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Improved Arrival Temperatures of Produce in a Modified Refrigerated Trailer

Abstract

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This publication describes the results of 14 test shipments of California naked-packed and wrapped iceberg lettuce shipped in a highway refrigerated trailer modified with a 3-inch-(7.6 cm) deep floor and 0.75-inch (1.9 cm) wall battens. The trailer was equipped with a conventional refrigeration unit or with a bottom-air-delivery refrigeration unit. On arrival at eastern markets, naked-packed lettuce loaded directly on the floor of a trailer with the conventional refrigeration system had a temperature spread of 15°F (8.3°C) compared with a spread of 11°F (6.1°C) for lettuce in a trailer with the bottom-air refrigeration system. The maximum lettuce temperature on arrival was 4°F (2.2°C) lower in the trailer with the bottom-air-delivery system than that in the trailer with the conventional system. For wrapped lettuce loaded on pallets in the trailer with the conventional refrigeration system, the temperature range on arrival was 19°F (10.6°C) compared with 14°F (7.8°C) in the trailer with the bottom-air-delivery system. The maximum lettuce temperature on arrival was 5°F (2.8°C) lower in the trailer with bottom-air- delivery than in the other type of trailer.

Keywords: arrival temperatures, bottom-air-delivery system, iceberg lettuce, refrigerated trailer.

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Improved Arrival Temperatures of Produce in a Modified Refrigerated Trailer

R. Tom Hinsch, William G. Kindya, and Roger E. Rij[1]

Introduction

Shipments of western iceberg lettuce constitute the largest volume of any single perishable item shipped out of California and represent more than 25 percent of all fresh fruit and vegetables shipped out of State (*4*).[2] More than 87 percent of this lettuce was shipped by highway truck in 1980. Approximately 40 percent was shipped during the hot summer months of June through September (*5*).

In 1979, the California iceberg lettuce industry expressed concern about the large number of high-temperature lettuce arrivals reported in shipments made during the warm summer months. In studies to determine the cause of high-temperature arrivals, Hinsch et al. (*3*) determined that naked-packed lettuce should be loaded on racks several inches off the duckboard floor of trailers with ribbed sidewalls, to minimize high-temperature arrivals. Naked-packed lettuce loaded on racks had arrival temperatures that averaged 4.6°F (2.6°C) cooler than naked-packed lettuce loaded directly on trailer floors (*3*). Lettuce loaded in trailers with recessed vertical-grooved walls arrived with product temperatures adjacent to the sidewalls that were about 2°F (1.1°C) cooler than similarly placed lettuce loaded in trailers with flatwalls. The temperature at destination for naked-packed lettuce loaded on the duckboard floor of highway trailers ranged from 35°F (1.7°C) to 68°F (20°C). For lettuce loaded on floor racks, the arrival temperatures ranged from 35°F (1.7°C) to 49°F (9.4°C).

A van container, used with the USDA-recommended bottom-air-delivery system, has proved itself capable of maintaining desirable transit temperatures in lettuce shipped overseas (*2*); however, highway trailers with this type of refrigeration system are not presently available for domestic transport. The bottom-air-delivery system has also been referred to as a reverse-airflow-delivery system and an under-the-load air-delivery system. In this publication, we will refer to it as the bottom-air-delivery system (fig. 1).

In 1980, the California iceberg lettuce industry supported a proposal to modify a 9-year-old, used, refrigerated highway trailer to provide more perimeter air circulation around the sides of the load and for air delivery under the load. In a previously published study, Hinsch showed that changing the interior design of a refrigerated produce trailer reduced the temperature spread in lettuce loads shipped during the warm summer months (*1*).

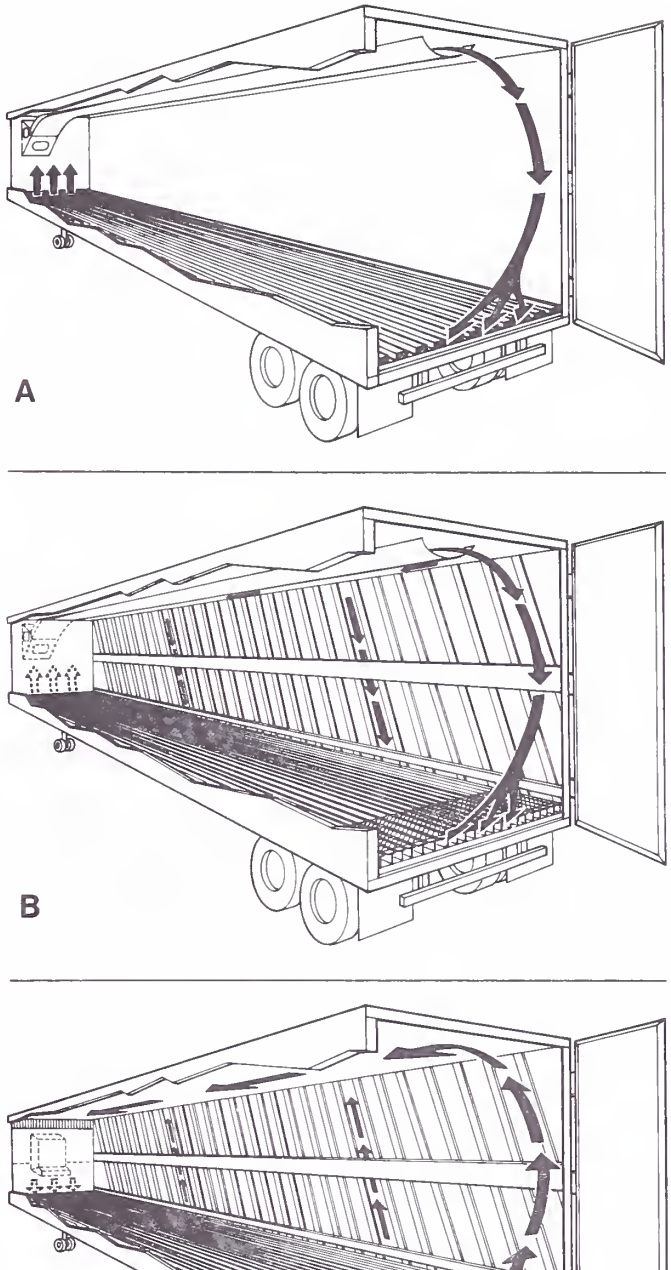

Figure 1. — *A*, Interior of a typical refrigerated highway truck with flat walls, duckboard-type floor, and no return air bulkhead; *B*, modified trailer with strips on the walls, deep "T" floor, and return air bulkhead with a conventional refrigerated air delivery system; and *C*, the same trailer with a bottom-air-delivery system.

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[2]Italic numbers in parentheses refer to Literature Cited, p. 6.

This study was conducted to determine (1) the effects of modifying a trailer's floor, sidewalls, and front bulkhead on the arrival temperature of lettuce when tightly loaded by mechanical means, and (2) the effects of using a bottom-air-delivery system in the modified trailer.

Procedure

A 9-year-old, 45-foot-long, refrigerated produce trailer with flat plywood sidewalls was modified by replacing the shallow, wornout duckboard or ribbed floor with an extruded aluminum, 3-inch-deep (7.6 cm) "T" floor (fig. 2). The trailer was further modified by nailing wood boards, 0.75 inch thick by 3.5 inches wide (1.9 cm by 8.9 cm), on 12-inch (30.5 cm) centers, on the sidewalls from the floor to the ceiling, which provided a maximum loading width of 88.5 inches (224.8 cm) inside the trailer. One 16-inch-wide (40.6 cm) and two 12-inch-wide (30.5 cm), smooth, reinforced fiberglass scuffplates were attached lengthwise along each sidewall to permit easy loading and to protect the wood boards and walls from damage. The 16-inch (40.6 cm) plate was at the floor level, and the two 12-inch (30.5 cm) plates were evenly spaced between the bottom panel and the ceiling.

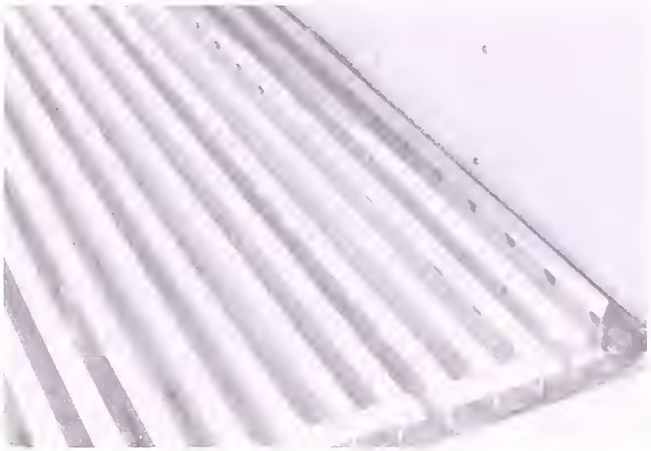

Figure 2. — Three-inch deep "T" section floor: A 15-inch-wide metal landing plate is placed at the rear door to prevent damage by forklift trucks. A piece of soft plastic foam attached to a rigid piece of lumber is placed at the end of the air channels to force the air up through the load.

A conventional, nose-mounted refrigeration unit, which was rated at 2,900 ft^3/min air volume at 0 static pressure, was installed with a canvas air duct that was attached to the ceiling and extended from the front to about two-thirds of the way to the rear of the trailer. A full, wall-to-wall, front bulkhead was installed inside the trailer. It extended from 4 inches (10.2 cm) above the floor to the ceiling. The air discharged through the canvas duct and returned at the bottom of the bulkhead, which prevented the refrigerated air from short-circuiting directly over the top of the load and returning to the evaporator coil of the refrigeration unit before passing through the load (fig. 1).

Four test shipments of lettuce were made in this trailer during 1980 from Salinas, Calif., to eastern U.S. cities. The average transit time for these tests was about 100 hours. The loads consisted of either (1) naked-packed lettuce in corrugated fiberboard boxes that were hand loaded or mechanically loaded directly onto the floor of the trailer in a pattern that was tight against the trailer sidewalls, or (2) consumer-wrapped lettuce in corrugated fiberboard boxes that were stacked on disposable 39-3/8 by 47-1/4-inch (100 by 120 cm) one-way, wooden pallets, mechanically loaded in a pinwheel pattern.[3]

Subsequently, the conventional refrigeration unit in the trailer was replaced with a nose-mounted unit of the same refrigeration capacity, but which delivered the cold air at the bottom of the front wall of the trailer and forced it into the 3-inch (7.6 cm) deep "T" floor (fig. 1). The first bulkhead was removed, and a new wall-to-wall bulkhead was fitted to the bottom-air-delivery unit. A plywood separator was constructed between the discharge and return side of the unit. The bottom of the bulkhead was made to fit flush with the top of the floor. A trap door was provided to clean out any debris that might collect. At the rear of the trailer, the channels in the "T" floor were blocked with foam plastic attached to a piece of lumber so that the refrigerated air would be forced up through the lettuce loads. The air returned to the refrigeration unit at the top of the bulkhead through a 9-inch (22.9 cm) opening that ran the width of the trailer.

Ten test shipments of lettuce were made in this modified trailer during the 1981 season from all California shipping points to eastern U.S. cities. The three types of loads tested were (1) naked-packed lettuce that was tightly stacked and loaded by mechanical means directly onto the floor of the trailer; (2) consumer-wrapped lettuce that was stacked on disposable 39-3/8 by 47-1/4 inch (100 by 120 cm) one-way pallets, mechanically loaded in a pinwheel pattern in the trailer; and (3) mixed loads comprised of each of the two load types. The thermostat was set at 35°F (1.7°C) for all lettuce loads. The naked and the wrapped lettuce were tightly loaded on the floor or pallet without leaving visible vertical or horizontal air channels.

A self-contained, in-transit recording instrument with 15 copper-constantan thermocouples was used to monitor the product pulp temperatures during transit in each load (fig. 3). Additional thermocouples were placed in the discharge and return airstreams of the refrigeration unit, and one was placed underneath the trailer in a shaded area to monitor ambient air temperatures. At destination, the pulp temperature of the lettuce in each box was measured at the 1/4-length, 1/2-length, and the 3/4-length positions in the trailer with a hand-held electric thermometer as the trailer was unloaded. At least 84 pulp temperature readings were recorded at destination in each of the 14 lettuce loads.

Results

Naked-Packed Lettuce Loaded on Trailer Floors

The pulp temperatures taken during loading of the naked-packed lettuce that was machine loaded in both types of trailers ranged from 33°F (0.6°C) to 37°F (2.8°C) (table 1). The temperature range was greater for naked-packed lettuce loaded in the

[3] In a pinwheel pattern, the pallets are loaded in the following (or similar) manner: First pallet crosswise against right sidewall, next pallet lengthwise against left sidewall, third pallet lengthwise against right sidewall, fourth pallet crosswise against left sidewall. The pattern is repeated until the trailer is filled.

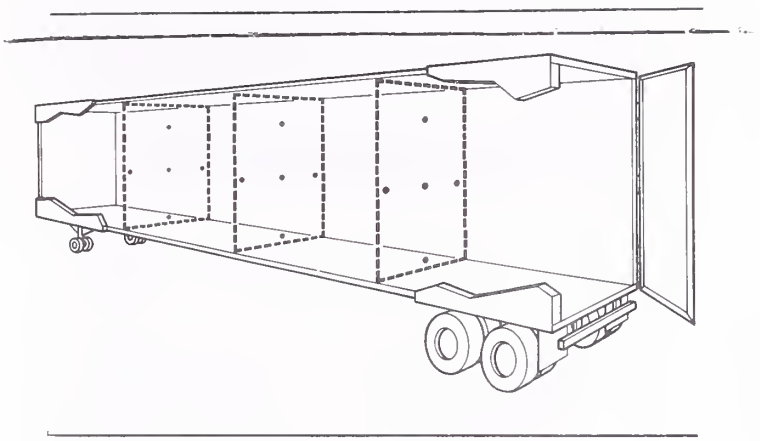

Figure 3.—Location of thermocouple sensors used to monitor product and air temperatures during the trailer evaluation studies. Cross sections are at the ¼-length, ½-length, and ¾-length of trailer.

Table 1.—High, average, and low loading and arrival temperatures of 3 types of lettuce loads shipped in a modified trailer with 2 types of air delivery systems, California to eastern markets, 1980-81

Temperature readings	Conventional air delivery system		Bottom-air-delivery system		
	Naked lettuce on floor	Wrapped lettuce on pallets	Naked lettuce on floor	Wrapped lettuce on pallets	Mixed lettuce loads
	°F	°F	°F	°F	°F
During loading:					
High temp.	37.0	40.0	36.0	40.0	38.0
Low temp.	34.0	35.0	33.0	33.0	32.0
Mean temp.	36.0	38.0	35.2	35.8	34.6
On arrival:					
High temp.	49.0	52.0	45.0	47.0	42.0
Low temp.	34.0	33.0	34.0	33.0	32.0
Mean temp.	39.4	39.2	37.4	37.5	36.5

experimental trailer with a conventional refrigeration unit (fig. 4) than comparable temperatures for naked-packed lettuce loaded in the trailer with the bottom-air-delivery system (fig. 5). During transit, the pulp temperature of the lettuce in both air delivery systems increased. The increase was slightly greater in the trailer with the conventional refrigeration system than in the same trailer with the bottom-air-delivery unit.

During unloading at eastern U.S. markets, the temperatures for naked-packed lettuce shipped in the modified trailer with the conventional refrigeration system ranged from a low of 34°F (1.1°C) to a high of 49°F (9.4°C) and averaged 39°F (4.1°C). As shown in table 2, the highest average temperatures were located along the sidewalls (40.4°F (4.9°C)) and in the bottom layer of the load (40.3°F (4.6°C)). The range in lettuce temperatures on arrival (table 3) was 15°F (8.3°C).

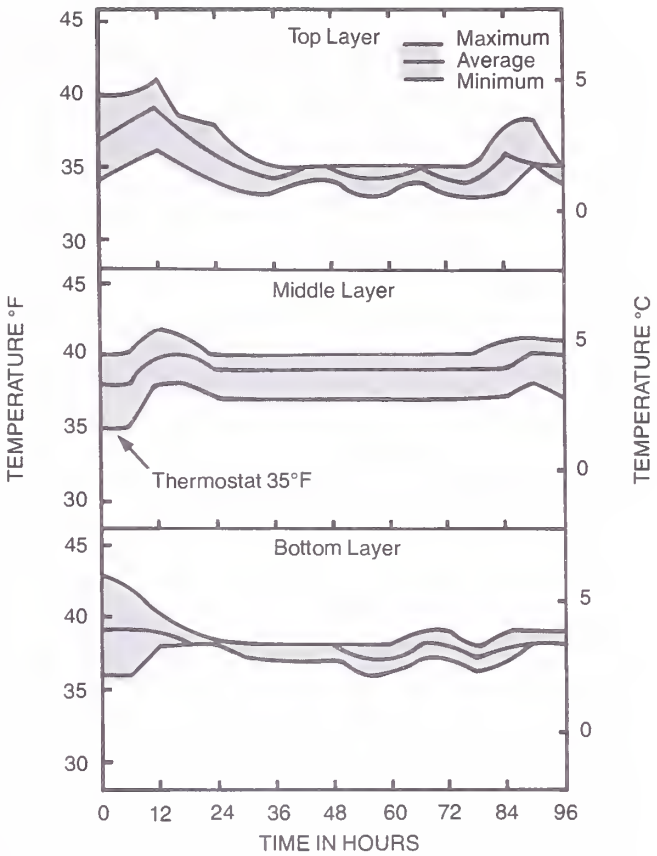

Figure 4.—High, average, and low temperatures of naked-packed lettuce placed on the trailer floor in a conventional air delivery system.

The temperatures for naked-packed lettuce shipped in the modified trailer with the bottom-air-delivery system ranged from a low of 34°F (1.1°C) to a high of 45°F (7.2°C) and averaged 37.4°F (3.0°C). The highest temperatures were in the top layer of the load (45°F (7.2°C)). The range in temperature in the trailer with the bottom-air-delivery system was 11°F (6.1°C), which was 4°F (2.2°C) lower than that in the same trailer equipped with a conventional refrigeration system.

The ambient temperatures during transit were similar during the tests with both types of refrigeration units.

Wrapped Lettuce Unitized on Wooden Pallets

The pulp temperature of wrapped lettuce unitized on wooden pallets in both types of trailers ranged from 33°F (0.6°C) to 40°F (4.4°C) during loading (table 1). The temperature range was greater for the lettuce loaded in the modified trailer with the conventional refrigeration unit (fig. 6) than for palletized wrapped lettuce loaded in the trailer with the bottom-air-delivery system (fig. 7).

On arrival, the pulp temperature of wrapped lettuce that was shipped unitized on wooden pallets in the trailer with the conventional refrigeration system ranged from 33° to 52°F (0.6° to 11°C). The lettuce located in the side rows had the highest average temperature (40.4°F (4.7°C)). The top layer arrived the coolest (35.9°F (2.6°C)). The average arrival temperature for

the load was 39.2°F (4.0°C). The high temperatures at the rear and middle positions in the load may have been a result of one load being exposed to high ambient temperatures during a particularly long period of unloading.

Wrapped lettuce that was unitized on wooden pallets and loaded in the trailer with the bottom-air-delivery system had a range of 14°F (7.8°C), which was 5°F (2.8°C) less than this type of load with the conventional refrigeration system. The lettuce located in the top layer and the sides was slightly warmer than the bottom layer and the center of the load. The average arrival temperature for this type of load in the bottom-air-delivery trailer was 37.5°F (3.1°C), or 1.7°F (0.9°C) lower than in the conventional air delivery trailer.

The ambient temperatures during transit were similar during the tests with both types of refrigeration units.

Mixed Lettuce Loaded on Trailer Floors and on Pallets

Two shipments were made in the modified trailer with the bottom-air-refrigeration system. Each shipment was partially loaded with naked-packed lettuce machine loaded on the floor and wrapped lettuce unitized on wooden pallets. The pulp temperatures of this lettuce ranged from 32° to 38°F (0° to 3.3°C) during loading in California. During transit, the temperatures increased slightly until they reached a high of 42°F (5.6°C) during unloading. The temperatures were fairly uniform from the rear of the trailer to the front of the trailer. They were also uniform from top to bottom and from side to side in the load on arrival.

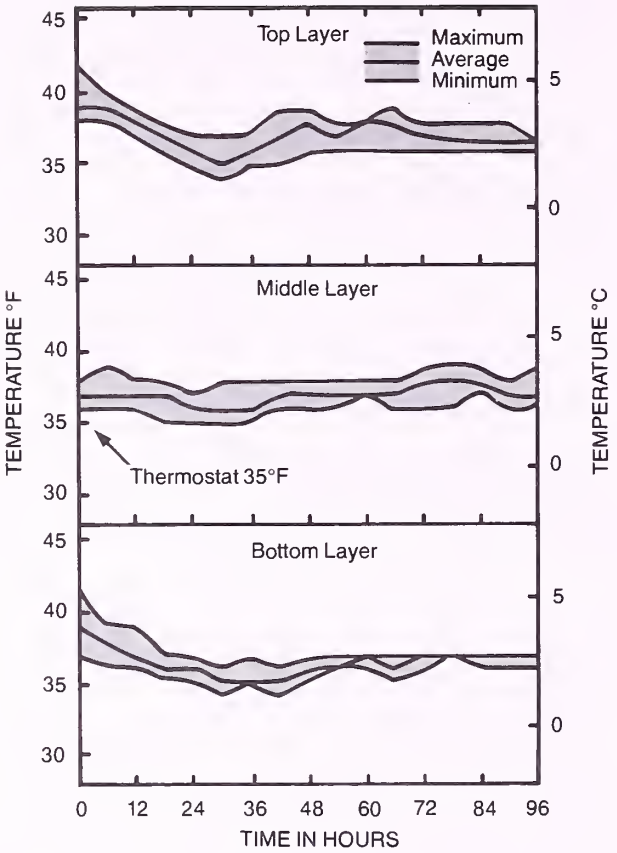

Figure 5. — High, average, and low temperatures of naked-packed lettuce placed on the trailer floor of a bottom-air-delivery system.

Table 2.—Top, middle, and bottom layers and side of the load arrival temperatures of lettuce shipped in 3 types of loads in a used highway trailer, modified to provide perimeter air circulation, with conventional and with bottom-air-delivery systems, California to eastern U.S. markets, 1980-81

Load position and temperature	Conventional air delivery system		Bottom-air-delivery system		Mixed lettuce naked on floor and wrapped on pallets
	Naked lettuce on floor	Wrapped lettuce on pallets	Naked lettuce on floor	Wrapped lettuce on pallets	
	°F	°F	°F	°F	°F
Top layer:					
High temp.	43.0	43.0	45.0	47.0	42.0
Low temp.	34.0	33.0	35.0	35.0	32.0
Mean temp.	38.4	35.9	38.8	39.8	36.2
Middle layer:					
High temp.	44.0	46.0	40.0	44.0	39.0
Low temp.	35.0	35.0	35.0	34.0	32.0
Mean temp.	38.5	39.5	37.1	36.8	36.5
Bottom layer:					
High temp.	49.0	45.0	40.0	39.0	40.0
Low temp.	35.0	35.0	34.0	33.0	32.0
Mean temp.	40.3	38.3	35.9	35.7	36.8
Sides of load:					
High temp.	49.0	52.0	41.0	47.0	42.0
Low temp.	35.0	34.0	38.0	34.0	32.0
Mean temp.	40.4	40.4	38.0	38.1	36.9

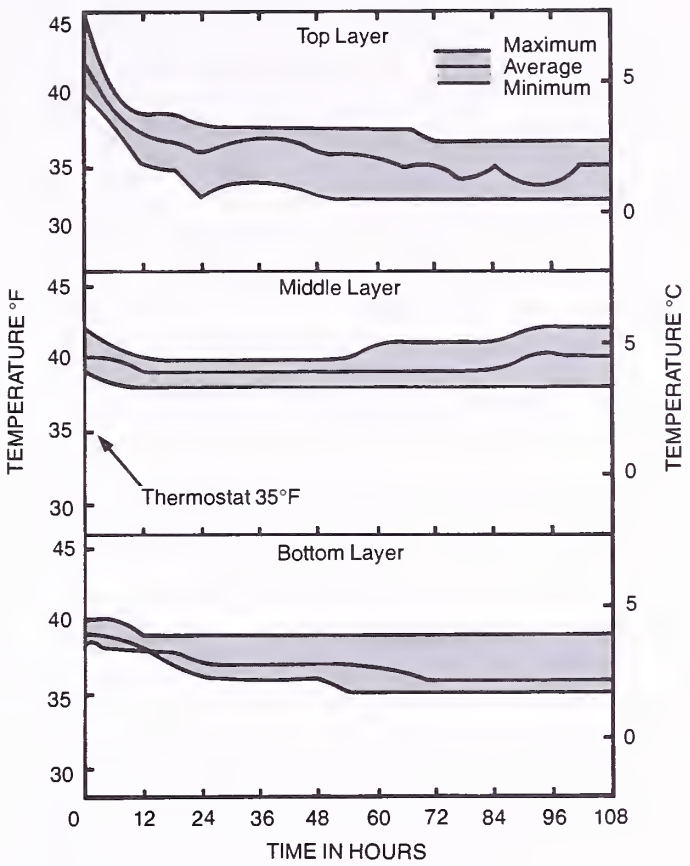

Figure 6. — High, average, and low temperatures of wrapped lettuce loaded on pallets in the trailer with the conventional air delivery system.

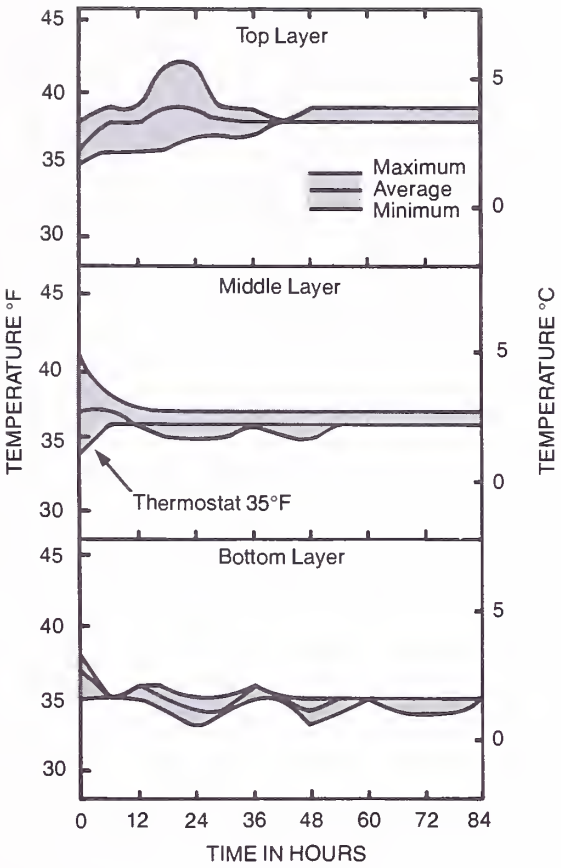

Figure 7. — High, average, and low temperatures of wrapped lettuce loaded on pallets in the trailer with the bottom-air-delivery system.

Table 3.—Front, middle, and rear arrival temperatures of lettuce shipped in 2 types of loads in a used highway trailer, modified to provide perimeter air circulation, with conventional and with bottom-air-delivery systems, California to eastern U.S. markets, 1980-81

Load position and temperature	Conventional air delivery system		Bottom-air-delivery system		Mixed lettuce naked on floor and wrapped on pallets
	Naked lettuce on floor	Wrapped lettuce on pallets	Naked lettuce on floor	Wrapped lettuce on pallets	
	°F	°F	°F	°F	°F
Front:					
High temp.	47.0	41.0	40.0	46.0	42.0
Low temp.	36.0	33.0	34.0	33.0	32.0
Mean temp.	39.2	37.4	36.7	36.8	36.2
Middle:					
High temp.	49.0	48.0	45.0	47.0	39.0
Low temp.	35.0	36.0	34.0	33.0	32.0
Mean temp.	40.0	39.8	37.8	37.4	36.5
Rear:					
High temp.	49.0	52.0	41.0	45.0	40.0
Low temp.	34.0	35.0	35.0	35.0	32.0
Mean temp.	38.5	40.8	37.8	38.3	36.8
All positions:					
High temp.	49.0	52.0	45.0	47.0	42.0
Low temp.	34.0	33.0	34.0	33.0	32.0
Mean temp.	39.4	39.2	37.4	37.5	36.5
Temperature: range in load	15	19	11	14	10

Conclusions

Modifying the floor and walls of refrigerated highway trailers to permit air to circulate over, under, and around the load perimeter contributed to lower arrival temperatures of lettuce at eastern markets than those in conventional refrigerated trailers. The spread between the high and low arrival temperatures was smaller in loads that were shipped in the modified trailer than those in trailers with flat walls and ribbed floors.

The spread in arrival temperatures can be reduced by an additional 4°F (2.2°C) by redirecting the refrigerated air under the load (bottom-air-delivery system). This modification also reduced the average arrival temperature by nearly 2°F (1.1°C).

Changing the interior design of refrigerated produce trailers by causing air to circulate freely around the load reduced the temperature spread in lettuce loads. The naked-packed lettuce that was floor loaded in conventional trailers had a temperature spread of 33°F (18.4°C) as shown in previous research (*3*). This spread was reduced to 15°F (8.3°C) in the experimental trailer with the over-the-load air delivery system and to 11°F (6.1°C) with the bottom-air-delivery system.

Discussion

It is important not to overload highway trailers so that air can get to the product. Tightly packing lettuce in cartons and then tightly loading the cartons in transportation equipment can result in warm arrival temperatures. The refrigerated air in most highway trailers is not pressurized. If there are no air passages between the tightly stacked lettuce cartons, the refrigerated air will return over the top of the load to the coils, resulting in a higher than desirable arrival temperature. For the modified trailer with the bottom-air-delivery system that is loaded too tightly, the air will return to the coil by traveling up the sidewalls and over the top of the load. This may result in warmer than desirable arrival temperatures for those lettuce cartons on the top of the load, especially toward the rear of the trailer.

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