LOADING WARM NAKED-PACKED AND WRAPPED LETTUCE AND COOLING IT IN TRANSIT-- ITS EFFECT ON QUALITY

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Arrival and subsequent quality of lettuce that was cooled in transit was not as good as that of lettuce vacuum cooled immediately after harvest.

Introduction

Iceberg lettuce is highly perishable, and constitutes the largest volume of any single perishable item shipped from California [6]. Most lettuce is transported in truck trailers (85%) or in trailers on railroad flat cars (TOFC) (12%) [7]. Previous studies by Hinsch et al. [4] have shown that presently used truck trailers do not satisfactorily maintain lettuce temperatures during transit even though the product has been precooled. This situation prevails especially during the hot summer months and when loads are tightly stacked, a frequent commercial practice [4]. Subsequent studies have shown that improving air circulation by modifying the system to deliver the air from underneath the load through a deep "T" floor, using conventional fan capacities, resulted in improved arrival temperatures [3].

According to USDA research, van-containers can cool loads of fresh fruits and vegetables that initially are warmer than desirable, but only if the containers have deep "T"-type floors, an under-the-floor air delivery system, high-capacity fans, and thermostat control on the discharge side of the evaporator coil [1]. Temperatures of lettuce in this type of equipment were maintained at or below 40°F (4.5°C) in TOFC cross-country shipments [2].

The respiration rate of lettuce is reduced by about one-half in an atmosphere containing 0.5% or 1.0% O_2, as compared to that in air [5]. At 68°F (20°C) a 50% decrease in the respiration rate would reduce vital heat production from 240,000 to 120,000 BTU per day per 20-ton load of lettuce. Therefore, if lettuce is loaded with a field temperature of about 68°F and the O_2 level around the load is lowered to less than 1%, the heat load due to respiration will be lower than if the lettuce had been held in normal air (21% O_2). Thus, a van-container equipped with high capacity refrigeration and atmosphere modification systems may be capable of accepting lettuce at field temperatures and cooling it satisfactorily in transit.

We report here on tests to determine the cooling capabilities of such van-containers and the quality of naked-packed or field-wrapped, non-precooled lettuce shipped under such a system.

Equipment and Procedures

Five pairs of vans loaded with naked-packed California iceberg lettuce were shipped to Maryland by piggy-back TOFC between August 1981 to April 1982. Each test included two identical vans, one loaded with lettuce that was commercially vacuum cooled before loading and the other with lettuce that was loaded at field temperature. The precooled lettuce was shipped under normal atmospheres, while the warm loads were shipped under a low-oxygen atmosphere.

The 40-foot (12.2 meter) long conventional van-containers were equipped with refrigeration systems with a rated high BTU capacity of 32,000 BTU per hour, to maintain 35°F at an ambient temperature of 100°F (1.5°C at 38°C).[1] The air ciruclation system was designed to produce an air flow of 3,000 cubic feet per minute (85 cubic meters) at a static pressure of 1.5 inches (3.5 cm) of water. The refrigerated air was delivered through a 3-inch (7.6 cm) deep "T"-type floor and returned at the top-front of the van. The thermostat was set at 32°F (0°C). All vans had flat sidewalls and were tightly loaded so there was no space between the sidewalls and the cartons. These vans were loaded with precooled, naked-packed lettuce and shipped under normal atmosphere (21% O_2). Some loads were mechanically loaded on corrugated slip sheets, some of which did not always stay completely under the load; some loads were hand-stacked directly on the floor.

The van-containers loaded with warm lettuce were also equipped with a nitrogen-based atmosphere modification system set to maintain 1.5% O_2 in the load. The O_2 level was not monitored during transit or on arrival.

A self-contained recorder equipped with 18 cooper-constantan thermocouples was used to monitor the temperatures of the lettuce and of the discharge and return air streams of the refrigeration system in each load during transit. At destination, the pulp temperature of the lettuce in each box at the 1/4-length, 1/2-length, and 3/4-length position was measured (up to 117 measurements per load) with a hand-held electric thermometer as each van-container was unloaded. Differences between the arrival temperatures measured with the in-transit recorder and the hand-held thermometer are a result of the larger number of observations taken with the hand-held thermometer, and because of averaging.

Three of the five shipping tests included comparisons of lettuce quality. In each of these tests, two boxes of naked-packed lettuce and two boxes of field-wrapped lettuce were placed in each van-container. The wrap used was 0.5 mil thick perforated polyethylene film. Each box of lettuce was weighed after packing. The lettuce that was loaded in the van-container with the vacuum cooled lettuce was reweighed immediately after cooling. The lettuce placed with the non-cooled load was not reweighed at shipping point. On arrival, the sample lettuce boxes were taken to the USDA laboratory at Beltsville, Maryland and reweighed to determine weight loss during transit.

One-quarter of the lettuce from each box was evaluated for butt color, discolored ribs, russet spotting, and decay after each of the following time periods and temperatures: (1) on arrival (6-7 days after harvest), (2) on arrival plus 3 days at 59°F (15°C), (3) on arrival plus 14 days at 37°F (3°C), and (4) on arrival plus 14 days at 37°F plus 3 days at 59°F. Comparable lettuce held at the ARS laboratory in Fresno was evaluated after holding under similar conditions and times.

Results

Temperatures

At loading, the precooled lettuce temperatures ranged from 34°F to 40°F (1°C to 4.5°C) (Table 1). During unloading, the lettuce temperatures ranged from 32°F to 42°F (0°C to 5.5°C). The average transit temperatures at three locations for the five lettuce loads that were precooled are shown in Figure 1. Most of the lettuce was cooled to an acceptable temperature of 40°F (4.5°C), or below, within the first hours of the transit period Table 2).

FIGURE 1. HIGH, LOW, AND AVERAGE TRANSIT TEMPERATURES OF PRECOOLED LETTUCE AT THE (a) 1/4-LENGTH, (b) 1/2-LENGTH, AND (c) 3/4-LENGTH LOCATIONS IN A VAN-CONTAINER WITH A BOTTOM AIR DELIVERY SYSTEM

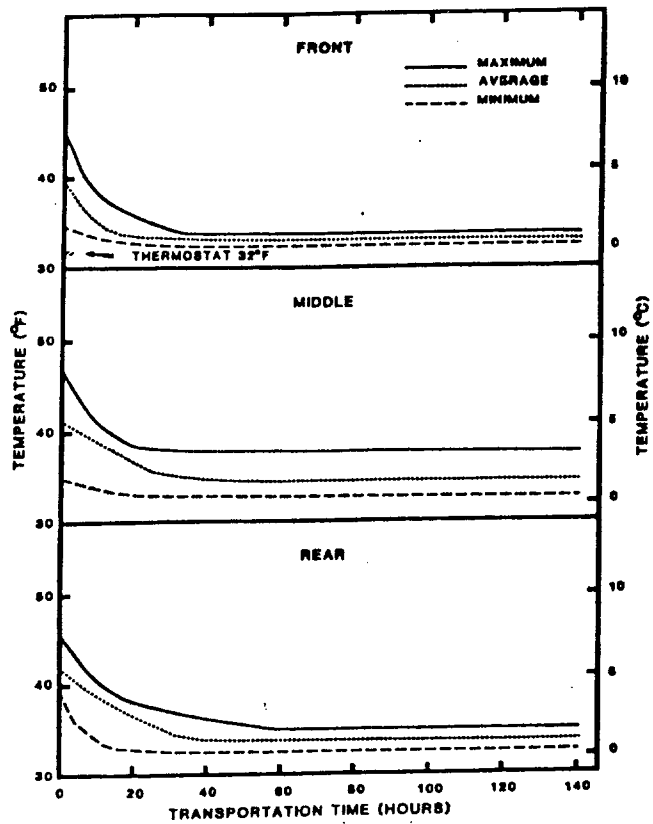


TABLE 1. HIGH, LOW AND AVERAGE LOADING AND ARRIVAL TEMPERATURES OF PRECOOLED AND NON-PRECOOLED NAKED-PACKED LETTUCE LOADED IN BOTTOM-AIR DELIVERY VAN-CONTAINERS SHIPPED BY RAIL FROM CALIFORNIA TO MARYLAND, 1981-82.

Type of Load	Loading Temperatures			Arrival Temperatures		
	High	Low	Average	High	Low	Average
	°F	°F	°F	°F	°F	°F
Precooled	40	34	37.2	42	32	35.1
Non-precooled	71	57	61.9	48	31	35.9

TABLE 2. ARRIVAL TEMPERATURES AT VARIOUS POSITIONS TAKEN DURING UNLOADING OF PRE-COOLED AND NON-PRECOOLED LETTUCE LOADED IN BOTTOM-AIR DELIVERY VAN-CONTAINERS SHIPPED FROM CALIFORNIA TO MARYLAND

Position in the load	Precooled lettuce		Non-precooled lettuce	
	Average	Range	Average	Range
	°F	°F	°F	°F
Layer				
Top	36.4	33-42	37.4	33-48
Center	35.0	33-37	35.9	31-39
Bottom	34.8	33-37	34.6	31-42
Side Rows	35.3	32-42	34.6	31-48
Stack				
1/4-length	35.4	33-42	35.6	31-48
1/2-length	35.4	32-40	36.1	33-46
3/4-length	34.7	32-40	36.0	33-44
Load		10		17

The temperature at loading for the non-precooled lettuce ranged from 57°F to 71°F (14°C to 21.5°C). During unloading, the lettuce temperatures ranged from 31°F to 48°F (-0.5°C to 9°C), a range of 17°F (9.5°C), which is greater than desirable. The average transit temperatures at three locations for the five non-precooled lettuce loads are shown in Figure 2. During the first 30 hours in transit, the lettuce in the van cooled at an average rate of about 0.5°F (0.3°C) per hour, regardless of position in the load. Some of the lettuce cooled at nearly 1°F (0.5°C) per hour.

Mechanical failure in the generator set that provides power for the refrigeration unit occurred on two of the test shipments, resulting in a loss of refrigeration. These power failures in the non-precooled lettuce loads are reflected in the higher than desired temperatures on arrival.

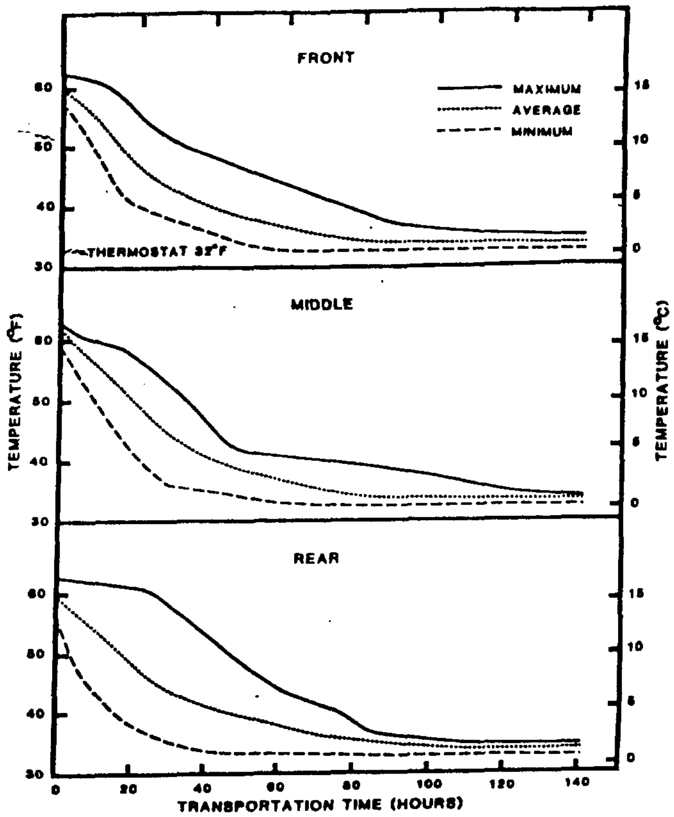
Weight Loss

Vacuum cooled naked-packed lettuce lost 2.5% of its initial weight, while wrapped lettuce lost 0.5% from the time of packing until arrival at the eastern market (Table 3). Both the naked-packed lettuce and the wrapped lettuce that was cooled in transit lost less than 0.5% of its weight.

Lettuce Quality

The quality of the vacuum cooled lettuce was slightly better on arrival at the eastern market than the quality of the lettuce that was cooled in transit (Table 4). The precooled lettuce had significantly shiter butts, and fewer heads had discolored ribs. The vacuum cooled wrapped lettuce had the least amount of rib discoloration, while the non-cooled naked-packed lettuce had the most rib discoloration. At the fourth examination, the non-

FIGURE 2. HIGH, LOW, AND AVERAGE TRANSIT TEMPERATURES OF NON-COOLED LETTUCE AT THE (a) 1/4-LENGTH, (b) 1/2-LENGTH AND (c) 3/4-LENGTH LOCATIONS IN A VAN-CONTAINER WITH A BOTTOM AIR DELIVERY SYSTEM



cooled naked-packed lettuce still had significantly more rib discoloration than the other three treatments. Russet spotting and decay were not problems on arrival; however, they became increasingly worse as the holding time for the lettuce was increased, but there was no statistically significant difference among the treatments.

Conclusions

The van containers with high capacity refrigeration and air circulation systems have the ability to reduce the temperature of lettuce at the rate of 0.5°F to 1°F (0.3°C to 0.6°C) per hour during transit. This rate contrasts with that for conventional refrigerated highway trailers that are unable to maintain loading temperatures of precooled lettuce when it is loaded in a similar manner and with comparable amounts of lettuce.

The arrival and subsequent quality of lettuce that was cooled in transit was not as good as that of lettuce vacuum cooled immediately after harvest, mainly because the lettuce cooled in transit had more discolored ribs and more decay than the precooled lots. The delay in cooling allowed more oxidation of the lettuce to occur. Butt color, which is viewed by the buying trade as an indicator of freshness, was whiter on arrival in the precooled lettuce than in the lettuce that was loaded warm.

Growers who have a limited volume of lettuce in an area that is not served by high investment commercial cooling facilities may find it economically feasible to use van-containers of the type we described for cooling and shipping if there are no serious adverse effects on quality of the product. The economics of using this type of equipment in competition with large scale commercial vacuum coolers needs to be determined. Research should include real estate location costs, equipment purchase and installation costs, energy requirements for each system, benefits of a stationary facility versus one that can be easily relocated, and the costs of losses to lettuce that may result from each cooling and shipping method.

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TABLE 3. WEIGHT OF ICEBERG LETTUCE THAT WAS VACUUM COOLED AFTER HARVEST AND SHIPPED SHIPPED TO EASTERN MARKETS COMPARED TO ICEBERG LETTUCE THAT WAS LOADED WARM AND COOLED IN TRANSIT TO EASTERN MARKETS, 1981-82[1]

	Weight of precooled lettuce at time of loading				Warm lettuce at time of loading			
	Naked-packed		Wrapped		Naked-packed		Wrapped	
	lbs.	kg.	lbs.	kg.	lbs.	kg.	lbs.	kg.
After packing	46.4	21.0	37.4	17.0	46.0	20.9	36.5	16.6
After cooling	45.8	20.8	36.7	16.7	[2]	[2]	[2]	[2]
On arrival	45.3	20.6	37.2	16.9	46.2	21.0	36.3	16.5
Weight loss	1.1	0.5	0.2	0.1	--	--	0.2	0.1
Percent weight loss	2.4	1.1	0.5	0.2	0	0	0.5	0.2

[1]Based on four boxes of each treatment for three replications.

[2]No observation made.

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TABLE 4. BUTT COLOR, DISCOLORED RIBS, RUSSET SPOTTING, AND DECAY OF NAKED-PACKED AND WRAPPED LETTUCE THAT WAS EITHER PRECOOLED BEFORE SHIPPING OR WAS SHIPPED WITHOUT PRECOOLING

Quality criterion and examination[1]	Precooled lettuce		Non-precooled lettuce		Lettuce held at Fresno laboratory	
	naked-packed	wrapped	naked-packed	wrapped	naked-packed	wrapped
			Ratings[2,3]			
Butt Color						
Exam 1	3 b	3 b	4 a	4 a	3	3
2	4 b	4 b	5 a	4 b	4	3
3	5 a	5 a	5 a	5 a	4	3
4	5 a	5 a	5 a	5 a	4	3
			Percent heads affected[3]			
Discolored Ribs						
Exam 1	52 b	22 c	78 a	61 ab	0	0
2	69 a	56 a	83 a	75 a	0	0
3	83 a	56 a	89 a	58 a	0	0
4	86 b	81 b	100 a	78 b	0	0
Russett Spotting						
Exam 1	0 a	0 a	0 a	0 a	0	0
2	0 a	6 a	6 a	2 a	8	0
3	33 a	36 a	36 a	39 a	12	0
4	61 a	64 a	61 a	72 a	0	4
Decay						
Exam 1	0 a	0 a	0	0	8	17
2	11 a	14 a	22 a	19 a	17	46
3	22 a	17 a	33 a	36 a	28	29
4	44 a	52 c	52 c	42 a	56	75

[1]Examinations were performed on the time schedule as discussed in the procedure.

[2]Ratings: 1 = white and 5 = dark red or reddish-brown.

[3]Numerals in a row followed by different letters differ statistically at the 5% level, based on Duncan's multiple range test. Data from lots examined at the Fresno laboratory are not included in statistical analyses.

FOOTNOTE

[1]This unit had a rated low BTU capacity of 12,000 BTU per hour to maintain 0°F at an ambient temperature of 100°F (-18°C at 38°C).

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