2
2	E	33	30.0	10.0	10.0	10.0	70.0	16.0	6.0	8.0	0
3	E	50	87.5	2.5	3.0	2.5	83.5	4.7	5.6	0	0
4	E	51	98.0	2.0	0	0	78.3	2.0	8.4	11.3	0
5	E	55	95.0	5.0	5.0	1.0	60.6	0.0	14.3	7.1	0
6	E	56	91.0	0.0	5.0	7.0	57.2	22.0	11.8	9.0	0
7	E	51	97.0	3.0	1.0	1.0	82.9	7.9	3.2	3.7	2.3
8	E	39	97.0	3.0	1.0	0	86.0	2.0	3.0	3.4	2.0
9	E	50	100.0	0	1.0	1.0	69.1	2.5	9.0	19.4	0
10	E		92.0	8.0	1.0	1.0	66.2	8.4	3.8	21.6	0

TOP ICE—PIGEONHOLE ICE—BUNKER ICE

1	G	61	97.0	3.0	5.0	5.0	76.0	9.9	2.8	4.9	5.6
2	K 2	56	90.0	10.0	10.0	10.0	60.0	26.0	13.0	1.0	0
3	G	50	97.5	2.5	3.0	2.5	88.5	2.0	9.5	0	0
4	G	48	98.0	2.0	0	0	89.0	2.0	4.1	4.6	0
5	G	55	95.0	5.0	5.0	1.0	62.7	10.6	13.8	6.9	0
6	G	51	91.0	9.0	5.0	7.0	60.0	5.0	3.0	7.0	0
9	G	64	100.0	0	1.0	1.0	74.3	4.0	6.0	15.7	0
10	G		92.0	8.0	1.0	1.0	82.1	2.9	8.2	6.8	0

TOP ICE—BUNKER ICE

1	F	65	90.0	10.0	6.0	0.0	77.5	7.0	1.4	9.2	4.9
2	K	51	90.0	10.0	0	20.0	56.0	27.0	10.7	6.4	0
7	K	40	98.0	2.0	1.0	1.0	83.3	8.2	4.2	2.9	1.4
8	K	39	97.0	3.0	1.0	0	93.1	4.2	1.4	.4	.0

¹ No wilting and practically no yellowing of leaves of heads in body-iced cars, while in the cars without top ice the top layers were wilted in tests 5 and 6; entire heads were wilted in tests 7, 8, 9, and 10, with from 4 to 11 percent of heads and jackets yellow or brown.

RATE OF COOLING

Data regarding the rate of cooling in transit were obtained only during December. As shown in table 18 the cauliflower cooled most rapidly in the cars receiving both top ice and pigeonhole ice. The cooling was slightly slower in the top-iced cars without pigeonhole

ice and was very slow in the cars without body ice under standard refrigeration. This condition is shown graphically in figure 11, which

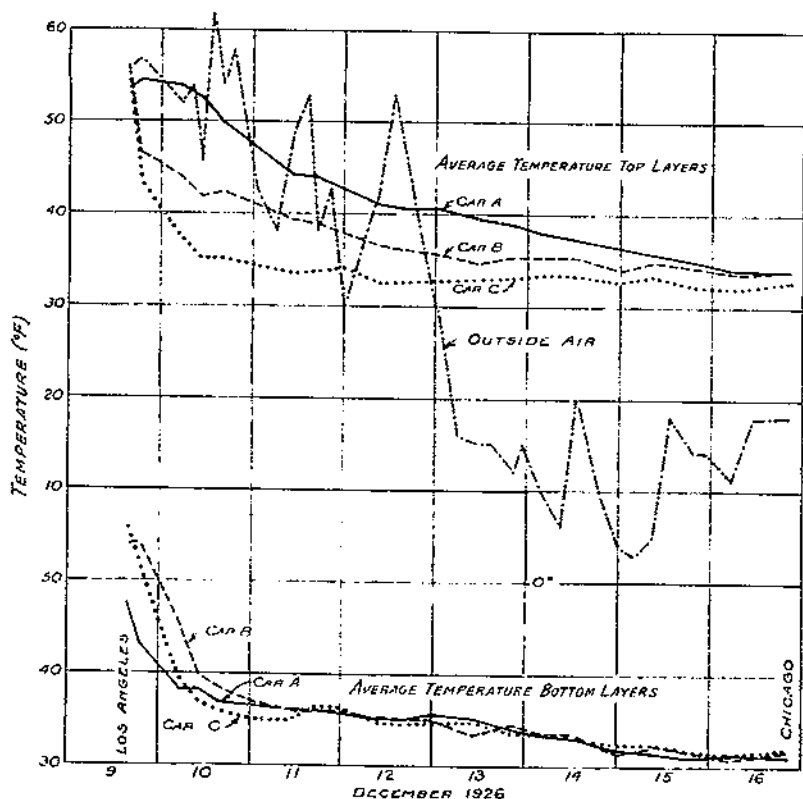


FIGURE 11. Outside air temperature and temperature of top and bottom layers of cauliflower in transit under the following conditions: Car A, standard refrigeration, no body ice; car B, initial icing and top icing; car C, initial icing, top icing, and pigeonhole icing.

gives the average temperatures in transit of the top and bottom layers in cars under the three methods of refrigeration. It is apparent that the body icing was effective in cooling the top layers and was necessary to cool the cauliflower below 40° F. during the first 36 to 48 hours (table 18).

Freezing was found in all of the test cars during the 1925 test, mainly in the crates along the side walls and near the doorway. Since thermometers were not placed at these locations but only along the center line of the load, the temperature records probably do not indicate the minimum temperatures that occurred in the cars. Freezing was most severe in the body-iced cars.

ICE MELTAGE

A comparison of the average total ice meltage in the test cars shipped under the three methods of refrigeration used for cauliflower, namely, top ice, top ice and pigeonhole icing, and bunker icing alone

(table 19) shows comparatively small differences, although there was a wide variance in the amount furnished the cars shipped under the different methods.

TABLE 18.—Time required for cauliflower to be cooled; also maximum, minimum, and average outside temperatures, and temperatures of top and bottom layers of experimental shipments in December 1925 and 1926

BUNKER ICE—NO BODY ICE														
Test		Time required for cauliflower to reach—				Temperature								
		40° F.		32° F.		Outside			Top layer			Bottom layer		
No.	Car	Top layer	Bottom layer	Top layer	Bottom layer	Maxi- mum	Mini- mum	Aver- age	Maxi- mum	Mini- mum	Aver- age	Maxi- mum	Mini- mum	Aver- age
Hours														
° F.														
1	E	82	4.0	0	0	80	20	40	66	36	42.6	66	20	35.0
2	E	82	4.0	0	0	63	3	27	55	34	39.0	47	31	33.8
TOP ICE—PIGEONHOLE ICE—BUNKER ICE														
1	G	17	4.5	168	220	80	20	40	63	32	34.4	63	27.5	34.2
2	K-2	5	7.0	134	131	63	3	27	56	35	34.0	57	31	35.6
TOP ICE—BUNKER ICE														
1	F	36	4.0	0	225	80	20	40	66	32	35.7	61	28	34.4
2	K	33	10.0	0	124	63	3	27	55	33	37.6	58	30	35.8

¹ Temperatures did not reach 32° F. during trip

DISCUSSION

Studies were conducted from 1925 to 1927, inclusive, on 22 cars of cauliflower shipped from western producing regions on the Pacific coast to eastern markets to determine whether body icing is necessary for the safe shipment of this commodity. These tests were conducted only during the winter and spring months.

These experiments showed that cauliflower can be shipped under standard refrigeration without any body ice during cold weather, but since at the time of shipment it is impossible to forecast weather conditions several days in advance, the use of top ice seems advisable throughout the entire year. Cauliflower shipped without body ice is likely to wilt and the resultant shrinkage decreases its attractiveness. Body icing is also effective in preventing browning of the jackets and wilting, but does not seem to prevent riciness, fuzziness, and spreading of the heads. The three latter conditions can develop in transit, but as they are indications of overmaturity they can usually be eliminated by not shipping overmature stock.

It is evident from the results obtained in the transportation tests that placing some ice in the load resulted in more rapid cooling and more uniform and lower transit temperatures than when all the body ice was placed on top of the load. The amount of body ice melted in transit varied with the outside temperatures and during these tests ranged from a minimum of 2,839 pounds to a maximum of 8,833

pounds. These amounts represent the approximate quantity of body ice actually melted to give the necessary refrigeration in transit. Additional ice should be supplied as a safety factor and to permit the receiver sufficient time to properly market the commodity. The fact that the average total meltage of the bunker ice in the body-iced cars with and without pigeonhole ice was only 2,666 and 1,640 pounds indicates that it was not greatly needed and suggests that body ice alone would be sufficient during the winter and spring months.

TABLE 19.—Record of ice supplied and melted in experimental shipments of cauliflower during December, January, March, and April, 1925-27

NO BODY ICE—BUNKER ICE														
Test		Days in car	Top			Pigeonhole			Bunker			Total		
Trip	Car		Sup- plied	Melted		Sup- plied	Melted		Sup- plied	Melted		Sup- plied	Melted	
		No.	Lb.	Lb.	Pct.	Lb.	Lb.	Pct.	Lb.	Lb.	Pct.	Lb.	Lb.	Pct.
1	F	10	0	0	0	0	0	0	18,365	7,965	42.0	18,365	7,965	42.0
2	A	12	0	0	0	0	0	0	14,502	4,212	29.0	14,502	4,212	29.0
3	F	11	0	0	0	0	0	0	10,600	6,350	60.0	10,600	6,350	60.0
4	F	12	0	0	0	0	0	0	10,600	6,600	62.3	10,600	6,600	62.3
5	E	12	0	0	0	0	0	0						
6	E	12	0	0	0	0	0	0	10,600	10,200	96.2	10,600	10,200	96.2
7	E	11	0	0	0	0	0	0						
8	F	14	0	0	0	0	0	0						
9	E	12	0	0	0	0	0	0						
10	F	12	0	0	0	0	0	0						
Average			0	0	0	0	0	0	12,973	7,067	54.5	12,973	7,067	54.5

TOP ICE—PIGEONHOLE ICE—BUNKER ICE

1	G	13	4,800	4,330	60.2	4,800	1,815	37.8	13,808	3,228	23.7	23,438	9,443	40.2
2	K-G	11	9,000	4,535	47.2	2,400	715	29.8	11,000	1,100	10.0	23,000	6,350	27.6
3	G	11	7,200	3,500	48.6	2,400	555	23.1	0	0	0	9,600	4,055	42.2
4	G	12	6,000	2,600	33.3	1,500	840	56.0	10,600	2,650	25.0	18,100	5,489	30.3
5	G	12	6,800	5,600	82.4	2,800	1,845	65.9	10,600	2,750	25.9	20,200	10,195	50.5
6	G	12	6,000	5,000	83.3	3,000	2,958	98.6	10,600	3,534	33.3	20,200	11,492	56.9
9	G	12	4,800	4,100	85.4	4,800	3,475	72.4						
10	G	12	4,800	4,000	83.3	4,800	4,173	86.9						
Average			6,250	4,215	67.4	3,357	2,040	60.4	11,330	2,666	23.5	19,100	7,837	41.0

TOP ICE—BUNKER ICE

1	F	13	9,600	6,645	69.2	0	0	0	13,425	2,825	21.0	23,025	9,470	41.1
2	H	8	7,200	4,535	63.0	0	0	0	10,500	1,310	12.5	17,700	5,845	33.0
7	K	12	7,500	5,345	71.3	0	0	0	10,500	1,100	10.5	18,000	5,445	30.3
8	K	13	7,500	3,705	49.4	0	0	0	10,500	1,325	12.4	18,000	5,030	28.0
Average			7,950	5,057	63.6	0	0	0	11,231	1,640	14.6	19,181	6,447	33.6

¹ Average of the 5 cars receiving bunker ice.

GREEN CORN

Green corn is grown in practically every State, but carlot shipments are largely confined to extreme Southern and Southeastern States during the spring months.

PACKAGE

In the tests reported herein the corn shipped from Florida and Alabama was packed in crates having inside dimensions of 14 by 11 by 22 inches or 13 $\frac{1}{4}$ by 11 by 22 inches, being strongly constructed and bound with wire.

LOAD

The cars shipped from Florida were loaded with the packages 7 rows wide, 4 layers high, and 12 stacks long, with 2 additional stacks, 1 each side of the doorway 1 layer high, making altogether 350 crates in each car. The cars were braced at the doorway with 1- by 1-inch strips.

Those from Alabama were loaded the full length of the car, seven rows wide, four layers high, except at the doorway which was loaded with four packages crosswise of the door and three layers high.

REFRIGERATION

The two experimental cars from Florida were shipped under standard refrigeration with 2 percent of salt, one car with and the other without top ice. The quantity of salt used was 2 percent of the weight of the ice placed in the bunkers of the cars at the various icing stations. On account of a delay in loading the top-iced car, the amount of top ice was weighed only in one end of the car. A total of 5,130 pounds was placed in this end. This end of the car and the car without top ice were loaded the same day.

The four experimental cars from Alabama were under standard refrigeration with 5 to 6 tons of top ice added.

LOCATION OF THERMOMETERS

Electrical resistance thermometers, previously described (p. 4), were used with the test from Florida, being inserted in ears of corn in crates located along the center line of the car at the top, third, and bottom layers at the doorway, quarter-length, and bunker positions. Air temperatures were obtained at the bottom bunker, at the doorway near the bottom of the load, and about 6 inches from the ceiling.

In the tests from Alabama recording thermometers were placed in the top and bottom layers of the doorway and bunker stacks.

EXPERIMENTAL WORK AND RESULTS

The experimental shipments consisted of one transportation test in June 1927 from Lawtey, Fla., to New York City comprising two cars, one with and the other without top ice. Four shipping tests of one car each under top ice were made in June 1933 from Loxley, Ala., to northern markets. One of these four cars was precooled for 4 hours with a portable precooling apparatus consisting of four 10-inch fans suspended in the top of the ice bunker immediately above the ice.

EXPERIMENTAL SHIPMENTS

INSPECTION

The corn in all the test cars was in good condition at time of loading. The cars were of good size, generally well filled, with husks of good green color. However, practically all of the corn in the shipping tests showed earworm damage.

RATE OF COOLING

There was not a great deal of difference in the rate of cooling in the bottom layers between the top-iced and non-top-iced cars shipped from Florida, but, as shown in figure 12, the average temperature of

the top layer of the top-iced car cooled to below 50° F. about 36 or 40 hours sooner than in the non-top-iced car. The temperature of the corn at time of loading was about the same in both cars with outside temperatures ranging between 55° and 85°.

The rates of cooling in two of the top-iced cars shipped in 1933, as obtained with recording thermometers placed in the crates, are given in figure 13; one load (car A) had been precooled with a portable precooling apparatus. Three percent, or about 288 pounds, of salt was placed on the ice in the car prior to the beginning of precooling. As the precooler was used in the car only 4 hours, it is probable that

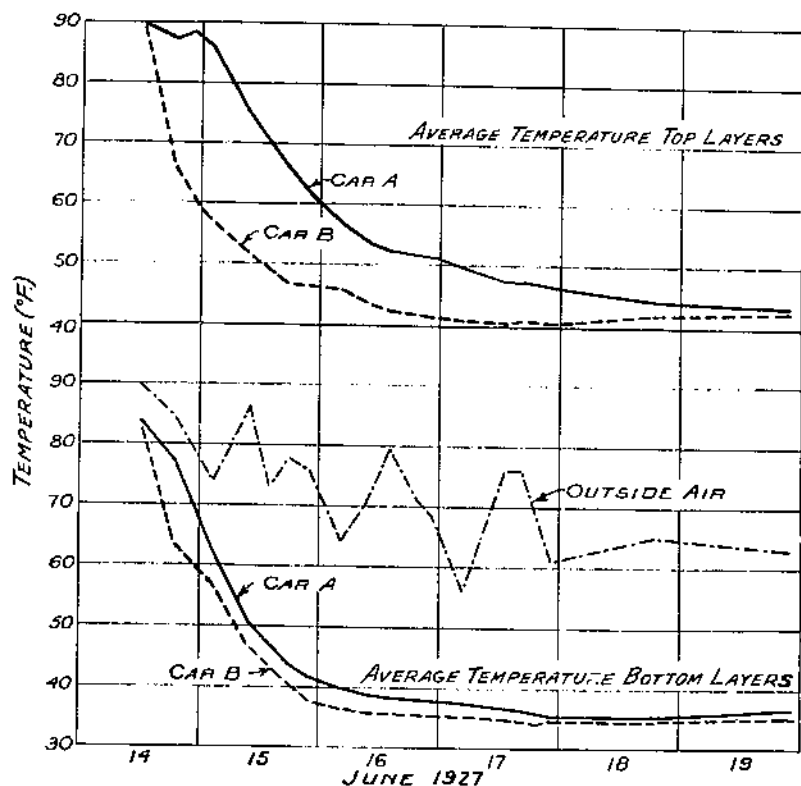


FIGURE 12.—Outside air temperature and temperatures of top and bottom layers of corn in transit shipped under standard refrigeration with 2 percent of salt: Car A without top ice; car B with top ice.

better results would have been secured if its operation could have been continued longer, 6 to 8 hours' precooling generally being considered necessary with this type of equipment.

With the exception of those at the top doorway position the temperatures in the car receiving salt (car A) dropped to 50° F. in about 30 hours, whereas it took 65 to 72 hours to reach the same temperature in the car receiving no salt (car B), except for the bunker positions. This difference corresponds to that obtained in the other two experimental cars shipped about the same time.

ICE MELTAGE

The top-iced car and the car without top ice from Florida were supplied with 25,680 and 28,359 pounds of bunker ice, respectively, of which 15,920 pounds and 18,809 pounds melted. Practically all of the 5,130 pounds of top ice placed on the one end of the top-iced load was melted after 4 days in transit. This makes an approximate total meltage of 21,000 pounds for the top-iced car and 18,809 pounds for the car without top ice.

From 10,000 to 12,000 pounds of ice was placed over the top of the loads shipped from Alabama. Practically all of this ice was melted at time of arrival at destination 4 to 5 days later. It is apparent from the temperatures shown in figure 13 that the top ice was largely

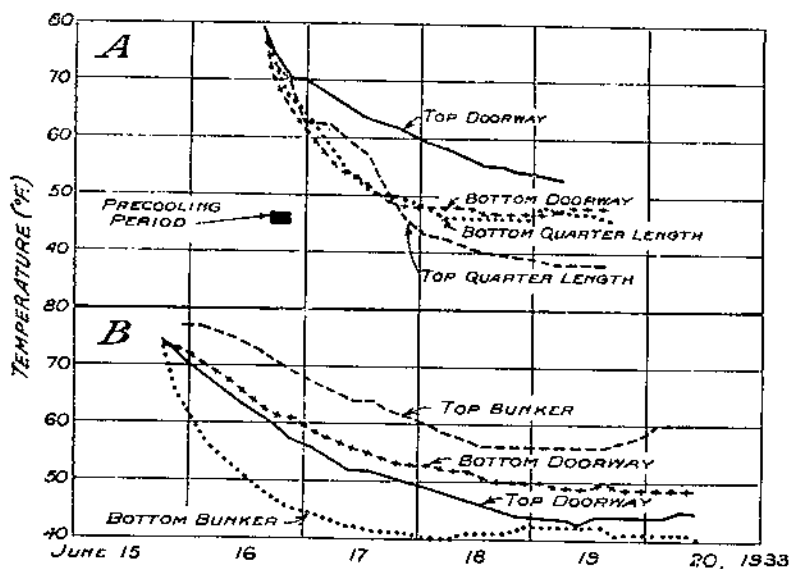


FIGURE 13.—Temperatures of green corn in transit under the following conditions: Car A, pre-cooled 4 hours, standard refrigeration, salt and top ice; car B, standard refrigeration and top ice.

melted after 3 days in transit, as there was no further decrease in top-layer temperatures after 3 days and in one position there was a marked increase.

PRECOOLING EXPERIMENTS

Experiments have been conducted at the Arlington Experimental Farm to determine the length of time necessary to cool corn by various methods and to find the effect on loss in total sugars after different periods at different temperatures.

RATE OF COOLING

Green corn is difficult to cool. As shown in figure 14, approximately 21 hours were required for cooling the corn at the center of a crate from 80° to 40° F. in still air having a temperature of 31°. The slow rate of cooling is no doubt owing to the high rate of respiration and the insulating effect of the husks. The same amount of cool-

ing was accomplished in about 9 hours when the corn was placed in moving air at the same temperature. When corn was immersed in nonagitated ice water (32° to 34° F.) that in the center of the package cooled to 55° in 1 hour, 50° in 2 hours, 41° or 42° in 3 hours, and 40° in 4 hours. Corn placed in an air temperature of 70° to 74° increased temporarily from an initial temperature of 80.5° to 83°, and finally cooled to a minimum of 73° in 46 hours.

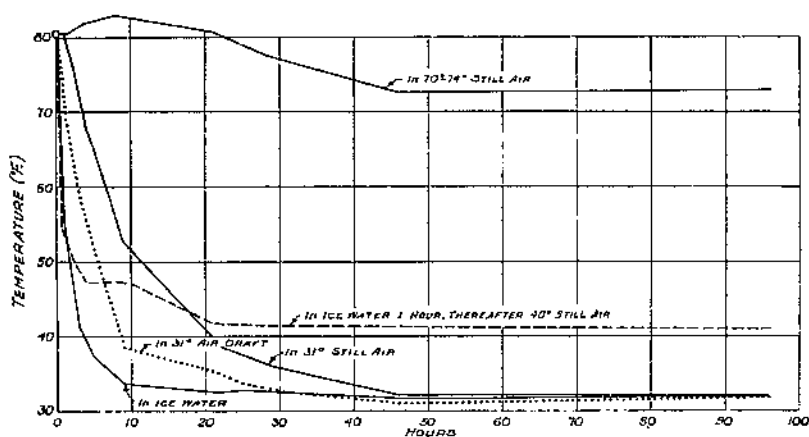


FIGURE 14.—Comparative rate of cooling green corn under different conditions.

RELATION OF TEMPERATURE TO TOTAL SUGAR

Green corn has the best flavor if eaten shortly after picking when the sugar content is highest. It is evident from table 20 that there is a definite relation between the percentage of total sugars lost and the temperature at which the corn is stored. This corn was picked and immediately placed in storage. Very little sugar was lost during the first 3 hours, especially when the corn was held at 50° F. or below. After 24 to 72 hours in storage, the loss in total sugars was high in all lots except that stored continuously at 32°.

TABLE 20.—Average loss in total sugars of green corn, picked direct from the field, after storage at different temperatures

Treatment	Average loss in total sugar after—		
	3 hours	24 hours	72 hours
	Percent	Percent	Percent
Ice water 1 hour; 40° F. air storage.....	2.35	16.91	36.76
Ice water 1 hour; 70° F. air storage.....	13.90		63.93
32° F. air storage.....	0	3.69	7.56
50° F. air storage.....	.88	19.89	38.13
80° F. air storage.....	10.78	51.33	(¹)

¹ Discarded.

Rose, Wright, and Whiteman¹ recommend that corn for consumption fresh should be cooled quickly to 32° to 36° F. after harvest.

¹ ROSE, D. H., WRIGHT, R. C., and WHITEMAN, T. M. THE COMMERCIAL STORAGE OF FRUITS, VEGETABLES, AND FLORISTS' STOCKS. U. S. Dept. Agr. Cir. 278, 40 pp. 1933.

They state that experimental lots of green corn, fresh from the field and chilled in ice water, can be held in 32° storage for 30 days without apparent loss of quality.

DISCUSSION

These experiments consisted of one transportation test and four shipping tests, with a total of six cars, and precooling tests with green corn, to determine the need for body icing and the effectiveness of precooling methods.

The data indicate the necessity for quick cooling of green corn. Ice on top of the load is necessary in transit. It is evident that standard refrigeration is not sufficient to remove the field heat and the heat of respiration fast enough to prevent deterioration in the quality of the corn.

Quick cooling to a low temperature is essential to preserve the quality and condition of corn and to prevent excessive loss of sugar and browning of the husks. The corn earworm has become a serious pest causing large losses, in many districts practically every ear being infested. Since the activity of many insects decreases with a decrease in temperature, it is probable that quick cooling would decrease the damage done by earworms to the corn while in transit. Although there is no evidence to show at what temperature the corn earworm becomes inactive or nearly so, it is believed that temperatures at which corn would be stored or transported to prevent undue loss of sugars would also inhibit the activity of the worms to such an extent that damage in transit would be negligible.

The amount of damage done by earworms to corn during transit is of importance to both shippers and receivers. United States grades permit a small amount of earworm injury at the tip of the ear in U. S. No. 1 grade, but it is entirely possible that corn meeting these requirements at time of shipment might not do so at destination, because of the activity of the worms in transit unless they are suppressed by unfavorable temperatures.

The use of salt on the bunker ice is beneficial in lowering temperatures in cars loaded with green corn. While the amount used varies from 1 to 5 percent, a minimum of 5 percent probably should be used with shipments of green corn because of the unusual difficulty in refrigerating such a load.

The results indicated that a minimum of 5 to 7 tons of top ice, in addition to standard refrigeration and salt, are necessary for shipments of green corn during a transit period of 3 to 5 days, because cars receiving this amount arrived at destination after a 4-day transit period with only 300 to 500 pounds of ice remaining on top of the load.

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END